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Editorial

Arbuscular Mycorrhiza and Its Influence on Crop Production

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Citation: Hristozkova, M.; Orfanoudakis, M. Arbuscular Mycorrhiza and Its Influence on Crop Production. *Agriculture* **2023**, *13*, 925. https://doi.org/10.3390/agriculture13050925

Received: 19 April 2023
Revised: 21 April 2023
Accepted: 21 April 2023
Published: 23 April 2023

Arbuscular mycorrhizal fungi (AMF) have become attractive as bio stimulants in agriculture due to plant nutrient uptake enchantment and stress tolerance. Plants frequently interact with microbes under natural conditions, which directly mediate plant responses to environmental adversities. As a crucial element of soils, microbes are an integral part of the agricultural ecosystem. AMF are ubiquitous widespread soil microorganisms that can form symbiotic associations with most of agricultural plants. These beneficial microbes can offer an array of advantages to host plants. The focus of this Special Issue is to consider different points of view relating to the use of AMF as an environmentally friendly tool both in greenhouse and field crop production. This perspective is emphasized by the published studies on the application of mycorrhizal fungi to enhance crop performance and production as well as on the role of these soil microorganisms in crop stress tolerance and sustainability improvement.

The application of mycorrhizal fungi for the vegetable production is recommended because it can have a positive effect on the yield and quality although lower dose of mineral fertilizers was applied [1]. Franczuk et al. [1] hypothesize that AMF inoculation of the sweet pepper root system will make it possible to reduce the amount of mineral fertilizers without a significant reduction in fruit yield and quality. The purpose of the research was to determine the effect of AMF inoculation time and mineral fertilizer doses (100%, 50%, and 25% of the basic dose) on selected plant growth parameters, fruit biometric features, and yield and on the accumulation of selected nutrients and minerals in the fruits. The authors have found that AMF inoculation of the root zone resulted in high sweet pepper yields of good quality. In particular, mycorrhizal fungi applied to the root system during seedling production positively affected the pepper yield and biometric characteristics, with fruits of the thickest pericarp and the largest mass. Despite the reduction in top dressing dose by 50% and 75%, AMF contributed to the accumulation of similar amounts of phosphorus (P) in the sweet pepper fruits. The top-dressing dose of 50% applied during seedling production to the experimental units with mycorrhizal fungi resulted in a significant increase in the content of potassium (K), calcium (Ca), and magnesium (Mg). A significant increase in the amount of sodium (Na) in the fruits was noted in the experimental units with mycorrhizal fungi applied to the roots when the seedlings were transferred to pots.

The uses of biofertilizers can alleviate the harmful effects of salinity and increase the absorption and availability of P while increasing productivity and yield [2]. Thus, the investigation of Masrahi et al. [2] was conducted to evaluate the useful influences of the combinations between phosphorus P fertilizer rates and arbuscular mycorrhizal fungi (AMF) as well as phosphate solubilizing bacteria (PSB) to improve P management under salinity stress related to yield and its components as well as N, P, and K uptake in barley. The findings revealed that the combination AMF + 100% RDP improved plant height, length of spike, spikes weight, number of spikes plant^{-1}, weight of 1000-grain, straw yield, grain yield, uptake of N, P, K in grain, and uptake of N, phosphorus P, K in straw. AMF showed greater efficiency and effectiveness compared to PSB in improving yield and its components for all studied traits. The authors recommended inoculating the soil with AMF or PSB with the addition of phosphate fertilizer at the recommended dose under salinity conditions.

Another point of view of mycorrhizal fungi application is underlined by the research paper of Geneva et. al., which described the response to drought stress of *golden berry* plants inoculated with arbuscular mycorrhizal fungi *Claroideoglomus claroideum* and propagated in vitro as well as from seeds [3]. The implementation of mycorrhizal symbiosis was determined by root colonization, glomalin content, and alkaline and acid phosphatases in roots and soil. The plant protection was assured by enzyme and non-enzyme antioxidants. The adapted in vitro-propagated plants demonstrated higher resistance to drought than plants developed from seeds, indicated by increased growth parameters (shoot, root biomass, fruit number), plastid pigment content, antioxidant activity, and less enhancement of oxidative markers levels in water-deficient conditions. The findings in the present research are relevant to obtain the optimal mycorrhizal association and type of propagation in an adverse environment for golden berry development and will lead to the establishment of a database and model of varied plant responses to stressful conditions such as drought.

The effect of mycorrhizal fungi, preceding crops, mineral and biofertilizers on maize intercropping with cowpea was studied by field experiment, thus demonstrating that berseem gave the best results as a preceding crop and gave the highest values of maize and cowpea, followed by sugar beet as a preceding crop, while wheat recorded the lowest values. Fertilizer treatments had significant effect on all maize and cowpea traits. The treatment 75% NPK + arbuscular mycorrhiza fungi (AMFs) (T2) gave the highest values [4]. Meanwhile, no significant differences were found between fertilizer treatments T1 (100% NPK mineral) and T2 (75% NPK + arbuscular mycorrhiza fungi (AMFs)) combination on all studied characters of maize. The interaction had a significant effect on most studied characters of maize and cowpea in the two growing seasons. The cultivation of the two components of intercropping after berseem with T2 fertilizer recorded the highest values. Mixing the third cut of cowpea with maize straw significantly increased the quality and digestibility of forge in both seasons [4].

Phosphorus is the second most significant macro-nutrient in rice productivity. P immobilization in some soil makes it unavailable for crops to absorb [5]. This fact defines the goal of the research by Elekhtyar et al. [5]. The authors examined the effects of microbial and chemical sources of phosphorus fertilizers on the Egyptian Sakha 106 rice cultivar by applying different sources of phosphorus, the goal being to increase the bioavailability of soil P for plants and allow it to be mobilized biologically to change it from an insoluble form to a soluble and available form for rice to absorb. The application of combinations of biofertilizers, i.e., arbuscular mycorrhizal fungi (AMFs), phosphate-solubilizing bacteria (PSBs), and single super phosphate (SSP), beneficially improved P bioavailability in soil. When compared with the applied biological or chemical P fertilizer alone, the combination of two biofertilizers (AMFs and PSBs) and one of the chemical P fertilizers, i.e., single super phosphate (SSP), orthophosphoric acid, or hydroxyapatite, showed the highest crop productivity and improved all examined characteristics. The findings of this study showed that the combination of the foliar spraying of phosphate-solubilizing bacteria (PSBs), top-dressing with arbuscular mycorrhizal fungi (AMFs), the foliar spraying of phosphorus nanoparticles (PNPs), the foliar spraying of phosphoric acid (PA), and the basal application of 75% single super phosphate (SSP) improved the grain yield of the Sakha 106 Egyptian rice cultivar, helping plants and soil by solubilizing fixed P in Egyptian paddy soil and reducing chemical P fertilizers by 25%, thus lowering the use of chemical P fertilizers, reducing P leaching, and minimizing pollution.

Many terrestrial plants form reciprocal symbioses with beneficial fungi in roots; however, it is not clear whether *Vicia villosa*, an important forage and green manure crop, can coexist with these fungi and how such symbiosis affects plant growth and soil properties. That is why the aim of the He et al. [6] research paper is to analyze the effects of inoculation with three arbuscular mycorrhizal fungi (AMF), i.e., *Diversisporas purca*, *Funneliformis mosseae*, and *Rhizophagus intraradices*, and an endophytic fungus *Serendipita indica* on plant growth, root morphology, chlorophyll and sugar levels, soil nutrients, and aggregate size distribution and stability in *V. villosa* plants. The beneficial fungi colonized the roots with colonization rates of 12% to 92%, and they also improved plant growth performance and root morphology to varying degrees, accompanied by the most significant promoted effects after *R. intraradices* inoculation. All AMF significantly raised chlorophyll *a* and *b* levels, carotenoid, and total chlorophyll concentrations, along with a significant increase in leaf sucrose, which consequently formed a significantly higher accumulation of glucose and fructose in roots providing carbon sources for the symbionts. Root fungal colonization was significantly positively correlated with chlorophyll levels, leaf sucrose, and root glucose. In addition, inoculation with symbiotic fungi appeared to trigger a significant decrease in soil Olsen-P and available K and a significant increase in NH_4-N, NO_3-N, and glomalin-related soil protein levels, plus a significant increase in the proportion of water-stable aggregates at the size of 0.5–4 mm as well as aggregate stability. This improvement in soil aggregates was significantly ($p < 0.01$) positively correlated with root fungal colonization rate and glomalin-related soil protein concentrations.

In conclusion, the Special Issue "Arbuscular Mycorrhiza and Its Influence on Crop Production" is a small step ahead toward putting together the puzzle of plant–microbe interactions. The studies in this SI reveal that AMF can improve crops' nutrient status and enhance their quality and yield in the face of challenges to produce enough healthy food to supply the global population, under the current conditions of climate change and biodiversity degradation.

Author Contributions: Conceptualization, M.H. and M.O.; investigation, M.H. and M.O.; writing—review and editing, M.H. and M.O.; visualization, M.H. and M.O. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: We would like to sincerely thank all authors who submitted papers to the Special Issue of Agriculture entitled "Arbuscular Mycorrhiza and Its Influence on Crop Production", as well as the reviewers of these papers for their constructive comments and thoughtful suggestions, and the editorial staff of Agriculture.

Conflicts of Interest: The authors declare no conflict of interest.

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