Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 5 (8): 1378-1384, 2005
ISSN 1812-5654

Predicting the Effect of Some Yield Stabilizing Agents on Increasing Drought Resistance in Barley

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Abstract: This study was carried out to predict the role of two yield stabilizing agents (magnesium carbonate and sodium salicylate) on barley yield under water stress condition. Four hulled barley cultivars and two hull-less were sprayed with magnesium carbonate or sodium salicylate twice during vegetative growth and the last irrigation was skipped. Different growth and yield parameters were measured for five bordered plants. Data for mean temperature and relative humidity % were collected and averaged over the two growing seasons. Three groups of prediction equations were developed. The first group is an overall of the six barley cultivars prediction equations under the above mentioned treatments using plant attributes and weather parameters. The second group predicted barley yield over all the normal (hulled) cultivars only. The third group predicted barley yield over the two hull-less barley cultivars. Results indicated that the highest reduction in yields as result of skipping the last irrigation were obtained by Giza 126. Whereas, the lowest reduction in biological yields were obtained by 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. Results also showed that both temperature and relative humidity % were highly and negatively correlated with barley yields. The three yield attributes were positively correlated with barley grain, straw and biological yields, except for plant height, which was negatively correlated with grain yield. All the three developed groups of prediction equations had high degree of precision because R^2 was high and SE% was low. Thus, it allowed us to predicted the expected yield under optimum conditions, under water stress and under the application of yield stabilizing agents, in addition to water stress. Furthermore, percent reduction in yield as a result of skipping the last irrigation and the improvement in yield as a result the application of yield stabilizing agents were estimated too.

Key words: Yield prediction, weather parameters, water stress, Yield Stabilizing Agents (YSA), magnesium carbonate, sodium salicylate, yield attributes, 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[1]. 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[2]. which may be achieved by using yield stabilizing agents, such as magnesium carbonate and sodium salicylate[3]. Yield stabilizing agents are substances involved in increasing drought resistance by tending to cause xermorphy and/or stabilization of cell structure[4].

Skipping the last irrigation in barely at premature stage could be useful in saving irrigation water, however it could reduce final yield due to incomplete development of barley grains[5]. Thus, it is important to identify barley genotypes with high yield potential and with high yield stability under drought stress[6]. Moreover, defining variables to be used for accurate barley yield prediction under water stress during grain filling stage would be beneficial, if it could be done before imposing the stress and if the effect of weather is included[7].

Weather parameters, such as temperature and relative humidity have great effect on barley yield. Temperature is

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the primary factor driving crop development and accordingly influences yield[8]. Relative humidity also has a great effect on yield, where water losses to the atmosphere decreases with increasing relative humidity[9]. Weather parameters, in addition to plant attributes could be used to predict yield[10-12].

The objectives of this study were to distinguish between different barley cultivars in their tolerance to water stress at premature stage; to assess the effect of sodium salicylate and magnesium carbonate as yield stabilizing agents on barley yield under water stress by skipping the last irrigation; 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 2002/03 and 2003/04 at the Agricultural Experimental Station of National Research Centre, Shalakan, Kalubia Governorate, Egypt to predict the role of 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 five replicates was used. Barley cultivars were assigned to the main plots, whereas skipping the last irrigation and application of two types of YSA 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 dS m^{-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 L^{-1}). Barley seeds were sown on the 3rd and 5th of December 2002 and 2003, respectively. Potassium fertilizer was added at the rate of 24 kg/fed (K_2SO_4). Nitrogen fertilizer as 45kg/fed was divided into two equal doses, the first was added at tillering and the second was added at shooting. Plants were irrigated every 21 days. The last irrigation was skipped at grain premature stage. Either of magnesium carbonate or sodium salicylate (g L^{-1}) 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 their growth were completed at heading. Furthermore, these three attributes are important components of both grain and straw yields. At harvest, grain, straw and biological yields were determined.

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

	Year			
	2002/03		2003/04	
Months	Temp. (°C)	RH %	Temp. (°C)	RH %
December	18.70	40.00	16.10	66.00
January	18.00	41.00	14.50	57.00
February	16.20	41.00	15.80	66.00
March	16.20	62.00	18.20	67.00
April	20.80	60.00	21.40	59.00
Mean	17.98	48.80	17.20	63.00

Data for mean temperature (MTemp, °C) and Relative Humidity % (RH) were collected from planting date to heading date and averaged over the two growing seasons of 2002/03 and 2003/04 (Table 1).

Statistical analysis

1. Analysis of variance for split-split plot design was done to find out the significance of the studied treatments[13]. Means of the studied characters were compared by Least Significant Difference (LSD) at 5% level of significance.
2. Percent decrease in barley yields as a result of skipping the last irrigation were calculated. Moreover, percent decrease in yields as a result of application of magnesium carbonate and sodium salicylate were also calculated.
3. Simple correlation coefficients[13] between weather parameters and barley yields and its attributes were calculated to determine the strength of the relationship between them.
4. Regression analysis[14] was used to develop equations to predict barley yield under water stress during 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 increase 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.

Three groups of prediction equations were developed. The first group is a general one, which is an overall of the six barley cultivars prediction equations under the above mentioned treatments using plant attributes and weather parameters. The second group predicted barley yield over all the hulled cultivars only

(Giza 123, Giza 125, Giza 126 and Giza 2000) under the above mentioned conditions. The third group predicted barley yield over the two hull-less barley cultivars (Giza 129 and Giza 130). The developed groups of equations were compared with its R^2 and SE% to determine its accuracy.

RESULTS AND DISCUSSION

Means of barley yields: Results (Table 2) showed that number of tillers/plant, number of spikes/plant and plant height were not affected by skipping the last irrigation (at grain premature stage) over all the cultivars. Grain, straw and biological yields were decreased as a result of water stress at premature stage. Application of either sodium salicylate or magnesium carbonate reduced the adverse effect of water stress and increased barley yields.

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

Percent reduction in barley yields as a result of the application of yield stabilizing agents and water stress: Results also showed that all the cultivars positively responded to sodium salicylate and magnesium carbonate and yield losses were decreased (Table 3).

In addition, the losses in the yields of Giza 126 were relatively high when water stress was imposed and even after the application of yield stabilizing agents. However, 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 reflectant, which helped in reducing heat load on leaves and in penetration of more solar radiation into the canopy for photosynthesis[15]. This result is in agreement with what was found by El-Kholy *et al.*[16]. Therefore, it could be recommended to apply magnesium carbonate to reduce the harm effect of water stress on final yield.

Simple correlation between weather parameters and plant attributes: Results (Table 4) 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[17] found that high temperature and humid weather were not suitable for barley growth and resulted in low yield. Furthermore, results also indicated that number of tillers/plant, spike number/plant and plant height were positively correlated

Table 2: Yield and yield components of barley as influenced by water stress and the application of yield stabilizing agents

	Yield components						
Varieties	Treatments	TiN/pl	SpN/pl	PLH (cm)	GY (kg/fed)	SY (kg/fed)	BY (kg/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	2.90	4.90	7.87
	WS+SS	3.25	4.00	99.10	3.10	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	2.80	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	8.80
	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	2.80	6.10	8.62
G 2000	Control	2.50	5.40	110.50	3.45	3.82	6.76
	WS	2.25	4.40	102.50	3.10	3.25	5.83
	WS+SS	2.88	4.80	105.30	3.23	3.33	6.12
	WS+MC	3.00	5.00	106.40	3.25	3.50	6.29
$LSD_{0.05}$	Control	0.39	n.s.	2.33	0.074	0.244	0.225
	WS	0.36	n.s.	1.76	0.055	0.313	0.310
	WS+SS	0.80	n.s.	4.70	0.054	0.489	0.451
	WS+MC	0.50	0.800	3.30	0.105	0.346	0.319

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 premature stage; WS+SS = Water Stress at 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 reduction and/or increase in barley yield as influenced by water stress and application of YSA

		Yield		
Varieties	Treatments	Grain (kg/fed)	Straw (kg/fed)	Biological (kg/fed)
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 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 4: Simple correlation coefficients between weather parameters, yield and yield components of barley

Variables	Grain yield (kg/fed)	Straw yield (kg/fed)	Biological yield (kg/fed)
Temperature (°C)	-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

with barley grain, straw and biological yields, except for plant height, which was negatively correlated with grain yield. This could be attributed to that long stems could result in plants lodging and thus could reduce grain yield.

Barley yield prediction

Prediction equations overall the six barley cultivars: One general equation for each treatment, in addition to the control was developed to be applicable to predict the yield of any other barley cultivars. All the developed equations in this group were characterized by high R^2 and low SE%, which an indication of high precision.

Control: Under optimum conditions and overall the six barley cultivars, both temperature and relative humidity % 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 indication of grain yield[18]. 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 attributes. Number of spikes/plant was negatively correlated with straw yield, where any increase of it would reduce straw yield.

$$\hat{y}_{grain} = -126.50 - 9.09(MTemp)^{*} - 0.54(RH)^{*} + 0.22(TiN/Pl) + 0.02(SpN/Pl)^{*} - 0.06(PlH)^{**} \quad (1)$$
$$R^2 = 0.939 \qquad SE\% = 3.29$$

$$\hat{y}_{straw} = 105.44 - 7.93(MTemp)^{*} - 0.44(RH)^{*} + 0.08(TiN/Pl) - 0.02(SpN/Pl) + 0.07(PlH)^{**} \quad (2)$$
$$R^2 = 0.973 \qquad SE\% = 1.79$$

Skipping the last irrigation: Under water stress, relative humidity % 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[19]. 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[18]. The above mentioned trend of number of tillers/plant, number of spikes/plant and plant height were observed under water stress too.

$$\hat{y}_{grain} = 135.98 - 10.05(MTemp)^{*} + 0.61(RH)^{*} + 0.03(TiN/Pl) + 0.08(SpN/Pl)^{*} + 0.01(PlH)^{**} \quad (3)$$
$$R^2 = 0.969 \qquad SE\% = 1.66$$

$$\hat{y}_{straw} = 258.40 - 19.53(MTemp)^{*} + 1.20(RH)^{*} + 0.12(TiN/Pl) - 0.46(SpN/Pl) + 0.05(PlH)^{**} \quad (4)$$
$$R^2 = 0.975 \qquad SE\% = 2.76$$

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 still pronounced and plant height is positively correlated with both grain and straw yields. The rest of yield attributes followed the above mentioned trend.

$$\hat{y}_{grain} = 293.79 - 21.81(MTemp)^{**} + 1.32(RH)^{*} + 0.09(TiN/Pl) + 0.05(SpN/Pl)^{*} + 0.01(PlH)^{**} \quad (5)$$
$$R^2 = 0.968 \qquad SE\% = 3.97$$

$$\hat{y}_{straw} = 474.08 - 35.10(MTemp)^{**} + 2.14(RH)^{**} + 0.28(TiN/Pl)^{**} - 0.23(SpN/Pl)^{*} + 0.03(PlH) \quad (6)$$
$$R^2 = 0.964 \qquad SE\% = 5.93$$

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).

$$Y\hat{}_{grain} = 210.08 - 15.67(MTemp)^{**} + 0.94(RH)^{**} - 0.08(TiN/Pl) + 0.12\,(SpN/Pl)^{*} + 0.02(PlH)^{**} \quad (7)$$
$$R^2 = 0.962 \qquad SE\% = 3.94$$

$$y\hat{}_{straw} = 207.99 - 16.33(MTemp)^{**} + 1.01\,(RH)^{**} + 0.18(TiN/Pl)^{*} - 0.10(SpN/Pl) + 0.13(PlH)^{**} \quad (8)$$
$$R^2 = 0.958 \qquad SE\% = 4.87$$

Prediction equations for the hulled cultivars: The yields of Giza 123, Giza 125, Giza 126 and Giza 2000 under the different treatments were used to develop a set of equations, specifically for predicting the yield of hulled barley cultivars. All the developed equations in this group were characterized by high R^2 and low SE%, which an indication of high precision. The above mentioned trend of weather parameters and yield attributes were also observed for this group of equations.

Control

$$y\hat{}_{grain} = 28.15 - 10.26(MTemp)^{*} - 1.35(RH)^{*} + 0.45(TiN/Pl)^{**} + 0.30(SpN/Pl)^{**} - 0.07(PlH)^{**} \quad (9)$$
$$R^2 = 0.939 \qquad SE\% = 3.01$$

$$y\hat{}_{straw} = 226.71 - 17.46(MTemp)^{**} - 1.09(RH)^{**} + 0.64(TiN/Pl)^{**} - 0.59(SpN/Pl)^{**} + 0.09(PlH)^{**} \quad (10)$$
$$R^2 = 0.966 \qquad SE\% = 2.05$$

Skipping the last irrigation

$$y\hat{}_{grain} = -41.57 - 10.26(MTemp)^{**} + 0.60(RH)^{**} + 0.01(TiN/Pl) + 0.02(SpN/Pl)^{*} + 0.01(PlH) \quad (11)$$
$$R^2 = 0.977 \qquad SE\% = 1.65$$

$$y\hat{}_{straw} = -9.66 - 0.50(MTemp)^{*} + 0.03(RH)^{*} + 0.09(TiN/Pl) - 0.01(SpN/Pl) + 0.06(PlH)^{**} \quad (12)$$
$$R^2 = 0.970 \qquad SE\% = 1.61$$

Application of sodium salicylate and skipping the last irrigation

$$y\hat{}_{grain} = 40.15 - 2.34(MTemp)^{**} + 1.12(RH)^{*} + 0.07(TiN/Pl) + 0.05(SpN/Pl)^{*} + 0.05(PlH)^{**} \quad (13)$$
$$R^2 = 0.964 \qquad SE\% = 1.66$$

$$y\hat{}_{straw} = -12.55 - 0.83(MTemp)^{*} + 0.5\,(RH)^{*} + 0.21(TiN/Pl)^{**} - 0.01(SpN/Pl) + 0.05(PlH)^{**} \quad (14)$$
$$R^2 = 0.958 \qquad SE\% = 2.01$$

Application of magnesium carbonate and skipping the last irrigation

$$y\hat{}_{grain} = 229.24 - 16.74(MTemp)^{**} + 1.00(RH)^{**} + 0.03(TiN/Pl) + 0.01(SpN/Pl) + 0.01(PlH) \quad (15)$$
$$R^2 = 0.914 \qquad SE\% = 4.25$$

$$y\hat{}_{straw} = 530.39 - 39.94(MTemp)^{**} + 2.41\,(RH)^{**} + 0.06(TiN/Pl) - 0.39(SpN/Pl) + 0.08(PlH)^{**} \quad (16)$$
$$R^2 = 0.842 \qquad SE\% = 6.58$$

Prediction equations for the hull-less cultivars: The yields of Giza 129 and Giza 130 under the different treatments were used to develop a set of equations, specifically for predicting yield of hull-less cultivars. All the developed equations in this group were also characterized by high R^2 and low SE%, which an indication of high precision. The above mentioned trend of weather parameters and yield attributes were also observed for this group of equations.

Control

$$y\hat{}_{grain} = 135.97 - 9.93\,(MTemp)^{*} - 0.60(RH)^{*} + 0.03\,(TiN/Pl) + 0.004(SpN/Pl)^{*} - 0.001(PlH) \quad (17)$$
$$R^2 = 0.923 \qquad SE\% = 2.21$$

$$y\hat{}_{straw} = 263.65 - 19.17(MTemp)^{**} - 1.16(RH)^{**} + 0.03(TiN/Pl)^{*} - 0.08(SpN/Pl) + 0.003(PlH)^{*} \quad (18)$$
$$R^2 = 0.961 \qquad SE\% = 1.67$$

Skipping the last irrigation

$$y\hat{}_{grain} = -12.05 - 1.26(MTemp)^{**} + 0.08(RH)^{**} + 0.09(TiN/Pl) + 0.04(SpN/Pl)^{*} + 0.02(PlH) \quad (19)$$
$$R^2 = 0.974 \qquad SE\% = 2.55$$

$$y\hat{}_{straw} = 94.65 - 7.03(MTemp)^{**} + 0.43(RH)^{**} + 0.14(TiN/Pl) - 0.18(SpN/Pl)^{*} + 0.08(PlH) \quad (20)$$
$$R^2 = 0.968 \qquad SE\% = 2.05$$

Application of sodium salicylate and skipping the last irrigation

$$y\hat{}_{grain} = 43.48 - 2.93(MTemp)^{**} + 0.16(RH)^{*} + 0.28(TiN/Pl) + 0.05(SpN/Pl)^{*} + 0.05(PlH)^{**} \quad (21)$$
$$R^2 = 0.968 \qquad SE\% = 2.51$$

$$y\hat{}_{straw} = 31.26 - 2.26(MTemp)^{**} + 0.13(RH)^{*} + 0.10(TiN/Pl) - 0.02(SpN/Pl)^{*} + 0.05(PlH)^{**} \quad (22)$$
$$R^2 = 0.949 \qquad SE\% = 2.23$$

Application of magnesium carbonate and skipping the last irrigation

$$\hat{y}_{grain} = 143.37 - 9.96(MTemp)^{**} + 0.63(RH)^{**} + 0.03(TiN/Pl) + 0.13(SpN/Pl) + 0.08(PlH) \quad (23)$$

$R^2 = 0.948$ SE%= 5.51

$$\hat{y}_{straw} = 181.60 - 13.01(MTemp)^{*} + 0.75(RH)^{*} + 0.45(TiN/Pl)^{*} - 0.41(SpN/Pl)^{*} + 0.02(PlH) \quad (24)$$

$R^2 = 0.954$ SE%= 2.13

CONCLUSIONS

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.

The developed prediction equations could be a useful decision-making tool to attain early yields 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. This allowed us to calculate the expected yield under optimum conditions, under water stress and under water stress with the application of yield stabilizing agents. Thus, percent reduction in yields as a result of skipping the last irrigation and the improvement in yields as a result the application of yield stabilizing agents could be estimated. Depending on how large is the expected yield losses then we could decide if we skip the last irrigation or not. All of the three 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.

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