American-Eurasian Journal of Agronomy 13 (3): 46-52, 2020
ISSN 1995-896X

DOI: 10.5829/idosi.aeja.2020.46.52

Effect of Zn Forms on Yield and Fatty Acids Profile of Some Canola (*Brassica napus* L.) Varieties Grown in Sandy Soil

Tarek A. Elewa, Howida H. Khedr, Elham A. Badr and Manal F. Mohamed

Field Crops Research Department, Agricultural and Biological Division,
National Research Centre, Giza, Egypt. P.O. Box: 12622

Abstract: Careful use of nanotechnology can ensure help in maximizing plant productivity especially in poor soils. Nanoparticles have potential to improve growth and yield of plant. Two field experiments were carried out during the two successive season (2018/2019 and 2019/2020) at the Research and production Station of National Research Centre; Al-Nubaria District; El-Behaira Governorate, Egypt. The study was undertaken to investigate the effect of foliar application Zinc oxide nanoparticles (control, 40 ppm normal and 20ppm NPs) on yield and its components, of some canola (*Brassica napus* L.) varieties (Serw 4, Serw 6 and Pactol) under reclaimed sandy soil. The results showed that, foliar application of ZnO nano particle increased all studied characters of yield and its components (seed yield, oil yield (kg/fed) and oil %). Serw 4 variety surpassed Serw6 and PactoI in all studied yield characters. The interaction between Serw 4 and ZnO 20 ppm NPs produced the highest values in all studied characters on yield and its components. Seed oil content was increased in of Serw 4seeds (42.19%) followed by Serw6 (41.80 %), while Pactol produced the lowest (41. 79%) oil percentage Oil yield (kg/fed) different significantly among canola varieties. The highest oil yield (410.93) was obtained with Serw 4, while the lowest (348.95) was by Pactol. Regarding canola oil profile .the results showed that Oleic acid was increased inPactoI(61.18%); Linoleic acid was increased in Serw 4(22.17%) accompanied by Erucic acid was increase (2.29%) while the lowest linolenic acid was reported by PactoI(8.26%). Canola varieties differed in their content of erucic acid in oil. The lowest content was recorded by Pactol variety while the other two varieties were similar in their content. Generally, foliar application of Zn forms resulted in erucic acid reduction and reached to <1% for Pactol variety compared to the other two varieties. Application of ZnO (20ppmNPs) caused substantial reduction in erucic acid and the reduction was more pronounced than Zn O (40ppm) only.

Key words: Canola varieties · Fatty acid composition · Seed yield. Seed oil % · ZnO nanoparticles

INTRODUCTION

Rapeseed (*Brassica napus* L.) is an important oil crop grown in different parts of the world. The global production area exceeding 31 million hectares with annual production of over 21 million tons of oil [1]. Although the wide range of environments suitable for its production intensive efforts is made to define optimal agricultural practices to approach the genetic potential of cultivars' seed and oil yield, [2]. The variability in oil content is high [3] and [4]. These variations are more and affected by the environment and production system than the cultivar [5], [6] and [7]. In Egypt canola is considered to be a promising crop expected to contribute in reducing oil deficiency gap between production and consumption of edible oil. Canola can successfully grown indifferent soil types it may produce a relatively high economic yield with low inputs mainly nitrogen fertilizer. Zinc (Zn) is an essential mineral nutrient that acts as an important biotic limiting factor toward plant growth, development, fertility and protection. It has many functions in metabolic processes. Hence, modern agricultural research needs to develop novel formulations of nutrient solutions, fertilizers and pesticides [8] therefore , nanoparticles of metal oxides have specific physiochemical properties surface, electrical and optical), different from their bulk counterparts. Among different metal oxide nanoparticles, the most commercially utilized ones in different industries areis zinc oxide [9]. The usage of zinc oxide nanoparticles (ZnO NPs) at appropriate concentrations

Corresponding Author: Tarek A. Elewa, Field Crops Research Department, Agricultural and Biological Division, National Research Centre, Giza, Egypt. P.O. Box: 12622.

(based on the plant species, developmental stage and treatment method) improved the growth, physiology and protection of different plant species, such as *Pisum sativum* [10], *Zea mays* [11] and *Leucaena leucocephala* [12]. Therefore , the aim of this work is to study the effect of Zinc oxide forms application as nanoparticles or normal Zn on yield and its components, as well as, seed quality of some "canola" (*Brassica napus* L.) varieties.

MATERIALS AND METHODS

Two field experiments were carried out at the Research and Production Station, National Research Centre, Al-Emam Malek Village, Nubaria District Al-Behaira Governorate, Egypt, during the two successive winter seasons 2018/2019 and 2019/2020 to study the effect of application Zinc oxide nanoparticles on yield and its components, as well as, seed quality of some "canola" (*Brassica napus* L.) varieties. Soil samples from two depths (0-30 cm from soil surface) before canola planting were taken with "augar" for soil analysis. Mechanical and chemical analysis of the soil site is presented in Table (1) according to [13]. Nitrogen fertilizer was added after sowing at a rate of 60 kg N/fed. as ammonium nitrate (33.5%N) in two equal doses at 21 and 35 days after sowing. Normal cultural practices of growing canola were according to the recommendations of this district.

Experimental Treatments

Canola Varieties: The three tested canola varieties were:

- Serw (4) produced via anther culture from Vido variety (Sweeden), El- Serw Experimental Station, Damietta Governorate, Agriculture Research Center, Ministry of Agriculture, Egypt.
- Serw (6) it is a haploid plant selected from German variety Primire, El- Serw Experimental Station.
- Pactol variety which was obtained from Oil Crops Council, Ministry of Agriculture, Dokki, Giza, Egypt.

Zn Levels:

- Control
- Zn Normal (ZnO 40 ppm)
- Zn Nano (ZnO 20 ppm)

The experimental design was split- plot with four replications. The main plots were devoted to the canola varieties, while Zn levels treatments were randomly occupied the sub plots, respectively. The experimental unit area was 10.5 m^2(1/400 fed.) consisting of ten rows (3.5 m long and 30 cm. between rows).Seeds were sown at a rate of 3.00 kg/ fed (one fed = 4200m^2) in November 20th in 2018/2019 and 2019/2020 growing seasons, respectively. The preceding crop was maize in the two growing seasons.

Yield and Yield Components: At harvesting a random sample of ten plants from each plot were taken to determine the following traits:

- Plant height (cm/plant)
- Number of pods / plant.
- Number of seeds / pod.
- Seed yield / plant (g).
- 1000-seed weight (g).

Plants of one square meter from the middle part of each plot were harvested. These plants were dried under sunshine for one week and seeds were cleaned after separated from the pods and the following traits were estimated:

- Seed yield (kg / fed).
- Oil yield (kg/fed) = oil percent x seed yield (kg /fed).

Fatty Acids Composition: Crude oil of seeds (2nd season only) was used as authentic material for identification the following fatty acids according to [14].

Procedure fatty acids methyl esters were analyzed by Gas Liquid Chromatography (GLC), Hp-6890 GC Method-HEWLEH Packard Hp-6990 series. The fractionation of fatty acid methyl ether was conducted using coiled glass, column (30 m x 320 mm "diameter" x 0.25 mm "film thickness"). The column oven temperature was programmed at 8°C/min. from 70 to 270°C, then isothermally at 270°C for 10 minutes with nitrogen at 30 ml/min.

Standard fatty acid methyl / esters mentioned before were used as standard authentic sample for identification of fatty acids. The amount of each individual fatty acid in the oil under investigation was determined according to [15] and relative percentages were calculated from the following equation:

$$\text{Fatty acid \%} = \frac{\text{Area under each peak}}{\text{Area under all peak}} \times 100$$

Statistical Analysis: The analysis of variance procedure of split-plot design according to [16].After testing the homogeneity of the error according to Bartlett's test, combined analysis for both seasons were done. treatments means were compared using [17] test at 5% of probability.

Table 1: Mechanical and chemical analysis of experimental soil

Mechanical analysis	Chemical analysis
Sand % 91.2	Organic matter% 0.3
Slit % 4.0	E.C mmhos/cm^3 0.3
Clay % 4.8	pH 7.4
$CaCO_3$ 1.3	Soluble N ppm 7.7
Soil Texture Sandy	Available P ppm 2.9
	Exchange K ppm 19.8

RESULTS AND DISCUSSION

Effect of Canola Varieties: Data in Table (2) indicated that the Serw 4 variety surpassed the other two varieties (Serw6 and Pactol)in all studied characters and gave the highest values of plant height (cm), no. of pods/plant, no. of seeds/pod, seed yield/plant(gm), weight of 1000seed(gm), seed yield(kg/fed), [oil%(42.19%) and oil yield(410.93kg/fed)]

Pactol variety gave the lowest values or all studied characters. On the other hand, the oil yield was significantly different among canola varieties under study. The highest oil yield (410.93kg/fed) was produced by Serw 4, while the lowest (348.95kg/fed) bypactol. Such increase in oil yield could be attributed to the superiority of Serw 4 in growth and yield characters than the other two varieties to other canola varieties. These results are in harmony with those obtained by several investigators [18-25].

Effect of Foliar Application with ZnO: Data in table (2) showed that foliar treatment with ZnO NPs significantly affected all the studied characters. The highest values for plant height(146.85cm), no. of pods/plant (207.380), no. of seeds/pod(21.51), seed yield/plant(13.70 g), weight of 1000 seed (3.05g), seed yield (1030 kg/fed), oil (42.32%) and oil yield(435.90 kg/fed). However the control reported the lowest values for all studied characters. It seems that the use of Zn nano-particles increased pods and seed weight which reflected on total yield. Such increase could be attributed the vital role of Zn due to its role in metabolic processes [26-28]. Also, [27] emphasized the beneficial effects of nanoparticles at lower doses in peanut. Similarly, [29, 30] came to similar conclusion.

The Interaction Effect of Canola Varieties and Foliar Application with ZnO: The obtained data presented in Table (3) indicated that there were significant differences in all the studied characters due to the interaction between canola cultivars and the combinations of ZnO mineral fertilizers and ZnO nanoparticle. The interaction between Serw 4 and ZnO nanoparticle produced the highest values for plant height(155.70cm), no. of pods/plant (221.81), no. of seeds/pod (22.22), seed yield/plant (15.35 g), weight of 1000 seed (3.12g), seed yield (1127 kg/fed), oil (42.58%) and oil yield (425.88kg/fed). However the interaction between Pactol, ZnO mineral fertilizer and ZnO nanop article produced the lowest values for all the studied characters. The positive role of the interaction effect of canola varieties with foliar application with ZnO is evident for other crops and explained by [31, 32]. In this respect [33] mentioned that using this technology, we can increase the efficiency of micro- as well as macronutrients of plants.

Fatty Acid Composition: Data presented in (Fig 1) illustrated that all canola genotypes and foliar application with ZnO were different in their fatty acids contents. In general, a slight differences in saturated fatty acids between canola varieties and foliar application with ZnO. Serw-4 variety contained more amount of Palmitic acids (4.99 %) with (ZnO 20ppm Nps) followed by Serw-6 and Pactol. However another saturated fatty acids (Stearic, Arachidic and Behenic acid) not effect by foliar application with ZnO. Serw-4 gives the highest values for (Stearic and Behenic acids)(2.14% and 1.56%) followed by Pactol and Serw-6. while Serw-6 was the highest in Arachidic acid (3.36%) than Pactol (3.18%) variety. In this concern that, [34] reported that the majority of the variation in Palmitic (C16:0) due to the genotype main effect. Concerning, the unsaturated fatty acids Oleic, Linoleic, as well as, Linolenic acids were increased by using foliar application ZnO (20ppmNPs) while Erucic acid was decreased by using foliar application ZnO (Fig. 2). Pactol and Serw-6 varieties produced more amount of Oleic acid (61.18 and 60.49%), respectively when fertilized by foliar application with ZnO (20ppmNPs). However the lowest value of Oleic acid (57.22) was recorded by Serw-4 variety without foliar application. The interaction between Serw-4 variety x ZnO(20ppmNPs) recorded the highest value of Linoleic acid (22.17%), while the lowest value of Linoleic acid (19.75) with Serw-6 variety without foliar application. Also, data in Table (4) showed that, Linolenic acid was the highest (9.77) with Serw-4 and Serw-6 treated

Table 2: Effect of variety and Zinc oxide application forms on canola yield and its components (Means of two seasons 2018/2019 and 2019/2020)

Treatment	Plant height (cm/plan)	No. of pods /plant	No. of seeds / pod	Seed yield /plant g)	Weight of1000 seed(g)	Seed yield (kg/fed.)	Oil (%)	Oil yield (kg/fed.)
Varieties								
Serw 4	150.34a	210.81a	21.64a	14.02a	3.06a	974a	42.19a	410.93a
Serw 6	139.71b	196.65b	20.86b	12.27b	3.04a	867b	41.80b	362.41b
Pactol	133.54c	190.61c	20.60c	12.07c	2.96b	835c	41.79b	348.95c
Zn Treatments								
Control	135.50c	195.45c	20.48c	11.86c	2.98b	752c	41.93b	315.31c
ZnO (40ppm)	141.25b	199.50b	21.12b	12.80b	3.04a	894b	41.53c	371.28b
ZnO (20ppmNPs)	146.85a	207.38a	21.51a	13.70a	3.05a	1030a	42.32a	435.90a

Table 3: Interaction effect of variety and Zinc oxide application forms on canola yield and its components (Means of two seasons 2018/2019 and 2019/2020).

Variety	Treatment	Plant height (cm/plant)	No.of pods /plant	No. of seeds / pod	Seed yield /plant (g)	Weight of 1000 seed(g)	Seed yield (kg /fed.)	Oil (%)	Oil yield (kg /fed.)
Serw 4	control	144.55d	205.57c	20.98d	12.70d	2.99bcd	800d	42.25ab	338.00d
	ZnO(40ppm)	150.77b	211.36b	21.72b	14.00b	3.07ab	991b	41.73bc	413.54b
	ZnO (20ppmNPs)	155.70a	221.81a	22.22a	15.35a	3.12a	1127a	42.58a	425.88a
Serw6	Control	134.57f	193.20f	20.30f	11.52g	2.93d	758e	41.62bc	315.48e
	ZnO (40ppm)	139.01e	197.40e	20.93d	12.34e	2.98bcd	855c	41.22c	352.43c
	ZnO (20ppmNPs)	145.55c	202.95d	21.34c	12.94c	2.98cd	987b	42.54a	365.87b
Pactol	Control	127.38g	187.56h	20.14f	11.37h	3.00bcd	696f	41.92ab	291.76f
	ZnO (40ppm)	133.96f	189.74g	20.69e	12.07f	3.06abc	835c	41.63bc	347.61cd
	ZnO (20ppmNPs)	139.28e	197.39e	20.98d	12.79d	3.06bcd	974b	41.83bc	356.42b

Table 4: Effect of application Zinc oxide forms on fatty acid composition of some canola varieties in 2019/2020 season

		Fatty acids (%)								
		Saturated				Unsaturated				
Treatment		Palmitic (16:0)	Stearic (18:0)	Arachidic (20:0)	Behenic (22:0)	Oleic (18:1)	Linoleic (18:2)	Linolenic (18:3)	Erucic (22:1)	*Erucic (22:1) Reduction (%)
Serw 4	Control	4.56	2.14	3.17	1.56	57.22	20.55	8.51	2.29	-
	ZnO (40ppm)	4.80	1.53	2.17	1.08	58.21	21.39	9.21	1.62	29.3
	ZnO (20ppmNPs)	4.99	0.89	0.81	0.81	59.66	22.17	9.77	0.92	69.8
Serw6	Control	4.17	1.99	3.36	1.51	58.56	19.75	8.42	2.26	-
	ZnO (40ppm)	4.56	1.30	2.16	1.16	59.65	20.52	8.81	1.86	18.7
	ZnO (20ppmNPs)	4.83	0.90	0.95	0.85	60.49	21.04	9.77	1.19	47.4
Pactol	Control	3.59	2.00	3.18	1.51	59.68	19.92	8.26	1.87	-
	ZnO (40ppm)	4.03	1.33	2.08	1.19	60.23	20.71	8.94	1.51	19.3
	ZnO (20ppmNPs)	4.38	0.86	0.96	0.90	61.18	21.22	9.52	0.99	47.1

*Relative to the control treatment in each variety

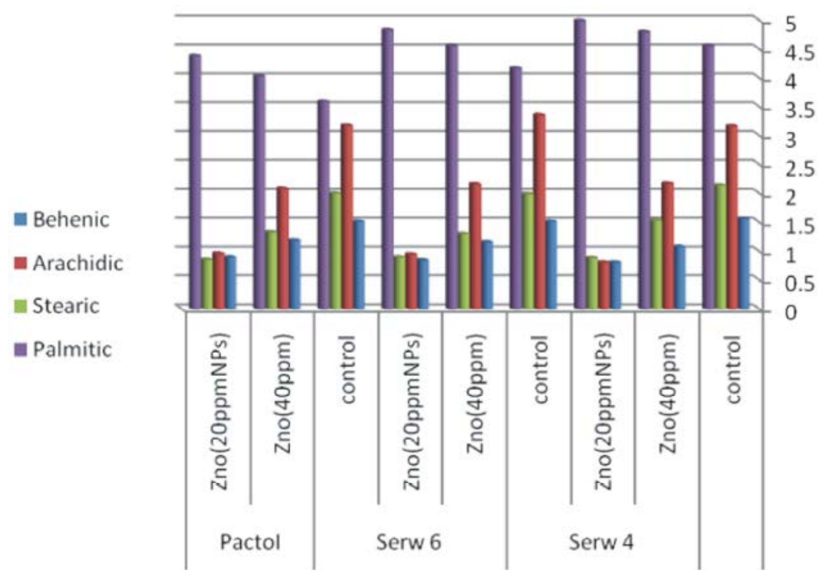

Fig. 1: The interaction effect of varieties and foliar application of ZnO forms on saturated fatty acids

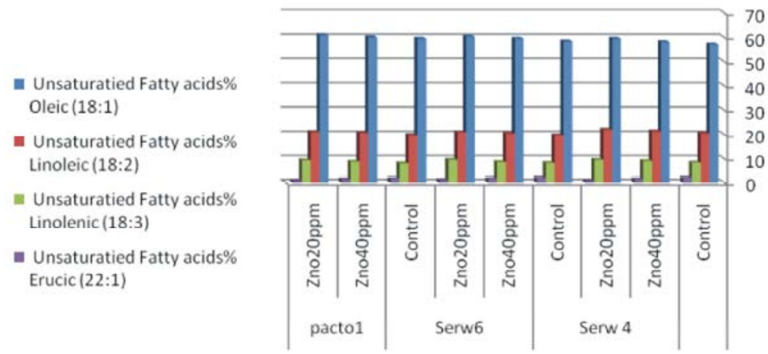

Fig. 2: The interaction effect of varieties and foliar application of ZnO forms on unsaturatedfatty acids

with ZnO (20ppmNPs), while the lowest content of Linolenic acid (8.26%) was recorded by Pactol without foliar application. On contrast, in all canola varieties increasing by using foliar application with ZnO gradually decreased the Erucic acid, the lowest content of Erucic acid (0.92 and 0.99%) was recorded with Serw-4 and Pactol when foliar applied ZnO at (20ppmNPs) was sprayed (Table 4). The beneficial role of the Zn application to canola varieties reflected on fatty acid profile conistituents through polyunsaturated fatty acids Linoleic and Linolenic as well as the reduction of erucic acid . This magnitude was confirmed by [35, 36].

Erucic Acid Reduction: Since the varieties used in this experiment are not 0-0 type it is very important to evaluate the Erucic acid content due to the human direct consumption in dietary. It is clear from (Table 4) that canola varieties differed in their content of erucic acid in oil. The lowest content was recorded by Pactol variety while the other two varieties were similar in their content. Generally, foliar application of Zn forms resulted in erucic acid reduction and reached to <1% for Pactol variety compared to the other two varieties. Application of ZnO (20ppmNPs) caused substantial reduction in erucic acid and the reduction was more pronounced than Zn O (40ppm) only. Such reduction may be attributed to the vital role of Zn nano particles in fatty acid formation as well as the dilution effect resulted from the increase in oil production (Table3). Similar results were obtained by [10]. [29]stated that, ZnO NPs promoted the root and shoot length and root and shoot biomass .

CONCLUSION

It could be concluded from this study that foliar fertilization with ZnO forms resulted in seed and oil yield. Application of ZnO(20ppmNPs) effect on canola yield and quality was more pronounced and favored under sandy soil conditions.

REFERENCES

1. FAOSTAT. FAOSTAT Data. 2016. Available online: www.faostat.fao.org (accessed on 14 March 2018).
2. Friedt, W. and R. Snowdon, 2009. Oilseed rape. In Oil Crops; Volmann, J., Rajcan, I., Eds.; Springer: New York, NY, USA, pp: 91126.
3. Salunkhe, D.K., J.K. Chavan, R.N. Adsule and S.S. Kadam, 1992. Sunflower. In World Oilseeds, Chemistry, Technology and Utilization; Salunkhe, D.K., Chavan, J.K., Adsule, R.N., Kadam, S.S., Eds.; Van Nostrand Reinhold: New York, NY, USA, pp: 97139.
4. Rodrigues, I.M., J. Coelho, M. Graça and V.S. Carvalho, 2012. Isolation and valorization of vegetable proteins from oilseed plants: Methods, limitations and potential. J. Food Eng., 109: 337346.
5. Turinek, M., M. Bavec, M. Repi¡c, M. Turinek, A. Urbanek-Krajnc, C. Möllers, A Tres and F. Bavec, 2017. Effects of intensive and alternative production systems on the technological and quality parameters of rapeseed seed (*Brassica napus* L. 'Siska'). J. Sci. Food Agric., 97: 26472656. [CrossRef].
6. Takashima, N.E., D.P. Rondanini, L.E. Puhl and D.L. Miralles, 2013. Environmental factors affecting yield variability in spring and winter rapeseed genotypes cultivated in the southeastern Argentine Pampas. Eur. J. Agron., 48: 88100. [CrossRef]
7. Ana Marjanovi´c-Jeromela, Sreten Terzi´c and Mirjana Jankulovska, 2019. Miroslav Zori´c Dissection of Year Related Climatic Variables and Their Effect on Winter Rapeseed (*Brassica napus* L.) Development and Yield. Agronomy, 9: 517; doi: 10.3390/agronomy9090517.

8. Encalada, M.A., K.M. Hoyos, S. Rehecho, I. Berasategi, M.G.I. De Ciriano, D. Ansorena, *et al*., 2011. Anti-proliferative effect of *Melissa officinalis* on human colon cancer cell line. Plant. Foods Hum Nutr.2011;66:328334.https://doi.org/10.1007/s11130-011-0256-y
9. Rastogi, A., M. Zivcak, O. Sytar, H.M. Kalaji, X. He, S. Mbarki, *et al*., 2017. Impact of metal and metal oxide nanoparticles on plant: a critical review. Front Chem., 5:78.https://doi.org/ 10.3389/fchem.2017.00078.
10. Mukherjee, A., Y. Sun, E. Morelius, C. Tamez, S. Bandyopadhyay, G. Niu, *et al*., 2016. Differential toxicity of bare and hybrid ZnO nanoparticles in green pea (*Pisum sativum* L.): a life cycle study. Front Plant Sci., 6:1242. https://doi.org/10.3389/fpls.2015.01242.
11. Subbaiah, L.V., T.N.V.K.V. Prasad, T.G. Krishna, P. Sudhakar, B.R. Reddy and T. Pradeep, 2016. Novel effects of nanoparticulate delivery of zinc on growth, productivity and zinc biofortification in maize (*Zea mays* L.). J Agric Food Chem., 64: 37783788. https://doi.org/10.1021/acs.jafc.6b00838
12. Venkatachalam, P., M. Jayaraj, R. Manikandan, N. Geetha, E.R. Rene, N. Sharma, *et al*., 2017. Zinc oxide nanoparticles (ZnONPs) alleviate heavy metal-induced toxicity in *Leucaena leucocephala* seedlings: a physiochemical analysis. Plant Physiol Biochem., 110: 59 69. https://doi.org/10.1016/j.plaphy.2016.08.022.
13. Jackson, M.L., 1982. Soil Chemical Analysis, Prentice-Hall, Inc. Analytical Chemists, Official Methods of Analysis, 11th Ed., Washington, D.C.
14. Stahl, E., 1967: Thin Layer Chromatography. A Laboratory Handbook. E.d. Springer Verloag Berline pp: 359 Heidel Berg, New York.
15. Nelson, J.P., A.J. Millum and H.D. Fister, 1970. Gas chromatographic determination of tocopherols and sterols in soya studges and residues an improved methods. J. Am. Oil Chem. Sci., 47: 259-261.
16. Snedecor, G.M. and W.G. Cochran, 1990. Statistical Methods, 8th ed. Iowa State Univ., Pre, Anes, Iowa, U.S.A.
17. Duncan, D.B., 1955. Multiple Range and Multiple F-tests. Biometrics, 11: 1-42
18. Hassan, K.H. and M.S. El-Hakeem, 1996. Response of some rape seed cultivars to nitrogen rates and plant density under saline condition at Siwa Oasis. Ann. Agric. Sci. Cairo, 41(1): 229242.
19. Said, E.M. and M.M. Keshta, 1999. Response of some canola (*Brassica napus* L.) cultivars to different nitrogen fertilization levels. J. Agric. Sci. Mansoura Univ., 24(4): 16891697.
20. Sharief, A.E. and M.M. Keshta, 2000. Response of some canola cultivars (*Brassica napus* L.) to different sources and levels of nitrogen fertilizer in soil affected by salinity. Zagazig J. Agric. Res., 27: 603616.
21. Leilah, A.A., S.A. Al-Khateeb, S.S. Al-Thabet and Al-K.M. Barrak, 2003. Influence of sowing dates and nitrogen fertilizer on growth and yield of canola. Zagazig. J. Agric. Res., 30(3): 591605.
22. Asfour, M.M., 2006. Genetical and Physiological Studies on Canola. Ph.D. Thesis, Fac. Agric., Minufiya, Univ. Egypt.
23. Mekki, B.B., A. Faida Sharara and Kowthar G. El-Rokiek, 2010. Effect of weed control treatments onyield and seed quality of some canola cultivars and associated weeds in newly reclaimed sandysoils. American-Eurasian J. Agric. & Environ. Sci., 7(2): 202-209.
24. El-Habbasha, S.F. and M.S. Abd El-Salam, 2201). Response of two canola varieties (*Brassica napus* L.)To nitrogen fertilizer levels and zinc foliar application. Int. J. Acad. Res., 2(2): 60-66.
25. Mekki, B.B., 2013. Yield and quality traits of some canola varieties grown in newly reclaimed sandy soils in Egypt. World Applied Sciences Journal, 25(2): 258-263.
26. Franklin, N.M., N.J. Rogers, S.C. Apte, G.E. Batley, G.E. Gadd and P.S. Casey, 2007. "Comparative toxicity of nanoparticulate ZnO, bulk ZnO and ZnCl2 to a freshwater microalga (*Pseudokirchneriella subcapitata*): the importance of particle solubility," Environmental Science & Technology, 41(24): 8484-8490.
27. Prasad, T.N., P. Sudhakar, Y. Sreenivasulu, *et al*., 2012. "Effect of nano scale zinc oxide particles on the germination, growth and yield of peanut, " Journal of Plant Nutrition, 35(6): 905927.
28. Naderi, M.R. and A. Abedi, 2012. Application of nanotechnology in agriculture and refinement of environmental pollutants. J. Nanotechnology, 11(1): 18-26.
29. Mahajan, P., S.K. Dhoke and A.S. Khanna, 2011. Effect of nano- ZnO particle suspension on growth of mung (*Vigna radiata*) and gram (*Cicer arietinum*) seedlings using plant agar method. J. Nanotechnol. 2011: 17. doi:10.1155/2011/696535.

30. Manzo, S., A. Rocco, R. Carotenuto, P.F. De Luca, M. Miglietta and G., Rametta, 2011. Investigation of ZnO nanoparticles' ecotoxicological effects towards different soil organisms. Environ. Sci. Pollut. Res., 18: 756763.
31. Raliya, R. and J.C. Tarafdar, 2013. ZnO nanoparticle biosynthesis and its effect on phosphorous-mobilizing enzyme secretion and gum contents in cluster bean (*Cyamopsis tetragonoloba* L.). Agric Res., 2: 4857.
32. Burman, U., M. Saini and Praveen-Kumar, 2013. Effect of zinc oxide nanoparticles on growth and antioxidant system of chickpea seedlings. Toxicol. Environ. Chem., 95(4): 605612.
33. Tripathi, D.K., S. Singh, V.P. Singh, S.M. Prasad, N.K. Dubey and D.K. Chauhan, 2017. Silicon nanoparticles more effectively alleviated UV-B stress than silicon in wheat (*Triticum aestivum*) seedlings. Plant Physiol. Biochem., 110: 7081.
34. McCartney, C.A., R. Scarth, P.B.E. McVetty and J.K. Daun, 2004. Genotypic and environmental effects on fatty acid concentration of canola grown in Manitoba. Can. J. Plant Sci., 84: 749-758.
35. Getinet, A., G. Rakow, J.P. Raney and R.K. Downey, 1997. The inheritance of erucic acid content in Ethiopian mustard. Can. J. Plant Sci., 77: 33-41.
36. Rahman, M.H., 2002. Fatty acid composition of resynthesized *Brassica napus*and trigenomic *Brassica* void of genes for erucic acid in their Agenomes. Plant Breed., 121: 357-359.