Response of Three Flax Genotypes (*Linum usitatissimum* L.) to Foliar Spraying with Different Concentration of Zinc and Boron under the Dryland Conditions of Nineveh Governorate

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Abstract:

A field experiment was conducted during the winter season for the years 2018-2019 and 2019-2020 successively to study the effect of foliar application of zinc and boron on growth traits, yield components and quality of three flax genotypes (Lithuania, Ariana and Linot).

The experiment included three concentrations of zinc (0,5 and 10 mg zinc/L) and three concentrations of boron (0, 6 and 12 mg boron/L) implemented according to the factorial experiment in a Completely Random Block Design.

The main findings could be summarized as follows:-

The results indicate that the Lenot genotype gave the highest values for the traits of plant height, stem diameter, number of fruiting branches, number of capsules/plant, number of seeds/capsule, weight of thousand seeds, total seed yield (tons/ha) and oil yield (tons/ha). for seasons 2018-2019 and 2019-2020 respectively.

Foliar application with zinc on plant leaves at a concentration of 5 mg zinc/liter led to a significant increase in plant height, number of fruiting branches, number of capsules/plant, number of seeds/capsule, weight of thousand seeds, total seed yield (tons/ha), oil yield (tons/ha) in both growing seasons.

Adding boron application on plant leaves at a concentration of 6 mg boron/liter led to a significant increase in plant height, stem diameter, number of fruiting branches, number of capsules/plant, number of seeds/capsule, weight of thousand seeds, total seed yield (tons/ha) and oil yield (tons/ha) for seasons 2018-2019 and 2019-2020, respectively.

In general, it can be concluded that the highest total yield of seeds per unit area can be achieved by planting Lenot genotype and adding zinc on plant leaves at a concentration of 5 mg/L and boron at a concentration of 6 mg/L with in Dryland Conditions of this study.

Key words: Zinc, Boron, Flax Genotypes, *Linum usitatissimum* L.

استجابة ثلاثة تراكيب وراثية من الكتان (*Linum usitatissimum* L.) للرش الورقي بتراكيز مختلفة من الزنك والبورون تحت الظروف الديمية لمحافظة نينوى

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الملخص:

أجريت تجربة حقلية أثناء فصل النمو الشتوي من العامين المتعاقبين 2018–2019 و 2019–2020 لدراسة تأثير الرش الورقي بعنصري الزنك والبورون في صفات النمو ومكونات الحاصل والنوعية لثلاثة تراكيب وراثية من محصول الكتان (ليتوانيا، أريانا و لينوت). تضمنت التجربة ثلاثة تراكيز لعنصر الزنك (0،5 و10 ملغم زنك/لتر) وثلاثة تراكيز من عنصر البورون (0، 6و12 ملغم بورون/لتر) نفذت وفق نظام التجارب العاملية بتصميم القطاعات العشوائية الكاملة. وتتلخص النتائج الرئيسة بالاتي:–

تشير النتائج بأن التركيب الوراثي لينوت أعطى أعلى قيم لصفات ارتفاع النبات، قطر الساق، عدد الافرع الثانوية، عدد الكبسولات/ نبات، عدد البذور/كبسولة، وزن الألف بذرة، حاصل البذور الكلي (طن/هكتار)، نسبة حاصل الزيت (طن/هكتار) في كلا الموسمين 2018–2019 و 2019–2020 على التوالي.

أدى الرش الورقي بعنصر الزنك على أوراق النبات بتركيز 5 ملغم زنك/لتر إلى زيادة معنوية في ارتفاع النبات، عدد الافرع الثمرية، عدد الكبسولات/ نبات، عدد البذور/كبسولة، وزن الألف بذرة، حاصل البذور الكلي (طن/هكتار)، نسبة حاصل الزيت (طن/هكتار) في كلا موسمي النمو.

أدى إضافة البورون رشاً على اوراق النبات بتركيز 6 ملغم بورون/لتر إلى زيادة معنوية في ارتفاع النبات، قطر الساق، عدد الافرع الثمرية، عدد الكبسولات/ نبات، عدد البذور/كبسولة، وزن الألف بذرة، حاصل البذور الكلي (طن/هكتار) حاصل الزيت (طن/هكتار) في كلا الموسمين 2018–2019 و 2019–2020 على التوالي.

عموماً، يمكن الاستنتاج بأن أعلى حاصل كلي من البذور في وحدة المساحة يمكن أن يتحقق بزراعة التركيب الوراثي لينوت وإضافة الزنك على أوراق النبات بتركيز 5 ملغم /لتر والبورون بتركيز 6 ملغم /لتر تحت الظروف الديمية لهذه الدراسة.

الكلمات الدالة: الزنك، البورون، التراكيب الوراثية لمحصول الكتان.

Introduction:

Flax genotypes seeds contains about 35 to 40% of oil, have been long used in human and animal diets, in industry as a source of oil and as the basic component or additive of various paints or polymers (Al-Doori, 2012). Recently there has been a growing interest in the probiotic properties of flax, regarding its beneficial effects on coronary heart disease, some kinds of cancer and neurological and hormonal disorders. The beneficial effects are mostly due to flax lipids. Flax oil is the richest plant source of linoleic and linolenic polyunsaturated fatty acids, which are essential for humans since they cannot be synthesized by body and must be ingested in food. Flaxseed oil is qualitatively different from the more common vegetable oils with high PUFA proportions, such soya, sunflower, rape and olive oil, etc. Flax oil is a rich source of the following unsaturated fatty acids: oleic (C18, 16–24%), linoleic (C18, 18–24%), and linolenic acid (C18, 36–50 %) (Flachowsky *et al*., 1997). It has a relatively low glucosinolate content (El-Beltagi *et al*., 2007). Flax is a high sensitive plant to zinc and boron deficiency (Alloway, 2008) mostly results in pollen grains sterility, less leaf, chlorosis and dwarfing (Movahedy Dehnavy *et al*., 2009). It has been shown that foliar spray of zinc sulfate on leaves of plant increased seed yield, capsule number in plant, seed number in capsul, thousand weight, seed oil and protein (Bybordi and Malakouti, 2007). Similarly it has been shown that foliar application of zinc has significantly increased seed yield, thousand weight, oil content, seed number in capsul, oil and seed yield in plant (Siavashi *et al*., 2004). Boron plays a major role in the transfer of food to seeds, increase the level of cytokinins in plants helps in transporting food made with leaves to storage places and pouring into roots and seeds. With the help of atmospheric nitrogen-fixing streptococcus bacteria. Boron is one of the most sensitive and specialized microelements, noting that high concentrations of it cause toxicity to plants. Therefore, soil and irrigation water must be analyzed before using it to ensure that it is not toxic to flax crop (Al-Doori and Shaker, 2012). Concerning micronutrients i.e. zinc and boron, it is stated that availability of micronutrients is affected greatly by pH, $CaCo_3$ content, organic matter and soil texture. So according to incredible role of micronutrients elements on quantity and quality of crops, this study was conducted to evaluate yield and quality response of three Flax genotypes (*Linum usitatissimum* L.) to different concentrations of foliar spraying of zinc and boron under the dryland conditions to Nineveh governorate.

Materials and Methods:

Two filed experiments were carried out during two winter successive seasons 2018-2019, 2019-2020 at AL-Hamdanea location which is located 30km from Mosul to investigate the effect of three concentration of foliar application of zinc and boron on the growth, yield and quality of three Flax genotypes (Lithuania, Aryana and Linote). AL-Hamdanea is located in the east region of Mosul city at Nineveh province, regarding climate, the region is placed in the semiarid temperature zone with cold winter and hot summer. Average rainfall is about 375 mm that most rainfall happens between winter and spring. The representative soil sample (0-30 cm depth) was taken before planting, to determine some physical, chemical and nutritional properties using the methods description by Black, 1965, Jackson, 1973, Page *et al*., 1982 and Tandon, 1999. Soil of filed experiments were clay loom having 43.44 ppm with nitrogen, 11.39ppm phosphorus, 153.00 ppm potassium, 3.51 ppm zinc and boron 4.00 ppm ratios respectively as an average of both seasons (table 1). Concentration of zinc in soil was found by atomic absorption spectrophotometer with wave length 213.9 nm. (APHA, 1998). Boron in soil was determined by atomic absorption spectrophotometer using curcumin and oxalic acid indicator at 540 nm wave length.

Table -1- The physical and chemical traits of soil filed experiments in both seasons.

seasons	2018-2019	2019-2020
physical traits		
Sand (%)	27.00	22.00
Silt (%)	33.00	35.00
Clay (%)	40.00	43.00
Texture	Clay Loom	Clay Loom
Chemical traits		
O.M. ($g.kg^{-1}$)	10.23	11.54
Available N (ppm)	46.72	40.17
Available P (ppm)	10.12	12.66
Available K (ppm)	162.00	144.00
Total $CaCo_3$ ($g.kg^{-1}$)	8.44	9.22
Available Zn (ppm)	3.80	3.22
Available B (ppm)	4.20	3.80
pH	7.40	7.20
E.C. mmhos/cm	0.86	0.62

Each experiment included eighty one experimental units comprising the combinations of three concentration of foliar application [0-0, 5-6 and 10-12 $mg.L^{-1}$ of zinc as zinc sulphate ($ZnSo_4.7H_2o$ 35% Zn) and boron as boric acid (H_3Bo_3 17%B) respectively and three Flax genotypes with three replications. Seeds of these genotypes were obtained from the industrial crops company, Baghdad. Each plot 18 m^2 (5*3.6), included six rows 60 cm apart and five meters long and the distance between hills were 15 cm apart to attain a plant population of 111.110 $plants.hectar^{-1}$. Super phosphate 60 $kg.ha^{-1}$ (45%P_2O_5) and 40 $kg.ha^{-1}$ potassium

(48%K_2O) were applied to soil during sowing period, nitrogen fertilizers was applied in the form of urea 100 kg.ha^{-1} (46%N) in two equal doses, immediately after thinning (two weeks from sowing) 15 days later. Sowing dates were on the third and fifth of November for 2018-2019, 2019-2020 seasons, respectively. After two weeks from sowing seedlings were thinned to one plant per hill. The plots were weeded twice, the first one after two weeks from sowing and the second after four weeks from sowing. The external two rows were left as border. Two of the remaining rows were devoted for estimating plant growth and some traits. Normal cultural practices of growing Flax were conducted in the usual manner followed by farmers of the district. Sample of twenty plants except guarded plants was taken from each treatment, then the following data were recorded: plant height (cm): The height of the main stem from ground level to the tip of the plant, stem diameter (cm): measured using a vernier (caliper) at the third node and number of fruiting branches/plant: was determined by counting the number of primary reproductive branches. At harvest, twenty plants except guarded plants were taken randomly from the two inner rows of each experimental plot, then the following data were measured; number of capsule per plant. Meanwhile, ten capsule were picked at random from these ten plants, and then the following traits were determined: Number of seeds per capsule. The ten selected plants, mentioned above, were cut, put in an envelope and dried naturally in the lab. Their seeds were added to their respective seeds of the ten capsule in the small bags and weighed. Then weight of thousand seed (g) was estimated by counting thousand seeds at random from each plot and weighed using a sensitive balance. Oil seed content was determined using Soxhlet method (A.O.A.C., 1980). The experimental design was factorial experiment in a Completely Random Block Design with three replications according to Snedecor and Cochran, 1982. Then Duncan's multiple range test (Duncan, 1955) was used to compare among means (Bailer and John, 2020).

Results and Discussion:

Genotypes performance:

The results in table 10 indicate that flax genotypes significantly differed in plant height, stem diameter, number of fruiting branches, number of capsules per plant, no. of seeds per capsule, 1000 seeds weight (g.), seed yield per hector, oil percentage and oil yield (ton.ha^{-1}) in both seasons. Linote genotype exceeded Lithuania and Aryana genotypes in the above mentioned traits in both seasons. However, Linote genotype exceeded Lithuania genotype by 55.21% and 54.42% as well as Aryana genotype by 29.52% and 21.58% in total seed yield per hector in the first and second seasons, respectively (table 2). Linote genotype exceeded Aryana and Lithuania genotypes in number of seeds per capsules in both seasons. The differences between flax genotypes in seed yield per hector might be attributed to their differences in growth traits such as number of fruiting branches reflected differences in yield components such as number of capsule per plant as well as 1000 seed weight and hence increased seed yield per plant as well as per unit area. Similar results were obtained by many investigators such as Andruszczak *et al*, (2105), Kalenska and Stoliarchuk (2018). The increases of Linote genotype in oil yield per hector compared with Aryana and Lithuania genotypes may be attributed to the genetically variation among the tested genotypes in yield components and consequently seed yield as well as oil percentage. Similar results were obtained by many investigators such as El-Borhamy and Amal (2016) and Chauhan (2018).

Zinc foliar application effect:

Results of statistical analysis showed that foliar application of zinc significantly affected all studied traits except stem diameter in first season (table 10). The highest values of the previously mentioned traits were obtained with the zinc foliar application (5 $mg.L^{-1}$). The increase in growth traits and yield components with the increase in zinc foliar application from 0 to 5 $mg.L^{-1}$ might be due to the function of zinc a form of tryptophan, the amino acid that constitutes indole acetic acid (IAA). Zinc is a component of both glyco dehydrogenases, which are necessary for the assimilation of proteins and glycine dipeptidases, which are necessary for glycolysis in the final stages of respiration, and for the formation of chlorophyll. It plays an important role in the germination of pollen on the stigmas of flowers, affecting the chloroplast structure, photosynthesis and plant tissues (Nofal *et al*., 2011). Seed $yield.ha^{-1}$ increased from 11.292, 1.503 to 1.519, 1.799 and 1.301, 1.647 $ton.ha^{-1}$ by increasing zinc foliar application from 0 to 5 and 10 $mg.L^{-1}$ in the growing seasons 2018-2019, 2019-2020, respectively (table 3). These increases represent 17.56, 19.69% respectively compared to the control group. The increase in seed yield with the increase of zinc foliar application might be due to the important role in germination of pollen on the stigmas of flowers, activating the growth and yield components (Al-Doori, 2012). The increase in zinc foliar application to 10 $mg.L^{-1}$ was associated with increase in seed oil content from 40.15, 42.39 to 43.54, 45.99% by increasing zinc foliar application from 0 to 10 $mg.L^{-1}$ in two growing seasons spring and autumn, respectively. The significant positive relations between seed oil content and high zinc foliar application were also reported by (Nofal *et al.*, 2001 and Al-Doori and Al-Dulaimy, 2012). Similar results were reported by others (Mostafa and Deep, 2003). Although the content of seed oil increased by the increase in zinc application to 5 $mg.L^{-1}$, the total oil $yield.ha^{-1}$ significantly increased as zinc application increased up to 5 $mg.L^{-1}$. oil $yield.ha^{-1}$ increased from 0.455, 0.539 to 0.551, 0.658 $ton.ha^{-1}$ by increasing zinc application from 0 to 5 $mg.L^{-1}$ in 2018-2019 and 2019-2020 seasons respectively. The increase in oil yield with the increase in zinc application up to 5 $mg.L^{-1}$ might be attributed to the increase in seed $yield.ha^{-1}$ and oil percentage. these results are in harmony with those obtained by others (Nofal *et al.*, 2011 and Bakry *et al.*, 2012).

Boron foliar application effect:

Boron controls the percentage of water in the plant as well as absorption of water from soil. It has to do with the movement of sugars to their storage places. Which is important for pollination processes inside the flower. It affects the absorption of some elements such as nitrogen, potash, calcium and zinc (Al-Doori and Shaker, 2012). Concerning the effect of boron foliar application on some growth traits, seed $yield.ha^{-1}$ and its components, the results in table 4 indicate that growth traits, seed yield and its components were significantly affected by boron foliar application in both seasons 2018-2019 and 2019-2020. Also, Increasing boron foliar application to (6 $mg.L^{-1}$) significantly increased plant height, stem diameter, number of fruiting branches, number of capsule /plant, no. of seeds/ capsule, 1000 seeds weight (g.) in both seasons. In general, increasing boron foliar application from 0 to 6 $mg.L^{-1}$ increased plant height by 28.52% and 51.46%, increased stem diameter by 92.41% and 176.41% in 2018-2019 and 2019-2020, respectively. In addition, increasing boron foliar application from 0 to 6 $mg.L^{-1}$ increased seed yield per hector by 38.10% and 27.56% and increased oil yield per hector by 47.05% and 40.26% in 2018-2019 and 2019-2020 seasons respectively. Increasing boron foliar application from 6 to 12 $mg.L^{-1}$ caused decrease in previous traits for both seasons. Table 1, also showed that the available boron in soil is in the range of low level from 4.00 ppm, although flax required a high quantity of boron, this reflected the response of flax crop to this element when increasing the concentration from 0 to 12 $mg.L^{-1}$. These results are in agreement with those reported by (Shaker and Al-Doori, 2009 and Shaker and Al-Doori, 2011). The increases in seed yield with increasing boron foliar application level may be attributed to the increases in stem diameter, number of seeds $head^{-1}$, 1000 seed weight reflected increases of seed yield per hector. These results are in agreement with those reported by Coke and Whittington (1968). The increases in oil yield per hector with increasing boron foliar application dose to 6 $mg.L^{-1}$ may be attributed to the increases in yield which reflected increases in seed yield per unit area and hence oil yield per hector. These results are in agreement with those reported by Al-Doori and Shaker (2010).

Table -2-

Means number of some growth traits, yield components and quality as affected by genotypes during 2018-2019, 2019-2020 seasons, respectively.

seasons	genotypes	Plant height (cm)	Stem diameter (cm)	number of fruiting branches	number of capsule /plant	no. of seeds/ capsule	1000 seeds weight (g.)	yield (ton.ha^{-1})	oil (%)	oil yield (ton.ha^{-1})
2018-2019	Lithuania	102.000c	1.4592b	9.1219c	17.4170b	6.1219c	5.38000c	0.95563c	32.3922c	0.31861c
	Aryana	107.869b	1.8459a	10.0700b	18.5000a	7.0700b	5.82296b	1.23711b	34.8704b	0.44437b
	Linote	115.750a	1.8577a	11.4204a	18.7489a	8.4204a	6.65926a	1.92067a	35.9956a	0.70272a
2019-2020	Lithuania	95.444b	1.3859b	9.38000c	19.9737c	6.53593b	6.98000c	1.20944c	34.151c	0.41461c
	Aryana	104.277a	1.7581a	9.82296b	20.5996b	6.90815a	7.42296b	1.47007b	35.763b	0.52855b
	Linote	107.121a	1.8325a	10.65926a	21.8204a	6.98259a	8.25926a	2.27067a	37.540a	0.85944a

* The means values within column followed by the different letter are significant at 0.01% and 5% probability levels, respectively.

Table -3-

Means number of some growth traits, yield components and quality as affected by zinc foliar application during 2018-2019, 2019-2020 seasons, respectively.

seasons	Zn foliar application (mg.L^{-1})	plant height (cm)	stem diameter (cm)	number of fruiting branches	number of capsule /plant	no. of seeds/ capsule	1000 seeds weight (g.)	yield (ton.ha^{-1})	oil (%)	oil yield (ton.ha^{-1})
2018-2019	0	107.787c	1.64481	9.6219b	18.1270b	6.6219b	5.28630c	1.29226c	34.0956b	0.45588b
	5	113.401a	1.76963	10.5900a	18.9622a	7.5900a	6.80667a	1.51989a	35.0500a	0.55142a
	10	104.431b	1.73852	10.4004a	17.5767c	7.4004a	5.76926b	1.30126b	34.1126b	0.45839b
2019-2020	0	97.713c	1.5196c	9.28630c	20.2144b	6.66963c	6.88630c	1.50374c	35.432c	0.5399c
	5	106.883a	1.7788a	10.80667a	21.1744a	6.92889a	8.40667a	1.79926a	36.108a	0.6581a
	10	102.246b	1.6781b	9.76926b	21.0048a	6.82815b	7.36926b	1.64719b	35.913b	0.6045b

* The means values within column followed by the different letter are significant at 0.01% and 5% probability levels, respectively.

Table -4-

Means number of some growth traits, yield components and quality as affected by boron foliar application during 2018-2019, 2019-2020 seasons, respectively.

seasons	B foliar application ($mg.L^{-1}$)	plant height (cm)	stem diameter (cm)	number of fruiting branches	number of capsule /plant	no. of seeds/ capsule	1000 seeds weight (g.)	yield ($ton.ha^{-1}$)	oil (%)	oil yield ($ton.ha^{-1}$)
2018-2019	0	92.913c	1.1077c	9.3748c	17.5263b	6.3748c	5.06333c	1.18115c	33.4259c	0.40856c
	6	119.410a	2.1303a	11.5459a	19.4493a	8.5459a	7.42704a	1.63100a	35.9044a	0.60095a
	12	113.297b	1.9148b	9.6915b	17.6904b	6.6915b	5.37185b	1.30126b	33.9278b	0.45618b
2019-2020	0	77.727c	0.7800c	9.37185c	20.1748c	5.93000c	6.66333c	1.51300b	34.566c	0.5296b
	6	117.521a	2.1563a	11.42704a	21.7348a	7.30630a	9.02704a	1.93067a	37.963a	0.7422a
	12	111.593b	2.0403b	9.06333b	20.4841b	7.19037b	6.97185b	1.50652b	34.924b	0.5307b

* The means values within column followed by the different letter are significant at 0.01% and 5% probability levels, respectively.

Interaction effect of flax genotypes and zinc foliar application:

The interaction between flax genotypes and zinc foliar application had a significant effect on growth traits, seed yield.ha^{-1} and its components, except number of fruiting branches and oil content in 2018-2019 season, number of capsule per plant in 2019-2020 season, plant height, stem diameter, and number of seeds per capsule in both seasons as shown in table 5. The results showed that addition of the zinc application level i.e. 5 mg.L^{-1} to leaves of Linote genotype produced maximum 1000 seed weight and seed yield ha^{-1}, oil yield (ton.ha^{-1}) in both seasons, which were 2.197 and 2.560 ton.ha^{-1} of seed yield per hector and 0.811 and 0.977 ton per hector of oil yield in 2018-2019 and 2019-2020 seasons respectively. The lowest seed and oil yields per hector were produced from sowing Lithuania genotype without adding the zinc (0 mg.L^{-1}) in both seasons. Similar results were reported by (Nofal *et al.*, 2011 and Bakry *et al.*, 2012).

Interaction effect of flax genotypes and boron foliar application:

The interaction between flax genotypes and boron foliar application showed significant effects on some growth traits, yield components and quality in both seasons, except number of capsule per plant in 2018-2019 season, plant height in both seasons as illustrated in table 6. Data illustrated in table 6 show generally that Lithuania, Aryana and Linote genotypes appeared to be clearly affected by increasing rate of boron foliar application up to 6 mg.L^{-1} for some growth traits, yield components and quality, while they appeared to be little response to 12 mg.L^{-1} for those traits. On the other hand, Linote genotype reflected the greatest response to boron foliar application up to 6 mg.L^{-1}, with this regard, Al-Doori and Shaker, (2012) and Bakry *et al.*, (2012) found that application of boron produced maximum plant height, 1000 seeds weight and seed yield (kg ha^{-1}). The insignificant effect between genotypes and boron foliar application on other characteristic showed that each of these two factors acted independently on these traits.

Interaction effect of zinc and boron foliar application:

The interaction between zinc and boron foliar application had a significant effect on number of fruiting branches, number of seeds per capsule, 1000 seed weight and seed yield.ha^{-1}, except plant height, stem diameter, number of capsule per plant and oil content in both seasons and oil yield in the 2019-2020 season as shown in table 7. The results indicated that addition of the medium dose of zinc application (5 mg Zn per L^{-1}) with medium dose of boron foliar application (6 mg Zn per L^{-1})

produced the highest number of fruiting branches (11.88, 12.20 per plant) and total seed yield (1.76, 2.06 $ton.ha^{-1}$) in both seasons 2018-2019, 2019-2020, respectively. Similar conclusions were obtained by Bakry *et al*., (2012).

Interaction effect of flax genotypes, zinc and boron foliar application:

The interaction effect among the three certain factors showed significant effects on number of fruiting branches and total seed $yield.ha^{-1}$ in 2019-2020 season only, 1000 seeds weight in both seasons as illustrated in tables 8,9. The interaction between Linote genotype with zinc foliar application ($5mg.L^{-1}$) and boron foliar application in 6 $mg.L^{-1}$ gave a high rate for 1000 seeds weight (8.89, 10.49 gm.) in both seasons 2018-2019 and 2019-2020, respectively. It could be concluded that maximizing seed yield per unit area could be achieved by sowing flax Linote genotype with adding zinc dose of 5 $mg.L^{-1}$ and boron foliar application with concentration of 6 $mg.L^{-1}$ in the environmental conditions of east region of Mosul city at Nineveh Governorate.

Table -5- Means number of some growth traits, yield components and quality as affected by interaction between genotypes and zinc foliar application (mg.L^{-1}) during 2018-2019, 2019-2020 seasons, respectively.

genotypes	Zinc foliar application (mg.L^{-1})	plant height (cm)	Stem diameter (cm)	number of fruiting branches	number of capsule/ plant	no. of seeds/ capsule	1000 seeds weight (g.)	yield (ton.ha^{-1})	oil (%)	oil yield (ton.ha^{-1})
2018-2019 season										
Lithuania	0	98.527	1.3178	8.5089	17.647b	5.5089	5.0922f	0.9506fg	32.383	0.3157fg
	5	106.789	1.5822	9.4267	18.783a	6.4267	6.3389c	1.0221ef	32.9322	0.3491ef
	10	100.684	1.4778	9.4300	15.820c	6.4300	4.7089g	0.89411g	31.8611	0.29090g
Aryana	0	105.506	1.6789	9.5567	18.530a	6.5567	5.1411f	1.27422d	34.5156	0.45465d
	5	116.574	1.7733	10.402	19.008a	7.4022	6.3500c	1.33967d	35.777	0.49328d
	10	101.528	1.9056	10.2511	18.622a	7.2511	5.9778d	1.09744e	34.3178	0.38516e
Linote	0	116.840	1.9378	10.8000	18.20ab	7.8000	5.6256e	1.65189c	35.3878	0.59723c
	5	119.329	1.9533	11.9411	19.094a	8.9411	7.7311a	2.19789a	36.4400	0.81183a
	10	111.082	1.8322	11.5200	18.28ab	8.5200	6.6211b	1.91222b	36.158	0.69910b
2019-2020 season										
Lithuania	0	88.749	1.26444	9.0922f	19.264	6.41444	6.6922f	1.180g	34.272ef	0.4082f
	5	100.900	1.46556	10.338c	20.171	6.61556	7.9389c	1.275f	33.7656f	0.4320f
	10	96.684	1.42778	8.7089g	20.485	6.57778	6.3089g	1.160g	34.4167e	0.4035f
Aryana	0	100.061	1.61778	9.1411f	19.967	6.76778	6.7411f	1.420e	35.237d	0.5061e
	5	107.686	1.88111	10.350c	20.924	7.03111	7.9500c	1.560d	36.0000c	0.5650d
	10	105.083	1.77556	9.9778d	20.906	6.92556	7.5778d	1.410e	36.0511c	0.5145e
Linote	0	104.329	1.67667	9.6256e	21.411	6.82667	7.2256e	1.898c	36.787b	0.7053c
	5	112.062	1.99000	11.731a	21.918	7.14000	9.3311a	2.560a	37.9733a	0.9774a
	10	104.971	1.83111	10.621b	22.131	6.98111	8.2211b	2.353b	37.8589a	0.8954b

* The means values within column followed by the different letter are significant at 0.01% and 5% probability levels, respectively.

Table -6- Means number of some growth traits, yield components and quality as affected by interaction between genotypes and boron foliar application (mg.L^{-1}) during 2018-2019, 2019-2020 seasons, respectively.

genotypes	Boron foliar application (mg.L^{-1})	plant height (cm)	Stem diameter (cm)	number of fruiting branches	number of capsule/ plant	no. of seeds/ capsule	1000 seeds weight (g.)	yield (ton.ha^{-1})	oil (%)	oil yield (ton.ha^{-1})
2018-2019 season										
Lithuania	0	87.70	0.969i	8.61h	16.49	5.61h	4.312i	0.782i	31.52	0.2538i
	6	112.20	1.816e	10.40e	18.84	7.40e	6.774c	1.145e	33.48	0.3913f
	12	106.10	1.593f	8.36i	16.92	5.36i	5.053g	0.940h	32.18	0.3107h
Aryana	0	91.90	1.323g	8.83g	18.37	5.83g	5.477f	1.093g	33.84	0.3824g
	6	118.30	2.206b	11.11b	19.66	8.11b	7.629b	1.475d	36.42	0.5461d
	12	113.40	2.009d	10.27f	18.03	7.27f	4.363h	1.143f	34.35	0.4046e
Linote	0	99.10	1.031h	10.69c	18.22	7.69c	6.327d	1.669c	34.92	0.5895c
	6	127.70	2.370a	13.13a	19.85	10.13a	7.878a	2.273a	37.81	0.8655a
	12	120.40	2.142c	10.45d	17.63	7.45d	5.773e	1.821b	35.26	0.6532b
2019-2020 season										
Lithuania	0	72.793	0.6633h	8.31i	19.784d	5.81333e	5.912i	1.1027f	32.85i	0.36203f
	6	111.348	1.85d1d	10.77c	20.653c	7.00111d	8.374c	1.4106e	35.82e	0.5050d
	12	102.192	1.6433e	9.05g	19.483d	6.79333e	6.653g	1.1148f	33.79e	0.37676f
Aryana	0	79.727	0.9066f	9.48f	19.820d	6.05667f	7.077f	1.3153e	34.43g	0.45310e
	6	118.508	2.2533b	11.63b	21.278b	7.40333b	9.229b	1.6975d	38.09b	0.64673c
	12	114.596	2.1144c	8.36e	20.70bc	7.26444c	5.963e	1.3973e	34.77f	0.4858de
Linote	0	80.662	0.7700g	10.33d	20.92bc	5.92000g	7.927d	2.1208b	36.42c	0.7739b
	6	122.708	2.3644a	11.88a	23.272a	7.51444a	9.478a	2.6837a	39.99a	1.07482a
	12	117.992	2.3633a	9.77e	21.268b	7.51333a	7.373e	2.0073c	36.22d	0.72956

* The means values within column followed by the different letter are significant at 0.01% and 5% probability levels, respectively.

Table -7- Means number of some growth traits, yield components and quality as affected by interaction between zinc and boron foliar application (mg.L^{-1}) during 2018-2019, 2019-2020 seasons, respectively.

Zinc foliar application (mg.L^{-1})	Boron foliar application (mg.L^{-1})	plant height (cm)	Stem diameter (cm)	number of fruiting branches	number of capsule /plant	no. of seeds/ capsule	1000 seeds weight (g.)	yield (ton.ha^{-1})	oil (%)	oil yield (ton.ha^{-1})
2018-2019 season										
0	0	92.042	1.0422	8.383e	17.810	5.383e	4.1889h	1.028g	32.816	0.347e
	6	119.03	2.0956	11.034b	19.270	8.034b	6.9033c	1.618b	35.730	0.589b
	12	112.28	1.7967	9.447d	17.300	6.447d	4.7667g	1.22ef	33.733	0.430d
5	0	96.390	1.1033	9.82cd	18.500	6.82cd	6.6267d	1.384d	33.968	0.486c
	6	123.906	2.1967	11.886a	20.300	8.886a	8.2033a	1.765a	36.430	0.663a
	12	119.90	2.0089	10.062c	18.060	7.062c	5.5900e	1.41cd	34.751	0.504c
10	0	90.306	1.1778	9.92cd	16.740	6.92cd	5.3000f	1.13fg	33.490	0.391d
	6	115.28	2.0989	11.716a	18.700	8.716a	7.1744b	1.508c	35.546	0.550b
	12	107.702	1.9389	9.56cd	17.210	6.56cd	4.8333g	1.264e	33.290	0.433d
2019-2020 season										
0	0	73.598	0.67000	8.188e	19.638	5.82000	5.7889h	1.339e	33.983	0.45855
	6	113.038	2.03111	10.90c	20.912	7.18111	8.5033c	1.829b	37.803	0.69653
	12	106.503	1.85778	8.766g	20.092	7.00778	6.3667g	1.341e	34.511	0.46473
5	0	81.946	0.88667	10.62d	20.276	6.03667	8.2267d	1.694c	34.691	0.59670
	6	120.461	2.24667	12.20a	21.942	7.39667	9.8033a	2.065a	37.985	0.79751
	12	118.241	2.20333	9.590e	20.795	7.35333	7.1900e	1.638c	35.062	0.58035
10	0	77.639	0.78333	9.300f	20.608	5.93333	6.9000f	1.505d	35.025	0.53383
	6	119.064	2.19111	11.17b	22.350	7.34111	8.7744b	1.896b	38.102	0.73257
	12	110.036	2.06000	8.833g	20.564	7.21000	6.4333g	1.539d	35.198	0.54710

* The means values within column followed by the different letter are significant at 0.01% and 5% probability levels, respectively.

Table -8- Means number of some growth traits, yield components and quality as affected by interaction between genotypes, zinc and boron foliar application($mg.L^{-1}$) during 2018-2019 seasons.

Genotypes	Zinc ($mg.L^{-1}$)	Boron ($mg.L^{-1}$)	plant height (cm)	Stem diameter (cm)	number of fruiting branches	number of capsule/ plant	no. of seeds/ capsule	1000 seeds weight (g.)	yield ($ton.ha^{-1}$)	oil (%)	oil yield ($ton.ha^{-1}$)
Lithuania	0	0	83.397	0.9133	7.4867	17.2367	4.4867	4.0367n	0.79267	31.0867	0.25264
		6	110.060	1.7000	9.8633	18.9400	6.8633	6.7400de	1.18967	34.0633	0.40968
		12	102.123	1.3400	8.1767	16.7667	5.1767	4.5000l	0.86967	32.0000	0.28496
	5	0	92.853	1.0600	8.7367	18.2333	5.7367	5.9000g	0.87267	31.8433	0.28833
		6	116.053	1.9000	10.7733	20.2833	7.7733	7.6167c	1.18233	33.6500	0.41012
		12	111.460	1.7867	8.7700	17.8333	5.7700	5.5000hi	1.01133	33.3033	0.34903
	10	0	86.797	0.9333	9.5967	14.0000	6.5967	3.0000o	0.67967	31.6200	0.22058
		6	110.597	1.8467	10.5567	17.3000	7.5567	5.9667g	1.06300	32.7400	0.35403
		12	104.660	1.6533	8.1367	16.1600	5.1367	5.1600ij	0.93967	31.2233	0.29811
Aryana	0	0	90.930	1.0733	8.2567	18.4300	5.2567	4.4300lm	0.98633	33.1233	0.33726
		6	114.927	2.1000	10.5300	19.5933	7.5300	7.0933d	1.55000	36.1867	0.57156
		12	110.660	1.8633	9.8833	17.5667	6.8833	3.9000n	1.28633	34.2367	0.45514
	5	0	97.123	1.5300	9.2567	18.5333	6.2567	6.2000fg	1.30333	34.7900	0.46810
		6	129.000	2.2600	11.4433	20.3333	8.4433	8.1000b	1.58267	37.1267	0.59648
		12	123.600	2.0700	10.5067	18.4167	7.5067	4.7500kl	1.13300	35.4167	0.41527
	10	0	87.793	1.3667	8.9800	18.1333	5.9800	5.8000gh	0.98967	33.6133	0.34177
		6	110.930	2.2567	11.3633	19.6267	8.3633	7.6933c	1.29333	35.9500	0.47029
		12	105.860	2.0933	10.4100	18.1067	7.4100	4.4400lm	1.00933	33.3900	0.34342
Linote	0	0	101.800	1.1400	9.4067	17.7667	6.4067	4.1000mn	1.30633	34.2400	0.45362
		6	132.127	2.4867	12.7100	19.2767	9.7100	6.8767de	2.11667	36.9600	0.78742
		12	124.060	2.1867	10.2833	17.5667	7.2833	5.9000g	1.53267	34.9633	0.55065
	5	0	99.193	0.7200	11.4700	18.7800	8.4700	7.7800bc	1.97633	35.2733	0.70217
		6	126.663	2.4300	13.4433	20.2933	10.4433	8.8933a	2.53133	38.5133	0.98279
		12	124.663	2.1700	10.9100	17.9533	7.9100	6.5200ef	2.08600	35.5333	0.75052
	10	0	96.327	1.2333	11.1833	18.1000	8.1833	7.1000d	1.72333	35.2433	0.61258
		6	124.333	2.1933	13.2300	19.3967	10.2300	7.8633bc	2.17000	37.9500	0.82618
		12	112.587	2.0700	10.1467	17.3667	7.1467	4.9000jk	1.84333	35.2833	0.65855

* The means values within column followed by the different letter are significant at 0.01% and 5% probability levels, respectively.

Table -9- Means number of some growth traits, yield components and quality as affected by interaction between genotypes, zinc and boron foliar application($mg.L^{-1}$) during 2019-2020 seasons.

Genotypes	Zinc ($mg.L^{-1}$)	Boron ($mg.L^{-1}$)	plant height (cm)	Stem diameter (cm)	number of fruiting branches	number of capsule/ plant	no. of seeds/ capsule	1000 seeds weight (g.)	yield ($ton.ha^{-1}$)	oil (%)	oil yield ($ton.ha^{-1}$)
Lithuania	0	0	68.730	0.6300	8.0367n	19.0867	5.7800	5.6367n	1.1260km	32.4200	0.36538
		6	105.393	1.7067	10.7400de	19.6967	6.8567	8.3400de	1.3896ij	36.730	0.51042
		12	92.123	1.4567	8.5000l	19.0100	6.6067	6.1000l	1.03633lm	33.6667	0.34901
	5	0	77.520	0.7100	9.9000g	19.7033	5.8600	7.5000g	1.16933kl	32.5100	0.38015
		6	114.053	1.9167	11.6167c	20.7400	7.0667	9.2167c	1.482hi	34.983	0.51877
		12	111.127	1.7700	9.5000hi	20.0700	6.9200	7.1000hi	1.175kl	33.803	0.39731
	10	0	72.130	0.6500	7.0000o	20.5633	5.8000	4.6000o	1.01300m	33.6200	0.34057
		6	114.597	1.9300	9.9667g	21.5233	7.0800	7.5667g	1.3596ij	35.740	0.48598
		12	103.327	1.7033	9.1600ij	19.3700	6.8533	6.7600ij	1.13km	33.890	0.38397
Aryana	0	0	74.930	0.7900	8.4300lm	19.2900	5.9400	6.0300lm	1.25300jk	33.6233	0.42130
		6	115.260	2.1500	11.0933d	20.3633	7.3000	8.6933d	1.650fg	37.520	0.61908
		12	109.993	1.9133	7.9000n	20.2500	7.0633	5.5000n	1.383ij	34.570	0.47810
	5	0	83.790	0.9800	10.2000fg	19.8900	6.1300	7.8000fg	1.47000i	34.7900	0.51141
		6	120.333	2.3767	12.1000b	21.7433	7.5267	9.7000b	1.7826f	38.460	0.68561
		12	118.933	2.2867	8.7500kl	21.1400	7.4367	6.3500kl	1.4330i	34.750	0.49797
	10	0	80.460	0.9500	9.8000gh	20.2800	6.1000	7.4000gh	1.22300k	34.8800	0.42658
		6	119.930	2.2333	11.6933c	21.7300	7.3833	9.2933c	1.660fg	38.283	0.63550
		12	114.860	2.1433	8.4400lm	20.7100	7.2933	6.0400lm	1.376ij	34.990	0.48146
Linote	0	0	77.133	0.5900	8.1000mn	20.5400	5.7400	5.7000mn	1.63967g	35.9067	0.58897
		6	118.460	2.2367	10.8767de	22.6767	7.3867	8.4767de	2.4500c	39.160	0.96009
		12	117.393	2.2033	9.9000g	21.0167	7.3533	7.5000g	1.606gh	35.296	0.56706
	5	0	84.527	0.9700	11.7800bc	21.2367	6.1200	9.3800c	2.44300c	36.7733	0.89854
		6	126.997	2.4467	12.8933a	23.3433	7.5967	10.4933a	2.9313a	40.513	1.18814
		12	124.663	2.5533	10.5200ef	21.1767	7.7033	8.1200ef	2.3060d	36.633	0.84576
	10	0	80.327	0.7500	11.1000d	20.9833	5.9000	8.7000d	2.28000d	36.5767	0.83435
		6	122.667	2.4100	11.8633bc	23.7967	7.5600	9.4633bc	2.67000	40.283	1.07623
		12	111.920	2.3333	8.9000jk	21.6133	7.4833	6.5000jk	2.11000	36.716	0.77586

* The means values within column followed by the different letter are significant at 0.01% and 5% probability levels, respectively.

Table- 10- Analysis of variance F values for some growth traits, yield and yield components and quality during 2018-2019, 2019-2020 seasons, respectively.

S.O.V	D.f	M.S. for 2018-2019 season								
		Plant height (cm)	stem diameter (cm)	number of fruiting branches	number of capsule/ plant	no. of seeds/ capsule	1000 seeds weight (g.)	yield (ton.ha^{-1})	oil (%)	oil yield (ton.ha^{-1})
Replications	2	814.36532	1.26601964	9.73592593	28.5816049	9.3942592	0.537777	8.163549	136.8616	1.215564
G	2	1576.3471**	1.4554756**	36.025525**	13.538627**	38.1655899**	11.394**	6.6499**	91.760**	1.0354**
Zn	2	587.5498**	0.1049754 n.s.	7.1071259**	13.140927**	7.1191243**	16.294**	0.4486**	8.0549**	0.0800**
B	2	5125.5761**	7.7768082**	37.1383444**	30.682786**	38.1629445**	44.577**	1.4648**	46.359**	0.2710**
G × Zn	4	161.475 n.s.	0.145218 n.s.	0.127957 n.s.	4.7828493**	0.186917 n.s.	1.8387**	0.2004**	1.4220 n.s.	0.0291**
G × B	4	13.737 n.s.	0.2638561**	2.881292**	0.831880 n.s.	2.781574**	2.64903**	0.0553**	0.9534 n.s.	0.0153**
Zn × B	4	24.6521 n.s.	0.041763 n.s.	1.169842**	0.744264 n.s.	1.2398715**	1.61352**	0.04247*	0.9539 n.s.	0.00530*
G × Zn× B	8	14.7337 n.s.	0.084356 n.s.	0.326640 n.s.	0.637936 n.s.	0.3521497 n.s.	1.6416**	0.0208 n.s.	0.4862 n.s.	0.0025 n.s.
Error	52	0.08737235	0.2273695	0.6851947	0.2956695	0.0734038	0.012699	0.622117	0.002120	0.002120
Total	80									
S.O.V	D.f	M.S. for 2019-2020 season								
Replications	2	343.04938	0.37210000	1.07555556	3.55864198	0.37718090	0.53777	0.07788	5.6492593	0.0215878
G	2	1000.9476**	1.5462111**	22.7890074**	23.8147604**	1.634617**	11.3945**	8.2578**	77.5655**	1.44151**
Zn	2	567.5780**	0.4612148**	32.5889407**	7.0877679**	0.5412125**	16.2944**	0.5896**	3.26933**	0.09465**
B	2	12445.1025**	15.7327370**	89.1545851**	18.4211716**	15.5427982**	44.5772**	1.5947**	94.0812**	0.40447**
G × Zn	4	37.976 n.s.	0.0102981 n.s.	7.3548296 **	0.228877 n.s.	0.0367984 n.s.	1.838 **	0.2642**	1.74974**	0.04596**
G × B	4	42.406 n.s.	0.2237925**	10.5961407**	2.1297308**	0.2895929**	2.6490**	0.1121**	1.91900**	0.03271**
Zn × B	4	27.853 n.s.	0.0142407 n.s.	6.4541185**	0.598743 n.s.	0.0465401 n.s.	1.6135**	0.0157*	0.3382 n.s.	0.00193 n.s.
G × Zn× B	8	18.996 n.s.	0.010426 n.s.	13.132800 **	0.284041 n.s.	0.0768262 n.s.	1.641 **	0.019 **	0.6720 n.s.	0.00181 n.s.
Error	52	28.01092	0.02964872	0.0488034	0.2235138	0.07464876	0.04880	0.00628	0.41592	0.001221
Total	80									

*,** Significant at the 0.05 and 0.01 probability levels, respectively. and n.s. not Significant.

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