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Using Prediction Models to Evaluate the Effect of Potassin-p on Barley Grain Yield Grown under Water Stress Conditions

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Abstract: Two field experiments were conducted on six barely cultivars (Hordeum vulgare L.) i.e. Giza 123, Giza 125, Giza 126, Giza 129, Giza 130 and Giza 2000 to assess the impact of pottasin-P on barley grain yield under water shortage conditions and to develop different models to predict grain barely yield. The obtained results proved that grain yield was reduced as a result of skipping t he last irrigation in all cultivars. However, a noticeable improvement was observed in grain yield due to the application of potassin-P under water stress conditions. Furthermore, the application of potassin-P under water stress conditions proved to be effective in increasing N, P, and K percentage in barley grain in all tested cultivars. Higher correlation coefficients between yield components and grain yield of hull-less cultivars were observed, compared with the one between yield components and grain yield of hulled cultivars, which consequently reflected by the ability of hull-less cultivars to withstand adverse growth conditions. Three models were developed to predict grain yield for both hulled and hull-less cultivars. Each model contains three equations representing the three treatments. These models were compared for its precision using R^2 and SE%. Percent difference between actual and predicted grain yield for the above mentioned models was low. The developed models could be a useful decision-making tool to attain early grain yield prediction in barley. However, using temperature and relative humidity as predictors could limit the applicability of these models to other sites than South Delta region.

Key words: Barley, yield components, water stress, potassin-P, nutrient composition, weather parameters, prediction models, models validation

INTRODUCTION

Barley (*Hordeum vulgare* L.) is characterized by relatively high drought tolerance, where it can grow with lesser soil moisture. Skipping the last irrigating in barley is one way to save irrigation water. In turn, several precautions should be done to prevent high yield losses as a result of skipping the last irrigation. One of these precautions is spraying potassin-P during vegetative growth. potassin-P is a foliar fertilizer, which contains both potassium and phosphorous elements. Potassium is essential in maintenance of osmotic potential and water uptake[2] and had a positive impact on stomatal closure[7], which increase tolerance to water stress. Phosphorous plays an important role in membrane integrity[6], as well as enzymes activities[11].

Barley growth is regulated by several factors such as, climate, soil moisture, prevalence of weeds, pests and diseases[12]. Therefore, growth pattern could unexpectedly changes as a result of the interaction of these factors, which consequently affecting grain yield. Under these circumstances, predicting barley grain yield using actual vegetative measurements might be helpful in deciding whether to skip the last irrigation or not. Since barley vegetative growth is terminated by the appearance of the ear[12], several vegetative measurements could be used as predictors for yield. These measurements should be characterized by being highly correlated with grain yield. Tillers number/plant, spikes number/plants and plant height are highly correlated with grain yield and were used to predict yield[13]. Other yield attributes are also highly correlated with grain yield and were used to predict yield, such as spikes number/m^2 [9] and tillers number/m^2[10].

The objectives of this study were (i) to assess the impact of potassin-P on barley grain yield under skipping the last irrigation. (ii) to develop different models to predict barely grain yield prior to imposing water stress.

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MATERIALS AND METHODS

Two field experiments were carried out during the two growing seasons of 2003/04 and 2004/05 at the Agricultural Experimental Station of National Research Centre, Shalakan, Kalubia Governorate, Egypt to develop different models to predict barely grain yield under the different treatments. Four barley hulled cultivars were used in this experiments. Giza 123 and Giza 2000 were used to develop prediction models for hulled cultivars and Giza 125 and Giza 126 were used to validate the models. In addition, two hull-less barley cultivars i.e. Giza 129 and Giza 130 were used to develop the models for hull-less cultivars. A split-split plot design with four replicates was used. Barley cultivars were assigned to the main plots, whereas the application of potassin-P and skipping the last irrigation were distributed in the subplots. Soil mechanical and chemical characteristics are presented in Table (1).

Barley seeds were sown on the 5th and 7th of December 2003 and 2004, respectively. Potassium fertilizer was added at the rate of 24 kg/fed (K_2SO_4). Nitrogen fertilizer was added as 45 kg/fed and divided into two equal doses, the first dose was added at tillering and the second dose was added at shooting. Plants were irrigated every 21 days. The last irrigation was skipped at grain premature stage. Potassin-P (30% K_2O and 10% P_2O_5) at the rate of 1 lit/fed were sprayed twice during vegetative growth 40 and 47 days after sowing. At heading, number of tillers/plant, number of tillers/m^2, number of spikes/plant, number of spikes/m^2, spike length and plant height were measured for five bordered plants. Furthermore, grain yield were determined at harvest. Mean temperature and relative humidity from planting to heading date were averaged and used in the prediction (Table 2).

Chemical analysis was carried out on barley grains to estimate N, P, K and carbohydrates contents according to A. O. A. C.[1] .

Statistical analysis:

- Simple correlation coefficients[14] between weather parameters, barley grain yield and its attributes were calculated to determine the strength of the relationship between them.
- Regression analysis[3] was used to develop equations to predict barley grain yield under optimum condition, under water stress during grain premature stage and under the application of potassin-P and water stress. Two parameters were used to increase the precision, coefficient of determination (R^2) and standard error of estimates (SE%). 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 models were developed to predict grain yield for both hulled and hull-less cultivars. Each model contains three equations representing the three treatments. Model (1) used plant height, number of tillers/plant, and number of spikes/plant. Model (2) used plant height, number of tillers/m^2, and number of spikes/m^2. Model (3) used spike length, mean temperature and relative humidity from planting to heading. These models were compared for its precision using coefficient of determination (R^2) and standard error of estimates (SE%).

The above mentioned models were validated against actual field data. Regarding to the hulled cultivars, grain yield, in addition to yield attributes of Giza 125 and Giza 126 planted in this experiments were used to validate the models under the three treatments (control, skipping the last irrigation and the application of potassin-P and skipping the last irrigation). Regarding to the hull-less cultivars, grain yield, in addition to yield attributes of Giza 129 and 130 were obtained from published paper by El-Kholy *et al*.[14] and used to validate the models for the control and skipping the last irrigation only. There was no available data to validate the models under the condition of the application of potassin-P and skipping the last irrigation.

RESULTS AND DISCUSSIONS

Grain chemical constituents: Application of potassin-P under normal irrigation did not show any increase in N, P, and K contents for all tested cultivars, compared with the control treatment. However, a slight increase in carbohydrates percentage was observed for Giza 123, Giza 125, and Giza 2000 (Fig. 1 (a-d)). Under water stress condition, application of potassin-P showed a pronounced effect, where the percentage of N, P, and K increases in all tested cultivars, compared to untreated ones. Furthermore, carbohydrates percentage showed a pronounced increase in Giza 123, Giza 125, and Giza 2000 (Fig 2 (a-d)).

Table 1: Soil mechanical and chemical characteristics over the two growing seasons

Chemical characteristics		Mechanical characteristics	
pH	7.55	Clay %	33.4
Ec (dsm^{-1})	0.26	Silt %	59.1
K^+	0.80	Sand %	7.5
Mg^{++}	0.50	Soil texture	Clay loam
HCO_3	0.40		
Ca^{++}	1.10		
SO_4^{-} (meq/lit)	0.58		

Table 2: Average of temperature and relative humidity for the two growing seasons

	2003/04		2004/05	
	MTemp (°C)	RH %	MTemp (°C)	RH %
December	16.10	66.00	16.50	57.00
January	14.50	57.00	14.50	62.00
February	15.80	66.00	14.50	66.00
March	18.20	67.00	16.20	53.00
April	21.40	59.00	19.10	53.00

Table 3: Grain yield of hulled versus hull-less cultivars and percent difference between them.

Treatment	Grain yield (ton/fed)		% difference between hulled and hull-less
	Hulled	Hull-less	
Control	3.33	3.64	08.41
Water stress	3.03	3.40	10.88
Potassin-P + water stress	3.07	3.45	11.10

Comparison between hulled and hull-less cultivars: Results in Table (3) showed that grain yield was reduced as a result of skipping the last irrigation in both hulled and hull-less cultivars. Furthermore, a noticeable improvements in yield was observed as a result of the application of potassin-P. Results in that table also showed that the yield of hull-less cultivars surpass the yield of hulled cultivars under control by 8.41%. Under water stress during grain premature stage, the hull-less cultivars had higher tolerance to water stress and out yielded the hulled cultivars by 10.88%. Even under the application of potassin-P and skipping the last irrigation, the hull-less cultivars out yielded the hulled cultivars by 11.10%.

Correlation coefficients between grain yield of hulled cultivars and its attributes: Results in Table (4) showed that both mean temperature and relative humidity were negatively correlated with barley grain yield for the hulled cultivars in the period from planting to heading. This results is in agreement with what was found by [4] and [5]. Results also showed that plant height was positively and highly correlated with grain yield (r = 0.924), followed by tillers number/m^2 and spikes number/m^2 (r = 0.855 and 0.852, respectively). This could be attributed to the role that mobilization from stem reserve plays during grain filling. In addition, tillers play an important role in photosynthesis during grain filling and spikes number is an indirect indicative of grain yield [8].

Correlation coefficients between yield of hull-less cultivars and its attributes: Results in Table (5) showed that both mean temperature and relative humidity were negatively correlated with grain yield of the hull-less cultivars, except for spikes number/m^2 and tillers numbers/m^2 where both were positively correlated with mean temperature and relative humidity. That could be explained partially by the high tolerance of hull-less cultivars, which is probably a result of the ability of spikes and tillers to withstand heat stress during vegetative growth. Spikes number/plant had the highest correlation coefficient with grain yield (r = 0.884), followed by spike length and plant height (r = 0.870 and 0.805, respectively). During grain filling, spikes photosynthesis contribute heavily to barley grain yield[6].

Higher correlation coefficients between yield components and grain yield of hull-less cultivars, were observed compared with the one between yield components and grain yield of hulled cultivars (Table 4 versus Table 5), which consequently reflected by the ability of hull-less cultivars to withstand adverse growth conditions.

Prediction of the yield of hulled cultivars:

Control treatment: Regarding to the control treatment, equation (3) was more precise than equation (1) and (2) because R^2 was the highest and SE% was the lowest. During the period from planting to heading, mean temperature was significantly and negatively affecting

Table 4: Correlation matrix between grain yield hulled cultivars and its attributes

	Mtemp	RH	TN/p	SN/p	PH	SN/m^2	TN/m^2	SpL	GY
Mtemp	1								
RH	1.000	1							
TN/p	-0.514	-0.501	1						
SN/p	-0.488	-0.475	0.949	1					
PlH	-0.867	-0.858	0.746	0.723	1				
SN/m^2	-0.801	-0.792	0.699	0.641	0.94	1			
TN/m^2	-0.801	-0.791	0.721	0.683	0.95	0.997	1		
SpL	-0.703	-0.691	0.840	0.789	0.87	0.795	0.806	1	
GY	-0.951	-0.946	0.601	0.576	0.92	0.852	0.855	0.82	1

Mtemp= mean temperature; RH= relative humidity; TN/P=tillers number/plant; SN/P=spikes number/plant; PH=plant height; SN/m^2=spikes number/m^2; TN/m^2=tillers number/m^2; SpL=spike length; GY=grain yield.

Table 5: Correlation matrix between grain yield hull-less cultivars and its attributes

	Mtemp	RH	TN/p	SN/p	PH	SN/m^2	TN/m^2	SpL	GY
Mtemp	1								
RH	1.000	1							
TN/p	-0.720	-0.708	1						
SN/p	-0.713	-0.700	0.989	1					
PH	-0.759	-0.749	0.858	0.841	1				
SN/m^2	0.789	0.784	0.842	0.858	0.771	1			
TN/m^2	0.661	0.661	0.640	0.557	0.645	0.735	1		
SpL	-0.836	-0.826	0.889	0.875	0.889	0.783	0.633	1	
GY	-0.833	-0.823	0.861	0.884	0.805	0.774	0.445	0.87	1

Mtemp= mean temperature; RH= relative humidity; TN/P=tillers number/plant; SN/P=spikes number/plant; PH=plant height; SN/m^2=spikes number/m^2; TN/m^2=tillers number/m^2; SpL=spike length; GY=grain yield.

grain yield of hulled cultivars, whereas relative humidity significantly and positively affecting grain yield (equation (3)). This result is in agreement with what was found by [5] and [13]. Furthermore, spike length was positively correlated with grain yield.

$y^{\wedge}_{model(1)} = 5.40 + 0.44\,(TN/P)^{*} + 0.35\,(SN/P)^{**} - 0.04(PH)^{**}$
$R^2 = 0.90$ SE% = 3.40 (1)

$y^{\wedge}_{model(2)} = -5.09 - 0.02\,(TN/m^2) + 0.01(SN/m^2) + 0.08\,(PH)^{**}$
$R^2 = 0.87$ SE% =6.42 (2)

$y^{\wedge}_{model\ (3)} = 167.8 – 12.15\,(Mtemp)^{**} + 0.70(RH)^{**} + 0.01\,(SpL)$
$R^2 = 0.97$ SE% =3.11 (3)

Skipping the last irrigation: Regarding to the water stress treatment, equation (6) was more precise than equation (4) and (5) because R^2 was the highest and SE% was the lowest. The above mentioned trend for equation (3) was observed in equation (6).

$y^{\wedge}_{model\ (1)} = -2.20 -0.13\,(TN/P) + 0.50\,(SN/P)^{**} +0.03(PH)^{**}$
$R^2 = 0.85$ SE% =5.80 (4)

$y^{\wedge}_{model\ (2)} = 1.59 - 0.17\,(TN/m^2)^{**} + 0.14\,(SN/m^2)^{**} + 0.05(PH)^{*}$
$R^2 = 0.78$ SE% =12.19 (5)

$y^{\wedge}_{model\ (3)} = 347.0 – 24.08\,(Mtemp)^{**} + 1.43(RH)^{**} + 0.16\,(SpL)$
$R^2 = 0.93$ SE% =6.77 (6)

Potassin-P application and skipping the last irrigation: Regarding to the application of potassin-P and water stress, equation (7) was more precise than equation (8) and (9) because R^2 was the highest and SE% was the lowest. The application of potassin-P during plant growth provided the growing plants with potassium, which enhanced the ability of the plant to tolerate water stress. Similarly, it provided the growing plants with phosphorus, which enhanced the metabolic activities. Therefore, tillers and spikes per plant and plant height became more important predictors. Tillers are the main source for photosynthesis during vegetative growth for plant growth and storage in the stem. Spikes are an important source for photosynthesis during grain filling. Furthermore, remobilization from the stem also contributes to grain filling [6].

$y^{\wedge}_{model\ (1)} = -9.87 - 0.3\,(TN/P) + 0.11\,(SN/P) + 0.12(PH)^{**}$ (7)
$R^2 = 0.95$ SE% = 3.31

$y^{\wedge}_{model\ (2)} = -17.41 - 0.06\,(TN/m^2) + 0.07\,(SN/m^2) + 0.18(PH)^{**}$
$R^2 = 0.88$ SE% = 6.32 (8)

$y^{\wedge}_{model\ (3)} = 338.42 – 25.11\,(Mtemp)^{**} + 1.7(RH)^{**} + 0.26\,(SpL)$
$R^2 = 0.87$ SE% =11.78 (9)

Prediction of the yield of hull-less cultivars:

Control treatment: Regarding to the control treatment,

Table 6: Barley yield components used in the validation for the control treatment

Cultivars	Tillers/pl	Spikes/pl	Plant height	Tillers/m^2	Spikes/m^2	Spike length
Giza 125	2.38	3.25	110.01	265.75	264.75	7.25
Giza 126	2.25	3.13	114.13	239.38	238.38	8.38
Giza 129*	3.90	4.90	91.00	321.90	320.00	7.80
Giza 130*	4.20	5.20	109.10	297.40	297.00	8.70

*Source: El-Kholy *et al*. [5]

Table 7: Actual versus predicted grain yield and percent difference between them for hulled cultivars

Treatment	Cultivars	Actua yield	Model (1)		Model (2)		Model (3)	
			Predicted	PD %	Predicted	PD %	Predicte	PD %
Control	Giza 125	3.37	3.12	07.30	3.72	10.37	3.27	03.07
	Giza 126	3.19	2.86	10.14	3.73	17.05	3.27	02.76
Water stress	Giza 125	2.76	2.44	11.52	1.93	29.85	2.70	02.22
	Giza 126	2.80	2.51	10.07	2.46	11.67	2.88	02.94
PP+Water	Giza 125	3.07	2.94	04.13	2.46	19.85	2.32	24.48
Stress	Giza 126	3.00	2.96	01.19	2.48	17.34	2.54	15.34

PP + water stress = application of potassin-P and skipping the last irrigation

Table 8: Actual versus predicted grain yield and percent difference between them for hull-less cultivars

Treatment	Cultivars	Actua yield	Model (1)		Model (2)		Model (3)	
			Predicted	PD %	Predicted	PD %	Predicte	PD %
Control	Giza 129	2.70*	2.27	15.59	3.05	13.22	2.71	0.42
	Giza 130	2.75*	2.49	09.34	3.15	14.74	2.86	4.16
Water stress	Giza 129	2.35*	2.52	07.40	2.24	04.69	2.46	4.64
	Giza 130	2.73*	2.84	04.18	2.73	00.09	2.47	4.59

*source: El-Kholy *et al*.[5]

equation (12) was more precise than equation (10) and (11) because R^2 was the highest and SE% was the lowest. The above mentioned trend for equation (3) was observed in equation (10).

$y^\wedge_{model(1)}$= 0.77 - 0.07 (TN/P) + 0.18 (SN/P) - 0.01(PH)** (10)
R^2 = 0.86 SE% = 8.39

$y^\wedge_{model\ (2)}$ = 1.17- 0.006 (TN/m^2) + 0.009(SN/m^2)** + 0.01(PH)**
R^2 = 0.76 SE% =10.20 (11)

$y^\wedge_{model\ (3)}$ = 216.36 - 16.04 (Mtemp)** + 0.97(RH)** + 0.17(SpL)**
R^2 = 0.93 SE% =1.98 (12)

Skipping the last irrigation: Regarding to the water stress treatment, equation (15) was more precise than equation (13) and (14) because R^2 was the highest and SE% was the lowest. The above mentioned trend for equation (6) was observed in equation (15).

$y^\wedge_{model\ (1)}$= 1.72 -0.03(TN/P) + 0.005 (SN/P)** +0.02(PH)**
R^2 = 0.97 SE% =3.40 (13)

$y^\wedge_{model\ (2)}$ = -1.22 - 0.001 (TN/m^2)+ 0.003 (SN/m^2) + 0.0008(PH)**
R^2 = 0.94 SE% =2.26 (14)

$y^\wedge_{model\ (3)}$= 162.4 – 11.9 (Mtemp)** + 0.71 (RH)** + 0.01 (SpL)
R^2 = 0.98 SE% =1.54 (15)

Potassin-P application and skipping the last irrigation: Regarding to the application of potassin-P and water stress, equation (16) was more precise than equation 17) and (18) because R^2 was the highest and SE% was the lowest. The above mentioned trend for equation (7) was observed in equation (16).

$y^\wedge_{model\ (1)}$ = 0.48 - 0.40 (TN/P)** + 0.20 (SN/P)** + 0.02(PH)**
R^2 = 0.96 SE% = 2.05 (16)

$y^\wedge_{model\ (2)}$= 1.35 - 009 (TN/m^2) + 0.001 (SN/m^2) + 0.04 (PH)**
R^2 = 0.91 SE% = 3.15 (17)

$y^\wedge_{model\ (3)}$ = 108.05 – 7.77 (Mtemp)** + 0.46(RH)** + 0.04 (SpL)
R^2 = 0.95 SE% = 2.39 (18)

Finally, the proposed model for hulled cultivars contained equation (3), (6) and (7). Similarly, the proposed model for

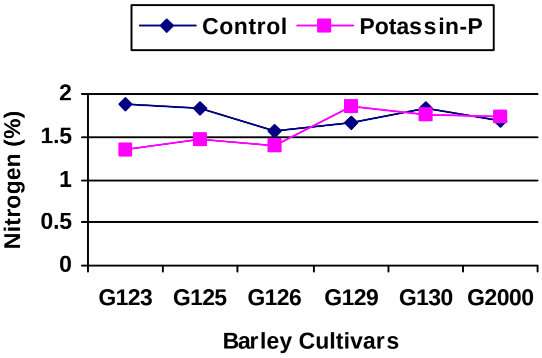

Fig 1 (a)

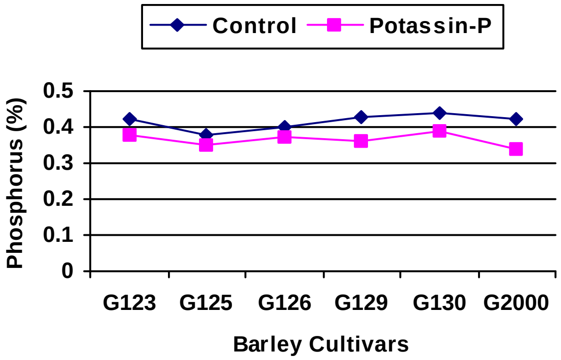

Fig. 1 (b)

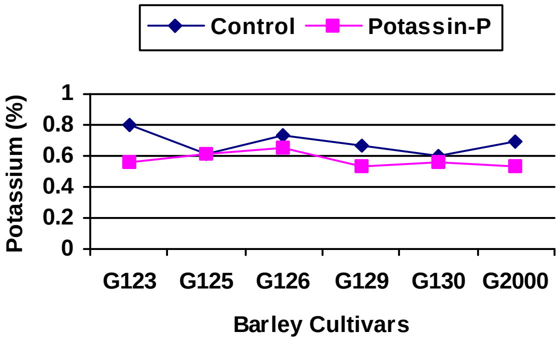

Fig. 1 (c)

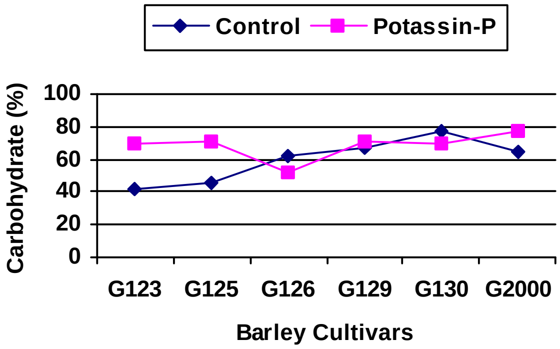

Fig. 1 (d)

Fig. 1 (a-d): Chemical constituents in Barley grain under normal irrigation and Potassin-P application

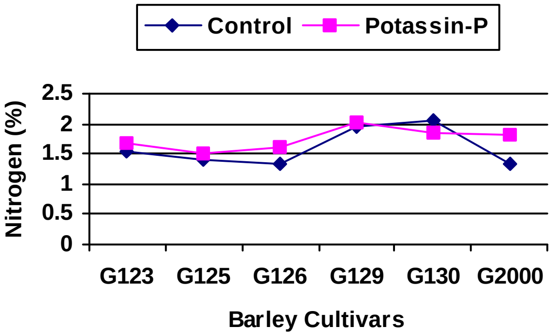

Fig. 2 (a)

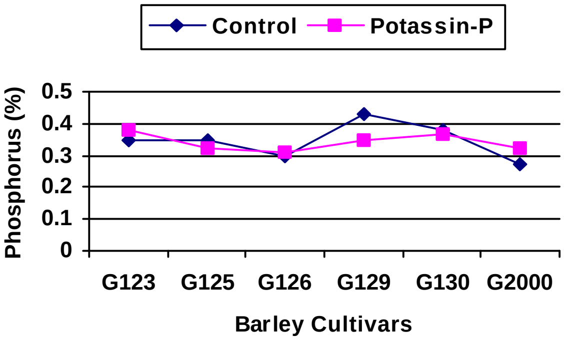

Fig. 2(b)

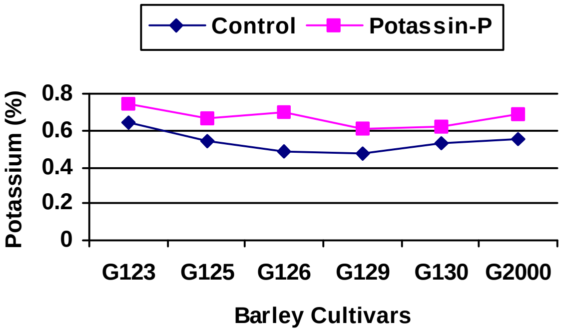

Fig. 2 (c)

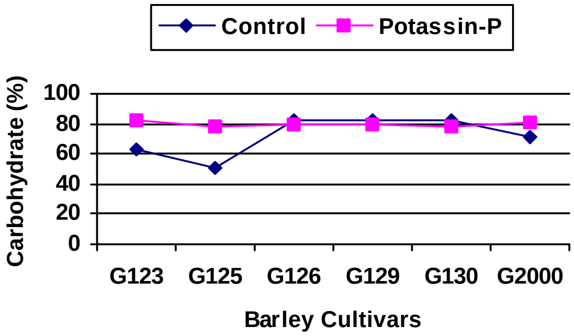

Fig. 2 (d)

Fig. 2 (a-d): Chemical constituents in Barley grain grown under water shortage condition and Potassin-P application hull-less cultivars contained equation (12), (15) and (16). These models can be summarized as follows:

Hulled cultivars:

$$y^{\wedge}_{\text{control}} = 167.8 - 12.15\ (\text{Mtemp})^{**} + 0.70(\text{RH})^{**} + 0.01\ (\text{SpL}) \qquad (3)$$

$$y^{\wedge}_{\text{water stress}} = 347.0 - 24.08\ (\text{Mtemp})^{**} + 1.43(\text{RH})^{**} + 0.16\ (\text{SpL}) \qquad (6)$$

$$y^{\wedge}_{\text{pp+water stress}} = -9.87 - 0.3\ (\text{TN/P}) + 0.11\ (\text{SN/P}) + 0.12(\text{PH})^{**} \qquad (7)$$

Hull-less cultivars:

$$y^{\wedge}_{\text{control}} = 216.36 - 16.04\ (\text{Mtemp})^{**} + 0.97(\text{RH})^{**} + 0.17\ (\text{SpL})^{**} \qquad (12)$$

$$y^{\wedge}_{\text{water stress}} = 162.4 - 11.9\ (\text{Mtemp})^{**} + 0.71\ (\text{RH})^{**} + 0.01\ (\text{SpL}) \qquad (15)$$

$$y^{\wedge}_{\text{pp+water stress}} = 0.48 - 0.40\ (\text{TN/P})^{**} + 0.20\ (\text{SN/P})^{**} + 0.02(\text{PH})^{**} \qquad (16)$$

Models validation: Data in Tables 6, 7 and 8 were used to validate the developed models for both hulled and hull-less cultivars. Regarding to the hulled cultivars, grain yield (Table 7) and its components (Table 6) of Giza 125 and Giza 126 were used to validate the three models. These two cultivars were planted in this experiment under the three treatments. Furthermore, regarding to the hull-less cultivars, yield (Table 8) and its components (Table 6) of Giza 129 and Giza 130 were used to validate the three models for control treatment and water stress only. These data were obtained from El-Kholy *et al*. [5]. Data on yield of barley under the application of potassin-P and water stress was not available to be used in validating the model. A value of 16.73 ºC as a mean of temperature from planting to heading was used in validating model (3), in addition to a value of 55.02 as a mean of relative humidity for the same period.

The value of each yield components were substituted in its relevant model and were multiplied by its coefficient to predict yield under the different treatments. The predicted yield was compared to the actual yield and percent difference between actual and predicted yields (PD%) was calculated (Tables 7 and 8).

Regarding to the two hulled cultivars, results in Table (7) showed that the lowest percent difference between actual and predicted yield was obtained for model (3) under control and water stress treatments for the hulled cultivars, where percent difference between actual and predicted yield were between 2.22-3.07 %. Regarding to application of potassin-P and skipping the last irrigation, the lowest percent difference between actual and predicted yield was observed for model (1), where it was 4.13 % and 1.19 % for Giza 125 and Giza 126, respectively.

Results in Table (8) showed that for the hull-less cultivars the lowest percent difference between actual and predicted yield was observed for model (3), where it was between 0.42-4.64 % under both control and water stress treatment.

Conclusion: An easy and precise model was develop to predict barley grain yield. The developed model could be a useful decision-making tool to attain early grain yield prediction. Thus, the developed model can predict barley grain yield under optimum condition, under skipping the last irrigation and under the application of potssain-p and skipping the last irrigation. Depending on how large is the expected yield losses a decision could be made on whether to skip the last irrigation or not. Regarding to control and skipping the last irrigation treatment for both hulled and hull-less cultivars, model (3) had the highest R^2 and the lowest SE%. Model (3) contains mean temperature in the period from planting to heading, relative humidity in the same period and spike length. Regarding to the application of potassin-P and skipping the last irrigation for both hulled and hull-less cultivars, model (1) had the highest R^2 and the lowest SE%. Tillers number/plant, spikes number/plant and plant height were the predictors used in model (1). Percent difference between actual and predicted grain yield for the above mentioned models was the lowest. However, using mean temperature and relative humidity as predictors could limit the applicability of the models to other sits than South Delta region.

REFERENCES

1. A.O.A.C, 1970. Association Agricultural Chemists. 200 Official Methods of Analysis, 12th ed., 44:94-117. Arlington, Virginia, USA.
2. Epstein, E. 1972. Mineral Nutrition of Plants: Principles and Perspectives. New York: Wiley. USA.
3. Draper, N.R. and H. Smith, 1987. Applied Regression Analysis. J ohn Wiley and Sons, Inc. New York.
4. El-Kholy, M.A., S.A. Ouda, M.S. Gaballah and M. Hozayn, 2005a. Predicting the interaction between the effect of anti-transpirant and weather on productivity of wheat plant grown under water stress. J. Agron. 4(1):75-82.

5. El-Kholy, M.A., M.S. Gaballah, S. El-Ashry and A. Oraby, 2005b. Combating drought using yield stabilizing agents in barley. J. Agric. Bio. Sci. 7(3):369-375.
6. Gardner, F.P., R.B. Pearce, R.L. Mitchell, 1985. Physiology of Crop Plants. Iowa State University Press. Ames. USA.
7. Humble, G.D. and T.C. Hsiao, 1969. Plant Physiology. Iowa State University Press. Iowa. USA.
8. Mc Master, G.S, 1997. Phonology, development, and growth of wheat (Triticum aestivum L.) shoot apex: A review. Adv. Agron. 59:63-118.
9. Megahed, M.A. and S.G. Mouhamed and A.M. Ali, 2001. Determination of the important factors of barley yield under different NPK fertilizer regime in new reclaimed area. Fayoum J. Agric. Res. & Dev.15(2) 125-134.
10. Megahed, M.A. and S.G. Mouhamed, 2001. Evaluation of some barley yield under some bio-fertilizer and nitrogen treatments using some statistical parameters. Zagzig J. Agric. Res. 28(6) 991-1008.
11. Mikii, B.B., M.A. El-Kholy and E.M. Mohamed, 1998. Effect of foliar application of potassin-P and plant spacing on seed yield, oil and fatty acids contents of prickly oil lattuce (Lactuca scariola L.). Proc. 8th Conf. Agron., Suze Canal Univ., Ismailia, Egypt, 28-29 Nov. 1998.
12. Mishra, B.N. and B.G. Shivakumar, 2000. Barley. *In*: Techniques and Management of Field Crop Production. Agrobios. India.
13. Ouda, S.A., M.S. Gaballah and M.A. El-Kholy, 2005. Predicting the effect of yield stabilizing agents on increasing drought resistance in barley. J. App. Sci. In press.
14. Sendecor, G.W. and W.G. Cochran, 1980. Statistical Method. 7th Edition. Iowa State University Press. Ames, Iowa, USA.