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Effect of Using Stabilizing Agents on Increasing Yield and Water Use Efficiency in Barley Grown under Water Stress

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Abstract: Two field experiments were conducted during the two successive seasons of 2004/05 and 2005/06 at the Agricultural Experimental Station of National Research Centre, Shalakan, Kalubia Governorate, Egypt to predict the effect of two yield stabilizing agents (magnesium carbonate and sodium salicylate) on barley yield and water use efficiency under skipping the last irrigation. Four hulled barley cultivars were used i.e. Giza 123, Giza 125, Giza 126, and Giza 2000, in addition to, two hull-less barley cultivars i.e. Giza 129 and Giza 130. Magnesium carbonate or sodium salicylate was sprayed twice during vegetative growth and the last irrigation was skipped. At heading, number of tillers/plant, number of spikes/plant and plant height were measured. Furthermore, at harvest, grain yield, straw yield and biological yield were determined. Data for mean temperature and relative humidity were collected from planting date to heading date and averaged over the two growing seasons. Simple correlation analysis and multiple linear regression analysis were done. Results indicated that the highest reduction in yields as result of skipping the last irrigation was obtained for Giza 126. Whereas, the lowest reduction in grain, straw and biological yields were obtained for the two hull-less cultivars. The application of magnesium carbonate had better effect on the yield of barley cultivars than the application of sodium salicylate. The highest water use efficiency was obtained for Giza 123 under all irrigation treatments, especially under the application of magnesium carbonate. Results also showed that both temperature and relative humidity were highly and negatively correlated with barley yields. Number of tillers/plant and number of spikes/plant were positively correlated with barley grain, straw and biological yields, and plant height, was negatively correlated with grain yield. The developed prediction equations could be a useful decision-making tool to attain early yields prediction, which could be helpful in deciding whether to skip the last irrigation or not.

Keywords: yield prediction, weather parameters, water stress, water use efficiency, yield stabilizing agents (YSA), barley cultivars.

INTRODUCTION

Recently, great interest was paid to barley because of its nutritive value as it used with wheat in bread making. Barley is a very hardy crop which can be grown in adverse agroclimatic conditions, such as drought (Mishra and Shivakumar 2000). Barley plant's tolerance to moderate levels of water stress is useful because of the pressure of saving irrigation water in Egypt for other non agricultural sectors. Stability of economic yield of barley in the presence of varying levels of water stress is very important (Guttieri *et al.,* 2001), which may be achieved by using yield stabilizing agents, such as magnesium carbonate and sodium salicylate (El-Kholy *et al.,* 2005b). Yield stabilizing agents are substances involved in increasing drought resistance by tending to cause xermorphy and/or stabilization of cell structure (Bergmann *et al.,* 1998).

Skipping the last irrigation for barely at grain premature stage could be useful practice to save irrigation water, however it would reduce final yield due to incomplete development of barley grains (El-Seidy and Khattab, 2000). Thus, it is important to identify different barley genotypes with high yield potential and with high yield stability under drought stress (El-Bawab, 2002). Furthermore, predicting the potential yield reduction

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before skipping the last irrigation could be important procedure to determine whether to skip the last irrigation or not. Therefore, defining yield attributes to be used for accurate barley yield prediction under water stress during grain filling stage would be essential. Moreover, the effect of weather parameter should be included to increase the accuracy of the prediction (Wilhelmi *et al.,* 2002). Weather parameters, such as temperature and relative humidity have great effect on barley yield. Temperature is the primary factor driving barley development and accordingly influences yield (Ritchie and NeSmith, 1991). Relative humidity also has a great effect on yield, where water losses to the atmosphere decreases with increasing relative humidity (Gardner, *et al.,* 1985). Weather parameters, in addition to plant attributes could be used to predict yield (Noureldin, *et al.,* 2003; Sowalim *et al.,* 2004; El-Kholy *et al.,* 2005a; Mouhamed and Ouda, 2006).

The objectives of this study were (i) to distinguish between different barley cultivars in their tolerance to water stress at grain premature stage. (ii) to assess the effect of sodium salicylate and magnesium carbonates as yield stabilizing agents on barley yield under skipping the last irrigation. (iii) to predict final barely yield at heading and prior to the imposing water stress.

MATERIALS AND METHODS

Two field experiments were conducted during the two successive seasons of 2004/05 and 2005/06 at the Agricultural Experimental Station of National Research Centre, Shalakan, Kalubia Governorate, Egypt to predict the role of two yield stabilizing agents on barley yield under skipping the last irrigation. Four barley hulled cultivars were used i.e. Giza 123, Giza 125, Giza 126, and Giza 2000, in addition to two hull-less barley cultivars i.e. Giza 129 and Giza 130. A split-split plot design with four replicates was used. Barley cultivars were assigned to the main plots, whereas skipping the last irrigation and application of two types of anti-transpiration magnesium carbonate (reflectant type) or sodium salicylate (stomatic type) were distributed in the subplots. The preceded crop was maize in both seasons and the soil type was clay loam with the following characteristics: 7.5% sand, 59.1% silt, 33.4% clay, pH=7.55, Ec=0.26 dsm^{-1}, Ca^{++}=1.1, Mg^{++}=0.5, Na^{+}=1.3, K^{+}=0.8, HCO_3=0.4, Cl^{-}=2.6, SO_4^{--}= 0.58 (meq/lit). Barley seeds were sown on the 3rd and 5th of December 2004 and 2005, respectively. Potassium fertilizer was added at the rate of 24 kg/fed (K_2SO_4). Nitrogen fertilizer as 45 kg/fed was divided into two equal doses, the first was added at tillering and the second was added at shooting. 1g/lit of either of magnesium carbonate or sodium salicylate were sprayed twice during vegetative growth at 40 and 47 days after sowing. At heading, number of tillers/plant, number of spikes/plant and plant height were measured for five bordered plants. These three yield attributes were chosen because its growth is completed at heading. Furthermore, these three attributes are important components of both grain and straw yields. The last irrigation was skipped at grain premature stage. At harvest, grain, straw and biological yields were determined. Data for mean temperature (MTemp, °C), and relative humidity % (RH) were collected from planting date to heading date for both growing seasons (Table 1).

Crop-water Relation Parameters:

Seasonal Actual Water Consumptive Use (Evapotranspiration):

Actual evapotranspiration (ET) was estimated by soil sampling just before and after 48 hours of each irrigation, and before harvest and calculated according to the equation of Israelsen and Hansen (1962) as follows:

$$CWU = (\Theta_2 - \Theta_1) * Bd * RD \qquad (2)$$

Where: CU is water consumptive use (mm), Θ_2 is soil moisture percentage by weight 48 hours after irrigation, Θ_1 is soil moisture percentage by weight 48 hours before next irrigation, Bd is bulk density in (g/cm^3) and RD is root depth.

Water Use Efficiency (WUE):

Water use efficiency (kg/m^3) values for the different treatments were calculated by the following equation (Vites, 1965).

$$WUE = \text{Seed yield (kg/fed)}/\text{Consumptive use } (m^3/fed) \qquad (3)$$

Table 1: Average of temperature and relative humidity for the two growing seasons.

Year Month	2004/05		2005/06	
	MTemp (ºC)	RH %	MTemp (ºC)	RH %
December	18.7	40	16.1	66
January	18.0	41	14.5	57
February	16.2	41	15.8	66
March	16.2	62	18.2	67
April	20.8	60	21.4	59
Mean	18.0	49	17.2	63

Soil moisture constants (% per weight) and bulk density (g/cm^3) in the depth of 0-60 cm are shown in Table (2).

Statistical Analysis:

- Analysis of variance for split-split plot design according to Snedecor and Cochran (1980) was done to find out the significance of the studied treatments. Means of the studied characters were compared by least significant difference (LSD) at 5% level of significance.
- Percent decrease in barley yield as a result of skipping the last irrigation was calculated. Moreover, percent decrease in yield as a result of application of magnesium carbonate and sodium salicylate was also calculated.
- Simple correlation coefficients (Steel and Torrie, 1980) between weather parameters and barley yields and its attributes were calculated to determine the strength of the relationship between them.
- Regression analysis (Draper and Smith, 1987) was used to develop equations to predict barley yield under water stress during grain premature stage and under water stress and the application of the two yield stabilizing agents. Two parameters, coefficient of determination (R^2) and standard error of estimates (SE%) were used to test the precision. In order to obtain a precision prediction, R^2 should be near to one and SE% should be near to zero. Coefficient of determination is the amount of variability due to all independent variables, and standard error of estimates is a measurement of precision i.e. closeness of predicted and observed yield to each other. The developed equations were compared with its R^2 and SE% to determine its accuracy.

RESULTS AND DISCUSSIONS

Means of Barley Yield and its Components:

Results in Table 2(a&b) indicated that all the studied characters were significantly affected by the irrigation treatments, except for number of tillers/plant where it was significant under skipping the last irrigation and the application of magnesium carbonate. The results also showed that the effect of applying of either yield stabilizing agents (sodium salicylate or magnesium carbonate) was more pronounced on barley yield than its attributes because the application was done before imposing of water stress, and thus affected only yields. Grain, straw and biological yields were decreased as a result of water stress at grain premature stage. Application of either sodium salicylate or magnesium carbonate reduced the harm effect of water stress and increased barley yield. This result is in agreement with what was found by El-Kholy *et al.,* (2005b).

Percent Reduction in Barley Yields as a Result of Skipping the Last Irrigation:

Results in Table (3) revealed that the highest reduction in grain, straw and biological yields as result of skipping the last irrigation were obtained for Giza 126 (14.78, 19.44, and 15.53 %, respectively). Whereas, the lowest reduction in grain, straw and biological yields were obtained for the two hull-less cultivars (Giza 129 and Giza 130). Therefore, it is recommended to plant either Giza 129 or Giza 130 under skipping the last irrigation because of its ability to withstand adverse growth conditions.

Percent Reduction in Barley Yield as a Result of the Application of Stabilizing Agents under Water Stress:

Results in Table (3) also showed that all the cultivars positively responded to the application of sodium salicylate and magnesium carbonate, where yield losses were decreased. The results also showed that the application of magnesium carbonate had better effect on the yield of the six barley cultivars than the application of sodium salicylate. This could be attributed to the action of magnesium carbonate as a refelectant, which helped in reducing heat load on leaves and increased penetration of more solar radiation into the canopy

Table 2a: Soil moisture constants of the experimental field at experimental site

Depth (cm)	Field capacity (%, w/w)	Wilting point (%, water)	Available water (mm)	Bulk density g/cm^3
0 – 15	42.15	19.01	40.0	1.15
15 – 30	34.62	16.90	30.1	1.24
30 – 45	27.36	16.92	20.6	1.20
45 – 60	27.15	16.24	22.1	1.28

Table 2b: Effect of the interaction between barley cultivars and irrigation treatments over the two growing seasons

		Yield components					
Variety	Treatment	TiN/pl	SpN/pl	PLH(cm)	GY(ton/fed)	SY(ton/fed)	BY (ton/fed)
G 123	Control	3.00	4.90	116.10	4.23	5.29	9.72
	WS	2.50	4.30	106.90	3.80	4.70	8.31
	WS+SS	2.70	3.80	108.50	3.90	4.85	8.44
	WS+MC	3.15	5.30	110.30	3.95	4.90	8.49
G125	Control	2.38	4.20	105.80	3.37	5.65	8.78
	WS	2.88	4.10	98.40	2.9	4.90	7.87
	WS+SS	3.25	4.00	99.10	3.1	5.10	7.90
	WS+MC	3.00	5.30	100.10	3.13	5.32	8.00
G126	Control	2.25	4.40	118.30	3.28	4.84	8.17
	WS	2.75	3.90	98.30	2.8	3.90	6.90
	WS+SS	2.38	3.50	112.40	2.94	4.05	6.86
	WS+MC	3.00	5.30	117.90	2.96	4.16	7.12
G129	Control	2.25	4.90	91.00	2.61	7.07	9.56
	WS	2.63	4.20	86.30	2.48	6.50	8.48
	WS+SS	2.38	4.50	90.00	2.51	6.65	8.8
	WS+MC	3.25	5.30	91.80	2.54	6.78	8.95
G130	Control	2.26	5.20	109.10	2.91	6.34	9.11
	WS	2.88	4.40	101.40	2.73	5.76	8.14
	WS+SS	2.75	4.50	104.00	2.76	5.94	8.23
	WS+MC	3.88	5.30	101.80	2.8	6.10	8.62
G 2000	Control	2.50	5.40	110.5	3.45	3.82	6.76
	WS	2.25	4.40	102.5	3.1	3.25	5.83
	WS+SS	2.88	4.80	105.3	3.23	3.33	6.12
	WS+MC	3.00	5.00	106.4	3.25	3.50	6.29
$LSD_{0.05}$	Control	0.39	n.s.	2.33	0.07	0.24	0.23
	WS	0.36	n.s.	1.76	0.06	0.31	0.31
	WS+SS	0.80	n.s.	4.70	0.05	0.49	0.45
	WS+MC	0.50	0.80	3.30	0.11	0.35	0.32

TiN/pl = number of tillers/plant; SpN/pl = number of spikes/plant; PLH = plant height (cm); GY=grain yield (kg/fed); SY = straw yield (kg/fed); BY = Biological yield (kg/fed);WS = water stress at grain premature stage; WS+SS = water stress at grain premature stage and the application of sodium salicylate; WS+MC = water stress at grain premature stage and the application of magnesium carbonate.

Table 3: Percent difference in barley yield under control, compared with yield under the rest of irrigation treatments over the two growing seasons.

		Percent difference in		
Variety	Treatment	Grain yield	Straw yield	Biological yield
Giza 123	WS	10.09	11.10	14.56
	WS+SS	7.73	8.27	13.26
	WS+MC	6.54	7.32	12.70
Giza 125	WS	13.95	13.32	10.34
	WS+SS	8.02	9.78	9.99
	WS+MC	7.13	5.89	8.86
Giza 126	WS	14.78	19.44	15.53
	WS+SS	10.38	16.29	12.90
	WS+MC	9.76	14.07	16.07
Giza 129	WS	5.12	8.05	11.32
	WS+SS	3.97	5.93	7.97
	WS+MC	2.83	4.09	6.40
Giza 130	WS	6.19	9.17	10.61
	WS+SS	5.16	6.41	9.67
	WS+MC	3.80	3.82	5.35
Giza 2000	WS	10.14	15.01	13.70
	WS+SS	6.46	12.92	9.41
	WS+MC	5.82	8.47	6.96

WS = water stress at grain premature stage; WS+SS = water stress at grain premature stage and the application of sodium salicylate; WS+MC = water stress at grain premature stage and the application of magnesium carbonate.

for photosynthesis (Gaballah and Moursy, 2004). This result is in agreement with what was found by El-Kholy, *et al.,* (2005b). Therefore, it could be recommended to apply magnesium carbonate to reduce the harm effect of water stress on final yield when last irrigation was skipping.

Measured Water Consumptive Use and Water Use Efficiency:

Results in Table (4) indicated that the highest consumptive water use was obtained for Giza 2000 under control treatment i.e. 1377 m^3/fed. Measured consumptive water use was the same under skipping the last irrigation and under skipping the last irrigation and the application of either sodium salicylate or magnesium carbonate. The highest water consumptive use under water stress treatments was obtained for Giza 125 variety i.e. 1114 m^3/fed. Water use efficiency was the highest for Giza 123 under all irrigation treatments: control, skipping the last irrigation, skipping the last irrigation and the application of sodium salicylate and skipping the last irrigation and the application of magnesium carbonate, where it was 2.91, 3.43, 3.52 and 3.57 kg/fed, respectively. The highest water use efficiency over all the cultivars and irrigation treatments was obtained for Giza 123 under the application of magnesium carbonate. Therefore, to increase water use efficiency under skipping the last irrigation, it is recommended to plant Giza 123 and apply magnesium carbonate (Table 4).

Table 4: Consumptive water use (CWU) and water use efficiency (WUE) for barley for both growing seasons

Variety	Control treatment		Water stress treatments			
	CWU (m^3/fed)	WUE (kg/m^3)	CWU (m^3/fed)	WUE under WS (kg/fed)	WUE underWS +SS (kg/fed)	WUE under WS +MC (kg/fed)
G 123	1359	2.91	1107	3.43	3.52	3.57
G 125	1366	2.29	1114	2.60	2.78	2.81
G 126	1371	2.16	1109	2.53	2.65	2.67
G 129	1369	1.86	1112	2.23	2.26	2.28
G 130	1373	2.04	1111	2.46	2.48	2.52
G 2000	1377	2.36	1113	2.79	2.90	2.92

WS = water stress at grain premature stage; WS+SS = water stress at grain premature stage and the application of sodium salicylate; WS+MC = water stress at grain premature stage and the application of magnesium carbonate.

Table 5: Simple correlation coefficients between weather parameters, yield components and barley yields

Variables	Grain yield (kg/fed)	Straw yield (kg/fed)	Biological yield (kg/fed)
Temperature (ºC)	-0.784	-0.816	-0.770
Relative humidity %	-0.774	-0.808	-0.760
Number of tillers/plant	0.901	0.889	0.851
Number of spikes/plant	0.893	0.888	0.908
Plant height (cm)	-0.961	0.988	0.924

Simple Correlation Between Weather Parameters and Plant Attributes:

Results in Table (5) showed that both air temperature and relative humidity in the period from planting to heading were highly and negatively correlated with barley yields. Mishra and Shivakumar (2000) stated that higher temperature and humid weather is not suitable for barley growth and resulted in low yield. Furthermore, results also indicated that number of tillers/plant and number of spikes/plant were positively correlated with barley grain, straw and biological yields. Moreover, plant height was negatively correlated with grain straw and biological yields. This could be attributed to that long stems could result in plants lodging, which could reduce grain yield (Gardner *et al.,* 1985).

Barley Yield Prediction:

Control Treatment:

Under optimum conditions and overall the six barley cultivars, both temperature (MTemp) and relative humidity (RH) were negatively correlated with barley yields, where any increase of them could reduce yields. Number of tillers/plant (TiN/Pl) and number of spikes/plant (SpN/Pl) were positively correlated with grain yield, where both are important attributes of grain yield. Tillers play an important role in photosynthesis during grain filling and spikes number is an indirect indicative of grain yield (McMaster, 1997). Furthermore, plant height (PlH) was negatively correlated with grain yield. Regarding to straw yield, number of tillers/plant and plant height were positively correlated with straw yield, where both are important yield attributes. Number of spikes/plant was negatively correlated with straw yield, where any increase in it would reduce straw yield.

[1] $\hat{y}_{grain}$ = -126.50- 9.09(MTemp)*- 0.54(RH)* +0.22(TiN/Pl) + 0.02(SpN/Pl)* - 0.06(PlH)**

R^2= 0.939 SE%=3.29

[2]$\hat{y}_{straw}$= 105.44 -7.93(MTemp)*-0.44(RH)*+0.08(TiN/Pl)-0.02(SpN/Pl) + 0.07(PlH)**

R^2=0.973 SE%=1.79

Skipping the Last Irrigation Treatment:

Under water stress, relative humidity (RH) was positively correlated with both grain and straw yields. This could be attributed to that under water stress high relative humidity reduces water losses to the atmosphere (Gardner *et al.,* 1985). Further, plant height became positively correlated with both grain and straw yields. This could be attributed to the role that mobilization from stem reserve plays under the condition of stomatal closure and photosynthesis reduction (McMaster, 1997). The above mentioned trend of number of tillers/plant, number of spikes/plant and plant height under control treatment were observed under water stress too.

[3]$\hat{y}_{grain}$= 135.98 - 10.05(MTemp)* + 0.61(RH)* + 0.03(TiN/Pl) + 0.08(SpN/Pl)* + 0.01(PlH)**

R^2= 0.969 SE%=1.66

[4]$\hat{y}_{straw}$= 258.40 -19.53(MTemp)* + 1.20 (RH)* + 0.12(TiN/Pl) - 0.46(SpN/Pl) + 0.05(PlH)**

R^2=0.975 SE%=2.76

Application of Sodium Salicylate and Skipping the Last Irrigation:

When the last irrigation was skipped and sodium salicylate was applied, the role of mobilization from stem reserve could be more pronounced and plant height was positively correlated with both grain and straw yields. The rest of yield attributes followed the above mentioned trend.

[5]$\hat{y}_{grain}$= 293.79 - 21.81(MTemp)** + 1.32(RH)* + 0.09(TiN/Pl) + 0.05(SpN/Pl)* + 0.01(PlH)**

R^2= 0. 968 SE%=3.97

[6]$\hat{y}_{straw}$= 474.08 -35.10(MTemp)** + 2.14 (RH)** + 0.28(TiN/Pl)**- 0.23(SpN/Pl)* + 0.03(PlH)

R^2=0. 964 SE%=5.93

Application of Magnesium Carbonate and Skipping the Last Irrigation:

The above mentioned trend of weather parameters and yield attributes were observed under the application of magnesium carbonate and skipping the last irrigation for both eq. [7] and [8].

[7]$\hat{y}_{grain}$= 210.08 - 15.67(MTemp)** + 0.94(RH)** - 0.08(TiN/Pl) + 0.12 (SpN/Pl)* + 0.02(PlH)**

R^2= 0.962 SE%=3.94

[8]$\hat{y}_{straw}$= 207.99 -16.33(MTemp)** + 1.01 (RH)** + 0.18(TiN/Pl)*- 0.10(SpN/Pl) + 0.13(PlH)**

R^2= 0.958 SE%=4.87

Conclusion:

The application of yield stabilizing agents and the ability of barley hull-less cultivars to tolerate water stress during grain premature stage were the two reasons for low yields losses. Grain yield was reduced by only 2.83% and 3.80%, whereas straw yield was reduced by only 4.09% and 3.82% for Giza 129 and Giza 130, respectively when magnesium carbonate was added and the last irrigation was skipped. Similarly, the reduction in the yield of hulled cultivars were also relatively low, between 5.82-9.76% for grain yield and between 5.89-14.07% for straw yield with the application of magnesium carbonate. Therefore, it is recommended to plant either Giza 129 or Giza 130 and use magnesium carbonate as a yield stabilizing agent. However, to increase water use efficiency under skipping the last irrigation, it is recommended to plant Giza 123 and apply magnesium carbonate.

The developed prediction equations could be a useful decision-making tool to attain early yield prediction (at heading) using only three easy vegetative measurements: number of tillers/plant, number of spikes/plant and plant height. These measurements along with temperature and relative humidity could be applied to the developed equations and potential barley yield could be predicted. This could allow us to calculate the expected yield under optimum conditions, under water stress and under water stress with the application of yield stabilizing agents. Depending on how large is the expected yield losses then we could decide if we skip the last irrigation or not. The developed groups of prediction equations had high degree of precision because R^2 was high and SE% was low. However, it would be only applicable under the weather condition of Delta region in Egypt.

REFERENCES

Bergmann, H., H. Eckert, C. Weber and D. Roth, 1988. Increasing crop plant drought resistance by chemical means. Internationale Zeitschrift der Landwirstschaft., 32(6): 466-469.

El-Bawab, A.M.O., 2002. Stability of different barley genotypes for yield and some agronomic characters. Egyptian Journal of Applied Science., 17(9): 118-129.

Draper, N.R. and H. Smith, 1987. Applied Regression Analysis. John Wilay and Sons, Inc. New York.

El-Kholy, M.A., S.A. Ouda, M.S. Gaballah and M. Hozayn, 2005. Predicting the interaction between the effect of anti-transpirant and weather on productivity of wheat plant grown under water stress. J. of Agron., 4(1): 75-82.

El-Kholy, M.A., M.S. Gaballah, S. El-Ashry and A. Oraby, 2005. Combating drought using yield stabilizing agents in barley. J. Agric. Bio. Sci., 7(3): 369-375.

El-Seidy, E.H. and A.B. Khattab, 2000. Heterosis and combining ability in barely under drought conditions at different growth stages. Proc. 9th Conf. Agron., Menufiya University, 167-172.

Gaballah, M.S. and M. Moursy, 2004. Reflectants application for increasing wheat plants tolerance against salt stress. Pak. J. Biol. Sci., 7: 956-962.

Gardner, F.P., R.B Pearce, R.L. Mitchell, 1985. Physiology of Crop Plants. Iowa State University Press. Ames. USA.

Guttieri, M.J., J.C. Stork, K O'Brien and E. Souza, 2001. Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. Crop Science, 41: 327-335.

Israelsen, O.W. and V.E. Hansen, 1962. Irrigation Principles and Practices. John Wiley & Sons, Inc. New York.

McMaster, G.S., 1997. Phonology, development, and growth of wheat (Triticum aestivum L.) shoot apex: A review. Advces in Agron,. 59: 63-118.

Mishra, B.N. and B.G. Shivakumar, 2000. Barley. *In*: Techniques and Manangement of Field Crop Production. Agrobios. India.

Mouhamed, S.G. and S.A. Ouda, 2006. Predicting the role of some weather parameters on Maize productivity under different defoliation treatments. J. Appl. Bio. Sci., 2(11): 920-925.

Noureldin, N.A., S.A. Ouda, and M. Fauze, 2003. Some procedures used in yield prediction of soybean under Egyptian conditions. Arab Unvi. J. Agri Sci. Ain Shams Unvi., 11(2): 607-617.

Ouda, S.A. and S.G. Mouhamed, 2005. Predicting the role of some weather parameters on maize productivity under different defoliation treatments. Sent for publications.

Sendecor, G.W., and W.G. Cochran, 1980. Statistical Method. 7th Edition. Iowa State University Press. Ames, Iowa, USA.

Sowalim S.M., S.A. Ouda and M.M. El-Tantawy, 2004. Predicting wheat yield at Delta region under different sowing dates using historical weather data. Annals of Agric. Sci. Moshtohor., 42(2): 489-497.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics, a Biometrical Approach. Mc-Grow-Hill Book Co., 2nd ed., New York, U.A.S.

Ritchie, J.T. and D.S. NeSmith, 1991. Temperature and Crop Development. *In*: Modeling plant and soil systems. American Society of Agronomy. Madison Wisconsin. USA.

Wilhelmi, O.V., K.G. Hubbard and D.A. Wilhite, 2002. Spatial representation of agroclimatology in a study of agricultural drought. Int. J. Climate., 22: 1399-1414.

Vites, F.G. Jr., 1965. Increasing water efficiency by soil management. Amer. Soci. Agron., Wisc., 26: 259-274.