

The effect of zinc application on annual ryegrass (*Lolium multiflorum*) under drought stress

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References

- Alves, A. A. C. & Setter, T. L. (2000). Response of cassava to water deficit: Leaf area growth and abscisic acid. *Crop Science*, 40, 131–137. <https://doi.org/10.1093/aob/mch179>
- Amanuel, B. A. et al. (2015). Forage yield and quality response of annual ryegrass (*Lolium multiflorum*) to different water and nitrogen levels. *African Journal of Range & Forage Science*, 32(2), 125–131. <https://doi.org/10.2989/10220119.2015.1056228>
- Ashkan, A. et al. (2020). Effects of foliar zinc application on yield and oil quality of rapeseed genotypes under drought stress. *Journal of Plant Nutrition*, 43(11), 1594–1603. <https://doi.org/10.1080/01904167.2020.1739299>
- Bano, A. et al. (2012). Role of abscisic acid and drought stress on the activities of antioxidant enzymes in wheat. *Plant, Soil and Environment*, 58, 181–185. <https://doi.org/10.17221/210/2011-PSE>
- Boominathan, P. et al. (2004). Long term transcript accumulation during development of dehydration adaptation in *Cicer arietinum*. *Plant Physiology*, 135, 1608–1620. <https://doi.org/10.1104/pp.104.043141>
- Bowen, H. J. M. (1979). Environmental chemistry of the elements. New York: Academic Press.
- Brambilla, D. M. et al. (2012). Impact of nitrogen fertilization on the forage characteristics and beef calf performance on native pasture overseeded with ryegrass. *Revista Brasileira de Zootecnia*, 41(3), 528–536. <https://doi.org/10.1590/S1516-35982012000300008>
- Cakmak, I. (2000). Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. *New Phytologist*, 146, 185–205. <http://dx.doi.org/10.1046/j.1469-8137.2000.00630.x>
- Cao, W. X., Wang, Z. L. & Dai, T. B. (2000). Changes in levels of endogenous plant hormones during floret development in wheat genotypes of different spike sizes. *Acta Botanica Sinica*, 42(10), 696–700. <https://doi.org/10.1007/s00299-019-02430-0>
- Cinar, S., Ozkurt, M. & Cetin, R. (2020). Effects of nitrogen fertilization rates on forage yield and quality of annual ryegrass (*Lolium multiflorum* L.) in central black sea climatic zone in Turkey. *Applied Ecology and Environmental Research*, 18(1), 417–432. https://doi.org/10.15666/aeer/1801_417432
- Clarke, N. D. & Berg, J. M. (1998). Zinc fingers in *Caenorhabditis elegans*: finding families and probing pathways. *Science*, 282, 2018–2022.
- Conti, S. et al. (1994). Genetic and environmental effects on abscisic acid accumulation in leaves of field-grown maize. *Euphytica*, 78, 81–89. <https://doi.org/10.1007/BF00021401>
- Dimkpa, C. O. et al. (2019). Zinc oxide nanoparticles alleviate drought-induced alterations in sorghum performance, nutrient acquisition, and grain fortification. *Science of The Total Environment*, 688, 926–934. <https://doi.org/10.1016/j.scitotenv.2019.06.392>
- Grzebisz, W. et al. (2008). Effect of zinc foliar application at an early stage of maize growth on patterns of nutrients and dry matter accumulation by the canopy: Part II. Nitrogen uptake and dry matter accumulation patterns. *Journal of Elementology*, 13, 29–40.
- Havlin, J. L. et al. (1999). Soil Fertility and Fertilizers – An introduction to nutrient management. 6th ed. New Jersey: Prentice Hall.
- Huang, B., Da Costa, M. & Jiang, Y. (2014). Research advances in mechanisms of grass tolerance to abiotic stresses: From physiology to molecular biology. *Critical Reviews in Plant Sciences*, 33(2-3), 141–189. <https://doi.org/10.1080/07352689.2014.870411>
- Hussain, S. et al. (2020). Combined Application of Potassium and Zinc Improves Water Relations, Stay Green, Irrigation Water Use Efficiency, and Grain Quality of Maize under Drought Stress. *Journal of Plant Nutrition*, 43(14), 2214–2225. <https://doi.org/10.1080/01904167.2020.1765181>

Ivanovic, M. et al. (1992). Inheritance of abscisic acid production in maize (*Zea mays* L.) leaves in response to rapid drought stress and in the field. *Maydica*, 37(4), 313–318.

Jones, J. B. (1990). Universal soil extractants: Their composition and use. *Communications in Soil Science and Plant Analysis*, 21(13-14), 1091–1101. <https://doi.org/10.1080/00103629009368292>

Karim, M. R. & Rahman, M. A. (2015). Drought risk management for increased cereal production in Asian Least Developed Countries. *Weather and Climate Extremes*, 7, 24–35. <https://doi.org/10.1016/j.wace.2014.10.004>

Karim, M. R. et al. (2012). Alleviation of drought stress in winter wheat by late foliar application of zinc, boron, and manganese. *Journal of Plant Nutrition and Soil Science*, 175(1), 142–151. <https://doi.org/10.1002/jpln.201100141>

Khan, H. R., Mc Donald, G. K. & Rengel, Z. (2004). Zinc fertilization and water stress affects plant water relations, stomatal conductance and osmotic adjustment in chickpea (*Cicer arietinum* L.). *Plant Soil*, 267, 271–284. <https://doi.org/10.1007/s11104-005-0120-7>

Krempfer, R. & Seres, L. (2010). The effect of zinc fertilization on the yield and element content of ryegrass. *Journal of Agricultural Sciences*, 38, 21-27. <https://doi.org/10.34101/actaagrar/38/2756>

Krishnan, S. & Merewitz, E. B. (2015). Drought Stress and Trinexapac-ethyl Modify Phytohormone Content Within Kentucky Bluegrass Leaves. *Journal of Plant Growth Regulation*, 34, 1–12.

Li, J. et al. (2000). Regulation of abscisic acid-induced stomatal closure and anion channels by guard cell AAPK kinase. *Science*, 287, 300–303.

Lindsay, W. L. & Norvell, W. A. (1978). Development of a DTPA Soil Test for Zinc, Iron, Manganese, and Copper. *Soil Science Society of America Journal*, 42, 421–428.

Ma, D. et al. (2017). Physiological responses and yield of wheat plants in zinc-mediated alleviation of drought stress. *Frontiers in plant science*. May 24, 8:860. <https://doi.org/10.3389/fpls.2017.00860>

Mathpal, B. et al. (2015). Zinc enrichment in wheat genotypes under various methods of zinc application. *Plant, Soil and Environment*, 61, 171–175. <https://doi.org/10.17221/41/2015-PSE>

Monjezi, F. et al. (2013). Effects of iron and zinc spray on yield and yield components of wheat (*Triticum aestivum* L.) in drought stress. *Cercetări Agronomice în Moldova*, 46(1), 23–32. <https://doi.org/10.2478/v10298-012-0072-z>

Lindsay, W.L. & Norvell, W.A. (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society America Journal*, 42, 421-428. <http://dx.doi.org/10.2136/sssaj1978.03615995004200030009x>

Poblaciones, M. J., Damon, P. & Rengel, Z. (2017). Foliar zinc biofortification effects in *Lolium rigidum* and *Trifolium subterraneum* grown in cadmium-contaminated soil. *Plos One*, 12(9).

Pospíšilová, J. (2003). Interaction of Cytokinins and Abscisic Acid During Regulation of Stomatal Opening in Bean Leaves. *Photosynthetica*, 41: 49–56. <https://doi.org/10.1023/A:1025852210937>

Pospíšilová, J., Synková, H. & Rulcová, J. (2000). Cytokinins and water stress. *Biologia Plantarum*, 43: 321–328. <https://doi.org/10.1023/A:1026754404857>

Procházka, S. et al. (1998). *Plants physiology*, Praha: Academia

Quarrie, S. A. et al. (1988). A monoclonal antibody to (S)-abscisic acid: its characterization and use in radioimmunoassay for measuring abscisic acid in crude extracts of cereal and lupin leaves. *Planta*, 173, 330–339.

Ren Z. et al. (2017). Structure determination and activity manipulation of the turfgrass ABA receptor FePYR1. *Scientific Report*, 7(1), 14022. <https://doi.org/10.1038/s41598-017-14101-9>

Sadoogh, F. S. et al. (2014). Adjusted nutrition of tomato with potassium and zinc in drought stress conditions induced by polyethylene glycol 6000 in hydroponic culture. *Journal of Greenhouse Culture Science and Technology*, 18, 67–80.

Seed service. (2020). Characteristics of grasses and their varieties. Seed service. Retrieved October 12, 2020 from <https://seedservice.cz/charakteristika-druhu-a-odrud-travSeo>, P. J. et al. (2009). The MYB96 transcription factor mediates abscisic acid signalling during drought stress response in Arabidopsis. *Plant Physiology*, 151, 275–289. <https://doi.org/10.1104/pp.109.144220>.

Sharp, R. E. (2002). Interaction with ethylene: changing views on the role of abscisic acid in root and shoot growth responses to water stress. *Plant, Cell and Environment*, 25(2), 211–222. <https://doi.org/10.1046/j.1365-3040.2002.00798.x>

Škarpa, P. et al. (2015). Foliar application of zinc reduces the risk of drought stress on poppy (*Papaver somniferum* L.). International Conference on Prosperous Oil Crops, Prague, 123–126.

StatSoft, Inc. (2013) STATISTICA (data analysis software system), version 12. www.statsoft.com

Steffens, J. C. (1990). The heavy metal-binding peptides of plants. *Annual Review of Plant Physiology and Plant Molecular Biology*, 41, 553–575. <https://doi.org/10.1146/annurev.pp.41.060190.003005>

Strivastava, L. M. (2002). Plant growth and development: Hormones and environment. Academic Press San Diego CA. <https://doi.org/10.1093/aob/mcg209>

Upadhyaya, H., Dutta, B. K. & Panda, S. K. (2013). Zinc Modulates Drought-Induced Biochemical Damages in Tea [*Camellia sinensis* (L) O Kuntze]. *Journal of Agricultural and Food Chemistry*, 61, 6660–6670. <https://doi.org/10.1021/jf304254z>

Vaghar, M. S. et al. (2020). Foliar application of iron, zinc, and manganese nano-chelates improves physiological indicators and soybean yield under water deficit stress, *Journal of Plant Nutrition*, 43(18), 2740–2756. <https://doi.org/10.1080/01904167.2020.1793180>

Velu, G. et al. (2016). Effect of drought and elevated temperature on grain zinc and iron concentrations in CIMMYT spring wheat. *Journal of Cereal Science*, 69, 182–186. <https://doi.org/10.1016/j.jcs.2016.03.006Get>

Wang, H. & Jin, J. (2007). Effects of Zinc Deficiency and Drought on Plant Growth and Metabolism of Reactive Oxygen Species in Maize (*Zea mays* L). *Agricultural Sciences in China*, 6 (8), 988–995. [https://doi.org/10.1016/S1671-2927\(07\)60138-2](https://doi.org/10.1016/S1671-2927(07)60138-2)

Wang, H., Liu, R. L. & Jin, J. Y. (2009). Effects of zinc and soil moisture on photosynthetic rate and chlorophyll fluorescence parameters of maize. *Biologia Plantarum*, 53, 191–194.

Xiong, L. M., Schumaker, K. S. & Zhu, J. K. (2002). Cell signalling during cold, drought, and salt stress. *The Plant Cell*, 14, 165–183. <https://doi.org/10.1105/tpc.000596>.

Yang, K. Y. et al. (2018). Remodeling of root morphology by CuO and ZnO nanoparticles: effects on drought tolerance for plants colonized by a beneficial pseudomonad. *Botany*, 96, 175–186. <https://doi.org/10.1139/cjb-2017-0124>

Zbiral, J. et. al. (2005). Plants biomass analysis: Unified work methods. 2nd ed., Brno: Ústřední kontrolní a zkušební ústav zemědělský.

Zhang, J., Zhang, X. & Liang, J. (1995). Exudation rate and hydraulic conductivity of maize roots are enhanced by soil drying and abscisic acid treatment. *New Phytologist*, 131, 329–336. <https://doi.org/10.1111/j.1469-8137.1995.tb03068.x>