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Foliar Zinc Application on Yield and Quality Characters of Soybean

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Present study was conducted to determine the effects of foliar application at different doses of Zn (0, 1500, 3000 and 4500 g ha^{-1}) on yield and some quality characters of soybean in the silty clay soils with high nutrient contents from experimental area of Black Sea Agricultural Research Institute, Turkey using A-3127 and A-3935 soybean cultivars during two consecutive years. Experimental design was a randomized complete block in split plot arrangement with three replications, utilizing cultivars as main plot and zinc rates as subplots. Results from both years indicate that successive zinc rates resulted in a significant increase in oil and protein contents of seed and oil yield. The successive doses of Zn also produced higher seed yield.

Key Words: *Glycine max*, Seed yield, Zinc treatment.

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] combines in one crop both the dominant world supply of edible vegetable oil and the dominant supply of high-protein feed supplements for livestock. Other fractions and derivatives of the seed have substantial economic importance in a wide range of industrial, food, pharmaceutical and agricultural products[1]. It is an important cash crop throughout different production areas of the world. Planted area has reached 83.61 million ha and resulted in 189.53 million ton production in worldwide[2] during 2005. Also, soybean ranks in the top five crops for hectares planted and total cash receipts generated[3] in US. These figures clearly demonstrate the importance of soybean, as well as the potential economic benefits possibly realized from productivity increases.

As macronutrient needs are meet, it become possible that micronutrient requirements of plants could be limiting optimum production. Zinc deficiency in crops is more widespread than the deficiency of any other micronutrient. It functions as a catalyst in many enzyme systems. Enzymes containing zinc may be important in metabolism of starch and nitrogen.

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Zinc also controls the synthesis of the amino acid tryptophan, which is a precursor to auxin, an important growth regulator[4]. The plants suffering from zinc deficiency exhibit short internodes and chlorotic areas in older leaves resulting in retarded growth and disturbed cell functions[5]. Zinc is one of the essential micro nutrients and soil zinc contents up to 1 ppm are considered as adequate[6]. About 50 % of Turkey soils (14 million ha^{-1}) are zinc-deficient[7]. It is also possible that levels of soil zinc accepted to be adequate may actually be insufficient[8]. Because the availability of zinc is decreased by increasing pH levels, low organic matter content and low adsorptive capacity[8] and high phosphorus contents[9].

Although the importance of zinc to crop growth is not in question, the need for zinc fertilization for soybean is not clear. Soybean has been reported to be medium sensitive to zinc deficiency in soil[8]. Results from previous studies on zinc application to soybean have been inconsistent. Zinc has been reported either to improve soybean yield[10-14] or not to affect it[15,16]. Although this element has been studied in other soybean production areas of the world, data are not available for Turkey. Thus, the main objective of the present study was to determine the effects of zinc applications at four rates on two soybean cultivars under Northern Turkey conditions.

EXPERIMENTAL

In this experiment, A-3127 and A-3935 soybean cultivars, well adapted Northern Turkey ecological conditions and representing mid-late maturity group. Zinc applied to soybean as zinc sulphate ($ZnSO_4 \cdot 7H_2O$). It contains 22 % of Zn, 11 % of S and 43 % of H_2O. The experiment was conducted out at Blacksea Agricultural Research Institute, Samsun. The experimental site is located in the Black Sea region, Northern Turkey (Latitude, 41º21'N; longitude, 36º15'W). The climate is semi-humid (R_f = 47.21), with temperatures ranging from 6.6ºC in February to 23ºC in August. The annual mean temperature is 14.2ºC and annual mean precipitation is 670 mm.

Sowing was performed on 14 May 1999 and 17 May 2000. To minimize moisture stress, experiment was irrigated using an overhead center-pivot system. Weed control was done by hand in both years when necessary. Experimental design was a randomized complete block in split plot arrangement with three replications, utilizing application cultivars as main plot and zinc rates (0, 1500, 3000 and 4500 g ha^{-1}) as subplots. Rates used in the experiment were the average rates for commercial uses suggested from other previous studies. Each plot consisted of 5 rows, 8 m in height. The width between rows was 0.7 m and plots were separated with a distance of 1 m. Zinc at the aforementioned rates were dissolved in 100 L ha^{-1} of water[3] and sprayed at V4-V5 development stage on the canopy[17]. The applications were made with a CO_2 backpack with a single nozzle wand and a length of hose to place zinc on the canopy. Pressure and nozzle size were adjusted to deliver the appropriate rate. Care was taken to minimize the effect of wind. The center three rows were harvested by hand. Yields were adjusted to 8 % moisture for all plots[18].

Physico-chemical analysis of soil: Some physico-chemical properties and nutrient contents of soil in experimental site taken from 0-20 cm depth of experimental site were determined as follows: particle size distribution by the hydrometer method; lime content by Scheibler calsimeter; soil reaction, pH in 1:2.5 (w/v) soil-water suspension by pH-meter and soil salinity by EC meter; organic carbon content by Walkley-Black method; total nitrogen by the Kjeldahl method; available phosphorus by Olsen method, exchangeable potassium by ammonia acetate extraction, Available Fe, Cu, Zn and Mn by extraction with diethylenetriaminepentacetic acid (DTPA) solution (0.005 M DTPA + 0.01 M $CaCI_2$ + 0.1 M triethanolamine (TEA) buffered at pH 7.3) and hot water extractable boron content by Azometin-H method[19,20].

Plant analyses methods: Sub-samples of each plot were obtained to determine the crude protein, oil and ash contents of seeds. Analyses were performed as described by Akyildiz[21]. In addition, oil yield as kg ha^{-1} was calculated for each sub-plot on the basis of seed yield and seed oil content values.

Statistical analysis: All data were analyzed using MSTAT statistical software and excel. The analysis of variance (ANOVA) and regression analyses were performed to compare the means of soybean variety in successive doses of Zn application. Regression graphs were also prepared for significant differences among treatments.

RESULTS AND DISCUSSION

Some physico-chemical properties of soil were determined according to Rowell[20]. The soil that was based on basalt contained 42.44 % clay, 41.92 % silt and 15.64 % sand. Soil texture can accordingly be classified as a silty clay. The pH in water was 7.9; oxidizable organic matter content 2.71 %, total soluble salt 0.04 % and total lime content 5.00 %. Macro (N, P and K) and micro nutrients (Fe, Cu, Zn, Mn and B) were 16.3 kg N da^{-1}, 16.23 kg P_2O_5 da^{-1}, 92.0 kg K_2O da^{-1}, 8.49 µg Fe g^{-1}, 2.94 µg Mn g^{-1}, 1.72 µg Zn g^{-1}, 2.95 µg Cu g^{-1} and 0.65 mg B g^{-1}, respectively. The results can be summarized as; soil sample have alkaline in pH, non saline, low (< 3 %) in organic matter content, moderate (5-15 %) in $CaCO_3$ content, low in nitrogen, high (< 16 kg da^{-1}) in phosphorus, high (> 111 kg da^{-1}) in potassium, adequate (> 4.5 µg g^{-1}) in iron, adequate (> 0.2 µg g^{-1}) in copper, adequate (> 1.0 µg g^{-1}) in zinc, adequate (> 2.0 µg g^{-1}) in manganese and adequate (> 0.5 µg g^{-1}) in boron.

Yield and quality characters: Seed yield values of two soybean cultivars affected by zinc at different rates tested and F values and probability levels for them are shown in Tables 1 and 2.

TABLE-1
EFFECTS OF FOLIAR APPLIED ZINC ON SEED YIELD OF TWO SOYBEAN CULTIVARS*

Cultivars	Years	Zinc rates (g ha^{-1})				Mean
		0	1500	3000	4500	
A-3127	1999	3385	3550	3653	3683	3568
	2000	3216	3500	3490	3566	3442
	Mean	3300	3525	3572	3625	3506**a**
A-3935	1999	3603	3740	3736	3654	3683
	2000	2967	2987	3091	3137	3045
	Mean	3285	3363	3413	3395	3364**b**
General mean		3293	3444	3492	3510	

*Values followed by different small letters are significantly different ($p < 0.05$)

TABLE-2
F VALUES FOR THE EFFECT OF ZINC AT DIFFERENT RATES ON PARAMETERS TESTED AND SIGNIFICANT CONTROL

	Seed yield	Oil content of seed	Oil yield	Protein content of seed	Ash content of seed
F values	2.60 ns	5.04*	5.00*	4.11*	0.30 ns

*Significant at the level of $p < 0.5$; ns: not significant

Mean yields were 3506 kg ha^{-1} for A-3127 and 3364 kg ha^{-1} for A-3935 and the yield difference between cultivars was found to be insignificant. On the other hand, seed yields also varied with years for both cultivars and, therefore, year x cultivar interaction was found to be significant statistically (Fig. 1). Foliar Zn application at successive rates produced higher yields in A-3127, but this increase was not statistically significant (Fig. 2).

As shown in Tables 2 and 3, according to the results of variance of analysis, no significant differences were found between seed oil content of cultivars. However, the results from regression analysis revealed that zinc rates tested had a significant effect on seed oil content of both cultivars (F = 5.04*) (Table-2). Zinc application in increasing rates resulted in higher seed oil content. The regression analyses were performed to determine the degree and kind of the relationship and revealed a significant quadratic relationship between zinc rates and seed oil content ($R^2 = 0.99$, when $p < 0.01$). This positive relationship was formulized as $y = -0.0000001x^2 + 0.0009x + 17.343$ where y = hypothetical yield and x = zinc rate (Fig. 3).

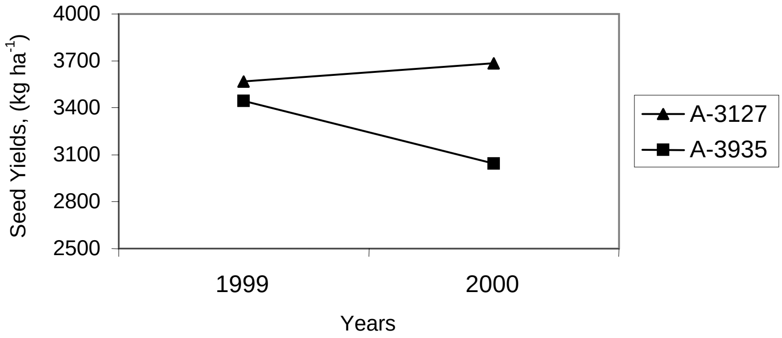

Fig. 1. Chances in seed yields of cultivars with years

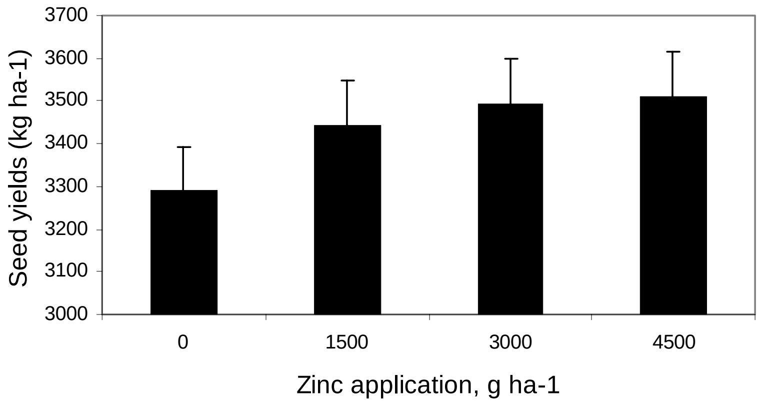

Fig. 2. Effects of zinc at different rates on yields of soybean as mean of two cultivars.

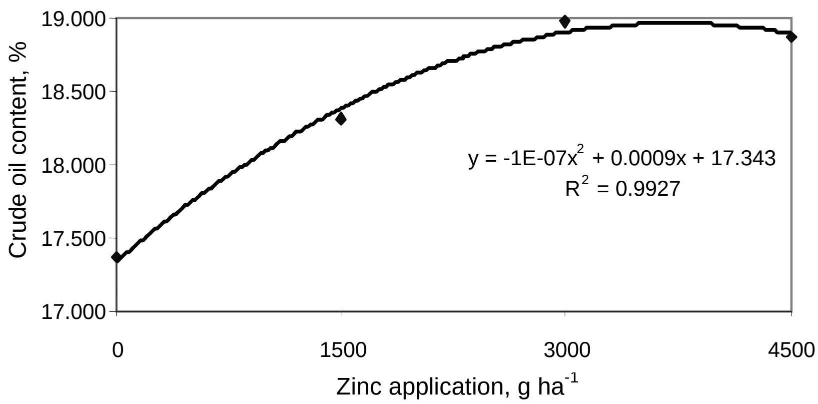

Fig. 3. Relation between zinc rates and seed oil content of soybean

TABLE-3
EFFECTS OF FOLIAR APPLIED ZINC ON SEED OIL CONTENT OF TWO SOYBEAN CULTIVARS

Cultivars	Years	Zinc rates (g ha^{-1})				Mean
		0	1500	3000	4500	
A-3127	1999	16.767	18.167	20.000	20.333	18.817
	2000	16.933	17.200	17.967	17.067	17.292
	Mean	17.683	19.000	19.583	20.400	18.054
A-3935	1999	18.600	19.833	19.167	20.467	19.517
	2000	17.167	18.067	18.800	17.633	19.917
	Mean	17.050	17.633	18.383	17.350	18.717
General mean		17.367	18.317	18.983	18.875	–

Oil yields increased with elevating levels of zinc application. 4500 g ha^{-1} of zinc produced the highest oil yield (663.7 kg ha^{-1}) when compared to control (575.5 kg ha^{-1}) (Table-4). Result from regression analysis revealed that the relationship between oil yield and zinc rates was quadratic ($R^2 = 0.98$ when $p < 0.01$) and could be formulized as $y = -0.00002\, x^2 + 1183\, x + 480.43$ (Fig. 4).

TABLE-4
EFFECTS OF FOLIAR APPLIED ZINC ON OIL YIELD OF TWO SOYBEAN CULTIVARS

Cultivars	Years	Zinc rates (g ha^{-1})				Mean
		0	1500	3000	4500	
A-3127	1999	567.9	647.6	731.0	748.4	673.7
	2000	546.1	604.2	627.4	608.6	596.6
	Mean	557.0	625.9	679.2	678.5	635.2
A-3935	1999	680.3	742.7	715.8	744.7	720.9
	2000	507.8	538.6	578.7	553.0	544.5
	Mean	594.0	640.7	647.2	648.9	632.7
General mean		575.5	633.3	663.2	663.7	–

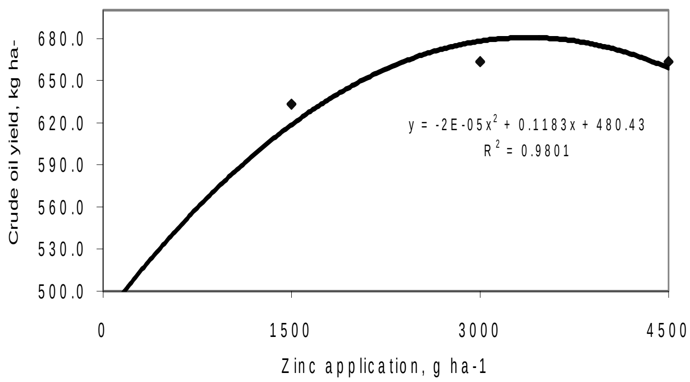

Fig. 4. Relation between zinc rates and oil yield of soybean

Seed protein content did not change with cultivars, however zinc application at increasing rates resulted in a significant increase in seed protein content except for zinc 4500 g ha^{-1} (Table-5). The increase was less evident than that of seed oil content. Similar to seed oil content and oil yield, there was a significant quadratic relationship between zinc rates and seed protein content ($R^2 = 0.90$ when $p < 0.01$) (Fig. 5). In Table-6, neither cultivars nor zinc rates tested had a significant effect on seed ash content.

TABLE-5
EFFECTS OF FOLIAR APPLIED ZINC ON SEED PROTEIN CONTENT OF TWO SOYBEAN CULTIVARS

Cultivars	Years	Zinc rates (g ha^{-1}) 0	1500	3000	4500	Mean
A-3127	1999	33.033	33.933	34.167	34.233	33.842
	2000	34.133	33.800	36.300	35.000	34.808
	Mean	33.583	33.867	35.233	34.617	34.325
A-3935	1999	32.733	34.400	34.767	34.700	34.275
	2000	33.100	33.467	36.367	36.200	34.783
	Mean	32.917	34.183	35.567	35.450	34.529
General mean		33.250	34.025	35.400	35.033	–

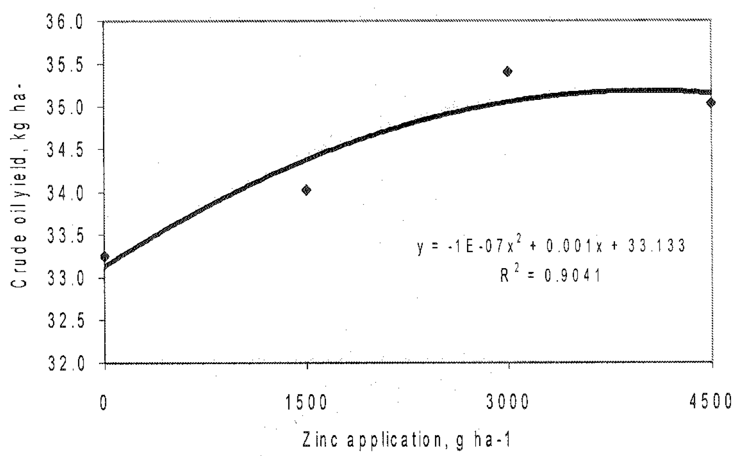

Fig. 5. Relation between zinc rates and seed protein content of soybean

Foliar Zn application produced higher yields in A-3127 than in A-3935. On the contrary, foliar Zn doses were not statistically significant on seed yield. This situation might be soil Zn levels. Soil Zn level is adequate, for this reason, seed yield might be non-significant. Some experiments had been different results on seed yield at Zn application. Many researchers[10-14] that Zn application was increased the seed yield of soybean. On the contrary, others[15,16] reported no effect on seed yield.

TABLE-6
EFFECTS OF FOLIAR APPLIED ZINC ON SEED ASH CONTENT OF TWO SOYBEAN CULTIVARS

Cultivars	Years	Zinc rates (g ha^{-1})				Mean
		0	1500	3000	4500	
A-3127	1999	5.220	5.440	5.550	5.000	5.302
	2000	4.220	4.800	4.880	4.770	4.667
	Mean	4.720	5.120	5.215	4.885	4.985
A-3935	1999	5.330	5.110	4.663	4.610	4.928
	2000	4.557	4.997	4.777	4.593	4.731
	Mean	4.943	5.053	4.720	4.602	4.830
General mean		4.832	5.087	4.967	4.743	–

Our results are in accordance with Chandel *et al.*[10] which reported that protein content of seed and protein yield increased with soil-applied Zn, Fe, B and Mo. Mo 0.5 kg ha^{-1}, zinc 5.0 ha^{-1} and B 2.0 ha^{-1} treatments produced the highest seed yield. Similarly, soil-applied zinc at a rate of 15 ha^{-1} increased seed yield, oil and protein contents of seed of soybean[14]. In contrary, Berlund and Helms[16] reported no response to zinc application on soyabean under Northern USA conditions, where zinc content was up to 1 ppm. Similarly, Kalia and Sharma[15] found soybean to be less responsive to Zn, Fe and B applications in soils with high pH levels. Despite the high soil zinc content, the observed positive response of soybean cultivars tested to zinc application. In present case, it can be attributed to high levels of phosphorus[9] or pH in the soil of experimental area[8].

Conclusion

Present results indicate that foliar Zn application at successive rates increased the seed yield, but the increase was found to be non-significant. Oil content of seed was increased by zinc application. Similarly, seed protein content also increased in response to successive Zn doses. However, this increase was less evident than that of seed oil content. Zinc application affected these quality components of soybean rather than seed yield. It is true that results from chemical analysis of soils is useful for determining the correct amount of fertilizer. Present results also indicated that this phenomenon may not be true necessarily and it would be more reasonable to adjust the fertilization doses according to the results of field-based studies and plant tissue analyses. Despite of our positive results, previous research with zinc applications to soybean was inconsistent and variable. Some of them have reported zinc applications to have positive effect on yield; while no significant response has been reported by the rest indicating further studies will be needed to clarify the effects on zinc treatments on yield and yield components of soybean.

REFERENCES

1. K.J. Smith and W. Huyser, World Distribution and Significance of Soybean, American Society of Agronomy, Madison, Wisconsin, pp. 1-22 (1987).
2. Anonymous, FAO Production Yearbook, Vol. 45 (2006).
3. J.R. Freeborn, Nitrogen and Boron Applications During Reproductive Stages for Soybean Yield Enhancement, Master thesis, State University, Virginia (2000).
4. H. Marschner, Mineral Nutrition of Higher Plants, Academic Press, San Diego, CA (1995).
5. S.M. Tistale, W.L. Nelson and J.D. Beaton, Soil Fertility and Fertilizers, Macmillan Publishing Company, New York, p. 754 (1985).
6. J. Ryan, G. Estefan and A. Rashid, International Center for Agricultural Research in the Dry Areas (ICARDA), p. 165 (2001).
7. F. Eyüpoglu, N. Kurucu and S. Talaz, Toprak Gübre Arastirma Enstitüsü, 620/A-002 Proje Toplu Sonuç Raporu, Ankara (1995).
8. B.J. Alloway, IZA Publications, Brussel (2004).
9. H.D. Foth and B.G. Ellis, Soil Fertility, Lewis Publishers, New York (1997).
10. A.S. Chandel, S.K. Tivari and S.C. Saxena, *Indian J. Agric. Sci.*, **56**, 62 (1989).
11. P.K. Gupta and K.K. Vyas, *Legume Res.*, **17**, 5 (1994).
12. L.W. Banks, *Aust. J. Exper. Agric. Anim. Husban.*, **22**, 226 (1998).
13. I.A., Rose, W.L. Felton and L.W. Banks, *Aust. J. Exper. Agric. Anim. Husban.*, **21**, 236 (1998).
14. D.A. Whitney, Kansas State University Agricultural Experiment Station and Cooperative Extension Service, p. 11 (2005).
15. B.D. Kalia and C. Sharma, *Indian J. Agron.*, **33**, 199 (1988).
16. D.R. Berglund and T.C. Helms, North Dakota State University, p. 7 (2003).
17. A.P. Mallarino, M.I. Hag, D. Wittry and M. Bermudes, *Agron. J.*, **93**, 1220 (2001).
18. M. Nalbant, *J. Agric. Fac. Ondokuz Mayis Univ.*, **5**, 1 (1990).
19. C.A. Black, D.D. Evans, J.L. White, L.E. Ensminger and F.E. Clark, Chemical and microbiological properties. Soil Science Society of America, Part 2, Madison, Wisconsin (1965).
20. D.L. Rowell, Soil Science: Methods and Applications, Longman, London, p. 350 (1996).
21. A.R. Akyildiz, Yemler Bilgisi Laboratuvar Kilavuzu, Ankara University Press, Ankara, pp. 27-33 (1984).

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