Barley growth and productivity as affected by soil amendments under fully and minimum irrigation conditions in Saudi Arabia

Mohammed H. Salem Almarshadi[1] and Saleh M. Ismail[1,2*]

[1]Arid Land Agriculture Department, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, B.O. Box 80208, Jeddah 21589, Saudi Arabia, malmarshadi@kau.edu.sa.
[2]Soil and Water Department, Faculty of Agriculture, Assiut University, 71526 Assiut, Egypt,
*e-mail: smii2001@gmail.com and smibrahim@kau.edu.sa

Abstract: A field experiment was conducted at Agriculture Experimental Research Station of King Abdulaziz University (KAU), Hada Alsham, Saudi Arabia, for two growing seasons to study the effect of different soil amendments on growth traits and yield of barley crop grown under dry land conditions. Two irrigation treatments using sprinkler irrigation method were studied, full irrigation level, (100% of required water) and minimum irrigation level (60% of full level). Under each irrigation level two soil amendments, humic acid (Ha) with a rate of 10 kg ha^{-1} and Gel Polymer (Gp) with a rate of 16 kg ha^{-1} beside the control (not amended) were investigated. Irrigation event was every two days in full irrigation level and every 4 days in minimum irrigation level. Results revealed that, full irrigation level was better than minimum one in most investigated characteristics. The barley growth and yield components increased with application of humic acid and gel polymers amendments compared to control.The best results obtained from humic acid treatment. Irrigation water use was improved under minimum irrigation level and with Ha treatment. Full irrigation level and amendment treatments increased N content in grains. On the basis of the present experiment 10 kg ha^{-1} and full irrigating are recommended for barley growth and yield. When water is a limited factor for agriculture production, minimum irrigation level is recommended to use because it saves 40% of irrigation water with minimal yield reduction.
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1. Introduction

The shortage of fresh water resources has been growing rapidly due to population growth and increasing living standards. As a result, fresh water resources are severely declined (WMO, 1997).Another constrain for global crop production is the climate change associated with global warming (Fischer *et al.,* 2002; Pan *et al.,* 2002; Lobell& Field, 2007.Bahrawi 2014, Elhag & Bahrawi, 2014). Barley is the main cereal grown in arid areas because it shows a conservative strategy in water use when compared to other species (Acevedo, 1987). In Saudi Arabia, it is mainly grown for grain and straw for small ruminants during winter. Average grain yield reduction of barley due to drought stress has been reported as 15 to 90% compared to unstressed yields (Edmeades *et al.,*1989; Fischer *et al.,*1989; Vicente *et al.,*1999). Generally a rainfall of 300 mm and above is considered enough for barley crop production but in spite of the low water need barley crop are facing drought stress (PARDYP, 2003). Without any management rain or irrigation water may be percolating beyond root-zone, resulted in environmental consequences and diminishes water reserves. Soil amendments represent a management strategy that could conserve moisture in soils. Some of them act as source of plant nutrients (Marcotea *et al.,*2001; Tejada & Gonzalez, 2003). Using several types of soil amendments help to conserve water in root-zone area.Therefore, water availability for barley crop is increases due to the reductions in run-off and/or deep percolation that will ultimately cause increase in yield. Beside water conservation soil amendments have different other benefits to quality of crop and soil (Peter *et al.,* 2005; Suganya & Sivasamy, 2006; Piccolo *et al.,* 2007). The objectives of this research were to determinethe effect of various amendments on barley yield and yield components and to generate knowledge related to management of barley under minimum and fully irrigated conditions.

2. Material and Methods

2.1. Experimental Location and design

A field experiment was carried out during the two consecutive seasons of 2012-2013 at the Agricultural experimental Research Station of King Abdulaziz University located at Hada-Al Sham, 110 km north east of Jeddah (21° 48′ 3″ N, 39° 43′ 25″ E). Analysis of some soil properties before the starting of the experimental site are shown in Table (1). The experiment was laid out in Randomized Complete Block Design (RCBD) with split plot management and three replications. The main plots contain two irrigation treatments using sprinkler irrigation system. Two soil amendments beside the control were investigated in the sub-plot.

Table 1: Soil Properties of the experimental site

Properties	0 – 30 cm
Sand (%)	64
Silt (%)	33
Clay (%)	3
Soil texture	Sandy-Loam
Organic matter (%)	0.78
pH (1:1)	7.75
EC (dSm^{-1})	0.75
N	0.09
P	0.24
K	0.20

2.2. Treatments and cultural practices

Two irrigation treatments were investigated under the current research namely: **I_{full}** (fully irrigated condition 100 % of water requirements)and I_{min} (minimum irrigated condition, 60% of I_{full}). The interval between consecutive irrigation is 2days for fully irrigation level while it was 4 days for the other one. Under each irrigation level two types of soil amendments beside the control (not amended soils) were investigated as follows:

1. Humic Acid (Ha) = 10 kg ha^{-1}
2. Gel Polymer (Gp) = 16 kg ha^{-1}
3. Control = No amendment

The other culture practices required for barley cultivation were applied as recommended.

The following plant Variables were recorded using standard agronomic procedures as described in Dauret *al.* (2011).

- Plant height
- LAI at boot stage
- Number of tillers m^2 at harvest
- Number of grains per spike
- 1000 grain weight
- Biological yield
- Grain yield
- Water use efficiency
- N, % in grain

2.3. Statistical analysis

Obtained data were analyzed using the statistical package software SAS (SAS Institute Inc., 2000, Cary, NC., USA). Comparisons between means were made by F-test and the least significant differences (LSD) at *P* = 5%.

3. Results

3.1. Effectson growth parameters

Plant height

Fully irrigation level significantly increased plant height compared to minimum irrigation level during the first season (Table 2). However, the differences were not significant during the second growing season. Both soil amendment treatments significantly increased plant height compared to control during the first season. The highest plant height was recorded in Gp treatments during the second season however the plant height of Ha and control treatments was the same. Result also indicated that, the plant height during the second growing season was higher than that during the first season.

Results of the interaction between irrigation levels and soil amendment treatments during the second season are presented in Figure (1). The results indicated that, the highest plant height obtained from full irrigation treatment and recorded in Gp treatment followed by Ha and control treatments respectively.

Leaf area index (LAI)

The observations for LAI in the experiment are shown in Table (2). Statistical analysis of the data showed that irrigation levels and soil amendments has significant effect on LAI of barley during the both growing seasons. Fully irrigated plots were higher than minimum ones during both seasons. The maximum LAI was observed for Ha followed by Gp and control treatments respectively.

Table 2: Plant height and leave area index as affected by irrigation regimes and soil amendment treatments

Variables	Plant Hight (cm)		Leaf Area Index	
	2012	2013	2012	2013
Water Regime (WR)				
I_{full}	32.8 ±2.9	45.6 ±3.7	1.0 ±0.09	1.05 ±0.08
I_{min}	23.9 ±1.6	44.2 ±1.9	0.8 ±0.01	0.89 ±0.09
F-test	**	*NS*	**	**
Treatments (T)				
Ha	30.0 ±3.5	44.1 ±2.9	1.15 ±0.16	1.27 ±0.08
Gp	29.0 ±3.7	46.4 ±3.7	0.83 ±0.08	0.90 ±0.08
Control	26.0 ±2.8	44.1 ±1.9	0.72 ±0.08	0.73 ±0.09
F-test	**	**	**	**
LSD (0.05)	2.21	0.94	0.038	0.037
Interaction (WR x T)				
F-test	*NS*	**	**	*NS*

Means with the same letter within each column are not significantly different, (NS), not significant; (-), not calculated.

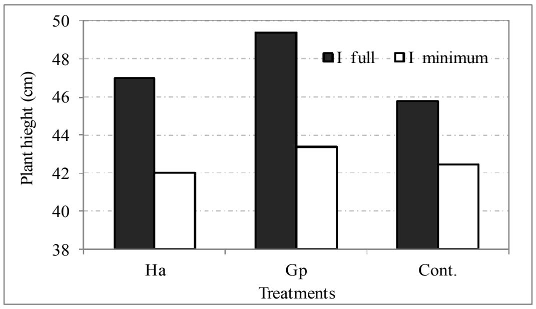

Fig. (1) Effect of the interaction between irrigation levels and soil amendment treatments on plant height during the second growing season

Results of the interaction between irrigation levels and soil amendment treatments in the first growing season presented in Figure (2) indicated that, the maximum LAI measured in Ha followed by Gp and control treatments respectively for full irrigation level and then followed by the same order in the minimum irrigation level.

Number of tillers m^{-2}

Results of number of tillers m^{-2} presented in Table (3) indicated that, fully irrigation level significantly increased tiller number compared to minimum irrigation level especially in the second growing season. The number of tiller in the second growing season was higher than that of the first growing season. Soil amendments treatments significantly increased tiller number. The maximum was found in Ha followed by Gp treatments while the least number was recorded in control treatment.

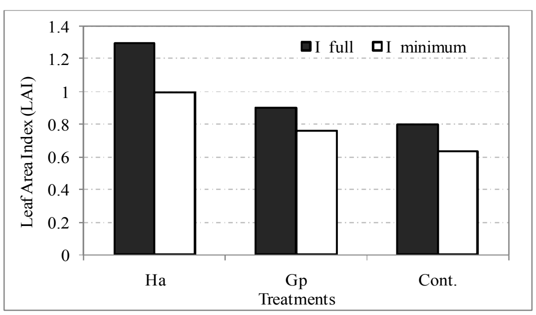

Fig. (2) Effect of the interaction between irrigation levels and soil amendment treatments on LAI during the first growing season.

The interaction of soil amendment treatments and irrigation level was significant only during the second season and presented in Figure (3). Results revealed that tiller number was higher in fully irrigation level in Ha, Gp and control treatments respectively than those of minimum irrigation level.

Effects on yield and yield components

Grains spike^{-1}

Data regarding number of grains spike^{-1} are presented in Table (4). Results revealed that, fully irrigation level increased number of grains/spike compared with minimum level. However the differences were significant during the second season. Soil amendment treatments significantly affect on number of grain/spike during both season (Table 4). Number of grain/spike was gradually decreased from Ha to Control, where the highest number was obtained from Ha treatments followed by Gp and control treatments respectively.

Table 3: Number of tillers as affected by irrigation regimes and soil amendment treatments

Variables	NO of Tillers/m^2	
	2012	2013
Water Regime (WR)		
I_{full}	143.8±15.7	225.7±29.2
$I_{min.}$	130.8±9.5	192.5±18.4
F-test	*NS*	**
Treatments (T)		
Ha	178.9±20.0	280.5±28.9
Gp	143.1±14.8	225.6±11.7
Cont.	89.7±7.7	121.0±16.7
F-test	*	**
LSD (0.05)	22.8	17.7
Interaction (WR x T)		
F-test	*NS*	*

Means with the same letter within each column are not significantly different, (NS), not significant; (-), not calculated.

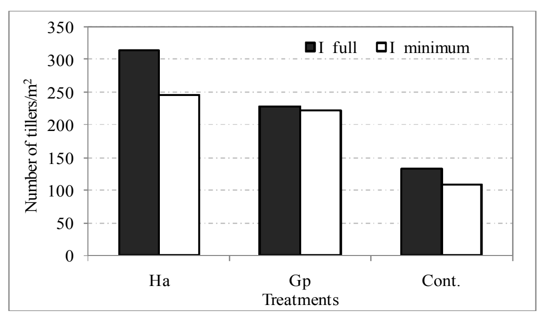

Fig. (3) Effect of the interaction between irrigation levels and soil amendment treatments on tiller number m^{-2} during the second growing season.

The interaction of irrigation level and amendment treatments was significant only in the second growing season and presented in Figure (4). Results revealed that, number of grain/spike was higher in Ha, Gp and control of fully irrigation level than Ha, Gp and control of minimum irrigation level.

Seed index (1000-grain weight)

Results of 1000-grain weight (g) shown in Table (4) indicated that, irrigation levels, soil amendments and their interaction were not significantly effect on weight.

Table 4: Grain/spike and seed index as affected by irrigation regimes and soil amendment treatments.

Variables	Grain/Spike		1000-grain Weight (g)	
	2012	2013	2012	2013
Water Regime (WR)				
I_{full}	24.9 ±2.3	38.9 ±3.3	34.04 ±0.37	34.66 ±0.35
$I_{minmum.}$	22.6 ±1.8	32.9 ±3.6	33.61 ±0.34	34.18 ±0.32
F-test	*NS*	*	*NS*	*NS*
Treatments (T)				
Humic Acid	26.3 ±3.0	41.3 ±4.3	34.5 ±0.3	34.8 ±0.34
Gel Polymer	23.3 ±1.7	37.1 ±4.0	33.9 ±0.21	35.0 ±0.01
Control	21.5 ±1.5	29.3 ±2.3	33.1 ±0.37	33.5 ±0.36
F-test	**	**	*NS*	*NS*
LSD (0.05)	2.37	2.61	-	-
Interaction (WR *T)				
F-test	*NS*	**	*NS*	*NS*

Means with the same letter within each column are not significantly different, (NS), not significant; (-), not calculated.

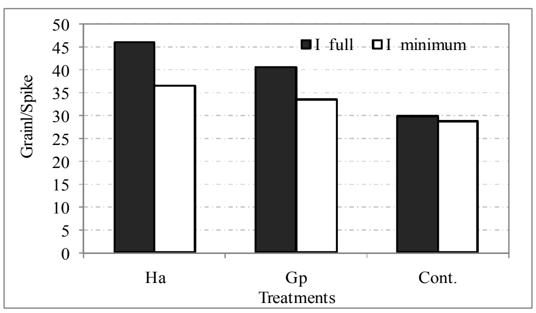

Fig. (4) Effect of the interaction between irrigation levels and soil amendment treatments on number of grain/spike during the second growing season

Biological yield (kg ha^{-1})

Large differences were found in biological yield between growing seasons (Table 5). The biological yield of the second season was more than double compared with the first season. Biological yield didn't show any significant differences as affected by irrigation levels. Soil amendment treatments indicated that, Ha increased biological yield compared to Gp but, the increase was not significant. Biological yield of both treatments was significantly higher than that of control treatments.

The interaction of irrigation levels and soil amendment treatments (Figure 5) was significant only during the second growing season. The highest biological yield was obtained from Ha of fully irrigation level followed by Gp and control treatments respectively. Biological yield of either Gp or control treatments was almost same for both irrigation levels.

Table 5: Biological and grain yields as affected by irrigation regimes and soil amendment treatments.

Variables	Biological Yield (kg/ha)		Grain Yield (Kg/ha)	
	2012	2013	2012	2013
Water Regime (WR)				
I_{full}	2421 ±225	6148 ±521	1271 ±125	3235 ±332
$I_{minmum.}$	2487 ±239	5467 ±523	1013 ±105	2245 ±241
F-test	*NS*	*NS*	*NS*	**
Treatments (T)				
Ha	3015 ±382	7512 ±754	1646 ±147	4096 ±410
Gp	2764 ±267	6969 ±481	1138 ±112	2935 ±400
Control	1583 ±160	2941 ±339	645 ±76	1189 ±124
F-test	**	**	**	**
LSD (0.05)	662	769	322	261
Interaction (WR *T)				
F-test	*NS*	*	*NS*	*

Means with the same letter within each column are not significantly different, (NS), not significant; (-), not calculated.

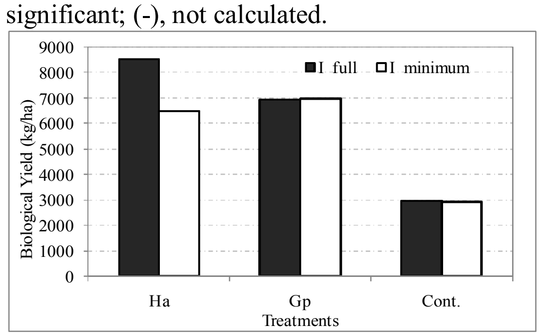

Fig. (5) Effect of the interaction between irrigation levels and soil amendment treatments on biological yield during the second growing season

Grain yield (kg ha^{-1})

Results of grain yield given in Table (5) showed the same trend as in biological yield but, the differences were highly significant as affected by irrigation levels and soil amendments except for minimum irrigation level during the first growing season. The difference in grain yield of this level was not significant. The highest grain yield as affected by the interaction between irrigation levels and amendment treatments (Figure 6), was obtained from fully irrigation level compared with minimum and from Ha followed by Gp and control treatments respectively as affected by soil amendment treatments.

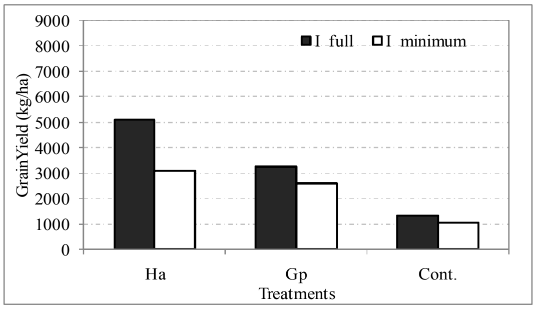

Fig. (6) Effect of the interaction between irrigation levels and soil amendment treatments on grain yield during the second growing season

3.2. Effects on Irrigation water use (IWU)

Results of irrigation water use as affected by irrigation level and soil amendment treatments are presented in Table (6). Results revealed that, minimum irrigation level significantly increased IWU for biological and grain yields in both seasons except for grain yield of the first growing season. Soil amendment treatments significantly increased IWU for both yield compared with control. During the first growing season, IWU of biological and grain yield were almost similar but significantly higher than that of control. In the second growing season, the highest IWU for both yields obtained from Ha followed by Gp and control respectively. IWU of the second growing season was higher than that of the first growing season.

Table 6: Water Use efficiency as affected by irrigation regimes and soil amendment treatments

Variables	Biological yield (kg/m^3/ha)		Grain yield (kg/m^3/ha)	
	2012	2013	2012	2013
Water Regime (WR)				
I_{full}	0.54 ±0.08	1.36 ±0.12	0.28 ±0.02	0.72 ±0.06
$I_{minmum.}$	0.92 ±0.1	2.02 ±0.24	0.37 ±0.04	0.83 ±0.09
F-test	*	*	*NS*	*
Treatments (T)				
Ha	0.86 ±0.07	2.14 ±0.19	0.47 ±0.05	1.13 ±0.05
Gp	0.85 ±0.09	2.06 ±0.28	0.34 ±0.03	0.84 ±0.09
Control	0.47 ±0.04	0.87 ±0.06	0.19 ±0.02	0.34 ±0.05
F-test	**	**	**	**
LSD (0.05)	0.21	0.26	0.08	0.07

Means with the same letter within each column are not significantly different, (NS), not significant; (-), not calculated.

3.3. Effects on grain's N content

Nitrogen content in grain is an indicator for grain quality. Increasing N content in grain will increase the protein content. The observations of N content (%) given in Figure (7) indicated that, the N% was higher in fully irrigation than in minimum level in both growing seasons (Figure 7A). Soil amendment treatments significantly increased the N content. The highest N content obtained from Ha followed by Gp and control treatments, respectively in both growing season (Fig. 7B).

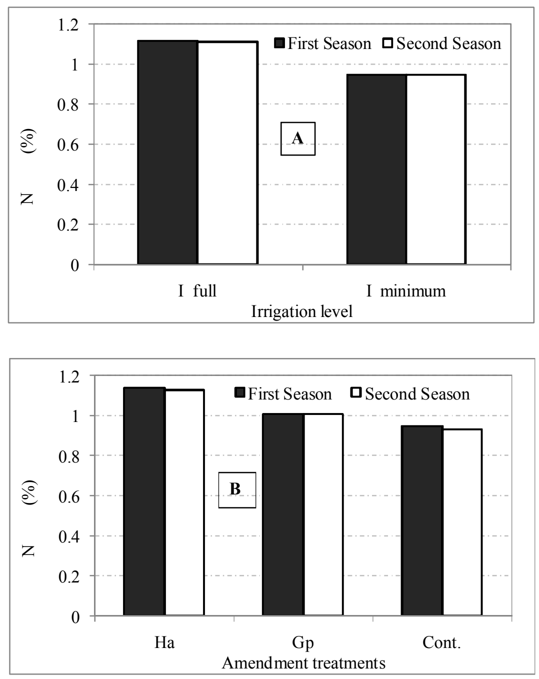

Fig.(7) Effect of irrigation level (A) and amendment treatments (B) on N content (%) of barley grains.

4. Discussion

The increase of plant height, LAI and number of tillers in fully irrigation level and for amended treatments especially Ha could be attributed to available soil water content. Increasing available water associated with fully irrigation level or retained as a results of amendments increase plant height, number of leaves and size, consequently increased LAI, and number of tillers.

On the other hand, reducing soil water content in minimum irrigation level and in control resulted in the reduction of growth parameters. LAI index is an important growth parameter that has inside plant photosynthetic pigments called as chlorophyll. Increasing leaf area up to certain level may increase number of spike and grain/spike consequently increase biological and grain yields. These measured variables are categorized as important growth and yield variables of a crop. The obtained results are in conformity with those of Renquist*et al.* (1982); Ahmad *et al.* (1986); Roberts *et al.*(1990); Delfine*et al.* (2005);Ismail & Ozawa (2007); Yaduvanshi& Sharma (2008); Mandal *et al.*(2009); Dadnia*et al.* (2010); Hammad*et al* .(2011); Mahdy*et al.* (2011); Rehman *et al.* (2011); Tahir *et al.* (2011); Fuertes-Mendizabal *et al.* (2012); Madani *et al.* (2012) and Ismail & Almarshadi (2013). They reported that, either for barley or related crops,the growth and yield is a great concern with improve soil condition including water availability in the soil, because water deficiency restricts normal crop growth resulting in enormous economic loss. In this experiment application of humic acid and gel polymers had improved soil moisture contents. Also, the above researchers have mentioned that Humic acid improves soil texture and is a source of nutrient; while gel polymer merely absorb water and releases slowly.

As we compared humic acid with gel polymer and both with control. Humice acid was superior because it may increase the nutrient availability and uptake beside high available water content. Gel polymer came in the second order, which enhanced the previous characteristics by absorbing more water and released it slowly to the plant. Alternately, humic acid was found encouraging as it significantly improved the barley growth and yield as supported by finding of the above researcher. Increasing retained water in soil is a fact for increasing crop yield especially in amendment treatments and consequently increased IWU. Increasing IWU of minimum irrigation level could be due to the high yield production in relation to water supply. Under water shortage, water stress or with practicing water deficit, most crops especially those growing in dry land conditions are wisely and efficiently use irrigation water. Our results are in conformity with those published by Al-Jamal *et al.* (2001); Lindenmayer *et al.* (2008); Ismail & Almarashadi, (2013). The important point we noted in the current research was that, minimum irrigation level might seems acceptable and recommended to use since the differences in grain/spike, biological yield were not significant compared with those of fully irrigation level. Using this level of irrigation will save 40% of irrigation water. Sometimes, fully irrigation was significantly higher especially in grain yield, however the increase in yield could be economically less than that of saving 40% of irrigation water. The reason for not-significant results of 1000-grain weight might seem due to much variation in data recorded from different plots especially during the first growing season.

In the present study, N significantly increased by irrigation level and soil amended treatments. Increasing amount of irrigation water could be a reason for increasing the solubility of N and consequently uptake. Frank & Roeth, (1996) reported that, humic acid reduce the need for nitrogen fertilizer and improve nutrient uptake, especially nitrogen, phosphorous, and sulfur. Moreover, humic substance act as a storehouse of N, P, S, and Zn.

Results of the second growing season were higher than that of the first growing season. The differences could be attributed to two problems had been faced in the first growing season.The first was damage of the crop by birds especially from grain filling to crop harvest stage. The second reason was weeds infestation which restricted the growth. As these two problems accurately controlled in the second growing season, the results were enhanced in all measured parameters.

5. Conclusions

The findings of this research clearly revealed that, full irrigation level was better than minimum level in most investigated variables. The barley growth and yield components increased with application of humic acid and gel polymers amendments compared to control. The best results obtained from humic acid treatment. Irrigation water use was enhanced under minimum irrigation level and with Ha treatment. Full irrigation level and amendment treatments increased N content in grains. On the basis of present experiment 10 kg ha^{-1} and full irrigating are recommended for barley growth and yield. But when water is a limited factor for agriculture production, minimum level is recommended to use because it saves 40% of irrigation water while the reduction in yield was not significant compared with full irrigation level. From economical point of view, losing part of yield and saving 40% of irrigation water is consider better and economical option than having the optimum yield with full irrigation level under dry land conditions.

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Corresponding Author:
Prof. Dr. Saleh Mahmoud Ismail
Department of Arid Land Agriculture, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, B.O. Box 80208, Jeddah 21589, Saudi Arabia.
E-mail: smii2001@gmail.com

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