1

Introduction

Drought is a very complex and highly uncertain natural hazard, particularly with regard to agriculture[1]. It causes serious threats to global water and food security[2,3]. Droughts have been occurring more frequently and over larger areas as a result of global warming[4,5].

According to climate models, many areas of the planet Earth will become drier by the year 2100. This could affect the rate of soil N cycling and availability[6,7]. Soil water influences the access of N to plants and microbes by regulating the processes like substrate advection and diffusion. Thus, drought affects the rate of N fixation and transformation by microbial processes[8,9]. Drought also reduces the activity of nitrifying bacteria present in the soil and slows down the organic matter decomposition and reduced production of NH_4^+ [10]. Decreased NH_4^+ in turn results in lesser conversion in to NO_3^- (lower mineralization)[11]. Phosphorus (P) ; an another essential macronutrient for plant growth and plays vital role during biological nitrogen fixation in legumes[12]. Though P is available in the soil solution in three forms, viz. organic P, adsorbed P and primary mineral P, the latter two are very less in quantity and non-available to plant. Hence, organic phosphate has to be mineralized by microorganisms to form $H_2PO_4^-$ or HPO_4^{2-} to make it plant available. Under drought situations, the activity of these microorganisms is likely to be hampered affecting the P availability in soil. Moreover, the activity of rhizospheric microbes are strongly affected by root exudates and other rhizodeposits[13]. Plants grown under adverse climatic conditions like drought are likely to alter the quantity and quality of root exudates.

Given their capacity to fixate atmospheric nitrogen, legumes are an affordable and nourishing sources of protein that are essential to animals including human[14,15]. They are the major sources of protein to humans as they satisfy around 33% of dietary protein requirement[16]. Presence of minerals like Fe, Zn, P, Ca, K and Mg along with

vitamins and complex carbohydrates place legumes next to cereals. Legume crops are susceptible to a number of abiotic threats, and crop yield has traditionally been restricted by drought[17]. Moreover, persistent water limitations in the semi-arid areas of south east Asia significantly affect the legume productivity [18] and deteriorates its grain quality. Drought stress reduces legume yield by affecting seed germination, carbon assimilation, net photosynthesis, nutrient uptake, cell turgor, photosystem II efficiency, stem growth, and root proliferation[20–23]. Effect on such processes become more severe when drought appears at the sensitive stages of crop development [17].

Various strategies have been adopted to tackle drought induced nutrient deficiency in crops. Among those, application of soil amendments such as farmyard manure (FYM) and biochar has been found effective in minimizing the drought induced impact on crop growth and yield due to improvement in different soil processes [24,25]. Biochar application as soil amendment reported to have positive influence in physiological and biochemical aspects of maize crop under drought [26]. Improvement in net photosynthesis rate, transpiration rate, antioxidant enzyme activities, and relative water content has been reported due to application of biochar under cultivation of different crops [26,27]. Similarly, use of farmyard manure as soil amendment has been documented to improve soil fertility, crop yield, soil organic matter, microbial activities and soil structure that promoted crop growth [28,29].

Though significant amount of work has been reported on the use of these soil amendment to tackle drought in crops[30,31], but the interactive effects of the same still needs more attention. Information on links and feedback between soil microbial communities vis-à-vis nutrient cycling and above ground crop performance are scarce. Under these perspectives, the present research initiative was undertaken to study the interaction of applied soil amendments (biochar and FYM) on Nitrogen and Phosphorus mineralization in drought under legume cultivation. The following objectives were formulated for the current study:

Objectives

1. To observe the soil nitrogen and phosphorus mineralization:
    a. under water deficit condition
    b. as influenced by organic amendments under water deficit condition
2. To study the management induced changes in soil biological properties under water deficit conditions.

3. To assess the impact of management induced responses on grain quality of legumes.

Hypothesis

We hypothesize that application of soil amendments will influence the nitrogen and phosphorus mineralization in acidic soil in drought situation.

References

[1] Dai, A. Drought under global warming: a review. *Wiley Interdisciplinary Reviews: Climate Change*, 2(1):45-65, 2011.

[2] AghaKouchak, A., Farahmand, A., Melton, F. S., Teixeira, J., Anderson, M. C., Wardlow, B. D., and Hain, C. R. Remote sensing of drought: Progress, challenges and opportunities. *Reviews of Geophysics*, 53(2):452-480, 2015.

[3] Hao, Z., and Singh, V. P. Drought characterization from a multivariate perspective: A review. *Journal of Hydrology*, 527:668-678, 2015.

[4] Liu, X., Zhu, X., Pan, Y., Zhao, A., and Li, Y. Spatiotemporal changes of cold surges in Inner Mongolia between 1960 and 2012. *Journal of Geographical Sciences 2015 25:3*, 25(3):259-273, 2015.

[5] Wu, J., Zhou, L., Mo, X., Zhou, H., Zhang, J., and Jia, R. Drought monitoring and analysis in China based on the Integrated Surface Drought Index (ISDI). *International Journal of Applied Earth Observation and Geoinformation*, 41:23-33, 2015.

[6] Feng, S., and Fu, Q. Expansion of global drylands under a warming climate. *Atmospheric Chemistry and Physics*, 13(19):10081-10094, 2013.

[7] Maestre, F. T., Eldridge, D. J., Soliveres, S., Kéfi, S., Delgado-Baquerizo, M., Bowker, M. A., García-Palacios, P., Gaitán, J., Gallardo, A., Lázaro, R., and Berdugo, M. Structure and functioning of dryland ecosystems in a changing world. *Annual review of ecology, evolution, and systematics*, 47:215, 2016.

[8] Manzoni, S., and Porporato, A. Soil carbon and nitrogen mineralization: Theory and models across scales. *Soil Biology and Biochemistry*, 41(7):1355-1379, 2009.

[9] Farooq, M., Wahid, A., Kobayashi, N., Fujita, D., and Basra, S. M. A. Plant drought stress: Effects, mechanisms and management. *Sustainable Agriculture*, 2009:153-188, 2009.

[10] Johnson, S., and Rejmánková, E. IMPACTS OF LAND USE ON NUTRIENT DISTRIBUTION AND VEGETATION COMPOSITION OF FRESHWATER WETLANDS IN NORTHERN BELIZE. *https://doi.org/10.1672/0277-5212(2005)025[0089:IOLUON]2.0.CO;2*, 25(1):89-100, 2005.

[11] Allen, K., Corre, M. D., Tjoa, A., and Veldkamp, E. Soil Nitrogen-Cycling Responses to Conversion of Lowland Forests to Oil Palm and Rubber Plantations in Sumatra, Indonesia. *PLOS ONE*, 10(7):e0133325, 2015.

[12] Elkoca, E., Kantar, F., and Sahin, F. Influence of Nitrogen Fixing and Phosphorus Solubilizing Bacteria on the Nodulation, Plant Growth, and Yield of Chickpea. *https://doi.org/10.1080/01904160701742097*, 31(1):157-171, 2007.

[13] Oburger, E., Gruber, B., Schindlegger, Y., Schenkeveld, W. D. C., Hann, S., Kraemer, S. M., Wenzel, W. W., and Puschenreiter, M. Root exudation of phytosiderophores from soil-grown wheat. *New Phytologist*, 203(4):1161-1174, 2014.

[14] Rubiales, D., and Mikic, A. Introduction: Legumes in Sustainable Agriculture. *Critical Reviews in Plant Sciences*, 34:2-3, 2015.

[15] Siddique, K. H. M., Loss, S. P., Regan, K. L., and Jettner, R. L. Adaptation and seed yield of cool season grain legumes in Mediterranean environments of south-western Australia. *Australian Journal of Agricultural Research*, 50(3):375-388, 1999.

[16] Kahraman, A., Ceyhan, E., and Harmankaya, M. Nutritional variation and drought tolerance in chickpeas (Cicer arietinum L.). *Journal of Elementology*, 20(2):331-341, 2015.

[17] Farooq, M., Gogoi, N., Barthakur, S., Baroowa, B., Bharadwaj, N., Alghamdi, S. S., and Siddique, K. H. M. Drought Stress in Grain Legumes during Reproduction and Grain Filling. *Journal of Agronomy and Crop Science*, 203(2):81-102, 2017.

[18] Daryanto, S., Wang, L., and Jacinthe, P. A. Global synthesis of drought effects on food legume production. *PLoS ONE*, 10(6)2015.

[19] Graham, P. H., and Vance, C. P. Legumes: Importance and Constraints to Greater Use. *Plant Physiology*, 131(3):872-877, 2003.

[20] Chowdhury, J., Karim, M., Khaliq, Q., Ahmed, A., and Khan, M. Effect of drought stress on gas exchange characteristics of four soybean genotypes. *Bangladesh Journal of Agricultural Research*, 41(2):195-205, 2016.

[21] Nadeem, M., Li, J., Yahya, M., Sher, A., Ma, C., Wang, X., and Qiu, L. Research Progress and Perspective on Drought Stress in Legumes: A Review. *International Journal of Molecular Sciences 2019, Vol. 20, Page 2541*, 20(10):2541, 2019.

[22] Ullah, A., Romdhane, L., Rehman, A., and Farooq, M. Adequate zinc nutrition improves the tolerance against drought and heat stresses in chickpea. *Plant Physiology and Biochemistry*, 143:11-18, 2019.

[23] Gusmao, M., Siddique, K. H. M., Flower, K., Nesbitt, H., and Veneklaas, E. J. Water Deficit during the Reproductive Period of Grass Pea (Lathyrus sativus L.) Reduced Grain Yield but Maintained Seed Size. *Journal of Agronomy and Crop Science*, 198(6):430-441, 2012.

[24] Sirousmehr, A., Arbabi, J., and Asgharipour, M. R. *Effect of Drought Stress Levels and Organic Manures on Yield, Essential Oil Content and Some Morphological Characteristics of Sweet Basil (Ocimum Basilicum) Extended Exergy Analysis (EAA) of Two Canola Farming Systems in Khorramabad, Iran View Project All.*; 2014.

[25] Paneque, M., De la Rosa, J. M., Franco-Navarro, J. D., Colmenero-Flores, J. M., and Knicker, H. Effect of biochar amendment on morphology, productivity and water relations of sunflower plants under non-irrigation conditions. *Catena*, 147:280-287, 2016.

[26] Sattar, A., Sher, A., Ijaz, M., Ul-Allah, S., Butt, M., Irfan, M., Rizwan, M. S., Ali, H., and Cheema, M. A. Interactive Effect of Biochar and Silicon on Improving Morpho-Physiological and Biochemical Attributes of Maize by Reducing Drought Hazards. *Journal of Soil Science and Plant Nutrition*, April 2020:1-8, 2020.

[27] Ullah, N., Ditta, A., Khalid, A., Mehmood, S., Rizwan, M. S., Ashraf, M., Mubeen, F., Imtiaz, M., and Iqbal, M. M. Integrated Effect of Algal Biochar and Plant Growth Promoting Rhizobacteria on Physiology and Growth of Maize

Under Deficit Irrigations. *Journal of Soil Science and Plant Nutrition*, 20(2):346-356, 2020.

[28] Blair, N., Faulkner, R. D., Till, A. R., and Poulton, P. R. Long-term management impacts on soil C, N and physical fertility. Part I: Broadbalk experiment. *Soil and Tillage Research*, 91(1-2):30-38, 2006.

[29] Kundu, S., Bhattacharyya, R., Prakash, V., Ghosh, B. N., and Gupta, H. S. Carbon sequestration and relationship between carbon addition and storage under rainfed soybean-wheat rotation in a sandy loam soil of the Indian Himalayas. *Soil and Tillage Research*, 92(1-2):87-95, 2007.

[30] Ali, S., Rizwan, M., Qayyum, M. F., Ok, Y. S., Ibrahim, M., Riaz, M., Arif, M. S., Hafeez, F., Al-Wabel, M. I., and Shahzad, A. N. Biochar soil amendment on alleviation of drought and salt stress in plants: a critical review. *Environmental Science and Pollution Research*, 24(14):12700-12712, 2017.

[31] Luo, G., Li, L., Friman, V. P., Guo, J., Guo, S., Shen, Q., and Ling, N. Organic amendments increase crop yields by improving microbe-mediated soil functioning of agroecosystems: A meta-analysis. *Soil Biology and Biochemistry*, 124:105-115, 2018.