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Original article

Effects of application of nitrogen fixing bacteria and plant residues on dry matter remobilization and yield of barley under water stress after anthesis

M. Niazi Ardakani[1], V. Barati[2*], E. Bijanzadeh[3]
1. Master's degree Student, Agro-ecology Department, Faculty of Agriculture and Natural Resources of Darab, Shiraz University, Shiraz, Iran
2. Assistant Professor of Agro-Ecology Department, Faculty of Agriculture and Natural Resources of Darab, Shiraz University, Shiraz, Iran
3. Associate Professor of Agro-Ecology Department, Faculty of Agriculture and Natural Resources of Darab, Shiraz University, Shiraz, Iran

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Extended abstract

Introduction

Grain yield of cereals significantly affects by assimilate remobilization in arid zones. Many factors including N fertilizer application affects assimilate remobilization in cereals (Ercoli et al., 2008). Many researches have been done aboat the effects of chemical N fertilizer under normal and water stress conditions on assimilate remobilization in arid environments (Ercoli et al., 2008; Barati and Ghadiri, 2017; Bahrani and Tahmasbi-sarvestani, 2006). However, the effects of other N sources such as crop ressidues and N fixing bacteria alone or in combination with chemical N fertilizers on assimilate remobilization and consequently grain yield was very scarce especially in arid zones. Therefore, there are two main questions; 1. Can using of Azospirillum brasilense as a N fixing bacteria instead of chemical N fertilizers or in combination with them in bio-agriculture boost the assimilate remobilization and consequently grain yield of barley under water stress conditions?, and 2. Can applying plant residues increase Azospirilum activity and consequently increase assimilate remobilization and grain yield in dry areas by improving water storage capacity or other mechanisms? For answering the above questions, the effects of application of N fixing bacteria (*Azospirillum brasilense*) and wheat residues on dry matter remobilization and barley yield under water stress after anthesis stage was evaluated in an arid zone of Southern Iran (Fars province).

Materials and methods

This research was conducted at the experimental farm of the Darab Agricultural College of Shiraz University. A split factorial experiment in a randomized complete block design with three replications were carried out in 2017 - 2018 growing season. Treatments included two levels of irrigation as the main plots [normal irrigation (IRN): irrigation based on the plant's water requirement up to the physiological maturity and another factor was deficit irrigation (IRDI): irrigation based on the plant's water requirement up to the anthesis stage (cutting of irrigation after anthesis)]. Also, sub plots were two levels of wheat residues [1. without residue, 2. returning 30% of wheat residues to soil] and four fertilizer sources [N0, no nitrogen fertilizer (control); N100, 100 kg N ha^{-1}; Bio + N50, Biofertilizer (*Azospirillum*

[*]Correspondent author: Vahid Barati; E-Mail: v.barati@shirazu.ac.ir

brasilense) + 50 kg N ha^{-1} and Bio, Biofertilizer (*Azospirillum brasilense*)]. Finally, dry matter of shoot samples were measured at the anthesis stage. In addition, at the end of growing season, grain yield, and dry matter of vegetative parts of shoot were measured. Then, assimilate remobilization, assimilate remobilization efficiency and contribution of pre-anthesis assimilate to grain were calculated by Ercoli et al., 2008 methods. Data were analyzed using SAS 9.1 software (SAS Institute, 2004).

Results and discussion

Overall, combined N fertilizer (Bio + N50) significantly increased grain yield (53%) in normal irrigation. Similarly, the grain yield was improved up to 12% under water stress conditions by Bio + N50. Water stress increased assimilate remobilization and contribution of pre-anthesis assimilate to grain in Bio + N50 treatment by 37 % and 148%, respectively, as compared with the normal irrigation treatment. The application of plant residues decreased the amount of assimilate remobilization, assimilate remobilization efficiency and contribution of pre-anthesis assimilate to grain in all fertilizer treatments. However, it did not significantly affect the grain yield.

Conclusion

Generally, considering the economic aspects and moving towards the sustainable agriculture, using of combined N fertilizer [Biofertilizer (*Azospirillum brasilense*) + 50 kg N ha^{-1}] in optimal irrigation conditions is recommended for farmers of Southern Iran. Furthermore, if cutting of irrigation after anthesis is considered because of irrigation water resource shortage, this fertilizer regime is recommended as compared with the other N sources due to the significant increase in assimilate remobilization (37%) and contribution of pre-anthesis assimilate to grain (148%) and lower grain yield reduction as compared with the normal irrigation conditions..

Keywords: *Azospirillum*, Inoculation, Grain yield

Table 1. Physical and chemical characteristics of the soil in 0-30 cm depth.

Characteristics	Unit	amount
Sand	%	38.12
Silt	%	44
Clay	%	17.88
O.C.	%	0.97
O.M.	%	1.68
EC	dS m^{-1}	1.09
pH		7.42
Total N	%	0.08
Available K	mg kg^{-1}	320
Available P	mg kg^{-1}	10
Fe	mg kg^{-1}	5.67
Mn	mg kg^{-1}	16.72
Cu	mg kg^{-1}	1.69
Zn	mg kg^{-1}	0.66

Table 2. Analysis of variance of grain yield (g m^{-2}), dry weight of the shoot at anthesis (g m^{-2}), dry weight of the vegetative parts of the shoot at maturity (g m^{-2}), dry matter remobilization (g m^{-2}), dry matter remobilization efficiency (%) and contribution of pre-anthesis assimilate to grain (%).

		Mean squars					
S.O.V.	Df	Grain yield	Dry weight of the shoot at anthesis	Dry weight of the vegetative parts of the shoot at maturity	Dry matter remobili–zation	Dry matter Remobili–zation efficiency	Contribution of pre-anthesis assimilate to grain
Replication (R)	2	2120.73^{ns}	17253.88**	12667.11*	678.63^{ns}	92.02^{ns}	23.86^{ns}
Irrigation regime (Ir)	1	170968.88^{ns}	4704.48^{ns}	23418.49^{ns}	7130.42^{ns}	614.90^{ns}	2559.38*
Error (a)	2	28798.88	7557.96	6577.88	6302.18	489.86	45.28
Residue (Re)	1	870.40^{ns}	18127.413*	293.88^{ns}	23037.49**	1228.77**	2649.43**
N Fertilizer source (N)	3	22859.25**	81947.76**	67543.22**	10762.35**	1207.30**	1514.22**
Ir × Re	1	162.14^{ns}	5191.68^{ns}	3988.91^{ns}	79.13^{ns}	9.56^{ns}	53.62^{ns}
Ir × N	3	13952.82**	3245.17^{ns}	4275.04^{ns}	6801.67**	352.75**	675.03**
Re × N	3	1489.81^{ns}	17899.53**	16815.05**	1726.11*	384.81**	616.09**
Ir × Re × N	3	5877.96^{ns}	4604.62^{ns}	3801.19^{ns}	1519.67^{ns}	127.53^{ns}	83.38^{ns}
Error (b)	28	2065.41	3730.30	3604.69	679.61	70.56	85.48
C.V$^{€}$ (%)		16.94	16.41	26.96	17.43	20.11	15.54

* and **: significant at the 5% and 1% probability levels, respectively. ns: Non significant.

€: Coefficient of variation.

Table 3. Effect of residue × N source interaction on dry weight of the shoots at anthesis, dry weight of the vegetative parts of the shoots at maturity, dry matter remobilization, dry matter remobilization efficiency and contribution of pre-anthesis assimilate to grain.

Residue	Nitrogen fertilizer source	Dry weight of the shoots at anthesis	Dry weight of the vegetative parts of the shoots at maturity	Dry matter re-mobilization	Dry matter re-mobilization efficiency	Contribution of pre-anthesis assimilate to grain
		-------------(g m^{-2})-------------			------(%)------	
Without residue	N_0£	339.4^{b}	159.6^{de}	179.9^{ab}	54.9^{a}	72.5^{ab}
	N_{100}££	463.2^{a}	270.6^{abc}	192.6^{a}	42.3^{bc}	65.5^{ab}
	Bio+ N_{50}¥	475.9^{a}	326.8^{a}	149.1^{bc}	32.2^{cd}	56.4^{bc}
	Bio¥¥	288.0^{b}	123.6^{e}	164.4^{abc}	57.9^{a}	73.2^{a}
With residue	N_0£	277.5^{b}	132.9^{e}	144.6^{c}	52.1^{ab}	67.7^{ab}
	N_{100}££	482.4^{a}	303.9^{ab}	178.5^{ab}	37.3^{cd}	64.9^{ab}
	Bio+ N_{50}¥	337.7^{b}	246.8^{bc}	90.9^{d}	26.7^{d}	32.2^{d}
	Bio¥¥	313.5^{b}	216.7^{cd}	96.7^{d}	30.9^{d}	43.3^{cd}

The Means in each column followed by the same letters are not significantly different at 5% probability level using Duncans multiple range test. N_0, no nitrogen fertilizer (control); N_{100}, 100 kg N ha^{-1}; Bio + N_{50}, Biofertilizer (*Azospirillum brasilense*) + 50 kg N ha^{-1}; Bio, Biofertilizer (*Azospirillum brasilense*).

Table 4. Interaction effect of irrigation regime × N source on grain yield, dry matter remobilization, dry matter remobilization efficiency and contribution of pre-anthesis assimilate to grain.

Irrigation regime	Nitrogen fertilizer source	Grain yield	Dry matter remobilization	Dry matter remobilization efficiency	Contribution of Pre-anthesis assimilate to grain
		--------(g m^{-2})--------		--------- --(%)----- -----	
No water stress	N_0£	264.8^{b}	177.2^{b}	60.3^{a}	66.9^{ab}
	N_{100}££	384.3^{a}	224.6^{a}	48.8^{b}	59.4^{ab}
	Bio+ N_{50}¥	404.9^{a}	101.1^{d}	26.3^{c}	25.5^{c}
	Bio¥¥	257.8^{bc}	144.2^{bc}	46.1^{b}	55.2^{b}
Water stress	N_0£	200.9^{c}	147.2^{bc}	46.8^{b}	73.3^{a}
	N_{100}££	206.7^{bc}	146.5^{bc}	30.7^{c}	71.0^{a}
	Bio+ N_{50}¥	225.6^{bc}	138.9^{c}	32.5^{c}	63.1^{ab}
	Bio¥¥	201.7^{c}	116.9^{cd}	42.7^{b}	61.4^{ab}

The Means in each column followed by the same letters are not significantly different at 5% probability level using Duncans multiple range test. N_0, no nitrogen fertilizer (control); N_{100}, 100 kg N ha^{-1}; Bio + N_{50}, Biofertilizer (*Azospirillum brasilense*) + 50 kg N ha^{-1}; Bio, Biofertilizer (*Azospirillum brasilense*).

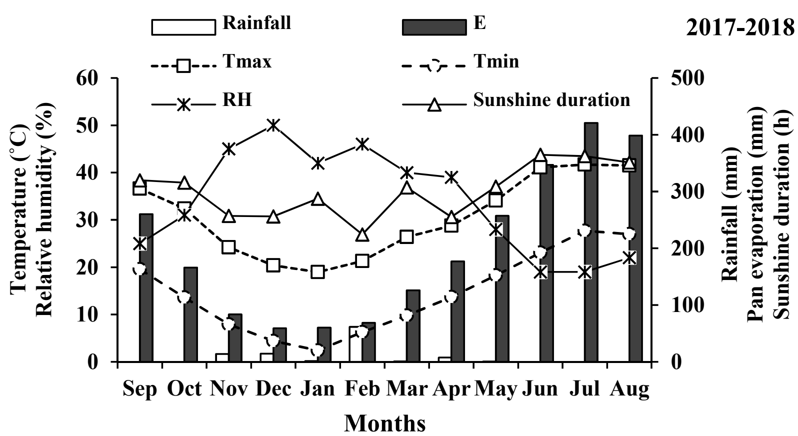

Fig. 1. Monthly rainfall, pan evaporation (E), sunshine duration, mean minimum and maximum air temperatures (T_{min} and T_{max}, respectively) and relative humidity (RH) during 2017- 2018 growing season.

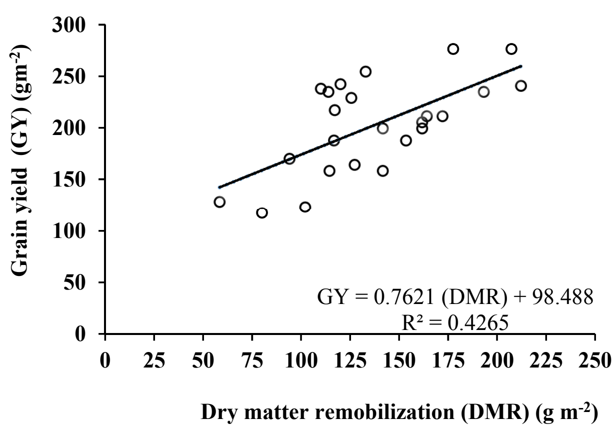

Fig. 2. Relationship between the grain yeild and dry matter remobilization under water stress after anthesis stage.