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Original article

Investigating response of yield traits and oil content of sesame variety (*Sesamum indicum* L.) to nano-magnesium fertilizer and biopolymer chitosan under limited water stress

J. Khordadi Varamin[1], F. Fanoodi[2*], J. Masoud Sinaki[2], Sh. Rezvan[2], A. Damavandi[2]
1. Ph.D. Student, Agronomy Department, Damghan Branch, Islamic Azad University, Damghan, Iran
2. Agriculture Department, Damghan Branch, Islamic Azad University, Damghan, Iran

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Extended abstract

Introduction
Sesamum, scientifically named Sesamum indicum L., is one of the oldest oilseed families and is adapted to warm and semi-warm regions and is known as the queen of oilseeds. The use of nanotechnology in the production of fertilizers results in optimal release and increased efficiency of absorption of nutrients in fertilizer which leads to significant economic and environmental benefits. Chitosan elicits stimulating defense mechanisms and is beneficial to plants, animals and humans and is environmentally friendly. Due to the fact that water stress and dehydration in Iran is always one of the most important agricultural problems and due to the importance of magnesium in photosynthesis of plants and also the use of different polymers such as chitosan to reduce the damage caused by stress, this study aimed to evaluate the effect of nano chitosan and magnesium application under water stress conditions on some sesame traits for sustainable agriculture development in Varamin region.

Materials and methods
In order to evaluate limited water stress and foliar application of magnesium and chitosan on growth and yielding traits and oil content of two sesame varieties, an experiment was conducted as a split factorial based on completely randomized blocks designed with three replications in a research farm in the southern Varamin Province, Iran, during 2016-17 growing season. Irrigation cut-off based on BBCH scale in three-level included: normal irrigation, 65 BBCH (flowering), and irrigation cut-off in 75 BBCH (capsule maturity) as the main factors. Sub-plot included a combination of three factors: two genotypes Oltan and Dashtestan-2, foliar application of Mg-nano in two levels non-application and foliar application (2 g/L) in 65 BBCH stage and foliar application of chitosan in three levels: non-application, foliar application of 4.8 g/L in 65 BBCH stage and 6.4 g/L in 75 BBCH stage.

Results and discussion
The results showed that the irrigation up to 65 BBCH caused a reducing 28.08, 20.8, 53.05, 54.04 and 23.10% in the average traits of number of capsules, 1000-grain weight, grain yield, LAI, and oil percentage content in compared to the normal irrigation treatment (control). The highest grain yield was achieved in the application of Mg-nano-fertilizer under normal irrigation in Dashtestan-2 variety with a

[*]Correspondent author Farzad Fanoodi; E-Mail: Farzadfanoodi@yahoo.com.

mean of 1188.2 kg/ha, which 16.3% increased in compared to the control treatment. The highest oil percentage was observed in the application of Mg-nano under normal irrigation was in Dashtestan-2 variety with an average of 50.38%, which 3.5% increase in compared to the control treatment.

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Conclusion

Finally, foliar application of Mg-nano and chitosan (4.8 g/L) under water stress conditions were able to compensate for damage and to modify the negative effects of stress.

***Keywords*:** BBCH scale, Drought stress, Foliar application, LAI, Sustainable agriculture

Table 1. Analysis of variance of morphology and yield traits of two sesame genotypes affected by limited water stress and foliar application of Mg-nano and chitosan fertilizers

S.O.V	df	Plant height	Stem diameter	Shoot dry weight	LAI
Block (B)	2	1.81^{ns}	2.11^{ns}	1.63^{ns}	0.02^{ns}
Limited water stress (LWS)	2	7507.56^{**}	123.03^{**}	2416.51^{**}	41.35^{**}
Error 1	4	83.22	0.97	5.33	0.033
Mg-Nano (Mg)	1	720.75^{**}	29.04^{**}	311.27^{**}	0.205^{**}
Chitosan (C)	2	2312.4^{**}	92.03^{**}	134.75^{**}	0.293^{**}
Variety (V)	1	173.79^{ns}	17.93^{**}	26.63^{**}	0.599^{**}
LWR × Mg	2	38.53^{ns}	3.34^{*}	40.82^{**}	0.005^{ns}
LWR × C	4	158.72^{ns}	0.18^{ns}	0.22^{ns}	0.001^{ns}
LWR × V	2	21.12^{ns}	2.01^{ns}	4.27^{ns}	0.032^{ns}
Mg × C	2	1.58^{ns}	0.18^{ns}	0.92^{ns}	0.007^{ns}
Mg × V	1	10.08^{ns}	6.26^{*}	10.34^{**}	0.001^{ns}
V × C	2	22.01^{ns}	0.18^{ns}	0.03^{ns}	0.006^{ns}
LWR × Mg × C	4	9.99^{ns}	0.19^{ns}	1.53^{ns}	0.006^{ns}
LWR × Mg × V	2	17.86^{ns}	4.84^{*}	3.24^{ns}	0.005^{ns}
LWR × V × C	4	16.88^{ns}	0.13^{ns}	0.71^{ns}	0.002^{ns}
Mg × V × C	2	11.19^{ns}	0.73^{ns}	1.65^{ns}	0.019^{ns}
LWR × Mg × V × C	4	35.6^{ns}	0.27^{ns}	1.72^{ns}	0.004^{ns}
Error	66	88.83	1.04	1.42	0.02
C.V	-	*7.53*	*6.26*	*5.75*	*5.8*

Table 1. Continued

S.O.V	df	طول کپسول Capsule length	تعداد دانه در کپسول No. grain per capsule	تعداد کپسول No. capsule	وزن هزار دانه 1000- grain weight
Block (B)	2	0.24*	398.73**	158.08**	0.23**
Limited water stress (LWS)	2	0.79**	1814.62**	7856.3**	4.06**
Error 1	4	0.06^{ns}	70.86^{ns}	23.67	0.13
Mg-Nano (Mg)	1	0.15^{ns}	374.08**	273.93**	2.02**
Chitosan (C)	2	0.19*	491.29**	1739.1**	1.75**
Variety (V)	1	0.01^{ns}	12.68^{ns}	524.48**	0.53**
LWR × Mg	2	0.03^{ns}	290.86**	70.26*	0.02^{ns}
LWR × C	4	0.01^{ns}	39.95^{ns}	15.11^{ns}	0.03^{ns}
LWR × V	2	0.01^{ns}	12.06^{ns}	101.15 *	0.02^{ns}
Mg × C	2	0.01^{ns}	32.19^{ns}	20.7^{ns}	0.03^{ns}
Mg × V	1	0.003^{ns}	0.23^{ns}	9.48^{ns}	0.04^{ns}
V × C	2	0.001^{ns}	8.12^{ns}	5.48^{ns}	0.01^{ns}
LWR × Mg × C	4	0.01^{ns}	16.22^{ns}	14.45^{ns}	0.03^{ns}
LWR × Mg × V	2	0.06^{ns}	24.56^{ns}	38.04^{ns}	0.01^{ns}
LWR × V × C	4	0.01^{ns}	13.59^{ns}	18.15^{ns}	0.01^{ns}
Mg × V × C	2	0.01^{ns}	2.4^{ns}	10.04^{ns}	0.01^{ns}
LWR × Mg × V × C	4	0.01^{ns}	48.06^{ns}	33.84^{ns}	0.01^{ns}
Error	66	0.052	43.11	26.52	0.03
C.V	-	*8.16*	*9.34*	*5.96*	*6.63*

Table 1. Continued

S.O.V	df	Grain yield	Biological yield	Harvest index	Oil percent	Oil yield
Block (B)	2	129094.3**	65334.4^{ns}	65.73**	27.35**	33091.36**
Limited water stress (LWS)	2	2875684.2**	96660218.5**	26.77**	1121.48**	990919.42**
Error 1	4	14681.3	213098.5	2.54	13.37	2891.8
Mg-Nano (Mg)	1	482801.4**	12450823.1**	8.97*	23.71*	119741.09**
Chitosan (C)	2	776521.2**	5389815.1**	123.41**	316.93**	270560.77**
Variety (V)	1	123670.3**	1065250.7**	11.86*	58.37**	54107.75**
LWR × Mg	2	50695.7**	1632897.8**	1.88^{ns}	32.74**	17949.7**
LWR × C	4	26368.64**	8695.4^{ns}	1.69^{ns}	10.82*	21595.04**
LWR × V	2	27722.02**	170675.8^{ns}	3.41^{ns}	59.05**	16736.54**
Mg × C	2	6682.8^{ns}	36951.1^{ns}	0.74^{ns}	10.67^{ns}	2776.38^{ns}
Mg × V	1	870.63^{ns}	413417.8**	0.4^{ns}	21.33*	1547.33^{ns}
V × C	2	359.53^{ns}	1178.9^{ns}	0.04^{ns}	1.57^{ns}	505.48^{ns}
LWR × Mg × C	4	2447.98^{ns}	61279^{ns}	1.31^{ns}	4.07^{ns}	495.56^{ns}
LWR × Mg × V	2	13051.34*	129705.8^{ns}	7.87*	2.36*	4860.91*
LWR × V × C	4	4060.69^{ns}	28278.5^{ns}	1.74^{ns}	7.47^{ns}	913.67^{ns}
Mg × V × C	2	272.75^{ns}	66198^{ns}	1.44^{ns}	11.1^{ns}	557.46^{ns}
LWR × Mg × V × C	4	5427.17^{ns}	68870.5^{ns}	1.03^{ns}	4.32^{ns}	567.94^{ns}
Error	66	4763.31	56946	2.01	4.72	1337.5
C.V	-	*9.64*	*5.75*	*8.26*	*5.07*	*11.41*

^{ns},*and **: No significant and significant at 5 and 1% levels ofprobability, respectively. LWS: Limited water stress

Table 2. Mean comparison of the effect of limited water stress and foliar application of Mg-nano and chitosan fertilizers on 1000-grain weight and LAI of two sesame varieties

Treatment	1000-grain weight (g)	LAI
Water stress levels		
Normal irrigation	3.17[a]	3.96[a]
Irrigation up to 65 BBCH	2.51[c]	1.82[c]
Irrigation up to 75 BBCH	2.75[b]	3.01[b]
Mg-nano fertilizer		
Non-application	2.67[b]	2.88[b]
Application	2.95[a]	2.97[a]
Chitosan		
Non-application	2.57[c]	2.83[b]
4.8 g/L	2.85[b]	3.00[a]
6.4 g/L	3.01[a]	2.96[a]
Variety		
Oltan	2.74[b]	2.85[b]
Dashtestan 2	2.88[a]	3.00[a]

Means in each column, having similar letter(s) are not significantly different at 5% probability level based on Duncan test

Table 3. The simple correlation between yield and yield components and oil content of sesame under limited water stress and foliar application treatments

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1												
2	0.73**	1											
3	0.78**	0.78**	1										
4	0.77**	0.67**	0.91**	1									
5	0.53**	0.44*	0.55**	0.53**	1								
6	0.56**	0.56**	0.73**	0.58**	0.56**	1							
7	0.75**	0.79**	0.91**	0.82**	0.50**	0.65**	1						
8	0.73**	0.79**	0.83**	0.68**	0.38	0.58**	0.81**	1					
9	0.79**	0.80**	0.93**	0.79**	0.55**	0.83**	0.92**	0.86**	1				
10	0.78**	0.78**	0.99**	0.91**	0.55**	0.73**	0.91**	0.83**	0.93**	1			
11	0.23	0.30	0.13	-0.06	0.13	0.47*	0.34	0.42*	0.46**	0.13	1		
12	0.78**	0.78**	0.83**	0.80**	0.49*	0.65**	0.81**	0.74**	0.84**	0.83**	0.23	1	
13	0.80**	0.80**	0.92**	0.80**	0.53**	0.81**	0.91**	0.84**	0.99**	0.92**	0.43*	0.89**	1

*and **: no significant and significant at 5 and 1% levels of probability, respectively and no sign was non
1- plant height, 2- stem diameter, 3- shoot dry weight, 4- LAI, 5- capsule length, 6- number of grain per capsule, 7- number of capsule, 8- 1000-grain weight, 9- grain yield, 10- biological yield, 11- harvest index, 12- oil percentage, 13- oil yield

Table 4. Stepwise regression for grain yield as dependent variables and other traits as independent variables

Attributes entered into the model	Coefficients	SE Coef	T-Value	P-Value
Constant	-47.5	34.1	-1.40	0.66
Shoot dry weight (X1)	15.479	0.782	19.79	0.000
LAI (X2)	7.58	3.84	1.97	0.051
Capsule length (X3)	13.49	5.97	2.26	0.026
Harvest index (X4)		0.993	18.73	0.000
R-Sq(adj)= 99.81%				
Y= -47.5 +15.479 X1 + 7.58 X2 +13.49 X3 +18.60 X4				

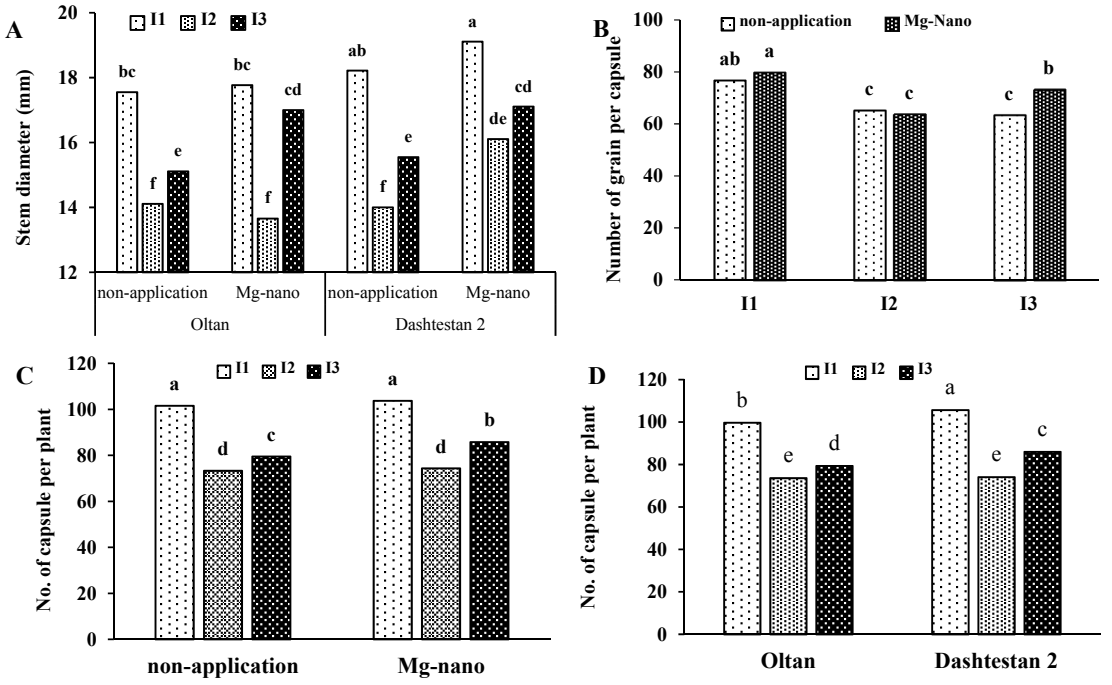

Fig. 1. Comparison mean interaction of limited water stress × Mg-nano fertilizer × variety on stem diameter (A), limited water stress × Mg-nano fertilizer on number of grain per capsule and number of capsule per plant (B and C), and limited water stress × variety on number of capsule per plant (D); (I1- normal irrigation, I2- irrigation up to 75 BBCH, I3- irrigation up to 85 BBCH)

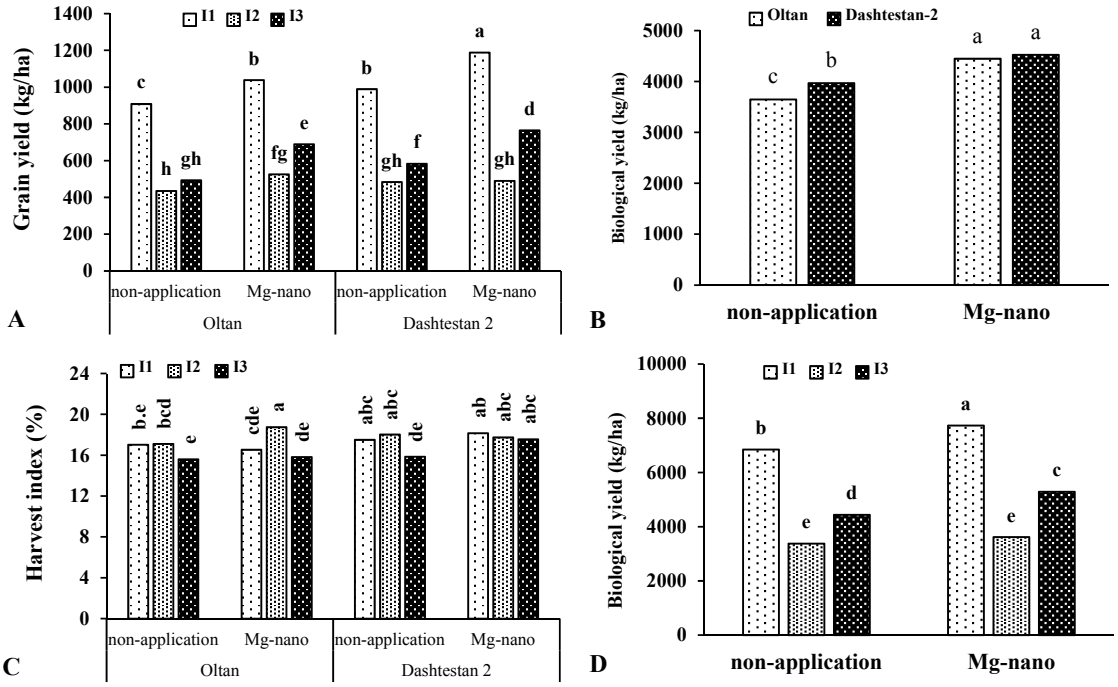

Fig. 2. Comparison mean interaction of limited water stress × Mg-nano fertilizer × variety on grain yield and harvest index (A and C), Mg-nano fertilizer × variety on biological yield (B), and limited water stress × Mg-nano fertilizer on biological yield (D); (I_1- normal irrigation, I_2- irrigation up to 75 BBCH, I_3- irrigation up to 85 BBCH)

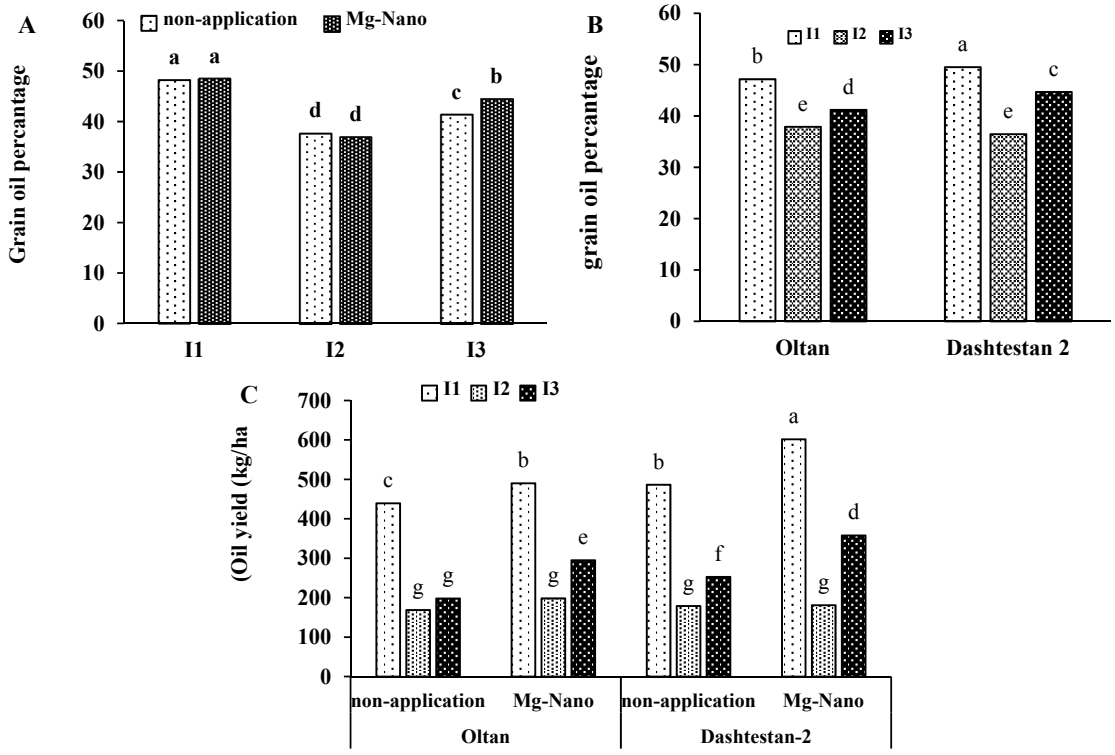

Fig. 3. Comparison mean interaction of limited water stress × Mg-nano fertilizer and limited water stress × variety on grain oil percentage (A and B), and limited water stress × Mg-nano fertilizer × variety on oil yield of sesame (C); (I1- normal irrigation, I2- irrigation up to 75 BBCH, I3- irrigation up to 85 BBCH)