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RESEARCH ARTICLE

Mycorrhizal fertiliser varieties and the conditions necessary for their effective use

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Abstract

The article is devoted to studying the range of mycorrhizal fertilisers in Ukraine and some countries of the European Union. The growth of fertilisers offered with mycorrhizal fungi in the organic farming market has been established. When selecting mycorrhizal fertilizers for grain and cereal crops (wheat, barley, corn), the most effective strains are Arbuscular Mycorrhiza (AM). It is shown that AM application during legume cultivation improves phosphorus absorption. Depending on the type of fruit and berry crops, endomycorrhiza and ectomycorrhiza should be correctly selected to prevent ineffective application. It has been proven that oil crops (sunflower, rapeseed) respond well to endomycorrhiza, which improves the absorption of nutrients. It has been set that when choosing a mycorrhizal fertiliser, farmers need to pay attention to fertilisers with a high concentration of spores, and it is also more effective to use a consortium of bacteria and mycorrhizal fungi (the most common and effective are *Glomus intraradices*, *Glomus mosseae*, and *Rhizophagus irregularis*).

Keywords: Mycorrhizae, Fertiliser application, Inoculation, Soil biota, Seed treatment, Yield, Biologics, Soil fertility, Soil structure

Introduction

The last twenty years of agriculture have been marked by a significant increase in the use of biofertilisers containing mycorrhizal fungi (Microbial Fertilizer, 2025). These fungi can form symbiotic associations with the root systems of plants. Species (*Glomus, Rhizophagus, Funneliformis*, etc.) that exhibit high sporulation and plant colonisation efficiency are used for microbial fertiliser production. In genetic engineering, DNA research identifies specific markers of effective strains and uses molecular genetic methods (PCR, sequencing) to select the best options (Varma et al., 2017). Inoculation is carried out on sterile substrates using vermiculite, perlite, etc., to cultivate mycorrhizal fungi. Further, cryopreservation is used for storage, i.e. the strains are stored in liquid nitrogen. The next stage is the production of dry granular or liquid forms for long-term storage - from six months to a year. The dry forms may take longer, but the appropriate temperature regime must be observed during storage.

Material and Method

When making fertilisers with mycorrhizal fungi, the manufacturer can add other biota, for example, nitrogen-fixing bacteria (*Rhizobium, Azospirillum*) and phosphate-mobilizing bacteria (*Bacillus, Pseudomonas*), which will also improve the consumption of nitrogen and phosphorus from the soil. Encapsulation can be used to extend the viability of fungi, i.e., the creation of biopolymer capsules (Varma et al., 2017). Also, clay substrates such as kaolinite and bentonite can be used as a matrix to preserve spores. The main issues in scientific circles regarding mycorrhizal fungi are improving the interaction of strains with plants and the ecosystem when growing crops. Their use increases the bioavailability of nutrients, namely phosphorus, potassium, nitrogen, zinc, and iron, due to the activity of mycorrhizal hyphae (Berruti et al., 2016). Then, it is possible to regulate the rates of mineral fertiliser application (Kharchenko et al., 2019, 2021). There is also the induction of mechanisms of systemic resistance to pathogens, increased resistance to drought, and the adverse effects of salinity and heavy metals (Hric et al., 2013).

It has been proven that using mycorrhizal fungi improves the synthesis of glomalin (glycoprotein), which strengthens soil aggregates. As a result, the structural and aggregate composition of the soil is improved, and the biodiversity of the rhizosphere is increased (Smith & Read, 2008).

When considering the development of innovative mycorrhizal fertilizers, it is crucial to highlight the role of genetic modification techniques, particularly CRISPR/CAS9. This approach can potentially enhance the metabolic pathways of mycorrhizal fungi and confer resistance to various abiotic stresses, marking a significant advancement in the field (Smith & Read, 2008).

Another interesting direction is the development of multimicrobial consortia, such as combinations of mycorrhizal fungal strains with beneficial bacteria and Trichoderma. One more promising direction is the use of nanotechnology for the encapsulation of fungal spores and integration with sensor technologies for monitoring root colonisation.

Biotechnology and bioengineering are actively developing in the EU, particularly in environmental biotechnology and bioenergy. This indicates a growing interest in the use of mycorrhizal fungi in agriculture. The production of mycorrhizal fertilisers is concentrated in Germany, Italy, Spain, the United Kingdom, France and the Netherlands. Since 2000, the number of companies selling arbuscular mycorrhizal inoculants has been growing steadily. In Europe, mycorrhizal fertilisers have a significant share in the biofertilizer market, accounting for about 63% of the market share in 2024 (Mycorrhiza Market Size, 2025). Their advantages explain this dominance in improving nutrient absorption and supporting organic farming. In general, the active use of mycorrhizal fertilisers is noted in the USA, Canada, Germany, France, and India.

A study by scientists from the European Union countries showed that the effectiveness of mycorrhizal fertilisers varies depending on the type of soil and fertilisation systems (Prettl et al., 2024). Thus, soils with a higher percentage of organic matter and microbial activity may exhibit a weak response to inoculation compared to soils with nutrient deficiencies.

It is crucial to recognise that the market has seen a rise in investment for research and development, leading to diverse products available at various price points (Zhang et al., 2022). The production and application of arbuscular mycorrhizal inoculants can be laborious and expensive, which may limit their use in large-scale conventional farming.

Mycorrhizal biofertilisers are effective for various crops, including cereals, legumes, oilseeds, fruits, and vegetables (Zakharchenko et al., 2023; Zakharchenko, Datsko et al., 2024). Based on field trials, Solomon et al. (2022) have established a positive effect of mycorrhiza on the yield, biomass of soybeans and corn in organic farming with a corresponding positive economic impact. The application of AM in potato cultivation has shown less favorable results, indicating that the effectiveness of mycorrhizal inoculation may differ depending on the type of crop and farming practices (Kovalenko et al., 2024; Prettl et al., 2024).

The effectiveness of mycorrhizal inoculation also depends on the existing soil biota (Hryhoriv et al., 2021, 2024). Some studies have indicated that applying mycorrhizal fertilisers without soil bacteria negatively impacts corn yield, highlighting the native soil microbiome's significant role in successful inoculation (Zakharchenko, Huang et al., 2024). But another one showed a positive effect (Tsyhanskyi, 2022).

Based on the review results, we can draw the following diagram, which shows the stages of reactions and effects of mycorrhizal fertilisers (Fig. 1).

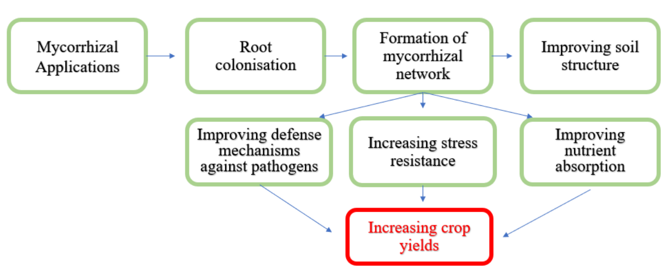

Figure 1. Effect of mycorrhizal fertilisers.

In Germany, the products of INOQ GmbH, which specialises in mycorrhizal inoculants, are well known. Dynomyco inoculants are also famous fertilisers (Dynomyco, 2025). A mycorrhizal fertiliser from RootMax is offered to tomatoes (Mycorrhiza for your plants, 2025). The production of biofertilisers aims to enhance nutrient absorption in plants and promote sustainable agriculture.

In 2022, the German market for mycorrhizal biofertilisers was estimated at approximately 43.32 billion US dollars, with a growth rate of 8.5% by 2028 (Mycorrhiza, 2024). It is proven that liquid inoculants are more popular than the dry powder form.

The products of Plant Health Care, the Mycorrhiza mixture from Dutch Ground Control, and Fungilife Mycorrhiza mixture are well-known in the Netherlands (Mycorrhiza, 2024).

The most well-known products in France are MycoApply from Novozymes, LALRISE from Lallemand Plant Care, and Mycorrhiza products from UPL Limited (France Mycorrhizae-Based Biofertilizers, 2025). The mycorrhizal fertiliser market in France in 2022 was estimated at 57.3 million USD, with a growth forecast of 7.8% until 2028. France is expected to hold the largest share of the mycorrhizal biofertiliser market in Europe due to the increase in the organic production of row crops and the decrease in the production of chemical fertilisers.

The market for mycorrhizal fertilisers in Ukraine is in the development stage. Scientific institutions are actively researching and developing such fertilisers, but specific information on the market size and the list of importers is limited. Thus, the Institute of Agricultural Microbiology and Agro-Industrial Production of the National Academy of Sciences of Ukraine, the Institute of Microbiology and Virology named after D.K. Zabolotny, and the BTU Centre and Bionorma conduct research in the field of microbiology and develop biofertilisers and microbial preparations for agriculture. Farmers, along with educational professionals, are actively studying the effectiveness of both created and imported microbial preparations. Their researches keep a particular focus on soil degradation issues, as well as the challenges posed by the high cost and limited supply of mineral fertilizers (Karpenko, 2023; Shelest et al., 2023; Vdovenko, 2020). The primary products that contain mycorrhizal fungi and are widely sold on the market are listed in Tab. 1.

Table 1. Components of the effectiveness of mycorrhizal biofertilisers used in Ukraine

Name of fertiliser/preparation, manufacturer	Components, filler*
Mycofriend. Private enterprise "BTU-Center" (Ukraine)	Glomus VS та Trichoderma Harzianum Streptomyces sp., Pseudomonas, Fluorescens and phosphate-mobilizing bacteria: Bacillus megaterium var. phosphaticum, Bacillus Subtilis, Bacillus Muciloginosus, The filler is sterile peat.
Melanoriz® Private enterprise "BTU-Center" (Ukraine)	Glomus sp. Bacillussubtilis, Bacillusmacerans, Arthrobacter sp., Paenibacillus polymyxa, Aspergillus terreus, Trichoderma lignorum, Trichoderma viride. The total number of viable cells is not less than 2.5x107 CFU/g. Filler – diatomaceous earth or other natural filler.
Mycofix Vitagro, Legum Technology (United Kingdom)	Glomus intraradices. The total number of viable cells is not less than at least 2000 spores/h. Filler - Dried algae medium. Powder form
Bionorma Mycorrhiza, PE "SPE "ECO-GARANT" (Ukraine)	Trichoderma viride, Glomus sp., Tuber melanosporum. The total number of viable cells is not less than 1.0 × 109 CFU/g—granular form. The filler is not specified.
Great White Granular One, Plant Success (USA)	Endomycorhizae, Glomus intraradices. Granular form. The filler is not specified. 132 propagules/g
Atlantica Trichomyx, Vitera Atlantica Agricola (Spain)	Endomycorrhiza (Rhizoglomus irregulare, Funneliformis mosseae, Funneliformis caledonium), Trichoderma hazarianum AE13 - 3x108 CFU/g, Trichoderma viride AE07 - 3x108 CFU/g, Ascophylum nodosum 5,0 %, NPKS, water-soluble powder. Substrate: bentonite, the mixture of biologically active substances.

*The composition of the components is taken from the manufacturers' websites

Mycofriend is suitable for most soil types with a pH of 5.3 or higher and is recommended for application at planting or seed treatment (Gamajunova et al., 2020). Melanoriz may be less effective in soils with high phosphate content (over 8%), effective on depleted and contaminated soils and recommended to be applied at planting or seed treatment (Marchenko, 2021; Vinyukov et al., 2023). Mycofix is recommended for seed application and is effective on all soil types (Yurchenko et al., 2024). Bionorma Mycorrhiza granules are ideal for seeding and broadcast application, with a manufacturer's guarantee of live cells for up to one year (Lemishko et al., 2022). Great White Granular One is relatively new in the Ukrainian market. However, the manufacturer does not publicly disclose all information about its composition; it can be used in soil and coconut substrate. The dry version of the Great White Granular 1 fertiliser is offered for application when growing vegetables, fruit crops, flowers, shrubs, and trees. It is also used during transplantation and poured into holes. Great White Mycorrhiza (powder form) is made from 16 different species of mycorrhizal fungi (9 species of endomycorrhiza, seven species of ectomycorrhiza, 14 species of beneficial bacteria and two species of Trichoderma). The same application can be said for the Spanish fertiliser Atlantica Trichomyx, although the composition of this fertiliser is much more interesting than that of the previous fertiliser. The table lists only the most popular microbial preparations with mycorrhiza available on the Ukrainian market. The MYKOS® Root Pack preparation (contains Rhizophagus intraradices) is also used in the hydroponic cultivation of crops on substrates. Plant Success Orca Liquid Premium Micorrhizae comprises four species of endomycorrhiza and 14 strains of beneficial bacteria and is recommended for hydroponics and when used as a substrate coco and soil. Mega Worm - consists of biohumus, mycorrhiza and Trichoderma. Voodoo Juice® Plus from Advanced Nutrients contains all 16 beneficial bacteria and fungi strains. EMOCHKY – Bokashi (with mycorrhiza) is made from the German concentrate «MikroVeda Farming Plus», which includes wheat bran fermented with a complex of effective microorganisms (photosynthetic, lactic acid bacteria, yeast, fermentative fungi, etc.).

Conclusions

Mycorrhizal fungi are ineffective on crops from certain families that do not form mycorrhizal associations, such as the Brassicaceae family (cabbage of all types, rapeseed, mustard, radish, horseradish, turnip), Amaranthaceae family, beets, spinach, etc. The root environment of these plants may contain specific compounds that inhibit the development of mycorrhizae, or these plants may lack mechanisms to perceive fungal hyphae.

It is important to identify the factors that influence the effectiveness of mycorrhizal fertilizers, such as:

- Environmental policy: countries with strict standards and sustainable development strategies are more likely to introduce biofertilisers;
- Organic farming: mycorrhizal fertilisers are an essential component in the technologies of growing crops according to the organic system;
- Scientific activity: intensive research by scientists into the effectiveness of mycorrhizal fertilisers contributes to introducing innovative products to the market.

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