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Mitigating the effect of drought stress on yield in wheat (*Triticum aestivum*) using arbuscular mycorrhiza fungi (*Glomus mosseae*)

BABITA RANI[1], SHASHI MADAN[2], POOJA[3], K D SHARMA[4], NISHA KUMARI[5] and ASHWANI KUMAR[6]

CCS Haryana Agricultural University, Hisar, Haryana 125 004

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ABSTRACT

The arbuscular mycorrhiza fungus (AMF) (*Glomus mosseae)* is a beneficial microorganism used in agriculture as an efficient tool to improve plant growth and nutrition by inducing symbiotic association with crops. The present investigation was conducted to study the contribution of arbuscular mycorrhizal fungus to drought tolerance in wheat (*Triticum aestivum* L.) grown under normal irrigated conditions and in water stress created by withholding irrigation at jointing and heading stage under net house environment. Wheat seeds of two wheat varieties WH 1025 and WH 1105 were grown in pots after treatment with or without the AMF. Under water stress conditions, the wheat variety WH 1025 performed better in terms of growth and yield attributes as compared to WH 1105. The results obtained showed a significant improvement by AMF on plant height, number of productive tillers, spike length, number of spikelet, grain/spike, grain weight/spike and test weight under both irrigated and drought stress condition. Biomass and grain yields were higher in plants treated with mycorrhiza than non-mycorrhizal plants of both the varieties irrespective of soil moisture. Therefore, the results suggest that mycorrhizal inoculation play a vital role in improving growth and yield in wheat by reducing the effects of drought stress and sustain the wheat crop under the semi-arid environments.

Key words: Arbuscular mycorrhizal fungi, Drought, Wheat, Yield

Drought is one of the most important factor limiting plant growth and crops production worldwide more than any other biotic or abiotic stress (Zheng *et al.* 2010). It is an ever-growing problem that harshly limits the crop production and result in important agricultural losses especially in arid and semi-arid areas (Heidari *et al.* 2017). The response of plants to drought stress is very complicated and they manage stress through stress avoidance approaches that depends on genotypes. Plants under stress try to maintain their metabolic and structural capacity to improve their potential under stress through modified gene expression (Almeselmani *et al*. 2011).

Among the diverse consequences of a drought effect on plant development in these ecosystems, restricted nutrient and water acquisition are commonly recognized. A possible approach to increase crop productivity is the application of arbuscular mycorrhizal fungi (AMF) (*Glomus mosseae*) as well as the intrinsic adaptation mechanisms developed by plants, under natural conditions as they grow in association with a number of soil microorganisms (Rani *et al*. 2017, 2018)).

Colonization of roots by AMF has been shown to improve productivity of numerous crop plants under drought stress (Al-Karaki and Clark 1998, Lott *et al*. 2011). This AMF symbiosis can be defined as a specialized system for nutrient uptake and transfer which is more efficient than roots alone. However, the uptake and transfer of nutrients to the host plant is not the only physiological role of AMF symbiosis rather in most of studied, the association between an AMF and a plant makes the host plant more tolerant to abiotic stresses **(**Dodd and Ruız-Lozano 2012**)**. Arbuscular mycorrhiza fungi are important in sustainable agriculture because they improve plant water relations and thus increase the drought resistance of host plants. AMF symbiosis also increases mineral uptake by increased acquisition of phosphorus and other low mobile mineral nutrients, which reduces the excessive use of fertilizers. They can also break down certain complex minerals and organic substances in the soil and make it available to their hosts **(**Mona 2001, Soliman *et al*. 2012).

Wheat (*Triticum* spp.), which is one of the first domesticated food crops, represents the second source of

[1]SRF (e mail: babitachahalkharb@gmail.com), [2]Professor (e mail: svmadan12@gmail.com), [4]Professor (e mail: kdutt1966@gmail.com), [5]Scientist (e mail: nikkys23@gmail.com), CCS HAU, Hisar. [3]Scientist (e mail: poojadhansu@gmail.com), ICAR-Sugarcane Breeding Institute, Regional Station, Karnal, Haryana 132 001. [6]Scientist (e mail: Ashwani.Kumar1@icar.gov.in), ICAR-Central Soil Salinity Research Institute, Karnal.

calories (after rice) and an important source of proteins in developing countries (Hossain and Teixeira da Silva 2013a, 2013b). Wheat is a widely adapted crop around the world, providing one third of the world's population with more than half of their calories and nearly half of their protein (Farshadfar *et al*. 2013). The higher proportional increase in wheat grain yield in water stressed plants due to AMF inoculation might be attributed to the smaller size of stressed plants (Sylvia *et al*. 1993) or to increased dependence of wheat on AMF for mineral and water uptake (Kanwal *et al.* 2015). Hasanpour *et al*. (2012) reported that AMF inoculation increased the protein percentage in grains compared to untreated plants under drought stress conditions. Sumera and Asghari (2009) reported that those changes which were observed in percentage and composition of grain protein were mainly due to differences in genome rather than from the environmental factors. However, the application of AMF inoculation to mitigate the adverse effect of water stress on growth, yield and quality of wheat plants is still unexplored. Therefore, the present study was aimed to evaluate the wheat varieties inoculated with AMF in terms of growth and yield performance under water deficit condition.

MATERIALS AND METHODS

The present investigation was carried out during *rabi* seasons of 2013-14 and 2014-15 on wheat varieties WH 1105 and WH 1025. Seeds were procured from Wheat and Barley Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar. The experiment was laid out in CRD factorial design. Seeds were sterilized with alcohol, washed 3-4 times with distilled water and dried on. Plants of two varieties of wheat were raised in earthen pots (20 × 16 cm) with 5 kg dune sand in natural conditions. In half of the pots, seeds were inoculated (20g/kg seeds) with AM fungi and in another half pots, seeds were sown without AM fungi. Six seeds were sown in each pot at uniform depth. Thinning was done one week after germination to leave two plants of uniform growth in each pot. The plants were supplied with nutrient solution (Hoagland and Arnon 1950) at regular intervals. The drought stress was created by withholding irrigation at jointing and heading stage. Soil moisture content was estimated gravimetrically which was 15.6 % in irrigated soil and 6.7 and 5.8% at jointing and heading stage respectively, under drought conditions.

Yield attributes were recorded on five randomly selected plants of each genotype for nine yield attributes, viz. plant height, number of productive tillers/plant, spike length, spikelets/ spike, grain number/spike, grain weight/spike, grain yield/plant, biomass/plant and test-weight. The results of yield attributes and yields showed similar trend during

Table 1 Effect of arbuscular mycorrhizal fungi on plant height, number of productive tillers/plant and spike length in wheat under normal and drought stress conditions

Yield attribute	Stages of water stress	WH 1025			WH 1105		
		Non-AMF	AMF	Mean	Non-AMF	AMF	Mean
Plant height (cm)	Control (Normal irrigated)	81.12	84.45	82.78	83.55	86.26	84.90
	Jointing stage stress	78.22	82.59	80.41	81.22	84.96	83.09
	Heading stage stress	74.99	77.85	76.42	76.37	79.78	78.07
	Mean	78.11	81.63		80.38	83.66	
	CD (P=0.05)	A (AMF treatment)		0.979	A (AMF treatment)		1.038
		B (Stress treatment)		1.199	B (Stress treatment)		1.272
		A × B (interaction)		NS	A × B (interaction)		NS
Number of productive tillers/plant	Control (Normal irrigated)	4.00	4.67	4.33	4.33	4.67	4.50
	Jointing stage stress	3.67	4.33	4.00	3.67	4.00	3.83
	Heading stage stress	3.67	4.33	4.00	3.67	4.33	4.00
	Mean	3.78	4.44		3.89	4.33	
	CD (P=0.05)	A (AMF treatment)		0.087	A (AMF treatment)		0.029
		B (Stress treatment)		0.106	B (Stress treatment)		0.036
		A × B (interaction)		NS	A × B (interaction)		NS
Spike length (cm)	Control (Normal irrigated)	8.57	8.93	8.75	8.99	9.25	9.12
	Jointing stage stress	7.80	8.49	8.14	8.62	8.92	8.77
	Heading stage stress	7.55	8.03	7.79	7.49	8.52	8.00
	Mean	7.97	8.48		8.37	8.89	
	CD (P=0.05)	A (AMF treatment)		0.211	A (AMF treatment)		0.420
		B (Stress treatment)		0.258	B (Stress treatment)		0.515
		A × B (interaction)		0.365	A × B (interaction)		NS

2013-14 and 2014-15; therefore, pooled analysis of data was carried out. All the data were subjected to analysis using the SAS (Version 9.3, SAS Institute Inc., Cary, NC, USA) at 5 % probability level to compare the mean differences.

RESULTS AND DISCUSSION

Results presented in Table 1 showed that plant height decreased under water stress but increased with AMF inoculation. The plant height of WH 1105 was more than WH 1025 under control as well as drought stress of both stages irrespective of the AMF inoculation. Maximum plant height (86.2 cm) was observed in AMF treated WH 1105 under normal irrigated conditions. As evident from Table 1, the number of productive tillers was decreased under drought stress. The AMF inoculation increased the number of productive tillers in both the varieties under control and water stress conditions. Number of productive tillers in AMF uninoculated and inoculated plants of WH 1025 decreased by 9.0 and 7.6% and 18.2 and 16.7% in WH 1105 respectively, under water stress imposed at jointing stage.

The differential response of wheat varieties was found for spike length under water stress and AMF inoculation, which increased with mycorrhizal inoculation. Spike length was found to be more (9.3 cm) in WH 1105 as compared to WH 1025 (8.9 cm) in AMF inoculated control plants. Under drought stress spike length decreased but per cent reduction was more in WH 1105 than WH 1025 in both AMF treated and untreated plant. The mycorrhizal inoculation increased the number of spikelet in both varieties under control and water stress created at both the stages. Number of spikelets in AMF inoculated plants of WH 1025 increased by 13.0 and 15.8 % and 8.5 and 13.5% in WH 1105 over the AMF untreated plants while imposing drought at jointing and heading stage, respectively. Under water stress number of spikelets decreased in both varieties irrespective of AMF treatments, however more reduction was observed in WH 1105 under water deficit (Table 1).

The grains/spike increased by mycorrhizal inoculation irrespective of water stress conditions. However, under water stressed conditions, AMF treatment increased the grain number in WH 1025 by 12.2 and 9.9% while in WH 1105 by 12.7 and 12.0% as compared to AMF untreated plants while stress was created at jointing and heading stage, respectively. The percent reduction in grain number was more in WH 1105 than WH 1025 under water deficit stress conditions. The grain weight/plant decreased under water deficit conditions however increase in grain weight was observed by AMF inoculation in both the varieties. Grain weight increased in WH 1025 with AMF inoculation by 14.0 and 22.2% while increase was 20.9 and 20.5% in WH 1105 as compared to AMF uninoculated plants when water stress imposed at jointing and heading stage. The

Table 2 Effect of arbuscular mycorrhizal fungi on number of spikelets/spike, grains/spike, grains weight/spike in wheat under normal and drought stress conditions

Yield attribute	Stages of water stress	WH 1025			WH 1105		
		Non-AMF	AMF	Mean	Non-AMF	AMF	Mean
Number of spikelets/ spike	Control (Normal irrigated)	17.00	19.00	18.00	17.33	18.67	18.00
	Jointing stage stress	15.33	17.33	16.33	15.67	17.00	16.33
	Heading stage stress	12.67	14.67	13.67	12.33	14.00	13.17
	Mean	15.00	17.00		15.11	16.56	
	CD (P=0.05)	A (AMF treatment)		0.558	A (AMF treatment)		0.808
		B (Stress treatment)		0.684	B (Stress treatment)		0.990
		A × B (interaction)		NS	A × B (interaction)		NS
Grains/spike	Control (Normal irrigated)	50.00	55.67	52.83	51.33	57.33	54.33
	Jointing stage stress	46.33	52.00	49.17	47.00	53.00	50.00
	Heading stage stress	44.00	48.33	46.17	43.00	48.33	45.67
	Mean	46.78	52.00		47.11	52.89	
	CD (P=0.05)	A (AMF treatment)		0.582	A (AMF treatment)		0.687
		B (Stress treatment)		0.713	B (Stress treatment)		0.841
		A × B (interaction)		NS	A × B (interaction)		NS
Grains weight/spike (g)	Control (Normal irrigated)	1.59	1.77	1.68	1.57	1.80	1.69
	Jointing stage stress	1.47	1.69	1.58	1.35	1.64	1.50
	Heading stage stress	1.35	1.65	1.50	1.25	1.50	1.38
	Mean	1.47	1.70		1.39	1.65	
	CD (P=0.05)	A (AMF treatment)		0.774	A (AMF treatment)		0.692
		B (Stress treatment)		0.948	B (Stress treatment)		0.848
		A × B (interaction)		NS	A × B (interaction)		1.199

grain weight decreased in both the varieties under drought stress but the absolute value of grain weight was higher in WH 1025 as compared to WH 1105 (Table 2).

The different effect of AMF treatment and drought stress on grain yield of both varieties is presented in Table 3. The AMF inoculation increased the grain yield/plant as compared to un-inoculation plants in variety WH 1025. Drought stress led to decrease the grain yield and more reduction was observed in WH 1105 than WH 1025. Under water stress created at jointing and heading stage, in AMF treated plants the grain yield decreased by 8.7 and 20.5% in WH 1025 while decrease was 31.0 and 39.2% in WH 1105, respectively, as compared to AMF untreated plants. The biomass/plant of WH 1105 and WH 1025 was found to be decreased under drought and increased by mycorrhizal inoculation in both varieties. In AMF inoculated plants the biomass per plant increased by 8.7% in WH 1025 and by 11.0% in WH 1105 when water stress was imposed at jointing stage over AMF untreated plants. Drought stress imposed at heading stage, the percent reduction was found to be 14.7 and 12.0% in WH 1025 however, in WH 1105 percent decrease was 20.0 and 14.0% in AMF untreated and treated plants, respectively. Test weight decreased under drought stress however, mycorrhizal inoculation increased the test weight in both the varieties. Test weight was found to be more in WH 1105 but during stress conditions percent reduction was observed more in WH 1105 as compared to WH 1025. The test weight of AMF untreated and treated plants of WH 1025 showed 6.5 and 5.2% decrease and 10.8 and 7.4% reduction in WH 1105 as compared to control plants respectively, when drought stress was imposed at heading stage (Table 3).

Drought stress is the most wide spread environmental stress, which affect plant growth and its productivity. It induces many physiological, biochemical and molecular responses which enable plants to develop tolerance mechanisms to adapt in limited environmental conditions (Habibpor *et al*. 2011, Rani *et al*. 2018). Morphological characters such as number of tillers, grains/spike , fertile tillers/plant, test weight, peduncle length, awn length, plant height, spike length, kernels/spike, grain weight/spike, etc. affect the wheat tolerance to the moisture shortage in the soil (Ahmadizadeh *et al*. 2011a,b). The grain yield of wheat is dependent on yield components and it has been observed that plant height, spike length and grains/spike were directly related to grain yield. Similarly, it has been reported that spikes/plant, grains/spike, 1000 grain weight, glumes weight and biological yield were directly related to grain yield of wheat. There was a considerable decrease in grain yield and yield component of both the varieties when stress was imposed at jointing and heading stage over control conditions (Table 1, 2 and 3). The result of present investigation are

Table 3 Effect of arbuscular mycorrhizal fungi on grain yield/plant, biomass/plant and test weight in wheat under normal and drought stress conditions

Yield attribute	Stages of water stress	WH 1025			WH 1105		
		Non-AMF	AMF	Mean	Non-AMF	AMF	Mean
Grain yield/ plant (g)	Control (Normal irrigated)	5.53	6.27	5.90	5.90	6.68	6.29
	Jointing stage stress	4.80	5.77	5.28	4.37	5.10	4.73
	Heading stage stress	4.57	5.20	4.88	4.10	4.80	4.45
	Mean	4.97	5.74		4.79	5.53	
	CD (P=0.05)	A (AMF treatment)		0.490	A (AMF treatment)		NS
		B (Stress treatment)		0.482	B (Stress treatment)		0.670
		A × B (interaction)		NS	A × B (interaction)		NS
Biomass/plant (g)	Control (Normal irrigated)	15.82	16.79	16.31	15.48	17.13	16.30
	Jointing stage stress	14.19	15.28	14.73	13.78	15.40	14.59
	Heading stage stress	13.79	14.99	14.39	12.90	15.02	13.96
	Mean	14.60	15.69		14.05	15.85	
	CD (P=0.05)	A (AMF treatment)		NS	A (AMF treatment)		NS
		B (Stress treatment)		NS	B (Stress treatment)		0.670
		A × B (interaction)		NS	A × B (interaction)		NS
Test weight (g)	Control (Normal irrigated)	38.70	39.93	39.32	41.02	41.44	41.23
	Jointing stage stress	37.96	39.24	38.60	40.66	41.15	40.90
	Heading stage stress	36.21	37.97	37.09	37.01	38.60	37.81
	Mean	37.62	39.05		39.56	40.39	
	CD (P=0.05)	A (AMF treatment)		0.848	A (AMF treatment)		0.600
		B (Stress treatment)		1.038	B (Stress treatment)		0.734
		A × B (interaction)		NS	A × B (interaction)		NS

in accordance with the results of Khalilzadeh *et al.* (2016) who reported significant differences between genotypes for grain yield, grains/spike and grain weight. Drought stress caused reduction in spike yield, grain yield and the grains/spike and it was related to the reduction of fertile spikes under water limiting conditions (Ahmadizadeh *et al*. 2011a). Nouri-Ganbalani *et al*. (2009) demonstrated that drought stress resulted in reduced pollination and grains/spike. The other researchers also reported that the averages of some mopho-physiological traits were decreased under drought stress (Khayatnejad *et al.* 2010, Ahmadizadeh *et al*. 2011). Wheat yield under field conditions normally increased with AMF inoculation (Table 1, 2 and 3). Similar to our findings Al-Karaki *et al*. (2004) reported the enhancement in grain and biomass yields on inoculation with AM fungi. The probable reasons for increase in yield traits were extension of root system with fungal mycelium and increase in uptake of phosphorus, nitrogen and other nutrients. It resulted in enhanced nitrogen fixation and also increased plant growth and yield parameters by dissolving insoluble phosphate thus increasing the amount of available phosphorus due to mycorrhizal association (Garshasbi *et al*. 2014, Wilson *et al*. 2016). Because of increased nitrogen and phosphorus availability, there was increase in chlorophyll content which resulted in maintaining green character for longer period and also contributed in higher grain yield. Chlorophyll content is positively associated with photosynthetic rate which increases biomass production and grain yield. Significant relationships between stay green and yield and yield components facilitate selection of high yielding genotypes under limited irrigation environment (Fernández-Lizarazo and Moreno-Fonseca 2016).

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