Research Journal of Agricultural Science, 51 (3), 2019

ZINC FOLIAR FERTILIZATION EFFECT ON SOME GRAVIMETRIC INDICES ON WHEAT

Adina-Daniela DATCU[1,2*], Ersilia ALEXA[3], Nicoleta IANOVICI[2], Florin SALA[1]

[1]Banat's University of Agricultural Sciences and Veterinary Medicine „King Michael I of Romania" from Timişoara, Soil Science and Plant Nutrition
[2]West University of Timișoara, Faculty of Chemistry, Biology, Geography, Biology-Chemistry Department
[3]Banat's University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania", Timisoara, Food Control, Faculty of Food Processing Technology
Corresponding author: dana_datcu19@yahoo.com

Abstract

This paper aim is to present data from a field experiment realized in 2018. The field is located in Didactic Station of Banat University of Agricultural Sciences and Veterinary Medicine „King Michael I of Romania" from Timişoara, Romania. The investigated species was Triticum aestivum ssp. vulgare, Ciprian cv. Wheat was fertilized during spring with a liquid complex which contain zinc. This microelement has diverse biological roles in plants, being involved in enzymatically driven metabolism and pollen tube development. Soils and plants zinc deficiency is a global problem. Zinc deficiency can also be observed in humans, particularly in developing countries. Thus, increasing zinc content in plants, especially in widely consumed worldwide cereals became of interest. In this research zinc was sprayed to leaves of wheat plants in five experimental doses. Intact leaves were analyzed in the laboratory and the values of some physiological parameters were determined. The studied indices were leaf dry weight, determined after drying in an oven, followed by a weighting, along with leaf ash content, as the mass of the ash obtained after an incinerating process and leaf organic matter, determined by subtracting the values of the second parameter from the first. Statistical processing was realized using PAST software v3. Regarding leaf dry weight, a polynomial trend explains the interdependency with zinc dose. The lowest values were obtained for the fertilizer with the minimum zinc content and the highest values were noticed for the maximum zinc dose. Same tendencies were observed for leaf ash content and leaf organic matter. Variance between the five variants was analyzed by one-way ANOVA between groups. Levene's test revealed that all data are homogenous. The Tukey's pairwise comparisons indicated significant differences between variants.

Keywords: *leaf organic matter, zinc, fertilization, foliar fertilizer, physiological response*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a main grain cereal widely consumed worldwide, a staple food for more than 50% of world population (RIZWAN et al., 2016) and enhancing its quality is nowadays a challenge. Micronutrient metals are essential nutrient elements required for healthy plant growth, as well as for structural and catalytic roles in proteins, which are involved in metabolism and development (HAYDON and COBBETT, 2007; RAWASHDEH and SALA, 2013, 2015). Zinc is an important trace element which plays a crucial role in enzymatically driven metabolism (TISDALE et al., 1984) and is important in pollen tube formation (PANDEY et al., 2006). A Zn insufficiency in plants has an effect on synthesis and functions of a large range of macromolecules, but also could result in a decrease of crops yield and quality (WATTS-WILLIAMS et al., 2017; COCCINA et al., 2019). Zinc deficiency in plants and soils is a major micronutrient disorder in more than 40 countries (ALLOWAY, 2004). Zn deficient soils constitute about 30% of the world agriculture soils and wheat is more prone to Zn deficiency compared to other cereals which compromised wheat growth and quality

(ALLOWAY, 2008; CAKMAK et al., 2017; JOY et al., 2017). Lately, Zn nanoparticles are of interest not only in paints, cosmetics or water remediation, but also in food fortification (WANG et al., 2016; CERVANTES-AVILÉS and CUEVAS-RODRÍGUEZ, 2017; HOU et al., 2018).

Zn fertilizers can be directly sprayed to leaves of growing plants (FAGERIA et al., 2009). Due to low mobility and toxicity of Zn, more than one Zn treatment is recommended to fulfill the requirement of plants. Foliar application of Zn at grain filling is directly related to higher grain Zn concentration. Soil + foliar application of Zn can greatly enhance grain yield and grain Zn concentration (YILMAZ et al., 1997). Soil applied Zn is a function of soil properties and has a low agronomic efficiency in alkaline soils (GREGORY et al., 2017; RAFIE et al., 2017). Zinc efficient wheat cultivars (genotypes that can grow and produce well on Zn deficient soils) response to Zn application reflects in grain yield and Zn concentration (MAQSOOD et al., 2009). Moreover, farmer friendly application methods are more quickly adopted by numerous farmers. A farmer friendly method should save labor charges and time, but also must assure a non-homogeneous application with significant increases of grains yield. HARRIS et al. (2008) found seed priming with $ZnSO_4$ a very cost-effective Zn application method that provided a net benefit-to-cost ratio of 75 for wheat.

Wheat grains contain about 25–30 μg Zn g^{-1} dry weight, while for a measurable impact of Zn biofortification on human health, a desired wheat grain Zn concentration should be > 50 μg g^{-1} dry weight (CAKMAK, 2008). The application of 20 kg $ZnSO_4$ ha^{-1} in combination with a foliar spray of 0.5% solution of $ZnSO_4$ (1 week after flowering) led to an 80% increase in grain Zn concentration, 61.3% in ethionine concentration, but also a decrease of 23.2% in phytic acid (BHARTI et al., 2013). The critical Zn concentration for the youngest emerged wheat leaves is 14 mg kg^{-1} dry weight (BRENNAN, 2001), at tillering and anthesis is 16.5 and 7 mg kg^{-1} dry weight, respectively (RILEY et al. 1992), and whole grain is 10 mg kg^{-1} (RILEY et al. 1992; RENGEL and GRAHAM 1995). Also, another study showed that Zn fertilization, up to 10 mg Zn kg^{-1} soil, increased activity of nitrate reductase and glutamine synthase in flag leaves after flowering. Moreover, an increase in Zn fertilization (up to 20 mg Zn kg^{-1} soil) was associated with a genotype-dependent increase in both the total and group specific (gliadins, glutenins, albumins, and globulins) protein concentration in the grain and the flour, respectively. This effect was followed by a decrease of all three protein types at 40 mg Zn kg^{-1} soil demonstrating the occurrence of an optimal fertilization rate for Zn. Moreover, studies have demonstrated that Zn nutrition can alter flour protein concentration and composition and thus flour quality (LIU et al., 2015).

Globally, about 1.1 billion people are at risk of Zn deficiency (KUMSSA et al., 2015). Thus, there is a need to increase grain zinc content and bioavailability, especially in developing countries (WELCH and GRAHAM, 2004; ZHAO and MCGRATH, 2009).

The aim of this study is to assess the relation between zinc doses and leaves features, through the investigation of some parameters like leaves dry weight, ash content and organic matter. These indices reflect the effect of the fertilizer on photosynthesis and mineral accumulation in leaves.

MATERIALS AND METHODS

The study was realized on *Triticum aestivum* (L.) ssp *vulgare*, Ciprian cultivar, grown in the Didactic Station of BUASVM Timișoara, Romania, where the soil has a clay texture with pH 6.73 (RAWASHDEH and SALA, 2014).

The experimental treatments consisted of five zinc complex fertilizer doses, named Zn 0 – Zn 4.

Prelevation was realized on June 2018. Samples representing wheat aboveground parts were collected and taken to the laboratory and all leaves were intact and were detached using a scalpel. The probes were then placed into an oven at 100 °C for 2 h. After this process, probes were weighted using an analytical balance, leaf dry weight (LDW) being obtained. Next, leaves were incinerated at 500 °C for 2 hours before recording the ash weights at the analytical balance (LAC in g). Also, leaf organic matter (LOM in g) was determined as difference between LDW and LAC (IANOVICI et al., 2012; IANOVICI, 2016). Data processing was realized using MS Excel 2013 and statistical analysis were performed using PAST software v3 (HAMMER et al., 2001).

RESULTS AND DISCUSSION

This research aimed to determine the values of some gravimetric parameters for the local wheat cultivar Ciprian.

Zn dose influence on leaf dry weight can be observed in Figure 1. The lowest value was obtained for Zn 0 samples (0.0063 g) and the highest was obtained for Zn 4 probes (0.0419 g). This variation depending on the controlled dosage of Zn is best described by relation (1), statistical accuracy being assured ($p = 0.010616$, $R^2 = 0.989$, $F = 93.194$).

$$LDW = 0.00095x^2 + 0.00081x + 0.01204 \quad (1)$$

x – Zn doses

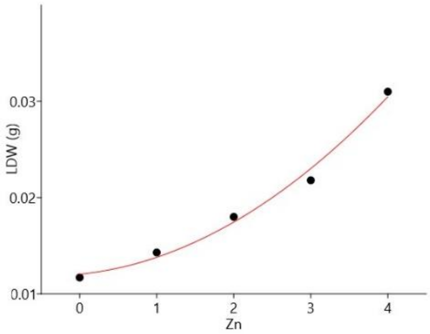

Figure 1. Zn dose influence on LDW

LAC variation depending on zinc dose can be observed in Figure 2.

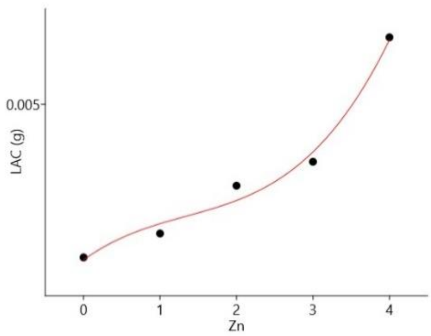

Figure 2. Zn dose influence on LAC

A similarity between this trend and LDW trend was noticed, with the lowest value for Zn 0 samples (0.0010 g) and highest value for Zn 4 samples (0.0085 g). Similar results regarding RWL changes (rate of weight loss) were reported by SALA et al. (2019), obtained under the influence of iron nanoparticles treatments in wheat.

LAC variation depending on the controlled dosage of Zn is best described by relation (2), statistical accuracy being assured (p = 0.15236, R^2 = 0.985, F= 22.834).

$$LAC = 0.0001333x^3 + 0.0005357x^2 + 0.00116x + 0.001749 \quad (2)$$

x – Zn doses

LOM variation depending on zinc dose can be observed in Figure 3. The influence of Zn dose on organic matter content can be best described by relation (3), in statistical accuracy conditions (p = 0.0056199, R^2 = 0.994, F = 176.94).

$$LOM = 0.0006929x^2 + 0.0007986x + 0.01013 \quad (3)$$

x – Zn doses

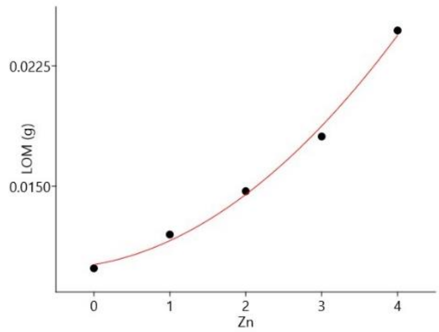

Figure 3. Zn dose influence on LOM

After the completion of statistical tests, all data were homogenous. Tukey`s comparisons can be observed in Table 1, with significant differences between samples from different variants, for all the investigated parameters.

Table 1

Tukey’s comparisons values for LDW, LAC and LOM for the five experimental variants

Parameter	Variant	Zn 0	Zn 1	Zn 2	Zn 3	Zn 4
LDW	Zn 0		0.5865	0.00682	5.95E-06	4.44E-13
	Zn 1	2.079		0.2275	0.00075	1.77E-11
	Zn 2	5.085	3.005		0.1963	1.90E-08
	Zn 3	8.204	6.125	3.119		3.39E-05
	Zn 4	15.68	13.6	10.59	7.473	
LAC	Zn 0		0.8385	0.01979	0.001293	1.15E-11
	Zn 1	1.462		0.2079	0.0248	3.14E-10
	Zn 2	4.537	3.075		0.8767	4.72E-07
	Zn 3	5.877	4.415	1.34		1.18E-05
	Zn 4	13.79	12.33	9.257	7.917	

LOM	Zn 0		0.5899	0.01316	6.96E-06	1.75E-12
	Zn 1	2.072		0.3349	0.0008527	1.54E-10
	Zn 2	4.752	2.68		0.1354	8.62E-08
	Zn 3	8.139	6.067	3.387		0.0002728
	Zn 4	14.71	12.64	9.962	6.575	

CONCLUSIONS

This study presented data from a field experiment on wheat fertilized with a liquid complex which contained zinc.

The investigated indices were leaf dry weights, ash and organic matter contents. For the minimum experimental dose, all parameters had the lowest values.

Regarding leaf dry weight, a polynomial tendency was noticed when the Zn dose increase. Same trends were observed for ash, but also for organic matter content. Thus, both leaves organic and inorganic contents present an interdependency with zinc dose.

ACKNOWLEDGEMENTS

The authors thank ARDS Lovrin for wheat seed and Didactic Station of BUASVM Timișoara for the equipment and support.

BIBLIOGRAPHY

ALLOWAY, B.J., 2004 − Zinc in soils and crop nutrition. International Zinc Association, Brussels, Belgium, pp: 116.

ALLOWAY, B.J., 2008 − Zinc in soils and crop nutrition, 2nd edn. International Zinc Association and International Fertilizer Industry Association, Brussels, Belgium, pp: 135.

BHARTI K., PANDEY N., SHANKHDHAR D., SRIVASTAVA P., SHANKHDHAR S., 2013 − Improving nutritional quality of wheat through soil and foliar zinc application. Plant Soil Environment, 59: 348−352.

BRENNAN, R.F., 2001 − Residual value of zinc fertilizer for production of wheat. Australian Journal of Experimental Agriculture, 41: 541–547.

CAKMAK, I., 2008 − Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? Plant and Soil, 302: 1–17.

CAKMAK, I., MCLAUGHLIN, M.J., WHITE, P. 2017 − Zinc for better crop production and human health. Plant and Soil, 411: 1-4.

CERVANTES-AVILÉS, P., CUEVAS-RODRÍGUEZ, G., 2017 − Changes in nutrient removal and flocs characteristics generated by presence of ZnO nanoparticles in activated sludge process. Chemosphere, 182: 672-680.

COCCINA, A., CAVAGNARO, T.R., PELLEGRINO, E., ERCOLI, L., MCLAUGHLIN, M.J., WATTS-WILLIAMS, S.J., 2019 − The mycorrhizal pathway of zinc uptake contributes to zinc accumulation in barley and wheat grain, BMC Plant Biology, 19: 133.

FAGERIA, N.K., FILHO, M.P.B., MOREIRA, A., GUIMARÃES, C.M. 2009. Foliar fertilization of crop plants. Journal of Plant Nutrition, 32: 1044–1064.

GREGORY, P.J., WAHBI, A., ADU-GYAMFI, J., HEILING, M., GRUBER, R., JOY, E.J., BROADLEY, M.R., 2017. Approaches to reduce zinc and iron deficits in food systems. Global Food Security, 15: 1-10.

HAMMER, Ø., HARPER, D.A.T., RYAN, P.D. 2001. PAST: Paleontological Satistics software package for education and data analysis. Paleontologica Electronica, 4 (1): 1-9.

HARRIS, D., RASHID, A., MIRAJ, G., ARIF, M., YUNAS, M., 2008 − 'On-farm' seed priming with zinc in chickpea and wheat in Pakistan. Plant and Soil, 306: 3-10.

HAYDON, M.J., COBBETT, C.S., 2007 − Transporters of ligands for essential metal ions in plants. New Phytologist, 174: 499-506.

HOU, J., WU, Y., LI, X., WEI, B., LI, S., WANG, X., 2018 − Toxic effects of different types of zinc oxide nanoparticles on algae, plants, invertebrates, vertebrates and microorganisms. Chemosphere, 16: 852-860.

IANOVICI, N., 2016 − *Taraxacum officinale* (Asteraceae) in the urban environment: seasonal fluctuations of plant traits and their relationship with meteorological factors. Acta Agrobotanica, 69 (3): 1677.

IANOVICI, N., CIOCAN, G.V., MATICA, A., SCURTU, M., ȘESAN, T.E., 2012 − Study on the infestation by *Cameraria ohridella* on *Aesculus hippocastanum* foliage from Timişoara, Romania. Annals of West University of Timişoara, series of Biology, 15 (1): 67-80.

JOY, E.J., AHMAD, W., ZIA, M.H., KUMSSA, D.B., YOUNG, S.D., ANDER, E.L., WATTS, M.J., STEIN, A.J., BROADLEY, M.R., 2017 − Valuing increased zinc (Zn) fertiliser-use in Pakistan. Plant and Soil, 411: 139-150.

KUMSSA, D.B., JOY, E.J., ANDER, E.L., WATTS, M.J., YOUNG, S.D., WALKER, S., BROADLEY, M.R., 2015 − Dietary calcium and zinc deficiency risks are decreasing but remain prevalent. Scientific Reports, 5: 10974.

LIU, H.E., WANG, Q.Y., RENGEL, Z., ZHAO, P., 2015 − Zinc fertilization alters flour protein composition of winter wheat genotypes varying in gluten content. Plant, Soil and Environment, 61: 195−200.

MAQSOOD, M.A., RAHMATULLAH S., KANWAL, T.A., ASHRAF, M., 2009 − Evaluation of Zn distribution among grain and straw of twelve indigenous wheat (*Triticum aestivum*) genotypes. Pakistan Journal of Botany, 41: 225–231.

PANDEY, N., PATHAK, G.C., SHARMA, C.P., 2006 − Zinc is critically required for pollen function and fertilisation in lentil. Journal of Trace Elements in Medicine and Biology, 20: 89–96.

RAFIE, M.R., KHOSHGOFTARMANESH, A.H., SHARIATMADARI, H., DARABI, A., DALIR, N., 2017 − Influence of foliar-applied zinc in the form of mineral and complexed with amino acids on yield and nutritional quality of onion under field conditions. Scientia Horticulturae, 216: 160-168.

RAWASHDEH, H., SALA, F., 2014 − Influence of iron foliar fertilization on some growth and physiological parameters of wheat at two growth stages. Scientific Papers. Series A. Agronomy, 17: 306-309.

RAWASHDEH, H., SALA, F., 2015 − Foliar application with iron as a vital factor of wheat crop growth, yield quantity and quality: a review. International Journal of Agricultural Policy and Research, 3 (9): 368-376.

RAWASHDEH, H.M., SALA, F., 2013 − The effect of foliar application of iron and boron on early growth parameters of wheat (*Triticum aestivum* L.). Research Journal of Agricultural Science, 45(1): 21-26.

RENGEL, Z., GRAHAM, R.D., 1995 − Wheat genotypes differ in zinc efficiency when grown in the chelate-buffered nutrient solution. I. Growth. Plant Physiology, 176: 307–316.

RILEY M.M., GARTRELL J.W., BRENNAN R.F., HAMBLIN J., COATES P., 1992 − Zinc deficiency in wheat and lupins in Western Australia is affected by the source of phosphate fertilizers. Australian Journal of Experimental Agriculture, 32: 455–463.

RIZWAN, M., ALI, S., ADREES, M., RIZVI, H., REHMAN, M.Z., HANNAN, F., QAYYUM, M.F., HAFEEZ, F., OK, Y.S., 2016 − Cadmium stress in rice: toxic effects, tolerance mechanisms, and management: a critical review. Environmental Science and Pollution Research, 23: 17859-17879.

SALA, F., BOLDEA, M., BOTĂU, D., PÎRVULESCU, A., GERGEN I. 2019 − Fe_3O_4 – water based magnetic nanofluid influence on weight loss of wheat seedlings under controlled conditions. Romanian Biotechnological Letters, 24 (2): 308-316.

TISDALE, S.L., NELSON, W.L., BEATEN, J.D. 1984 − Zinc in Soil Fertility and Fertilizers, 4th Edn. New York, NY: Macmillan Publishing Company, USA, 382–391.

WANG, P., LOMBI, E., ZHAO, F.J., KOPITTKE, P.M., 2016 − Nanotechnology: a new opportunity in plant sciences. Trends in Plant Science, 21: 699-712.

WATTS-WILLIAMS, S.J., TYERMAN S.D., CAVAGNARO, T.R., 2017 − The dual benefit of arbuscular mycorrhizal fungi under soil zinc deficiency and toxicity: linking plant physiology and gene expression. Plant and Soil, 420: 375–88.

WELCH, R.M., GRAHAM, R.D., 2004. Breeding for micronutrients in staple food crops from a human nutrition perspective. Journal of Experimental Botany, 55: 353–364.

YILMAZ, A., EKIZ H., TORUN, B., GULTEKIN, I., KARANLIK, S., BAGCI, S.A., CAKMAK, I., 1997 − Effect of different zinc application methods on grain yield and zinc concentration in wheat cultivars grown on zinc-deficient calcareous soils. Journal of Plant Nutr, 20: 461–471.

ZHAO, F.J., MCGRATH, S.P., 2009 − Biofortification and phytoremediation. Current Opinion in Plant Biology, 12: 373–380.