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Effect of Micro-Nutrients Foliar Application on Yield and Quality Traits of some Canola Genotypes Under Different Environmental Conditions

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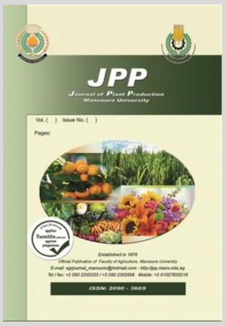

ABSTRACT

In order to evaluate some canola genotypes performance to micro-nutrient foliar spraying. Four field experiments in two different soil types i.e. clayey (S_1) and loamy sand (S_2) at two experimental farms, Faculty of Agriculture, Fayoum University, Egypt in the winter season of 2017/18 (Y_1) and 2018/19 (Y_2). Six canola genotypes i.e., G_1 (35/9), G_2 (26/18), G_3 (Duplo), G_4 (Drakkar), G_5 (Hanna) and G_6 (Serow4) and three micro-nutrient rates were studied. The Y_1 has higher significant values of plant height, pods dry weight, seed, oil and protein yields, Mn, Fe and Zn seed content. The S_1 significantly exceeded S_2 for most studied traits. The G_1 (35/9) line followed by G_6 (Serow4) variety recorded significantly the highest values of most growth traits, seed yield and its components as well as seed content of Mn, Fe, Zn, oil and protein. Foliar application of micro-nutrients by the highest rate significantly surpassed tap water (control) for all studied traits. The correlation coefficients showed that the seed, oil, and protein yields have significantly positively correlated with most studied traits. There are three traits, i.e. pods dry weight plant^{-1}, plant height and number of pods plant^{-1} were significantly ($P \leq 0.001$) participated in variation in seed yield ha^{-1}. The Results suggested that the G_1 line could be promising genotype, have a stable yield in the various environments (years and soil types) and more responsive to micro-nutrients nutrition under different environmental conditions.

Keyword: Canola, Genotypes, Micro-nutrients, Seed yields, Sites, Years

INTRODUCTION

In Egypt, there is a serious problem in the production of vegetable oils. In the 2013 year, the Egyptian total production of oil crops was 3676 t and total import quantity 34569 t, then the gap between production and consumption represented 90% of the total annual consumption of vegetable oils (according to FAO, 2020). Therefore, choosing genotypes which genetically different from the new oil crops characterized by the high stable yield from year to year are suitable for cultivation in various types of good or new reclaimed soils, with all their problems such as salinization or lack of nutrients necessary for the plant consequently, the canola plant was the compatible choice to achieve this goal. Where, the canola (*Brassica napus* L.) has genotypes that can strongly grow in various soil types and under many climatic conditions. Nowadays, the world total area is about 37579575 ha produced 75001457 t by average about 2000 kg/ha (FAO, 2020). Seasonal differences on growth traits and/or seed yield and its related traits, as well as seed chemical composition, were observed by many researchers among them Rameeh (2012), Jankowski *et al.* (2020) and Sikorska *et al.* (2020) for the number of branches, pods per plant, 1000-seed weight, Marjanović-Jeromela *et al.* (2019) and Sooran et al. (2020) for seed yield and oil content.

Emphatically, to recommend good genotypes must be tested under different types of soils to determine their productivity in various sites. Many researchers have emphasized these differences between locations. Escobar *et al.* (2011), Sher *et al.* (2017), Asadi Rahmani *et al.* (2018) found that sites have significant effect on chlorophyll content, seed yield, oil content, oil yield and protein content.

The genotypes differ greatly in growth and yield characteristics, as well as the seed components content. The genotype differences in many following traits i.e. chlorophyll content, plant height, number of branches and pods per plant, pod and seed dry weight, seed index, and biological, seed, oil, and protein yields were stated by Asfour (2013), Emam (2014), Tauseef *et al.* (2017), Khan *et al.* (2018), Manaf *et al.* (2019 a and b), Shahsavari (2019), Afsahi *et al.* (2020), Ashkiani *et al.* (2020) and Nargeseh *et al.* (2020). Micro-nutrients of manganese, iron, and zinc are considered important factors for the plant development, whether in the good or reclaimed soils by increasing the chlorophyll content, the efficiency of photosynthesis and improving the growth and yield characteristics by entering it directly or indirectly in many reactions in the plant. Tavakoli *et al.* (2014) mentioned that the effect of micro-nutrients is found in oxidation and reduction processes, as electron transport in photosynthesis (Mn), or a component of many enzymes associated with energy transfer, nitrogen reduction and fixation, and lignin formation (Fe) and have a catalytic, building, and activating role in the enzymes (Zn). The significant effect of micro-nutrients was reported by Afsahi *et al.* (2020) on chlorophyll content, Manaf *et al.* (2019 b) who found that Zn significantly improved plant height, number of siliques,

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100-seed weight, biological and seed yields. Also, with increasing micro-nutrient levels grain yield, protein content, protein yield, percentage of iron and zinc were increased (Payandeh *et al.*, 2020).

Therefore, the current study was aimed to estimate the solitary and interactively impact of the years, sites, and micro-nutrients foliar spraying on the performance of canola genotypes under different environmental condition.

MATERIALS AND METHODS

Initial characteristics of the investigated sites

Two sites with different soil texture were chosen at the Faculty of Agriculture farms, Fayoum University, Egypt, i.e. Dar-Ramad (29º 19'31.1"N; 30.0º 51'42.9" E) as a clayey soil texture and Demo (29º 17'39.74"N; 30º 54'57.76" E) as a loamy sand soil texture during two winter seasons of 2017/18 and 2018/19, to evaluate the effect of different rates of Mn, Fe and Zn foliar application on plant growth, yield and yield attributes as well as seed quality of canola genotypes. Representative soil samples were collected from the top 30 cm layer of the experimental plots, air-dried and sieved through a 2-mm screen. The physical properties of the investigated soils, such as; particle size distribution, particle density, bulk density, total porosity, air porosity, soil moisture content at 1/3 and 15 bar and the available water, and hydraulic conductivity were determined and calculated before conducting the used treatments. Also, some initial chemical properties of the studied soils, such as; pH, ECe, soluble cations and anions, $CaCO_3$% and organic matter content. The tested soils have two different textures, e.g. the soil of first site (S_1) was a clayey, while, in second site (S_2) was a loamy sand soil. The main characteristics of the soil according to Wilde *et al.* (1985) are given in Table 1.

Plant material, treatments and growth conditions

The experimental arrangement was split-plot in a randomized complete block design with four replicates. Canola genotypes were assigned to main-plots, while micro-nutrients levels were occupied the sub-plots. Tested canola genotypes was G_1 (35/9) and G_2 (26/18) as selected lines, and G_3 (Duplo), G_4 (Drakkar) G_5 (Hanna) and G_6 (Serow-4) as varieties. These divergent genotypes have been screed as different salt tolerant by Afiah *et al.* (1999). Genotypes origin and pedigree are shown in Table 2. The levels of micro-nutrients application was tap water, 300 and 600 ppm foliar spraying combination from Mn + Fe + Zn. The form of applied micro-nutrients was EDTA 13% Mn, EDDHSA 6% Fe and EDTA 14% Zn. Spraying treatments was carried out equally in two doses in 35 and 55 days from sowing. The soil was prepared by deep plowing, harrowing and leveling. Then, the experimental area was divided into plots. Each plot area (10.5 m^2) contains 5 rows, with 3.5 m long and 60 cm apart. Calcium supper-phosphate (15.5 % P_2O_5) at the rate of 355 and 475 kg ha^{-1} was added before ridging in S_1 (Dar-Ramad) and S_2 (Demo) farms respectively. Canola seeds were sown on 3 and 5 November in the first and second seasons, respectively in hills spaced 5 cm apart. Each plot was irrigated separately. All other recommended agricultural practices for canola seed production were adopted throughout the growing seasons according to the bulletin of Egyptian Ministry of Agriculture (712/2001). The metrological data of Fayoum province are presented in Table 3.

Table 1. Physical and chemical properties of the two experimental sites

	1- Physical properties											
	Particle size distributions			**Soil texture**	**Bulk density (g/cm3)**	**Particle density (g/m3)**	**Total porosity %**	**Air porosity %**	**Hydraulic Conductivity (cm/h)**	**Soil moisture content, % at**		
	Sand %	**Silt %**	**Clay %**	**class**						**Field capacity**	**Wilting point**	**Available water**
S_1	19.15	33.58	47.27	Clay	1.28	2.64	50.95	37.72	0.480	44.72	24.06	20.66
S_2	75.55	10.82	13.63	loamy Sand	1.55	2.66	42.03	27.15	2.589	20.02	10.87	9.15
1-	2- Chemical properties											
	pH in soil paste	ECe (dSm) in soil paste	Soluble cations, meq /L				Soluble anions, meq /L				$CaCO_3$ %	Organic matter%
			Ca^+	Mg^+	Na^+	K^+	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$		
S_1	7.88	2.26	6.48	5.45	9.81	0.19	-	2.28	7.77	11.88	5.26	1.71
S_2	7.59	3.61	11.25	6.16	17.55	0.78	-	2.64	13.62	19.48	7.69	0.83
	3- Available nutrients											
	Macro-nutrients (mg/kg)				Micro-nutrients (mg/kg)							
	N	P	K		Mn	Fe	Zn					
S_1	42	14.5	385		4.14	7.25	9.15					
S_2	35	9.75	212		4.41	5.32	8.22					

S_1 and S_2 refer to Dar-Ramad and Demo Farms respectively.

Table 2. Origin and pedigree of the canola genotypes

Name	**Pedigree**	**Origin**
G_1 (35/9)	C103/SIDO*2C103 9C-6SU-1SU-13SW-2SW0SW	Egypt
G_2 (26/18)	18C-21SU-4SW-15SW-1SW	Egypt
G_3 (Duplo)	Variety	Germany
G_4 (Drakkar)	Variety	Germany
G_5 (Hanna)	Variety	Germany
G_6 (Serow4)	Variety	Egypt

Chlorophyll *a* fluorescence

Samples from fresh canola leaves (the fourth leaf from the top of the plant) were taken at 75 days from sowing (50% of pods reach to final size) to estimate the Chlorophyll fluorescence (*Fv/Fm*, *Fv/F*$_0$, and PI) was determined according to Maxwell and Johnson (2000) and Clark *et al.* (2000) using (Handy PEA, Hansatech Instruments Ltd, Kings Lynn, UK).

Table 3. Meteorological data (Monthly averages of weather factors) for Fayoum Governorate in 2017/18 and 2018/19 seasons.

Month	Temperature C°		Relative	Wind	Rain fall
	Min	Max	Humidity %	Speed m sec^{-1}	(mm day^{-1})
2017/18 season					
Nov.	13.26	25.41	57.62	2.74	4.01
Dec.	6.47	18.01	70.67	2.49	0.75
Jan.	5.25	17.34	65.91	2.22	0.01
Feb.	5.94	19.88	59.75	2.34	0.08
Mar.	9.98	24.39	47.09	2.85	0.00
Apr.	13.19	29.68	37.32	3.36	0.21
2018/19 season					
Nov.	11.58	24.09	60.64	2.47	2.42
Dec.	9.79	20.96	64.48	2.11	0.03
Jan.	6.23	18.89	64.87	2.59	0.34
Feb.	10.07	22.91	50.98	2.08	0.15
Mar.	11.76	28.29	38.78	2.51	0.02
Apr.	14.33	30.63	36.47	3.02	0.33

Source: https://power.larc.nasa.gov/data-access-viewer/

Plant growth and yield measurements

At maturity, random sample of 10 guarded plants was taken from each plot to determine the growth traits (i.e., plant height, number of branches and pods plant^{-1}, pod dry weight plant^{-1}, seed dry weight plant^{-1}). From middle of each sub-plot, plants were used to determine 1000-seed weight (g), biological yield ha^{-1} and seed yield ha^{-1} as well as seed quality (oil % protein %, Mn, Fe, and Zn mg/100 g). Besides, oil and protein yields ha^{-1} which estimated by multiplying the oil or protein percent by seed yield ha^{-1}. Seed oil and protein percent were measured by the Near-Infrared Analyzer (Granlund and Zimmerman 1975). To assess the micro-nutrients contents (i.e. Mn, Fe, and Zn), seeds were dried and grounded to powdered form. The content of micro-nutrient mean value was assessed by an Atomic Absorption Spectrophotometer device (Perkin-Elmer, Model 3300).

Statistical analysis

The analysis of variance (ANOVA) technique for the split-plot arrangement was used to statistically analyzed according to Gomez and Gomez (1984), using the GenStat 12th edition software. Combined analysis of the two types of soil over the two years was done whenever homogeneity of variance was detected. LSD test at 5 and 1% probability level was applied to test the differences among treatment means. The stepwise linear regression model was done according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

The F test was performed for years, sites, main factors and all possible interactions for all studied traits as presented in Table 4.

Table 4. Analysis of variance model for combined data of split plot design of the separate experiments of growth and seed yield traits of canola genotypes as influenced by micro-nutrients foliar application

SOV	DF	chlorophyll *a* fluorescence	*Fv/Fm*	*Fv/ Fo*	PI	Plant height (cm)	No. of branches plant^{-1}	No. of pod plant^{-1}	Pod dry weight	Seed Dry weight plant^{-1}	Seed index (g)	Biological yield (ton ha^{-1})	Seed yield (kg ha^{-1})	Oil yield (kg ha^{-1})	Protein yield (kg ha^{-1})	Mn mg/g	Fe mg/g	Zn mg/g	Oil %	Protein %
Y	1	NS	*	NS	NS	**	NS	NS	*	NS	**	NS	NS	*	**	**	NS	NS	*	NS
S	1	**	**	NS	*	**	**	NS	**	NS	**	**	NS	**	**	**	**	NS	**	**
Y x S	1	**	**	*	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	NS
Rep/enviro	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A	5	**	NS	**	**	**	NS	**	**	**	**	NS	**	**	**	**	NS	**	**	**
Y x A	5	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x A	5	**	*	NS	**	**	NS	NS	NS	**	**	NS	NS	NS	NS	**	NS	NS	NS	**
Y x S x A	5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Error a	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B	2	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Y x B	2	NS	**	NS	NS	**	NS	NS	NS	NS	**	NS	NS	NS	**	**	NS	NS	NS	**
S x B	2	*	**	**	**	**	NS	NS	NS	**	**	NS	NS	NS	**	**	NS	NS	NS	NS
A x B	10	*	NS	NS	*	**	NS	NS	NS	*	**	NS	NS	NS	NS	**	NS	NS	NS	**
Y x S x B	2	NS	**	NS	NS	NS	NS	**	**	**	NS	NS	**	**	**	NS	NS	**	**	**
Y x A x B	10	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
S x A x B	10	**	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
YxSxAxB	10	**	NS	NS	NS	*	NS	*	NS	NS	*	NS	*	NS	NS	*	NS	*	NS	**
Error b	144		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CV (%)		5.10	0.30	3.20	7.80	6.70	16.20	18.00	20.20	15.70	3.30	7.20	14.50	14.20	9.60	9.80	10.50	9.70	1.90	2.80

Effect of genotypes and micro-nutrients on chlorophyll *a* fluorescence and performance index (PI)

The results in Table 5 cleared that the effect of years was significant only on F_v/F_m. Where, the differences between the two soil types were significant on chlorophyll *a* fluorescence, F_v/F_m and performance index (PI).

S_1 (Dar-Ramad farm) have significantly higher values of chlorophyll *a* fluorescence and PI by 13.90 and 10.45 % respectively than S_2 (Demo farm). S_1 was clayey texture maybe have more suitable factors than S_2 loamy sand texture (Table 1) for plant growth and development and this reflecting on chlorophyll fluorescence and PI. Sher *et al.* (2017) mentioned that the Haripur site, Pakistan which has higher organic matter and total N (g/kg) gave significantly the highest chlorophyll content index. Over all the years and sites, genotypes performance was significant on chlorophyll *a* fluorescence, Fv/F_0, and PI (Table 5). The G_1 line gave significantly higher chlorophyll *a* fluorescence, Fv/F_0, and PI values over all genotypes. The differences among tested genotypes may be due to the differences in genetic structure (Table 2) and their ability to react with environmental factors (Table 3). These findings were supported by Sher *et al.* (2017) and Afsahi *et al.* (2020) who found that canola genotypes differed significantly in chlorophyll content. Micro-nutrients foliar application has statistically increased all chlorophyll traits value. The rate of 600 ppm gave significantly higher values of chlorophyll *a* fluorescence, Fv/Fm, Fv/F_0 and PI by 25.51, 1.19, 5.70 and 38.45 as compared to tap water (control) respectively. These results are in agreement with those reported by Afsahi *et al.* (2020) who found that spraying Zn at 3.5 g/L caused the highest amount of chlorophyll a content 20.1% as compared to control. Combined analysis of variance demonstrated significant differences among Y×S, SxA, SxB, AxB, and SxAxB interactions. Accordingly, the site often participated in all significant interactions on the plant's chlorophyll content and photosynthetic efficiency. As well as the interaction between the main factors was significant on the same characteristics. Thus, the performance index was significantly affected as a result of the positive interaction of the main factors with sites. The significant interactions of SxB and AxB were found by Sher *et al.* (2017) and Afsahi *et al.* (2020) respectively.

Table 5. Combined data for canola genotypes chlorophyll traits as influenced by micro-nutrients foliar application in the two soils types, two years and their interactions.

Treatments	**Chlorophyll *a* fluorescence**	**Photosynthetic efficiency**		**Performance index (PI)**
		F_v/F_m	**F_v/F_0**	
Years (Y)	NS	*	NS	NS
Y_1 (2017/18)	57.62	0.84	5.42	10.25
Y_2 (2018/19)	57.67	0.85	5.41	10.28
LSD $_{0.05}$ (Y)	-	0.001	-	-
Sites (S)	**	**	NS	*
S_1 (Dar-Ramad)	61.39	0.84	5.43	10.57
S_2 (Demo)	53.90	0.85	5.40	9.57
LSD $_{0.05}$ (S)	0.58	0.001	-	0.56
Genotypes (A)	**	NS	**	**
G_1 (35/9)	62.30	0.85	5.59	11.98
G_2 (26/18)	54.55	0.85	5.47	9.73
G_3 (Duplo)	55.23	0.85	5.36	9.47
G_4 (Drakkar)	57.54	0.84	5.37	10.14
G_5 (Hanna)	56.47	0.84	5.22	9.70
G_6 (Serow4)	59.77	0.85	5.45	10.59
LSD $_{0.05}$ (A)	1.68	-	0.12	0.65
Micro-nutrients (B)	**	**	**	**
B_1 (Tap water)	50.64	0.84	5.26	8.79
B_2 (300 ppm)	58.73	0.84	5.41	10.29
B_3 (600 ppm)	63.56	0.85	5.56	11.73
LSD $_{0.05}$ (B)	0.85	0.001	0.05	0.23
Interactions (*F test*)				
Y x S	**	**	*	**
Y x A	NS	NS	NS	NS
S x A	**	*	NS	**
Y x B	NS	**	NS	NS
S x B	*	**	**	**
A x B	*	NS	NS	*
Y x S x A	NS	NS	NS	NS
Y x S x B	NS	**	NS	NS
Y x A x B	**	NS	NS	NS
S x A x B	**	NS	*	*
Y x S x A x B	**	NS	NS	NS

NS, *, and **= Not significant, significant at <0.05 and <0.01, respectively

Effect of micro-nutrients on some canola genotypes characters

Averages of plant height, number of branches and pods plant^{-1} as well as pods and seed dry weight plant^{-1} were illustrated in Table 6. Combined data cleared that plant height and pods dry weight were statistically affected by years. Y_1 significantly surpassed Y_2 and this variation perhaps due to variation in climatic data between the two years (Table 3). The seasonal effects were found by Rameeh (2012), Jankowski *et al.* (2020) and Sikorska *et al.* (2020) in a number of branches and pods per plant. The sites effect was significant on plant height, number of branches plant^{-1} and pods dry weight plant^{-1}. The S_1 exceeded S_2 by 11.02, 7.19 and 44.94 % for plant height, number of branches plant^{-1} and pods dry weight plant^{-1} respectively. The superiority of S_1 may be due to growing plant healthy in S_1 as compared to S_2 and plants have more chlorophyll content, photosynthetic efficiency and PI (Table 5). The highest values of mentioned traits were recorded with the G_1 (35/9) line.

Table 6. Combined data for some canola genotypes traits as influenced by micro-nutrients foliar application in the two soils types, two years and their interactions

Treatments	**Plant height (cm)**	**No. of branches plant^{-1}**	**No. of pods plant^{-1}**	**Pods dry weight (g)**	**Seed dry weight plant^{-1} (g)**
Years (Y)	**	NS	NS	*	NS
Y_1 (2017/18)	159.32	7.30	247.92	47.46	25.73
Y_2 (2018/19)	148.91	7.10	209.55	34.03	24.28
LSD $_{0.05}$ (Y)	2.98	-	-	9.45	-
Sites (S)	**	**	NS	**	NS
S_1 (Dar-Ramad)	162.16	7.45	236.08	48.22	25.42
S_2 (Demo)	146.07	6.95	221.40	33.27	24.58
LSD $_{0.05}$ (S)	3.64	0.23	-	6.94	-
Genotypes (A)	**	NS	**	**	**
G_1 (35/9)	165.46	7.35	256.54	47.73	30.63
G_2 (26/18)	149.33	7.02	219.12	35.96	22.45
G_3 (Duplo)	150.96	6.85	209.60	38.61	22.19
G_4 (Drakkar)	157.67	7.79	245.98	41.38	25.49
G_5 (Hanna)	149.71	7.42	207.23	40.32	23.29
G_6 (Serow4)	151.56	6.77	233.94	40.48	25.98
LSD $_{0.05}$ (A)	5.03	-	26.63	5.56	2.65
Micro-nutrients (B)	**	**	**	**	**
B_1 (Tap water)	139.74	5.07	146.83	27.31	15.33
B_2 (300 ppm)	156.58	7.56	239.18	42.57	25.81
B_3 (600 ppm)	166.02	8.97	300.20	52.36	33.87
LSD $_{0.05}$ (B)	2.94	0.33	11.74	2.35	1.12
Interactions (F test)					
Y x S	**	**	**	**	**
Y x A	NS	NS	NS	NS	*
S x A	**	NS	NS	NS	**
Y x B	**	NS	NS	NS	NS
S x B	**	NS	NS	NS	**
A x B	**	NS	NS	NS	*
Y x S x A	NS	NS	NS	NS	NS
Y x S x B	NS	NS	**	**	**
Y x A x B	NS	NS	NS	NS	NS
S x A x B	NS	NS	NS	NS	NS
Y x S x A x B	*	NS	*	NS	NS

NS, *, and **= Not significant, significant at <0.05 and <0.01, respectively.

There were no significant differences between G_4 (Drakkar) and G_6 (Serow-4) genotypes for plant height, number of pods plant^{-1} and dry weight of pods or seed plant^{-1}. The G_2 (26/18) line recorded the lowest values of plant height and pods dry weight plant^{-1} while, G_3 (Duplo) gave the lowest number of pods plant^{-1} and seed dry weight plant^{-1}. The superiority of G_1 was stated by Emam (2014) and Emam and Rady (2015) under sandy loam soil. Significant differences among canola genotypes growth traits were observed by Asfour (2013), Arrúa *et al.* (2017), Kandil *et al.* (2017), Tauseef *et al.* (2017) in plant height, Asfour (2013) in branches plant^{-1} and Rameeh (2012), Khan *et al.* (2018), Nargeseh *et al.* (2020) in pods plant^{-1}. A highly statistical effect for micro-nutrients foliar application on growth traits was found. Spraying rate of 600 ppm gave significantly higher plant height, number of branches and pods per plant as well as dry weight of pods and seeds per plant over years and sites when compared to the rate of 300 ppm or tap water which significantly differ from each other. The increasing percentages for the rate 600 ppm were 18.81, 76.92, 104.45, 91.72, and 120.94 % for the abovementioned traits, respectively as compared to tap water. All this increment by applying micro-nutrients at the rate of 600 ppm may be enhanced by the advantage in chlorophyll content and PI (Table 5). These results are in harmony with those reported by Manaf *et al.* (2017), Jarecki *et al.* (2019), Manaf *et al.* (2019 b), Payandeh *et al.* (2020) and Sikorska *et al.* (2020). The YxS, SxA, SxB, AxB, YxSxB and YxSxAxB interactions were significant on these traits with few exceptions. Plant height and seed dry weight significantly affected by SxA, SxB, and AxB interactions. While, the number of pods and pods dry weight plant^{-1} were statistically influenced by YxSxB interactions. The interaction of YxS was significant for all growth traits.

These results are in accordance with those announced by Rameeh (2012), Sher *et al.* (2017), Marjanović-Jeromela *et al.* (2019), Jankowski *et al.* (2020) and Sikorska *et al.* (2020).

Effect of micro-nutrients on canola genotypes seed yield and its components

The results in Table 7 show the canola seed yield and its traits were remarkably affected by different years. The Y_1 significantly overrides the Y_2 by 22.17, 21.65, and 23.72% for seed, oil, and protein yields respectively. Superiority of Y_1 over Y_2 probably due to the suitable climatic conditions for canola growth (Table 3) which consequently reflecting a good performance index (Table 5) then produced good growth traits (Table 6). Similar results were informed by Rameeh (2012) and Jankowski *et al.* (2020) for 1000-seed weight besides Marjanović-Jeromela *et al.* (2019) and Sooran *et al.* (2020) for seed yield. While Nargeseh *et al.* (2020) mentioned that years had no significant influence in seed yield. Canola yields were significantly influenced by soil types; S_1 had significantly the highest values of seed, oil, and protein yields i.e. 2403.98, 988.01, and 491.00 kg ha^{-1} of three yields respectively.

Table 7. Combined data for canola genotypes seed yield and its traits as influenced by micro-nutrients foliar application in the two soils types, two years and their interactions

Treatments	Seed index (g)	Biological yield (ton ha^{-1})	Seed yield (kg ha^{-1})	Oil yield (kg ha^{-1})	Protein yield (kg ha^{-1})
Years (Y)	NS	NS	**	**	**
Y_1 (2017/18)	3.12	7.82	2366.66	969.06	469.40
Y_2 (2018/19)	3.09	7.49	1937.22	796.61	379.40
LSD $_{0.05}$ (Y)	-	-	11.63	2.88	5.92
Sites (S)	*	**	**	**	**
S_1 (Dar-Ramad)	3.09	8.46	2403.98	988.01	491.00
S_2 (Demo)	3.12	6.85	1899.90	777.66	257.80
LSD $_{0.05}$ (S)	0.02	0.26	11.71	8.08	3.36
Genotypes (A)	**	**	**	**	**
G_1 (35/9)	3.54	9.39	2489.68	1041.07	476.50
G_2 (26/18)	2.99	7.67	1972.08	815.28	379.70
G_3 (Duplo)	2.87	6.89	1986.74	807.74	401.00
G_4 (Drakkar)	2.86	6.91	2089.74	850.43	428.30
G_5 (Hanna)	3.19	6.83	2105.42	847.01	427.50
G_6 (Serow4)	3.19	8.23	2267.97	935.49	433.40
LSD $_{0.05}$ (A)	0.07	0.42	138.37	56.56	28.93
Micro-nutrients (B)	**	**	**	**	**
B_1 (Tap water)	2.82	5.99	1702.04	669.43	304.60
B_2 (300 ppm)	3.12	7.82	2217.93	906.34	434.90
B_3 (600 ppm)	3.37	9.15	2535.84	1072.74	533.70
LSD $_{0.05}$ (B)	0.03	0.16	89.05	35.88	18.87
Interactions (F test)					
Y x S	**	**	**	**	**
Y x A	**	**	NS	*	NS
S x A	**	**	NS	*	NS
Y x B	NS	**	**	*	**
S x B	NS	**	**	**	**
A x B	**	**	NS	NS	NS
Y x S x A	*	**	NS	NS	NS
Y x S x B	NS	**	**	**	**
Y x A x B	**	**	NS	NS	NS
S x A x B	**	**	*	NS	NS
Y x S x A x B	**	**	NS	NS	NS

NS, *, and **= Not significant, significant at <0.05 and <0.01, respectively.

This trend perhaps enhances by results which observed on chlorophyll content, PI and growth traits (Table 5 and 6) as well as soil properties (Table 1). These results are in accordance with those announced by Escobar *et al.* (2011), Sher *et al.* (2017) and Asadi Rahmani *et al.* (2018). Canola genotype's performance significantly differed for seed yields. G_1 line significantly overtook all other genotypes for canola yields and seed index. G_1 line gave the highest values of seed index, biological, seed, oil, and protein yields i.e. 3.54 g, 9.39 t, 2489.68, 1041.07, and 476.50 kg ha^{-1}. G_6 (Serow-4) takes significantly the second rank after G_1 line for canola yields then G_5. The G_2 gave the lowest values of seed and protein yields, while G_3 gave the lowest value of oil yield. These results concerning differences among canola genotypes may be due to genetic structure (Table 2) and reacting with environmental climatic factors. The varietal differences were assured in several above-mentioned traits by Escobar *et al.* (2011), Rameeh (2012), Asfour (2013), Emam (2014), Rahnejat *et al.* (2015), Arrúa *et al.* (2017), Kandil *et al.* (2017), Sher *et al.* (2017), Tauseef *et al.* (2017), Khan *et al.* (2018), Manaf *et al.* (2019 a and b), Marjanović-Jeromela *et al.* (2019), Afsahi *et al.* (2020), Ashkiani *et al.* (2020), Jankowski *et al.* (2020), Nargeseh *et al.* (2020) and Sooran *et al.* (2020). Applying micro-nutrients foliar spray gave significantly abundance than tap water treatment (control) for canola yields and seed index (Table 7). The rate of 600 ppm statistically exceeded the rate of 300 ppm for biological, seed, oil, and protein yields as well as seed index by 17.01, 14.33, 18.36, 22.72, and 8.01 % respectively. These results are generally in agreement with those mentioned by Manaf *et al.* (2017), Jarecki *et al.* (2019), Manaf *et al.* (2019 a), Shahsavari (2019), Afsahi *et al.* (2020) and Payandeh *et al.* (2020). Data in Table 7 clear that biological yield was significantly affected by all interactions. Also, the dual interaction of YxS was significant for all canola yields and seed index. Canola seed, oil, and protein yields were statistically influenced by YxB, SxB, and YxSxB interactions. While the seed index and biological yield significantly affected by AxB and YxSxA interactions. It was obvious that the climatic factors and soil properties have a great role in the canola seed, oil, and protein yields because it positively reacted with the main factors under study. The significant interactions impact of canola seed yield and its components was stated by Escobar *et al.* (2011), Sher *et al.* (2017), Jankowski *et al.* (2020), Sikorska *et al.* (2020) and Sooran *et al.* (2020).

Effect of micro-nutrients on canola genotypes seed Mn, Fe and Zn content as well as oil and protein percent

The results presented in Table 8 showed that the canola seed composition of Mn, Fe, Zn, oil, and protein content. Seed micro-nutrient content was affected by years. Y_1 surely surpassed Y_2 by 25.64, 52.20, and 18.28 % for Mn, Fe, and Zn respectively. Rameeh (2012) and Marjanović-Jeromela *et al.* (2019) come to the same conclusion for the seasonal effect on seed content. The soil type's effect was significant for all seed chemical composition. Mn, Fe, oil %, and protein % were statistically higher in S_1, while S_2 has higher Zn content than S_1. The increase % of S_1 was 37.84, 35.38, 0.79, and 8.74 % for Mn, Fe, oil, and protein % respectively when compared to S_2.

Similar findings were observed by Hamama *et al.* (2003) and Sher *et al.* (2017). Highly statistical effect for canola genotypes on seed composition was detected. G_1 line recorded the high seed content of Mn, Fe, Zn, and oil %, but G_4 followed by G_5 recorded the highest protein % over all genotypes. It appears that the differences among the genetic makeup are due to the difference in its ability to absorb elements from the soil and thus its presence in plant seeds. There are differences in the seed content of the different genotypes of canola in its oil and protein content and that probably due to the differences in their genetic makeup. These results are similar with those stated by Hamama *et al.* (2003), Asfour (2013), Azam *et al.* (2013), Emam (2014), Arrúa *et al.* (2017), Sher *et al.* (2017), Khan *et al.* (2018), Manaf *et al.* (2019 a) and Marjanović-Jeromela *et al.* (2019). Regarding the micro-nutrients effect, canola plants respond to the higher rate of micro-nutrients to obtain the crest seed content of Mn, Fe, Zn, oil, and protein. The increment percentages of the rate of 600 ppm were 18.18, 21.00, 32.29, 3.83, and 7.43% above tap water for Mn, Fe, Zn, oil, and protein % respectively. Payandeh *et al.* (2020) stated similar findings. Concerning to interactions effect, with few exceptions, all interactions were significant except YxSxA or in protein%. The seed chemical compositions were sensitively affected by differences in climatic factors and sites as well as when treated by micro-nutrients foliar spray. Seed content interactions effect was mentioned by Sher *et al.* (2017), Marjanović-Jeromela *et al.* (2019), Sikorska *et al.* (2020) and Sooran *et al.* (2020).

Table 8. Combined data for canola genotypes seed quality as influenced by micro-nutrients foliar application in the two soils types, two years and their interactions

Treatments	Mn (mg/g)	Fe (mg/g)	Zn (mg/g)	Oil %	Protein %
Years (Y)	**	**	**	NS	NS
Y_1 (2017/18)	0.49	5.54	1.10	40.67	19.39
Y_2 (2018/19)	0.39	3.64	0.93	40.86	19.56
LSD $_{0.05}$ (Y)	0.02	0.21	0.04	-	-
Sites (S)	**	**	**	*	**
S_1 (Dar-Ramad)	0.51	5.28	0.80	40.93	20.29
S_2 (Demo)	0.37	3.90	1.22	40.61	18.66
LSD $_{0.05}$ (S)	0.02	0.18	0.02	0.31	0.18
Genotypes (A)	**	**	**	**	**
G_1 (35/9)	0.52	5.45	1.21	41.69	18.79
G_2 (26/18)	0.40	3.88	0.97	41.11	18.88
G_3 (Duplo)	0.41	4.28	0.89	40.25	19.96
G_4 (Drakkar)	0.43	4.57	0.97	40.32	20.25
G_5 (Hanna)	0.42	4.40	0.91	40.22	20.00
G_6 (Serow4)	0.46	4.96	1.11	41.00	18.97
LSD $_{0.05}$ (A)	0.03	0.37	0.05	0.39	0.28
Micro-nutrients (B)	**	**	**	**	**
B_1 (Tap water)	0.35	3.56	0.80	39.17	17.94
B_2 (300 ppm)	0.44	4.62	0.96	40.78	19.52
B_3 (600 ppm)	0.52	5.59	1.27	42.34	20.97
LSD $_{0.05}$ (B)	0.01	0.14	0.03	0.23	0.15
Interactions (F test)					
Y x S	**	**	**	*	NS
Y x A	**	**	**	**	NS
S x A	**	**	**	**	**
Y x B	**	**	**	*	**
S x B	**	**	**	**	NS
A x B	**	**	**	**	**
Y x S x A	NS	NS	**	NS	*
Y x S x B	**	**	**	**	**
Y x A x B	**	**	**	NS	**
S x A x B	**	**	**	*	**
Y x S x A x B	**	**	**	*	**

NS, *, and **= Not significant, significant at <0.05 and <0.01, respectively.

Canola yield analysis

Correlation Coefficients among canola yields and their traits

The simple correlation coefficients among canola yields and their traits were illustrated in Table 9. Seed yield (kg ha^{-1}) was highly positively correlated with all traits except with *Fv/Fm*. Oil and protein yields (kg ha^{-1}) take the same trend when they had a high positive correlation with all studied traits except *Fv/Fm* and Zn (mg/g). Same trend were obtained by Rameeh (2012), Asfour (2013), Azam *et al.* (2013) and Nargeseh *et al.* (2020). The results presented in Table 10 showed that there are three traits, i.e., pod dry weight plant^{-1}, plant height and number of pods plant $^{-1}$ were significantly ($P \leq 0.001$) participated in variation in seed yield ha^{-1}. It also noticed that 68.90% of the total seed yield ha^{-1} variations could be linearly related pod dry weight plant^{-1}, plant height, biological yield, and number of pods plant $^{-1}$. Besides, the seed yield, oil %, Zn and seed index were significantly ($P \leq 0.001$) participate in variation in oil yield (kg ha^{-1}). About 99.90% of the total oil yield variations could be related to these four traits. Table 10 clarified that there are three traits, i.e. seed yield, protein % and oil % were significantly ($P \leq 0.001$) contributed to variation in protein yield. Data revealed that 99.50% of the total protein yield ha^{-1} variations could be linearly related to these three traits. These observations are in harmony with those reported by Asfour (2013).

Table 9. Combined data for correlation coefficients among growth, seed yield and quality parameters of canola genotypes as influenced by micro-nutrients foliar application.

	Chl. *a*	*Fv/Fm*	*Fv/F0*	PI	PH	NB	NP	PDW	SDW	SI	BY	SY	OY	PY	Mn	Fe	ZN	OP	PP
Chl. *a* fluorescence	1																		
Fv/Fm	.000	1																	
Fv/F0	.383**	.474**	1																
Performance index (PI)	.624**	.269**	.723**	1															
Plant height (PH)	.514**	-.083	.233**	.312**	1														
No. of branches (NB)	.479**	.133*	.286**	.392**	.544**	1													
No. of pod (NP)	.498**	.128*	.314**	.378**	.668**	.645**	1												
Pod dry weight (PDW)	.487**	-.147*	.121*	.215**	.729**	.473**	.639**	1											
Seed dry weight (SDW)	.502**	.138*	.277**	.388**	.651**	.629**	.789**	.780**	1										
Seed index (SI)	.553**	.191**	.386**	.597**	.349**	.435**	.439**	.351**	.568**	1									
Biological yield (BY)	.731**	.137*	.448**	.629**	.417**	.429**	.459**	.390**	.454**	.629**	1								
Seed yield (SY)	.464**	-.072	.129*	.196**	.730**	.442**	.622**	.799**	.679**	.366**	.358**	1							
Oil yield (OY)	.496**	-.052	.163**	.239**	.746**	.478**	.655**	.804**	.715**	.406**	.395**	.994**	1						
Protein yield (PY)	.539**	-.073	.142*	.237**	.742**	.507**	.649**	.813**	.694**	.378**	.413**	.978**	.977**	1					
Mn	.657**	-.036	.293**	.509**	.389**	.372**	.338**	.403**	.318**	.472**	.692**	.365**	.379**	.427**	1				
Fe	.594**	-.008	.284**	.420**	.519**	.370**	.456**	.540**	.424**	.455**	.635**	.534**	.547**	.573**	.718**	1			
ZN	.186**	.279**	.295**	.380**	.079	.264**	.303**	.057	.334**	.432**	.196**	.040	.076	.033	.165**	.184**	1		
Oil % (OP)	.540**	.097	.402**	.514**	.503**	.570**	.583**	.433**	.647**	.569**	.536**	.398**	.486**	.425**	.310**	.347**	.321**	1	
Protein % (PP)	.630**	-.044	.188**	.348**	.437**	.548**	.440**	.432**	.433**	.277**	.461**	.370**	.393**	.543**	.467**	.432**	-.010	.404**	1

**** and * Correlation is significant at the 0.01 and 0.05 levels.**

Table 10. Correlation coefficient (r), coefficient of determination (R^2) and standard error of the estimates (SEE) for predicting seed, oil and protein yields (kg ha^{-1}) of canola genotypes as influenced by micro-nutrients foliar application.

	R	R^2	SEE	Sig.	Fitted equation
Seed yield (kg ha^{-1})	0.830	0.689	441.219	**	Seed yield = -332.23+ 19.809 PDW + 9.688 PH+ 0.804 NP
Oil yield (kg ha^{-1})	0.999	0.999	12.471	**	Oil yield = 820.239 + 0.41 SY + 20.54 OP+ 6.053 Zn – 7.477 SI
Protein yield (kg ha^{-1})	0.997	0.995	12.765	**	Protein yield = - 331.978 + 0.205 SY + 21.11 PP -2.365 OP

PDW= Pod dry weight, PH=Plant height, NP= Number of pods plant^{-1}, Seed yield, SI= Seed index, PP= Protein % and OP= Oil %.

CONCLUSION

Canola genotypes performance is affected by seasonal climatic factors, soil types and nutrients availability. Seasonal differences and site properties have a significant effect on canola chlorophyll content, growth and seed yield. Through years and sites, the G_1 (35/9) line is the best canola genotypes in growth and seed yield traits as well as seed composition Genotypes responded to the micro-nutrients foliar application up to 600 ppm. The correlation coefficients showed that the seed, oil and protein yields have significantly positively correlated with most studied traits. There are three traits, i.e. pods dry weight plant^{-1}, plant height and number of pods plant^{-1} were significantly ($P\leq 0.001$) participated in variation in seed yield ha^{-1}. Results suggested that the G_1 line could be promising genotype, have a stable yield in the various environments (years and soil types) and more responsive to micro-nutrients nutrition under different environmental conditions.

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تأثير الرش الورقي بالعناصر الصغرى علي انتاجية وجودة محصول بعض التراكيب الوراثية من الكانولا تحت ظروف بيئية مختلفة

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اقيمت تجربتان حقليتان في نوعين مختلفين من الأراضى الطينية (S_1) والرملية الطميية (S_2) خلال الموسمين الشتويين 2018/2017 (Y_1) و 2019/2018 (Y_2) في المزرعة البحثية بكلية الزراعة ، جامعة الفيوم ، مصر. لدراسة تأثير الرش الورقي علي انتاجية وجودة محصول بعض التراكيب الوراثية من الكانولا. واستخدم في هذه الدراسة ست تراكيب وراثية هى G_1(35/9)، G_2 (26/18)، G_3 (Duplo)، G_4 (Drakkar)، G_5 (Hanna)، G_6 (Serow4) واستخدم ثلاث معدلات من العناصر الصغرى. سجل العام الأول Y_1 قيم معنوية لارتفاع النبات ، الوزن الجاف للقرون والبذور ومحصول الزيت و البروتين ومحتوى البذور من المنجنيز والحديد والزنك. كذلك زادت قيم الصفات في الأرض الطينيةS_1 عنها في حالة الأرض الرملية الطمييه S_2 بشكل ملحوظ لمعظم الصفات المدروسة. سجلت السلالة G_1 (35/9) يليها الصنف G_6 (Serow4) أعلى القيم لمعظم الصفات المورفولوجية ، وصفات المحصول ومكوناته بالإضافة إلى محتوى البذور من المنجنيز والحديد والزنك والزيت والبروتين. فاق محتوي الاوراق من الحديد والزنك والمنجنيز عند الرش بالعناصر الصغري مقارنة مع الرش بالماء بشكل ملحوظ في جميع الصفات المدروسة. أظهرت معاملات الارتباط أن محصول البذور والزيت والبروتين ارتبطت بشكل إيجابي مع معظم الصفات المدروسة. هناك ثلاث صفات هى الوزن الجاف للقرون ، ارتفاع النبات وعدد القرون النبات ساهمت بشكل كبير في الاختلاف في محصول البذور. أظهرت الدراسة أن السلالة G_1 تعتبر تركيب مبشر ويمكن استخدامة في برامج التربية المستقبلية لتحسين محصول الكانولا حيث اعطت محصولا ثابتا في البيئات المختلفة (السنوات والأراضى) وكانت أكثر استجابة للتغذية بالعناصر الصغرى تحت ظروف التجربتان في كلا من نوعي التربة.