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Arbuscular mycorrhizae (*Glomus mosseae*) symbiosis for increasing the yield and quality of wheat (*Triticum aestivum*)*

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Two most important types of symbiosis between plant and micro-organisms are N_2 fixation and performing physiological and protective functions by mycorrhizae. The arbuscular mycorrhizal fungi grows within the host roots, intermittently forming branched, tree-like structures, known as arbuscules, which are the main sites of nutrient exchange (Simth and Reid 1997). The fungi form mutualistic association with the plant roots, providing the plant with water, phosphorus and other nutrients and help in protecting the roots from pathogens in exchange for photosynthates.

Intensive farming of rice-wheat or cotton-wheat systems is unable to sustain productivity gains of green revolution due to degradation of natural resources base of the soil including soil microbial activity. Often the soil in the region contains an abundance of nutrients but delivery to the crop itself may be limited resulting into poor crop yields. For example, the agronomic efficiency of applied phosphorus fertilizer is only 10–20% in the year of application, while a major portion of applied phosphorus and other nutrients become fixed in soil and unavailable to non-mycorrhizal crops. Thus, mycorrhizal fungi are important in mobilizing nutrients in the soil and transporting them back to the plants. However, our knowledge about this symbiosis in wheat is limited (Li *et al.* 2006). Therefore, a field experiment was conducted at CCS Haryana Agricultural University, Hisar. to study the performance of two wheat varieties with and without mycorrhizal inoculum under field conditions. Seed priming (soaking of seed overnight in water) was also done before inoculation to visualize its influence on the colonization of the fungi.

Two wheat varieties, 'PBW 343' (timely sown) and 'WH 1021' (late sown) were planted on 7 November and 23 December 2007 respectively. The arbuscular mycorrhiza fungi (AM) strain, *Glomus mosseae* was introduced in the soil, and the crop seeds were also inoculated with the fungi before seeding at a rate of 20 g/kg seed. Four treatments including seeding with dry or unprimed seed, primed seed (soaked in water overnight) and inoculation of unprimed seed with arbuscular mycorrhiza and primed seed with arbuscular mycorrhiza were replicated three times in a randomized block design. The soil of the experimental plot was low in organic carbon, available nitrogen and phosphorus and high in potash. The basal application of all nitrogen and phosphorus fertilizers was made before seeding to raise the levels of the two nutrients equivalent to 120 kg nitrogen and 60 kg P_2O_5/ha. The crop was planted after a pre-sowing irrigation, and four post sowing irrigations were applied at 25 days after seeding (crown root initiation), 50 days after seeding (late jointing), 85 days after seeding (heading) and 105 days after seeding (anthesis). Weeding was carried out manually. Yield-attributes such as number of spikes/m^2, number of grains/spike and 1000-seed weight and yields were recorded. Quality characters, protein content, starch and wet gluten in the grains was determined. Data were analyzed by Online Statistical Analysis (OPSTAT, CCS Haryana Agricultural University, Hisar)

The effect of different treatments was significant on the yield attributes and yields of wheat varieties except 1000–seed weight and harvest index. The crop in treatment primed seed inoculated with mycorrhiza produced significantly higher number of spikes/m^2 and grains/spike than primed seed followed by unprimed seed inoculated with mycorrhiza and unprimed seed (Table 1). The latter two treatments did not differ significantly. The number of spikelets/spike was statistically similar in treatments primed seed and primed seed inoculated with mycorrhiza but significantly higher than in treatments unprimed seed and unprimed seed inoculated with mycorrhiza, which showed no differences between them. The biological yield was recorded highest in treatment primed seed inoculated with mycorrhiza and lowest in treatment unprimed seed (Table 2). The treatments primed seed, unprimed seed inoculated with mycorrhiza and primed

*Short note

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Table 1 Yield attributes as influenced by different treatments

Treatment	'PBW 343'			'WH 1021'		
	Spikes/m^2	Spikelets/spike	Grains/spike	Spikes/m^2	Spikelets/spike	Grains/spike
Unprimed seed	469.6	19.3	44.6	361.6	19.0	41.0
Primed seed	589.6	23.0	64.0	468.3	22.3	61.3
Unprimed seed inoculated with mycorrhiza	503.6	19.0	46.3	391.3	18.6	43.6
Primed seed inoculated with mycorrhiza	648.6	23.3	69.0	518.6	23.3	68.0
CD (*P*=5%)	52.41	1.19	3.26	33.59	1.15	2.86
CV (%)	5.63	3.21	3.25	4.54	3.16	3.01

Table 2 Yields (kg/ha) as influenced by different treatments

Treatment	'PBW 343'		'WH 1021'	
	Biomass	Grain yield	Biomass	Grain yield
Unprimed seed	1 5 696.6	5 168.6	9 100.5	3 921.7
Primed seed	1 8 871.2	5 752.0	10 652.5	4 483.9
Unprimed seed inoculated with mycorrhiza	17 989.4	5 337.9	9 947.0	4 005.6
Primed seed inoculated with mycorrhiza	19 223.9	6 507.2	11 111.1	4 672.6
CD (*P*=0.05%)	1295.6	743.40	899.43	443.6
CV (%)	4.17	7.67	5.17	6.17

seed inoculated with mycorrhiza in 'PBW 343' and treatments primed seed and primed seed inoculated with mycorrhiza in 'WH 1021' showed no differences in biological yield. The grain yield was recorded significantly higher in treatment primed seed inoculated with mycorrhiza in 'PBW 343' and primed seed and primed seed inoculated with mycorrhiza in 'WH 1021' as compared to other treatments. The treatments unprimed seed and unprimed seed inoculated with mycorrhiza were at par. Protein content in both varieties and wet gluten in 'WH 1021' was higher in treatments primed seed and primed seed inoculated with mycorrhiza as compared to the treatments unprimed seed and unprimed seed inoculated with mycorrhiza. No clear difference in starch content existed among the treatments in 'WH 1021' (Table 3).

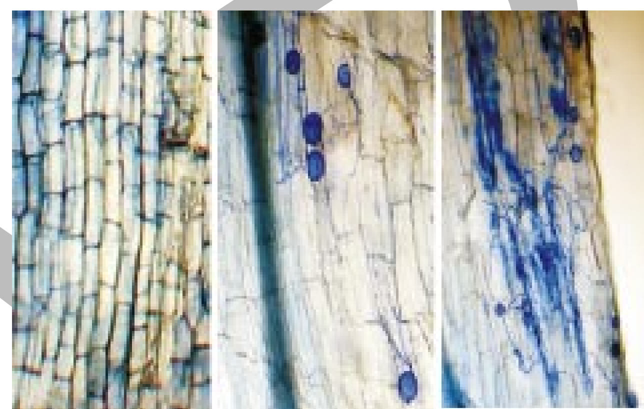

Fig 1 Colonization of *Glomus mosseae* in roots sampled after harvest in different treatments. A. Unprimed seed without inoculum, B. Unprimed seed with inoculum, C. Primed seed with inoculum

In plants, mycorrhizal fungi enter into root cells to form mutualitic association. Therefore, a practice which promote early establishment of plant root system may be helpful in rapid colonization of the fungi. Seed priming promote early plant vigour due to early establishment of deep roots. Our results showed fungal inoculation preceded by seed priming enhanced colonization compared to unprimed inoculated seeds (Fig 1), indicating that there is a great possibility of using mycorrhizae as a biological tool for increasing wheat yields in the region. Healthy seedlings produce profuse tillering, in which the number of spikes/m^2 were 43.4 and 29.5% higher in treatments primed seed inoculated with mycorrhiza and primed seed compared to unprimed seed.

Table 3 Grain quality varieties as influenced by different treatments

Treatments	'PBW 343'			'WH 1021'		
	Protein content (%)	Starch (%)	Wet gluten (%)	Protein content (%)	Starch (%)	Wet gluten (%)
Unprimed seed	11.77	66.67	29.17	12.33	65.90	27.87
Primed seed	12.63	66.43	30.77	12.93	65.23	29.43
Unprimed seed inoculated with mycorrhiza	11.80	66.63	29.60	12.43	65.70	28.23
Primed seed inoculated with mycorrhiza	12.23	66.67	30.23	12.90	65.53	29.27
CD (*P*=0.05%)	0.44	NS	NS	0.55	0.42	1.17
CV (%)	2.11	0.56	3.94	2.48	0.36	2.34

x

Although the number of spikelets/spike were equal in both primed seed and primed seed inoculated with mycorrhiza treatments but number of grains/spike were significantly higher in the latter than the former treatment. This was perhaps owing to increased rate of photosynthesis as well as the translocation of photo-assimilates in treatment primed seed inoculated with mycorrhiza achieved by flag leaves with high tissue water content, which is reported to be positively correlated with these characteristics (Kumar and Sharma 2009, Sharma and Kumar 2009). The improvement in yield-attributes due to fungal inoculation resulted into similar improvement in grain yield but the extent of yield increase varied among the two varieties, 25.8% in 'PBW 343' and 19.1% in 'WH 1021'. The fungal inoculation improved the quality of the grain, increasing protein content and wet gluten. The study revealed that the agricultural practices followed in the region are adversely affecting the colonization of indigenous mycorrhizae. Therefore, introducing inoculant arbuscular mycorrhiza fungi can make a positive contribution to wheat yield and quality and is vital for maintenance of ecosystem health and sustainability.

SUMMARY

A field study was conducted at CCS Haryana Agricultural University, Hisar on potential effects of arbuscular mycorrhiza fungi upon the growth, yield components and quality of wheat. The mycorrhizal inoculation improved yield attributes, yields and grain quality, and the effect was compounded when fungal inoculation was preceded by seed priming (soaking of seed overnight in water). The yield-attributes, number of spikes/m^2 and grains/spike were increased by 38.1 and 54.7% in 'PBW 343' and 43.4 and 65.8% in 'WH 1021', respectively due to fungal inoculation of primed seed over unprimed seed without inoculum. The respective yield gain was 25.8 and 19.1% in 'PBW 343' and 'WH 1021'. The protein content and wet gluten in the grains was improved significantly with fungi inoculation. After the harvest, the percent mycorrhizal infection on the roots of 'WH 1021' was estimated to be increased by more than two fold when primed seeds inoculated with fungi as compared to unprimed seeds.

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