The Results of a Pre-study to Determine The Effects of Zinc and Iron Foliar Fertilizer on Canola (*Brassica napus* L.)

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Abstract: Increasing canola yield, a winter oil crop, is important for its cultivation in the product pattern of the Mediterranean climate zone. Therefore, a study was planned to determine the impact of foliar application zinc (Zn), iron (Fe) and Zn + Fe combination on the yield and quality of canola. The experiment was arranged in a Randomized Complete Block Design with four replications. Zinc (3.0% v/v), iron (7.5% w/w), and their combination were foliar sprayed at rosette and flowering stages. The highest number of siliques per plant, number of seeds per silique, seed index, and seed yield were recorded in the Fe application. Zn + Fe combination significantly increased the oil and protein content, whereas Zn application exhibited higher oil and protein yield performance. It was concluded that using iron and zinc separately regarding yield and quality is economically beneficial.

Keywords: Canola, iron (Fe), oil and protein quality, yield components, zinc (Zn)

Kanolada (*Brassica napus* L.) Çinko ve Demir İçerikli Yaprak Gübrelerinin Etkisi Üzerine Bir Ön Çalışma

Öz: *Kışlık bir yağ bitkisi olan kanolanın veriminin artırılması, Akdeniz iklim bölgesinin ürün deseninde yetiştirilmesi yönünden önemlidir. Bu nedenle, çinko (Zn), demir (Fe) ve Zn + Fe kombinasyonunun yapraktan uygulanmasının kanolanın verim ve kalitesi üzerindeki etkisini belirlemek için bir çalışma planlanmıştır. Deneme Tesadüf Blokları Deneme Desenine göre dört tekrarlamalı olarak düzenlenmiştir. Çinko (%3,0 v/v) ve demir (%7,5 w/w) ve bunların kombinasyonu rozet ve çiçeklenme aşamalarında yapraktan uygulanmıştır. En yüksek bitkide harnup sayısı, harnupta tohum sayısı, tohum indeksi ve tohum verimi Fe uygulamasında kaydedilmiştir. Zn + Fe kombinasyonu yağ ve protein içeriğini önemli ölçüde artırırken, Zn uygulaması yağ ve protein verimi için daha yüksek performans sergilemiştir. Çalışma sonucunda demir ve çinkonun ayrı ayrı kullanılmasının hem verim hem de kalite açısından ekonomik olarak faydalı olduğu sonucuna varılmıştır.*

Anahtar kelimeler: *Çinko (Zn), demir (Fe), kanola, verim bileşenleri, yağ ve protein kalitesi*

INTRODUCTION

Canola is the world's most cultivated and consumed oil crop after soybean (Anonymous, 2020). Canola cultivation area and production worldwide are approximately 36.1 million ha and 74.0 million tons, respectively (Anonymous, 2023). In Türkiye, 188 thousand tons of canola are produced on approximately 52.5 thousand ha, and the average yield is 3430 kg ha^{-1} (TUIK, 2020). In many plant cultivations, it has been reported that the application of microelements in the form of foliar fertilizers increases the effectiveness of macro elements and that foliar sprays are more effective than soil application due to adverse soil properties such alkalinity (Arif et al., 2006; Narimani et al., 2010; Zayed et al., 2011). Oil crops such as canola are highly susceptible to Fe and Zn deficiency, which manifests as reduced leaf area, chlorosis and dwarfism (Vanisha et al., 2013; Sanwal et al., 2016). Especially in many alkaline and calcareous agricultural areas, zinc deficiency occurs, although the results of soil analyses show that it is sufficient (Hacısalihoğlu, 2020). Moreover, Zn interacts negatively with iron (Fe) due to the interference of Fe in the absorption of Zn on root surfaces in plants (Prasad et al., 2016).

In another study, the highest grain yield, biological yield, oil yield and oil content were recorded in Fe+Zn foliar application (Zakerin et al., 2014). Similarly, foliar spray of Fe+Zn+Mg combination increased 1000-kernel weight, grain yield, oil content and harvest index, according to the study conducted by Bahrani and Pourreza (2014). Some researchers found that soil Zn application significantly affected seed yield but increased oil content insignificantly (Aytaç et al., 2016). Foliar application of Zn and Fe together with urea increased Zn and Fe content in grain and stover, and grain and biological yield were significantly higher (Dhaliwal et al., 2021). In dose experiments with Zn, a foliar spray of 5 g/L exhibited the highest oil and seed yield, yield components, chlorophyll content and relative water content in the leaf (Afsahi et al., 2020).

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Also, it was found that Zn and Fe application was more effective on yield and increased the protein content of the seed, especially in cultivation under arid conditions in rapeseed (Pourgholam et al., 2013) and sunflower (Yadavi and Khadem Hamzeh, 2018). Considering that in the coastal zone of the Aegean Region, the information on the impact of Fe and Zn combined application on yield attributes and quality characteristics in rapeseed is scarce, the aim of this study was to assess the variability of agronomical and quality parameters in winter rapeseed affected by Fe and Zn foliar sprays in strong alkaline and calcareous soil.

MATERIAL AND METHODS

The study was conducted in the experimental field of Adnan Menderes University Faculty of Agriculture Research and Application Farm (37°45'22'' N; 27°44'52'' E). The canola cultivar, DK Exception (*Brassica napus* L.), was grown in the 2021-2022 winter growing season. The seeds were sown on 22 November 2021, according to the Randomized Complete Block Design with four replications. The factors examined in the study were the foliar application of iron and zinc and their combination with the control. Each plot consisted of 4 rows with a length of 8.75 m. The distance between rows was 20 cm, and the distance between rows was 5 cm. 11.0 kg ha^{-1} seed was used.

The meteorological data of Aydın province for a long-term period show that the lowest average minimum temperature was in January at -1.95 °C, and the highest average temperature was in June at 39.82 °C. The highest average precipitation was 107.88 mm in January, and the lowest was 12.71 mm in June. The highest long-term average humidity was 73.79 in December, and the lowest was 50.07 in June. When the climate data of the Koçarlı district of Aydın province in 2021-2022 were investigated, the lowest average minimum temperature was recorded in January at -4.60 °C and the highest average temperature was recorded in May at 36.60 °C. The maximum amount of precipitation was 155.90 mm in December. The highest average humidity was 84.60 in December.

The soils of the experiment area were loamy, salt-free, calcareous and strongly alkaline, and the amount of organic matter was low. Phosphorus and potassium contents were found to be insufficient. Indeed, the soil of the experimental area contains a very high level of iron and sufficient zinc (Mert-Akça and Atatanır, 2020).

Each plot was fertilized with 500 kg ha^{-1} of compose fertilizer (15:15:15) as basal fertilizer and 200 kg ha^{-1} of ammonium sulphate as top dressing at the stem elongation stage. Foliar fertilizer containing zinc (3% v/v) was supplied from Agro Flora® and iron (6.0% w/w) from a commercial fertilizer named RedFER®.The usage dose of both foliar fertilizers was 300 cc $da^{-1,}$ and 150 cc 100 L^{-1} of spreader-adhesive was applied. The 3rd application factor is the combined use of these two fertilizers. All three treatments were applied at two different periods, rosette and flowering. Control plots were sprayed with only 40 L da^{-1} of water. The experimental area was hoed once by hand for weed control. Plants were harvested on 6 June 2023.

Seed yield (Yield; kg ha^{-1}), plant height (PH; cm), the number of siliques per plant (NS/P), the number of seeds per silique (NS/S), the number of lateral branches per plant (NLB/P) and seed index (SI; g) were measured. The protein and oil content (%) of the seed by NIRS (near-infrared spectroscopy) were determined. Protein and oil yield (kg ha^{-1}) were calculated based on protein content, oil content and seed yield. Data were analyzed according to Randomized Complete Block Design using the JMP® statistical package program (JMP, 2018). For each trait, the means were compared using the LSD method at the 5% significance level (Steel and Torrie, 1980). A simple economic cost for 2023 was estimated, considering the selling price of the foliar fertilizers used and the cost of foliar fertilization.

RESULTS AND DISCUSSION

Variance analysis results are summarized in Table 1. The effects of foliar spray on NS/P, NS/S, seed yield, protein and oil content were significant. The difference between the treatments showed that Fe and Zn were sufficient in the soil where the experiment was carried out, but in calcareous and alkaline soils, the treatments may significantly affect yield and yield components. This finding is in agreement with the results reported by Arif et al. (2006), Narimani et al. (2010) and Zayed et al. (2011). Non-significant differences for the seed index indicated that different yield values resulted from NS/P and NS/S rather than the seed index.

Table 1. The results of the variance analysis of the effects of treatments on yield and quality parameters**.**

	Treatment (df=3)	**Error (df=9)**
PH	61.34	44.21
NLB/P	0.86	0.40
NS/P	8292.86**	423.73
NS/S	6.22*	1.14
SI	0.28	0.18
Yield	15960.43**	700.82
Oil Content	46.30**	0.47
Protein Content	13.22**	0.31

*, ** significant at the 0.05 and 0.01 probability levels, respectively

PH; Plant height, NLB/P; the number of lateral branches per plant, NS/P; the number of siliques per plant, NS/S; the number of seeds per silique, SI; seed index.

Foliar sprays of Fe significantly and positively affected the NS/P, NS/S and yield. The effect of Zn on yield and NS/S was found to be statistically similar to Fe, while Zn followed Fe application in terms of NS/P. Despite all these findings, the lowest NS/P was recorded in plots where Fe and Zn were applied together. NS/S and yield of these plots were higher than the control, whereas the values were lower than those of Fe and Zn applied separately. Many authors have stated that Zn+Fe combination treatment increased the yield and yield components in wheat (Habib, 2009; Sultana et al., 2018), soybean Heidarian et al. (2011), psyllium (Behrouznajhad et al. (2011) and common bean (Yousefi1 et al., 2023). On the contrary, it was reported that excess Zn nutrient element has an antagonistic effect with some microelements such as Fe, Mn and Cu under normal conditions (Aydın et al., 2005). Supporting this hypothesis, Bybordi and Mamedov (2010) determined that Fe, Zn and Fe+Zn combined treatments have similar yields in canola. Moreover, it was emphasized that the antagonism between iron and zinc may differ between plants depending on ferric-chelate reductase activity (Rietra et al., 2017). In our study, the effects of iron and zinc applications, both separately and together, were found to be more pronounced on oil and protein content. The combined treatment increased the oil content by 19.7 % and protein content by 23.1 % compared to the control. Zn and Fe applications followed the combined application for both quality parameters, respectively. According to the control, it is clearly seen that both separate and combined Fe and Zn applications positively affected the quality characteristics.

Bybordi and Mamedov (2010) reported that Fe, Zn and Fe+Zn combinations had similar oil content performances, whereas combined treatment had higher protein content than Zn and Fe, respectively. It has been emphasized in many studies that the use of these nutrients increases protein content by supporting amino acid synthesis (Zakaria et al., 2001; Kaya and Higgs, 2002).

Table 2. Comparison of means on yield, yield components and quality parameters of canola

	Control	Fe	Zn	Fe+Zn	LSD
PH (cm)	160.10	156.93	151.08	153.70	-
NLB/P	5.73	5.90	6.58	5.50	-
NS/P	256.37 b	321.64 a	282.97 b	213.37 c	32.93
NS/S	22.69 b	25.65 a	24.81 a	24.28 ab	1.71
SI (g)	3.48	4.02	3.54	3.47	-
Seed Yield (kg ha^{-1})	2900.20 c	4188.80 a	4171.50 a	3375.80 b	423.50
Oil Content (%)	40.10 d	43.13 c	45.73 b	48.00 a	1.09
Protein Content (%)	16.78 c	16.93 c	18.73 b	20.65 a	0.89
Oil yield (kg ha^{-1})	1163.00	1806.60	1907.60	1620.40	-
Protein Yield (kg ha^{-1})	486.70	709.20	781.30	697.10	-

PH; Plant height, NLB/P; the number of lateral branches per plant, NS/P; the number of siliques per plant, NS/S; the number of seeds per silique, SI; seed index.

The applications and the yield difference obtained in return were evaluated as the essential cost. The cost calculation was based on conditions where these foliar fertilizers were not used. Based on 2023 prices, the litre price of Agro Flora™ ZnP foliar fertilizer is 120 TL, and the 5 kg package price of RedFER™ fertilizer is 660 TL. The cost per hectare is 240 TL for Agro Flora ZnP and 800 TL for RedFer. When 6.0 L ha^{-1} fuel was used for the sprayer, a cost of approximately 280 TL was found for two applications. The yield difference compared to the control for both Zn and Fe was 1280 kg ha^{-1}. When the current canola price is approximately 130 TL kg^{-1}, the total income difference was calculated as 16640 TL ha^{-1}. Thus, the net profit for Zn was calculated as 16120 TL ha^{-1} and the net profit for Fe as 15560 TL ha^{-1}. It is seen that foliar fertilizer applications are economically advantageous in both applications.

CONCLUSION

The primary result of the study was that iron and zinc foliar applications significantly increased the number of siliques per plant and seed yield. The combination of Iron and Zinc increased the quality traits of protein and oil content. Considering the application costs and yield increase, it can be said that foliar fertilization will be profitable. The recommendations obtained as a result of the study could be summarized as follows: (1) future studies should be continued in different and more years, (2) dose studies of the nutrients to be used together and separately should be carried out, and (3) in addition, the number of plant nutrients to be used in combination should be increased.

REFERENCES

Afsahi K, Nazari M, Omidi H, Shekari F, Bostani AA (2020) The Effects of Different Methods of Zinc Application on Canola Seed Yield and Oil Content. Journal of Plant Nutrition 43(8):1070-1079. https://doi.org/10.1080/01904167.2020.1724299

Anonymous (2020) World Supply and Use of Oilseeds and Oilseed Products. In Oil Crops Yearbook. USDA Economic Research Service.

https://www.ers.usda.gov/data-products/oil-crops-yearbook/ Date of access: 08.09.2023

Anonymous (2023) World Agricultural Production: World Rapeseed Production 2022/2023. http://www.worldagriculturalproduction.com/crops/rapeseed.aspx Date of access: 10.09.2023

Arif M, Chohan MA, Ali S, Gul R, Khan S (2006) Response of Wheat to Foliar Application of Nutrients. Journal of Agricultural and Biological Science 1(4):256-259.

Aydın Ş, Çoban H, Yağmur B, Mordoğan N (2005) The Effect of Foliar Zn Applications on the Nutrient Element Contents of Leaf in Vineyard. Journal of Agriculture Faculty of Ege University 42(2):131-142.

Aytaç Z, Gülmezoğlu N, Kutlu İ, Tolay İ (2016) The Effect of Zinc Application on Yield and Oil Content of Rapeseed (*Brassica napus* ssp. *oleifera* L.) Cultivars. Journal of Soil Water 5(1):29-36.

Bahrani A, Pourreza J (2014) Effects of Micronutrients on Seed Yield and Oil Content of *Brassica napus* L. cv. Talayeh. Bangladesh Journal of Botany 43(2):231-233.

Behrouznajhad S, Zehtab-Salmasi S (2011) Effects of Foliar Application of Fe and Zn on Seed Yield and Mucilage Content of Psyllium (*Plantago psyllium*) at Different Stages of Maturity. Journal of Plant Physiology and Breeding 1(2):21-27.

Bybordi A, Mamedov G (2010) Evaluation of Application Methods Efficiency of Zinc and Iron for Canola (*Brassica napus* L.). Notulae Scientia Biologicae 2(1):94-103.

Dhaliwal SS, Sharma V, Shukla AK, Verma V, Sandhu PS, Behera SK, Singh P, Kaur J, Singh H, Abdel-Hafez SH, Gaber A (2021) Interactive Effects of Foliar Application of Zinc, Iron and Nitrogen on Productivity and Nutritional Quality of Indian Mustard (*Brassica juncea* L.). Agronomy 11(11):2333. https://doi.org/10.3390/agronomy11112333

Habib M (2009) Effect of Foliar Application of Zn and Fe on Wheat Yield and Quality. African Journal of Biotechnology 8(24):6795-6798.

Hacisalihoglu G (2020) Zinc (Zn): The Last Nutrient in the Alphabet and Shedding Light on Zn Efficiency for the Future of Crop Production under Suboptimal Zn. Plants 9(11):1471. https://doi.org/10.3390/plants9111471

Heidarian AR, Kord H, Mostafavi K, Lak AP, Mashhadi FA (2011) Investigating Fe and Zn Foliar Application on Yield and Its Components of Soybean (*Glycine max* (L) Merr.) at Different Growth Stages. Journal of Agricultural Biotechnology and Sustainable Development 3(9):189.

JMP (2018) SAS Institute Inc. 2018. JMP Statistical Software, Version 14. Cary, USA.

Kaya C, Higgs D (2002) Response of Tomato (*Lycopersicon esculentum* L.) Cultivars to Foliar Application of Zinc When Grown in Sand Culture at Low Zinc. Scientia Horticulturae 93(1):53-64. https://doi.org/10.1016/S0304-4238(01)00310-7

Mert Akça, H, Atatanır L (2020) The Revision of Soil Survey of Research and Application Farm Lands of Agriculture Faculty of Aydın Adnan Menderes University. Journal of Soil Science and Plant Nutrition 8(2):77-85. https://doi.org/10.33409/tbbbd.783664.

Narimani H, Rahimi MM, Ahmadikhah A, Vaezi B (2010) Study on the Effects of Foliar Spray of Micronutrient on Yield and Yield Components of Durum Wheat. Archives of Applied Science Research 2(6):168-176.

Pourgholam M, Nemati N, Oveysi M (2013) Effect of Zinc and Iron under the Influence of Drought on Prolin, Protein and Nitrogen Leaf of Rapeseed (*Brassica napus*). Annals of Biological Research 4(7):200-203.

Prasad R, Shivay YS, Kumar D (2016) Interactions of Zinc with Other Nutrients in Soils and Plants-A Review. Indian Journal of Fertilisers 12(5):16-26.

Rietra, R. P., Heinen, M., Dimkpa, C. O., & Bindraban, P. S. (2017). Effects of nutrient antagonism and synergism on yield and fertilizer use efficiency. Communications in soil science and plant analysis, 48(16), 1895-1920.

Sanwal SK, Mann A, Sharma PC, Krishnamurthy SL, Kumar A, Kumar A (2016) Quality Seed Production, Processing and Certification of Selected Field and Vegetable Crops in Salt Affected Areas. Training Manual; ICAR, Central Soil Salinity Research Institute Kamal: Haryana, India, 193-196.

Sultana S, Naser HM, Quddus MA, Shill NC, Hossain MA (2018) Effect of Foliar Application of Iron and Zinc on Nutrient Uptake and Grain Yield of Wheat under Different Irrigation Regimes. Bangladesh Journal of Agricultural Research 43(3):395-406.

Steel RGD, Torrie JH (1980) Principles and Procedures of Statistics, A Biometrical Approach (No. Ed. 2). McGraw-Hill Kogakusha Ltd., Tokyo, Japan, 663 pp.

TUIK (2020) Turkish Statistical Institute. https://www.tuik.gov.tr Date of access: 25.09.2023

Vanisha K, Atwal AK, Dhaliwal SS, Banga SK (2013) Assessment of Diverse Sesame (*Sesamum indicum* L.) Germplasm for Mineral Composition. The Journal of Plant Science Research 29(1):29–36.

Yadavi A, Khadem Hamzeh H (2018) The Effect of Irrigation Interval and Iron and Zinc Foliar Application on Some Morpho-Physiological Characteristics and Yield of Sunflower. Journal of Crop Production 11(2):77-90. https://doi.org/10.22069/EJCP.2018.12696.2018

Yousefi Z, Sharifi P, Rabiee M (2023) Effect of Foliar Application of Zinc and Iron on Seed Yield and Yield Components of Common Bean (*Phaseolus vulgaris*). AGRIVITA, Journal of Agricultural Science 45(1):154-162.

Zakaria M, Sawan A, Saeb Hafez, Basyony AE (2001) Effect of Nitrogen and Zinc Fertilization and Plant Growth Retardants on Cottonseed, Protein, Oil Yields, and Oil Properties. Journal of the American Oil Chemists' Society, 78:1087-1092. https://doi.org/10.1007/s11746-001-0394-9

Zakerin HR, Rad AS, Seifzadeh S, Valadabadi SA, Mohasses MM (2014) Evaluation the Effect of Zn, Fe Foliar Application and Variety on Quality and Physiological Characteristics of Canola (*Brassica napus* L.) under Different Ranges Water Deficit Stress. Advances in Environmental Biology 8(1):255-261.

Zayed BA, Salem AKM, Sharkawy HM (2011) Effect of Different Micronutrient Treatments on Rice (*Oriza sativa* L.) Growth and Yield under Saline Soil Conditions. World Journal of Agricultural Sciences 7(2)179-184.