# INCREASING SOUTH DAKOTA WHEAT PRODUCTION BY BENEFICIAL PLANT MICROBE INTERACTIONS

**Research report to the South Dakota Wheat Commission FY15**

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## RESEARCH QUESTION

Wheat is one of the major crops in South Dakota and the productivity of wheat is highly dependent on fertilizer additions, particularly of phosphate (P) and nitrogen (N). In 2011, 1.692 million tons of N fertilizer, 0.597 million tons of P fertilizer, and 0.107 million tons of K fertilizer were used in U.S. wheat production alone (National Agricultural Statistics Service - NASS, 2015). On average in 2009, farmers in SD applied 78 lb per acre urea, 33 lb per acre superphophate, and 16 lb per acre potassium chloride as fertilizers (USDA, 2014). The costs for these fertilizers increased dramatically in the last couple of years and this has doubled the expenditures of farmers for fertilizer input in the Great Plains (from 2,880 million Dollars in 2005 to 5,770 million Dollars in 2011). From 2012 to 2013, the expenses for fertilizer input, U.S. wide, increased by 6.9 % for N fertilizer and by 5.4% for P fertilizer (NASS, 2013). Therefore, research with the goal to improve the nutrient efficiency of wheat should represent an urgent priority to increase productivity and cost efficiency of wheat agriculture in SD.

Wheat is under field conditions normally associated with arbuscular mycorrhizal (AM) fungi and AM fungi can contribute substantially to the nutrient efficiency of their host. The mycelium of the fungus acts as an extension of the root system and improves the uptake of phosphate (P), nitrogen (N) and other elements. More than 50% of the P that is taken up by wheat is supplied by the AM fungus. In addition, the fungus increases the resistance of plants against abiotic stresses, such as drought and salinity, and against biotic stresses, such as various pathogens. It has been estimated that an efficient use of the symbiosis can substitute P applications of up to 222 kg superphosphate per ha and this would significantly increase the cost-efficiency of wheat production in the Northern Great Plains. However, conventional breeding techniques have reduced the responsiveness (yield increase in response to colonization) of wheat to this beneficial symbiosis. Wheat varieties that were developed before 1900 show a higher responsiveness to AM colonization than modern varieties. Long term goal of this project is to increase the efficiency with which wheat absorbs and utilizes phosphate and nitrogen through the colonization with beneficial arbuscular mycorrhizal (AM) fungi to lower the required fertilizer inputs and thereby reduce the wheat production costs and improve the environmental sustainability of wheat production.

## EXPERIMENTAL RESULTS

To achieve this goal, we conducted field and greenhouse studies to determine the impact of AM fungi on growth and productivity of different wheat varieties that are recommended for different areas of SD (iGrow, 2015).

### Field study

Eight different wheat varieties were planted in a randomized block design (4 rows with 20 seeds each) on the experimental fields near the SDSU campus. The colonization of the plants with AM fungi on some plots was suppressed or increased by regular additions of the fungicide Topsin M or the commercially available mycorrhizal additive MycoApply Ultrafine Endo, respectively. The mycorrhizal additive MycoApply Ultrafine Endo contains equal proportions of the four different AM fungi *Glomus intraradices, G. mosseae, G. aggregatum, G. etunicatum* (70 propagules per g each). The plants were harvested and we compared the colonization of the plants with AM fungi, and the biomass and yield on the experimental plots to control plots to which no fungicide or mycorrhizal additives were added. On the control plots the plants were colonized with the natural communities of AM fungi in the soil.

The fungicide treatment led to a significant decrease in the AM colonization of all wheat varieties. The wheat plants that were treated with Topsin M were still colonized with AM fungi (fungicide additions normally don´t suppress the AM colonization of the roots completely), but the root colonization of the control plots and the plots to which the mycorrhizal additives were added was 30 to 50% higher (Fig. 1A). The natural population of AM fungi in the soil was high, and the mycorrhizal additive did not lead to an increase in the AM colonization of the plant.

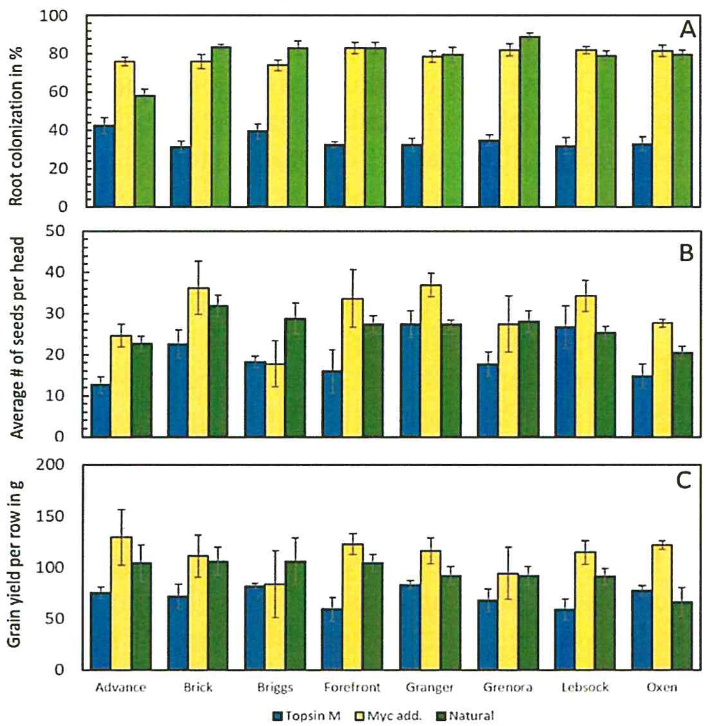


Fig. 1. AM root colonization (A), average number of seeds per head (B), and grain yield per row (C) of the different tested wheat varieties. The plots that were treated with Topsin M or the mycorrhizal additive are shown in blue or yellow, respectively, the control plots in green.

The mycorrhizal colonization of the plant led in several wheat varieties to a significant increase in the number of seeds per head, and the overall grain weight of the plots (Fig. 1B and C). The grain yields in the Topsin M treated plots were generally lower for all wheat varieties, but particularly the wheat varieties Advance, Forefront, Oxen and Lebsock showed significantly higher grain yields in those plots where the mycorrhizal colonization was not suppressed by Topsin M (control plots and plots that were treated with the mycorrhizal additive). Some of the varieties showed very substantial increases in grain yields. The grain yield for example of Forefront in the mycorrhizal additive treated plots was twice as high as in the Topsin M treated plots. The grain yields of the wheat varieties Oxen, Lebsock, Advance, and Forefront were generally higher in the plots that were treated with the mycorrhizal additive, although the mycorrhizal colonization of these plants did not differ from the control plots in which the plants were colonized by the natural communities of AM fungi in the soil. These differences could indicate that the mycorrhizal additive induces a shift in the AM fungal communities and increases the colonization of the plants by more beneficial AM fungal species. AM fungal species can differ greatly in the benefits that they provide to specific host plants. We are currently testing these differences in a greenhouse experiment to see whether the colonization with the fungal species in the mycorrhizal additive results in higher increases in growth and yield than the colonization with single isolates of one AM fungal species. Only in Advance were the increases in grain yield directly related to higher phosphate contents or concentrations. This could indicate that the observed benefits in the other wheat varieties were the result of other beneficial effects that are often described as a result of an AM fungal colonization (for example improved nutrition with N or K, higher resistance against pathogens, or drought).

## Greenhouse study

We studied the mycorrhizal dependency of the same wheat varieties also in a greenhouse study. Seeds of the wheat genotypes Brick, Granger, Grenora, Lebsock, Advance, Briggs, Oxen and Forefront were surface sterilized and pre-germinated and transplanted in 1 l pots. The plants were inoculated after one week with the AM fungus *Glomus intraradices* DAOM 197198. This fungal species is most commonly used in commercial products and is also included in the mycorrhizal additive that was used in the field experiment. We varied the nutrient supply of the plants and examined high or low P or high and low N conditions.

The mycorrhizal growth responses that we observed under greenhouse conditions were not as pronounced as under field conditions, but Advance showed also under greenhouse conditions a positive response to the colonization with AM fungi. The mycorrhizal responsiveness of the different wheat varieties differed from positive via neutral to slightly negative. Negative mycorrhizal growth responses were observed in Briggs and in Granger, in two wheat varieties that showed under field conditions no negative mycorrhizal response. Granger showed in the experimental plots to which the mycorrhizal additives were added under field conditions even slightly higher grain yields. There are several potential reasons that may explain the discrepancy between the field studies and the greenhouse conditions.

1. Difference in the mycorrhizal communities under field and under greenhouse conditions. While in the field studies the plants were colonized with several different AM fungi, were the plants in the greenhouse studies only colonized with one AM fungal species. However, fungi differ in the efficiency with which they are able to benefit the host plant, and it is now important to study which AM fungi are able to provide the highest benefit to wheat.
2. Differences in the growth conditions. While under field conditions plants compete with other organisms for the available nutrient resources, and many of these nutrient resources are often in forms that are unavailable for plants, there was no competition in the greenhouse experiments, and the nutrients were readily available for the plants. Mycorrhizal growth impacts are normally reduced under high nutrient supply conditions.
3. Impact of other microbial communities. AM fungi have an impact on the microbial communities in the soil, and it is known that AM fungi increase the activities particularly of beneficial microorganisms, but reduce the numbers of pathogenic microorganisms. For the greenhouse studies sterilized soil was used, and the growth of the plants is not affected by other microbial communities in the soil. It is planned to address the impact of these microbial communities in future experiments and the next funding cycle.
4. Differences in environmental conditions. Under field conditions the yield of plants is affected by a variety of abiotic and biotic environmental conditions, but these conditions did not play a role in the greenhouse experiment. For example, drought can cause under field conditions significant losses in wheat productivity, but it is known that AM fungi can significantly reduce the drought stress of plants. In addition, AM fungi are able to suppress plant pathogens that may have had an impact on the Topsin M plots in the field, but there was no pathogen stress in the greenhouse experiments.

In the next funding cycle we would like to address some of these problems, and are planning to follow up on the positive impacts that we observed in our field experiments, that clearly demonstrated that AM fungi can have a significant impact on wheat productivity under field conditions.