ISSN 1110-0419

Annals Of Agric. Sc., Moshtohor,
Vol. 45(4): 1269-1283, (2007).

PREDICTING WHEAT YIELD UNDER IRRIGATION STRESS AT GRAIN GROWTH STAGE IN SOUTH DELTA REGION

BY

Samia G.A. Mohamed
Central Laboratory for Design and Statistical Analysis Research, Agricultural Research Center, Giza, Egypt

ABSTRACT

A field experiments were carried out at Benha, Qalyoubia Governorate in 2004/2005 and 2005/06 growing seasons to study the effect of two wheat varieties (Sahka 93 and Giza 168) and five treatments (control, skipping irrigation at milk stage, skipping irrigation at milk stage together with application of $MgCO_3$, skipping irrigation at maturity stage, skipping irrigation at maturity stage with and application of $MgCO_3$) on wheat yield and its components. Results showed there was significant difference between Sakha 93 and Giza 168 for the studied characters, except for number of spikes/m^2 in the second season. Results also indicated that irrigation treatments had significant effect on all the studied characters in both seasons, except for grain weight/spike in the second season and crop index and harvest in both seasons. Furthermore, all studied characters were decreased as a result of skipping irrigation either at grain milk stage or at grain maturity stage. Sakha 93 was more tolerant to water stress during grain growth than Giza 168. Moreover, skipping irrigation at grain milk stage decreased yields more than skipping irrigation at final maturity stage for both varieties in the two seasons. The application of $MgCO_3$ reduced yield losses, especially for Giza 168. Results also indicated that there was a highly significant positive correlation between grain yield and plant height, number of sipkes/m^2, 100 grain weight, harvest index, grain weight/ spike and biological yield under all treatments. Plant height was positively correlated with straw yield and negatively correlated with straw yield under the application of $MgCO_3$ anti-transpiration agent. Simple correlation analysis between plant attributes and weather parameters indicated that in the stage from planting to tillering, both air temperature and soil temperature were positively correlated with grain and straw yields and yield components. Whereas, in the stages from planting to anthesis and from planting to physiological maturity, yields and its components were negatively correlated with either air temperature or soil temperature. Results of the regression analysis showed that either air temperature or soil temperature could be a good predicator of grain and straw yield. Furthermore, the most important macro and micro climatic factors were air and soil temperatures, relative humidity, variety, irrigation and length growth season.

INTRODUCTION

Wheat is the major cereal crop in Egypt as well as in the world. Grain yield is the integration of many variables that affect plant growth throughout the growing season. Hence, it is essential to detect the characters having the greatest influence on yield and their relative contributions to variation in yield. This is useful in designing and evaluating breeding programs and agronomic systems.

In Wheat, water stress during grain growth could have a severe effect on final yield compared with stress occurred during other stages (Hanson and Nelson, 1980). During grain growth, different sources for photosynthesis are exist. The main one is flag leaf, in addition to spike and stem tissues. Moreover, under water stress conditions, mobilization of stem nonstructural reserves increases (McMaster, 1997). Therefore, stomatal closure and the reduction of carbon exchange rate for photosynthesis at that stage could be overcome by mobilization of stem reserve (Gardner, *et al.*, 1985).

Weather parameters, such as air temperature, soil temperature and relative humidity have a great effect on wheat yield. Air temperature is the primary factor driving wheat development (Wilhelm and McMaster, 1995), and consequently influences yield (McMaster, 1997). The wheat shoot apex is located in the crown of the plant until internode elongation raises the apex above the soil surface. Therefore, during that time soil temperature is a better measure for plant growth and that could indirectly affect final yield (McMaster and Wilhelm 1998). Furthermore, soil temperature affects the growth of roots more than the growth of shoots, in addition, it has a great effect on nutrient absorption by plants such as nitrogen (Gardner, *et al.*, 1985). Relative humidity also has a great effect on yield, where water losses to the atmosphere decreases with increasing relative humidity (Gardner, *et al.*, 1985).

The objectives of this work were (i) to study the effect of skipping the irrigation at either grain milk stage or at final grain maturity stage on yield and its components; (ii) to determine whether mean air temperature or mean soil temperature could be accurately used to predict wheat yield at three phenological stages.

MATERIAL AND METHODS

Two field experiments were carried out at Shalakan, Qalyoubia Governorate in 2004/05 and 2005/06 growing seasons. The experimental design used was a spilt plot with three replications. The main plots included the five irrigation treatments, whereas the varieties Sakha 93 and Giza 168 were arranged in the subplots. Each plot was 1.2m X 3.5 m and consisted of six rows of 20 cm apart. The preceded crop was maize in both growing seasons. Soil texture was clay loam with 7.5% sand, 59.1% silt and 33.4% clay. Soil pH was 7.55, EC was 0.26 dS/m^{-1}, Ca^{++} 1.1, Mg^{++} 0.5, Na^{+} 0.5, K^{+} 1.13, and HCO_3^{-} 0.8. Sowing was done on the last week of November for the two growing seasons. The growing plants received recommended doses of fertilizers and recommended cultural practice. Either the 5th or the 6th irrigation was skipped. The 5th the 6th irrigation given during grain milk stage and the final maturity period, respectively were foliar spray of $MgCO_3$ (g/litter) was done twice i.e. 45 and 65 days after sowing to reduce transpiration and water loss from plants surface by causing stomatal closure. The treatments were therefore as follows:

- Control treatment (Full irrigation).
- Skipping the irrigation at grain milk stage.
- Skipping the irrigation at grain milk stage and the application of $MgCO_3$.

- Skipping the irrigation at grain maturity stage.
- Skipping the irrigation at grain milk stage together with foliar application of $MgCO_3$.

At harvest, ten random plants from each sub-plot were used to estimate. Plant height (PLH, cm), spike length (SpL, cm), number of spikes/m^2 (Sp/m^2), number of grains/spike (Gn/Sp), and grain weight/spike (Gw/Sp). At harvest, yield grain yield/fed (GY) in ton/fed, straw yield/fed (SY) in ton/fed and biological yield/fed (BY) in ton/fed was measured. Crop index (grain yield/straw yield) and harvest index (grain yield/biological yield) were calculated and used in the analysis.

Data of mean air temperature (AirMT, °C), mean soil temperature at the depth of 20 cm (Soil MT, °C) and are relative humidity (RH) were collected from Monthly agro-climatology bulletin (Ministry of Agriculture and land Reclamation) and averaged over the two growing seasons of 2004/05 and 2005/2006 (Table 1).

Table (1): Average of air and soil temperatures and relative humidity for three growth stages of wheat for the two growing seasons.

Growing season	Air mean temperature (°C)			Soil mean temperature(°C)			Relative humidity %		
	GS1	GS2	GS3	GS1	GS2	GS3	GS1	GS2	GS3
2004//05	15.4	15.7	18.5	22.4	20.8	20.6	65	66	63
2005/06	15.8	15.3	17.2	26.1	22.5	20.2	62	63	57
Mean	15.6	15.5	17.9	24.3	21.7	20.4	63	64	60

GS1=from planting to tillering; GS2= from planting to anthesis; GS3= from planting to physiological maturity.

Statistical analysis

1- Analysis of variance of the split plot design according to Snedecor and Cochran (1988) was done and the least significant difference ($LSD_{0.05}$) was evaluated to compare between treatments means.
2- Simple correlation coefficients Snedecor and Cochran, (1988) among wheat yield and its components were calculated. Furthermore, simple correlation coefficients between yield attributes and weather parameters were also calculated.
3- Regression analysis according to Draper and Smith, (1987) was done to develop equations to predict wheat yield under the above mentioned treatments at three growth stages. Coefficient of determination (R^2) and standard error (SE %) were used to test the precision of the predictions. To test the precision of the prediction, R^2 should be close to unity and SE% should be close 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.
4- Percent decease in wheat yields as a result of skipping the irrigation during grain milk and maturity stages were calculated. Moreover, percent increase in yields as a result of application of $MgCO_3$ was also calculated.

Two sets of prediction equations were developed to predict wheat grain and straw yield. The first set used mean air temperature, in addition to relative humidity and yield components, and the other set used mean soil temperature with the rest of the above mentioned variables.

RESULTS AND DISCUSSION

1. Analysis of variance

1.1. Effect of wheat varieties

Results in Table (2) showed that a significant difference between Sakha 93 and Giza 168 was found in all the studied characters, except for number of spikes/m^2 in the second season. Variety Sakha 93 outyielded variety Giza 168 in both growing seasons. Therefore, it could be concluded that under the conditions of Qalyoubia Governorate, growing Sakha 93 could give higher yield than Giza 186.

Table (2): Effect of wheat varieties the studied characters during 2004/2005 and 2005/2006 growing seasons.

Characters	Variety				L.S.D $_{0.05}$	
	Sakha 93		Giza 168			
	2004/05	2005/06	2004/05	2005/06	2004/05	2005/06
Plant height (cm)	98.65	101.05	102.05	103.85	3.19	2.17
Spike length (cm)	10.53	10.98	12.04	12.11	0.35	0.64
No. of grains/spike	63.33	63.60	70.37	71.54	4.02	2.62
Grain weight/ spike (g)	2.20	2.35	2.16	2.32	0.10	0.10
100–grain weight (g)	3.43	3.43	3.12	3.58	0.12	0.09
No. of spikes/m^2	286.9	281.05	267.30	276.0	34.90	N.S
Crop index	79.49	80.60	79.79	81.26	5.14	3.51
Harvest index	44.41	44.62	44.32	44.80	0.09	0.97
Grain yield (ton/fed)	2.61	2.73	2.25	2.40	0.09	0.07
Straw yield (ton/fed)	3.26	3.38	2.84	2.95	0.10	0.10
Biological yield (ton/fed)	5.87	6.11	5.11	5.36	0.16	0.05

1.2. Effect of irrigation treatments

Results presented in Table (3) showed that irrigation treatments had significant effect on all studied characters in both seasons, except for grain weight/spike in the second growing season and crop index and harvest index in both growing seasons. However, all the studied characters were decreased as a result of skipping the irrigation either at grain milk stage or at grain maturity stage. Khater *et al.* (1997) found that number of spikes/m^2, 100 grain weight, straw and grain yields were significantly decreased with decreasing available soil moisture content. The highest grain, straw and biological yields were obtained under the control treatment (full irrigation). Skipping the irrigation at grain maturity stage had less bad effect on wheat yield and its components, compared with skipping the irrigation at grain milk stage. This could be attributed to the fact that water stress during milking stage affects cells expansion, reduces grain growth rate and consequently reduces yield (McMaster and Smika, 1988). Furthermore, spraying wheat plants with $MgCO_3$ reduce the harm effect of water stress at grain growth stage. Similar results were obtained for wheat when plants were sprayed with $MgCO_3$, El-Kholy *et al.* (2005).

Table (3): Effect of irrigation levels on some attributes and yield characters of wheat during 2004/05 and 2005/2006 growing seasons.

Characters	Control		Irrigation treatments								$L.S.D._{0.05}$	
			skipping irrigation at grain milk stage		Skipping irrigation at grain milk stage and $MgCO_3$ application		Skipping irrigation at grain maturity stage		Skipping irrigation at grain maturity stage and $MgCO_3$ application			
	GS1	GS2	GS1	GS2	GS1	GS2	GS1	GS2	GS1	GS2	GS1	GS2
PLH	103.50	104.38	97.88	101.25	99.25	101.25	99.00	102.13	102.13	103.25	1.47	0.94
SpL	11.40	11.71	11.00	11.46	11.33	11.56	11.30	11.57	11.04	11.27	0.37	0.26
Gn/Sp	68.69	68.74	62.88	63.99	67.24	68.53	71.48	71.15	63.96	65.45	7.40	2.47
Gw/Sp	2.30	2.52	2.02	2.10	2.00	2.20	2.23	2.35	2.23	2.30	0.13	n.s
100-G	3.57	3.81	3.11	3.52	3.11	3.39	3.13	3.40	3.311	3.39	0.16	0.34
Sp/m^2	311.38	281.38	261.0	289.38	263.50	270.13	271.38	277.50	287.25	274.25	6.45	4.87
CI	83.89	83.75	76.46	78.44	76.42	78.31	78.70	80.43	82.72	83.73	n.s	n.s
HI	45.61	45.55	43.71	43.91	43.28	43.89	44.02	44.55	45.23	45.64	n.s	n.s
GY	2.75	2.85	2.25	2.41	2.22	2.37	2.42	2.54	2.51	2.65	0.06	0.06
SY	3.31	3.43	2.96	3.06	2.91	3.03	3.04	3.16	3.04	3.16	0.59	0.05
BY	6.09	6.30	5.26	5.47	5.13	5.40	5.42	5.69	5.55	5.81	0.09	0.07

GS1=2004/05 growing season; **GS2**= 2005/06 growing season; **PLH**=plant height (cm); **SpL**=spike length (cm); **Gn/Sp**=grain number/spike; **Gw/Sp**=grain weight/spike (g); 100-G=100-grain weight (g); Sp/m^2= number of spikes/m^2; **CI**=crop index; **HI**=harvest index; **GY**=grain yield (ton/fed); **SY**=straw yield (ton/fed); **BY**=biological yield (ton/fed).

2. Reduction in wheat yield as a result of irrigation skipping

Results in Table (4) showed that Sakha 93 was more tolerant to water stress during grain growth than Giza 168, where percent reduction in yield for Sakha 93 under water stress was lower than Giza 168. Skipping the irrigation at grain milk stage decreased yields more than skipping the irrigation at final maturity stage for both varieties in the two growing seasons. The application of $MgCO_3$ reduced yield losses, especially for Giza 168, where percent reduction in grain yield, for example, was 25.19 and 23.21% for both growing seasons, respectively before the application of $MgCO_3$. However, after the application, percent reductions in grain yield were 10.15 and 8.92% after the application of MgCO3 in the 1st and 2nd season, respectively. The same trend was observed for Sakha 93, where percent reduction in grain yield was 11.62 and 8.24% without the application of $MgCO_3$, when irrigation was skipped during grain maturity stage whereas, it was 7.39 and 5.49% after the application of $MgCO_3$ in the 1st and 2nd growing season, respectively. It could be concluded that saving irrigation water could be done if Sakha 93 was sown and sprayed with $MgCO_3$ and the last irrigation was skipped during grain maturity stage.

4. Simple Correlation analysis

Simple correlation coefficients between grain and straw yields and its components were calculated. In addition, simple correlation coefficients between wheat attributes and weather parameters were also calculated.

Table (4): Percent reduction and increase in wheat yields from the control as affected by five irrigation treatments for the two varieties.

Treat-ment	Grain yield (ton/fed)				Straw yield (ton/ fed)			
	Sakha 93		Giza 168		Sakha 93		Giza 168	
	Yield	% difference	Yield	% difference	Yield	% difference	Yield	% difference
	First season							
I1	2.84	-	2.66	-	3.50	-	3.12	-
I2	2.51	11.62	1.99	25.19	3.10	11.43	2.82	9.62
I3	2.46	13.38	1.99	25.19	3.11	11.11	2.71	13.14
I4	2.63	7.39	2.21	16.92	3.29	6.00	2.78	10.97
I5	2.63	7.39	2.39	10.15	3.32	5.14	2.77	11.22
	Second season							
I1	2.91	-	2.80	-	3.62	-	3.25	-
I2	2.67	8.24	2.15	23.21	3.22	11.05	2.90	10.77
I3	2.59	10.99	2.16	22.86	3.22	11.05	2.83	12.92
I4	2.70	7.21	2.37	15.36	3.41	5.80	2.90	10.77
I5	2.75	5.49	2.55	8.92	3.44	4.97	2.89	11.07

I1=control; I2=skipping irrigation at grain milk stage; I3=skipping irrigation at grain milk stage and application of $MgCO_3$ I4= skipping irrigation at grain maturity stage; I5= skipping irrigation at grain maturity stage and application of $MgCO_3$

Table (5): Simple correlation coefficients between wheat yield and its components for the two varieties over the two seasons.

Yield component	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
PLH(cm)(X1)	1.00										
SpL(cm) (X2)	0.36**	1.00									
Sp/m2(X3)	0.10	-0.42**	1.00								
Gn /Sp(X4)	0.27**	0.61**	-0.31**	1.00							
100/G(X5)	0.19**	-0.42**	0.66**	-0.51**	1.00						
HI (X6)	0.60**	-0.14	0.36**	-0.03	0.32**	1.00					
CI(X7)	0.24**	0.07	0.51**	0.04	0.19*	0.26**	1.00				
Gw/Sp(X8)	0.45**	0.06	0.36**	0.20**	0.30**	0.22**	0.19**	0.100			
GY/fed(X9)	0.19*	-0.44**	0.92**	-0.29**	0.76**	0.60**	0.46**	0.49**	1.00		
SY/fed(x10)	0.07	-0.59**	0.66**	-0.35**	0.73**	0.07	0.46**	0.46**	0.04	1.00	
BY/fed(x11)	0.15	-0.52**	0.83**	-0.32**	0.78**	0.36**	0.50**	0.46**	0.27**	0.36**	1.00

* Significant at 0.05%level of significance.

. Significant at 0.01%level of significance.

4. 1. Simple correlation between yield and its attributes:

Simple correlation coefficients between grain yield of wheat and its attributes in Table (5) Data indicated that there was a positive and highly significant correlation between grain yield and each of plant height, number of spikes/ m^2, 100 grain weight, harvest index, grain weight/ spike and biological yield. Spike length and number of grains/spike were found to be negatively and highly significantly correlated with grain yield.

4. 2. Simple correlation between plant attributes.

Results in Table (6) showed that plant height was negatively and highly significantly by correlated with wheat grain yield under the control treatment and under skipping irrigation at grain milk stage. Spike length and grain number/spike were found to be also negatively and significantly correlated with grain yield under all irrigation treatments. The negative effect of number of grains/spike on grain yield could be attributed to the fact that both grain number and grain weight are inter-correlated, where the increase in one of them could reduce the other (Gardner *et al.*, 1985). Number of spikes/ m^2 and 100-grain weight were positively and highly significantly correlated with grain yield under all treatments.

Table (6): Simple correlation coefficients between wheat grain yield and its components for the two varieties over the two growing seasons under each irrigation treatment.

Character	I1	I2	I3	I4	I5
PLH	-0.552**	-0.473**	0.172	0.322	-0.230
SpL	-0.617**	-0.887**	-0.775**	-0.637**	-0.301
Sp/m²	0.526**	0.986**	0.980**	0.943**	0.692**
Gn/Sp	-0.637**	-0.504**	-0.876**	-0.168	-0.502**
100-G	0.782**	0.718**	0.942**	0.847**	0.329
Gw/Sp	-0.110	0.135	-0.182	0.802**	0.594**

I1= control treatment; **I2**=skipping irrigation at grain milk stage; **I3**=skipping irrigation at grain milk stage and application of $MgCO_3$; **I4**= skipping irrigation at grain maturity stage; **I5**= skipping irrigation at grain maturity stage and application of $MgCO_3$; **PLH**=plant height (cm); **SpL**=spike length (cm); **Sp/m²**= number of spikes/m^2; **Gn/Sp**=grain number/spike; **100-G**=100-grain weight (g); **Gw/Sp**=grain weight/spike (g).

4.3. Simple correlation between wheat straw yield and its components

Results in Table (7) revealed that under control and water stress treatments, plant height was positively correlated with straw yield and was negatively correlated with straw yield under the application of the anti-transpiration agent. Probably, because mobilization from stem reserves indirectly affected plant height and negatively affected straw yield. Spike length negatively affected straw yield under water stress treatments and positively affected straw yield under the application of anti-transpiration agent. The growth rate of apical grains on the spike was usually slower than basal grains McMaster, (1997). Therefore, it is expected that under water stress all assimilates would go to basal grains and apical grains might fail to complete their growth and this could indirectly reduced spike length. Number of spikes/ m^2 was found to be positively correlated with straw yield under all irrigation treatments, except for skipping the irrigation at grain maturity stage plus the application of $MgCO_3$.

4.4. Simple correlations between wheat biological yield and its components:

Results in Table (8) indicated that there was a highly significant negative correlation coefficients between biological yield, under control and each of plant height, spike length, number of grains/spike and grain weight/spike, while number of spikes/m^2 and 100-grain weight was found to be highly significant and positively correlated with biological yield under control treatment.

Table (7): Simple correlation coefficients between wheat straw yield and its components average over the two varieties in the two seasons under each irrigation treatment.

Character	I1	I2	I3	I4	I5
PLH	0.585**	0.499**	-0.194	0.231	-0.124
SpL	-0.707**	-0.778**	-0.867**	-0.844**	-0.719**
Sp/m^2	0.420**	0.880**	0.819**	0.721**	0.122
HI	-0.859**	0.687**	0.617**	-0.337	-0.740**

I1= control treatment; I2=skipping irrigation at grain milk stage; I3=skipping irrigation at grain milk stage and application of $MgCO_3$; I4= skipping irrigation at grain maturity stage; I5= skipping irrigation at grain maturity stage and application of $MgCO_3$; **PLH**=plant height (cm); **SpL**=spike length (cm); **Sp/m^2**= number of spikes/m^2; **HI**=harvest index.

Table (8): Simple correlation coefficients between wheat biological yield and its components for the two varieties and two seasons under each irrigation treatment.

Character	I1	I2	I3	I4	I5
PLH	-0.588**	-0.488**	0.188	0.313	-0.102
SpL	-0.695**	-0.858**	-0.843**	-0.742**	-0.550**
Sp/m^2	0.468**	0.964**	0.933**	0.840**	0.414**
Gn/Sp	-0.742**	-0.444**	-0.831**	-0.218	-0.631**
100-G	0.826**	0.725**	0.919**	0.828**	0.458**
Gw/Sp	-0.588**	-0.197	-0.208	0.887**	0.589**

I1= control treatment; I2=skipping irrigation at grain milk stage; I3=skipping irrigation at grain milk stage and application of $MgCO_3$; I4= skipping irrigation at grain maturity stage; I5= skipping irrigation at grain maturity stage and application of $MgCO_3$; **PLH**=plant height (cm); **SpL**=spike length (cm); **Sp/m^2**= number of spikes/m^2; **Gn/Sp**=grain number/spike; **100-G**=100-grain weight (g); **Gw/Sp**=grain weight/spike (g).

4. 5. Simple correlations between plant attributes.

Results in Table (9) indicated that in the stage from planting to tillering, both air temperature and soil temperature were positively correlated with yields and their components. However, most of yield components were significantly correlated with air temperature, whereas only two yield components, i.e. grain weight/spike and harvest index were significantly correlated with soil temperature. Relative humidity was negatively correlated with yields and their components for the three growing stages. In the stages from planting to anthesis and from planting to physiological maturity, yields and its components were negatively correlated with both air temperature and soil temperature.

Table (9): Simple correlation coefficients between studied treatments with weather parameters during three growth stages over the two growing seasons.

Character	Air temperature			Soil temperature			Relative humidity		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
PLH	0.43**	-0.45**	-0.39**	0.17	-0.13	-0.43**	-0.43**	-0.42**	-0.03
SpL	0.14	-0.18*	-0.12	0.16	-0.20*	-0.14	-0.14	-0.10	-0.03
Sp/m^2	0.18*	-0.16	-0.19*	0.16	0.27**	-0.433	-0.18*	-0.23**	-0.18*
Gn/Sp	0.004	-0.04	-0.01	0.01	-0.03	-0.139	-0.004	0.03	0.083
100-G	0.30**	-0.23**	-0.27**	0.11	0.52**	-0.263	-0.263**	-0.39**	-0.30**
Gw/Sp	0.46**	-0.45**	-0.48**	0.20**	-0.24**	-0.46**	-0.46**	-0.47**	-0.25**
HI	0.12	-0.15	-0.23**	0.21**	0.08	0.026	-0.12	-0.11	-0.04
GY	0.23**	-0.21**	-0.23**	0.13	0.34**	-0.23**	-0.23**	-0.28**	-0.11
SY	0.20**	-0.16	-0.22**	0.01	-0.39**	-0.20**	-0.20**	-0.27**	-0.17
BY	0.24**	-0.22**	-0.25**	0.08	0.37**	-0.24**	-0.24**	-0.31**	-0.16

S1=from planting to tillering; S2= from planting to anthesis; S3= from planting to physiological maturity; **PLH**=plant height (cm); **SpL**=spike length (cm); **Gn/Sp**=grain number/spike; **Gw/Sp**=grain weight/spike (g); **100-G**=100-grain weight (g); **Sp/m^2**= number of spikes/m^2; **HI**=harvest index; **GY**=grain yield (ton/fed); **SY**=straw yield (ton/fed); **BY**=biological yield (ton/fed).

5. Wheat yield prediction

Wheat yield components, in addition to relative humidity and air temperature or soil temperature were used to predict yield under the different irrigation treatments and in the three growing stages. Different equations were developed.

5.1. Prediction equations for grain yield using air or soil temperature and relative humidity in the three stages

5.1.1. Control treatment

For wheat grown under optimum conditions, equation [2] was a little bit accurate than equation [1] or [3] in predicting grain yield because R^2 was higher (0.989) and SE% was lower (0.81) in the stage from to anthesis its counterpart in equation [1] or [3]. Under these conditions, both air temperature and relative humidity had significant effect on wheat yield from planting to tillering and physiological maturity, while soil temperature was found to be significant in the anthesis stage. In the three equations, the significant of all the predictors were consistent, i.e. variety, plant height, spike length, grain weight/spike, 100 grain weight, number of spikes/m^2, crop index and length of growth season in the three stages.

In the tillering stage

[1] $\hat{y}_{grain} = 158.75 + 1.183(V)^{*} - 0.084(PLH)^{**} - 0.9302(SpL)^{**} - 0041(G/Sp) - 0.708\ (Gwt/sp)^{*} - 1.824(100wt/G)^{**} + 0.01(Sp/m^2)^{**} - 0.025(CI)^{**} - 0.8158(LgS)^{**} - 0.0003\ (AirMT)^{*} - 0.0008(soil\ MT) - 0.0006(RH)^{*}$

$R^2 = 0.972$ SE% = 1.17

In the anthesis stage

[2] $\hat{y}_{grain} = 125.93 + 1.0093(V)^{*} - 0.071(PLH)^{**} - 0.804(SpL)^{**} - 0004(G/Sp)\ 0.707\ (Gwt/sp)^{*} - 1.597(100wt/G)^{**} + 0.0148(Sp/m^2)^{**} - 0.0262(CI)^{**} - 0.625(LgS)^{**} - 0.0113(AirMT) - 0.0164(soil\ MT)^{*} - 0.0006(RH)$

$R^2 = 0.989$ SE% = 0.81

In the physiological maturity stage

[3] $y\hat{}_{grain}$ = 142.73 + 1.130(V)*-0.0812(PLH)** - 0.898(SpL)** -0037(G/Sp)-0.731(Gwt/sp)*-1.760(100wt/G)**+ 0.017(Sp/m^2)** - 0.023(CI)**-0.7008(LgS)** - 0.00001(AirMT)*-0.162(soil MT)** - 0.0002(RH)*

R^2 = 0.969 SE% = 1.22

[2]Skipping irrigation at grain milk stage

Under the condition of skipping irrigation at grain milk stage, either equation [1],[2] or [3] could be used to predict wheat yield. Under these conditions, it seemed that soil temperature in the anathesis stages could be an important predictor for wheat yield. Furthermore, number of spikes/m^2 was found to be significant in the three stages. Whereas, variety, grain number/spike, 100 weight grain, crop index and length growth season harvest increased grain yield by the value of its coefficient. That could be an indicate that under water stress an important predictor for grain yield.

In the tillering stage

[1] $y\hat{}_{grain}$ = -13.2418 -0. 0147(V) +0.0049(PLH) - 0.0184(SpL) +0.0028(G/Sp) +0.0171(Gwt/sp)+0.0224(100wt/G)*+ 0.0083(Sp/m^2)** + 0.01(CI)+0.0483(LgS)+ 0.3531(AirMT) - 0.007(RH)

R^2 = 0.994 SE% = 1.5

In the anthesis stage

[2] $y\hat{}_{grain}$ = 10.7747 -.0153(V)*-0.0043(PLH) + 0.0224(SpL) +0029(G/Sp) +0.012(Gwt/sp)+0.0211(100wt/G)+ 0.0084(Sp/m^2)** + 0.0114(CI)**-0.0997 (LgS)** + 0.8665(AirMT)+0.0251(soil MT)* - 0.1345(RH)

R^2 = 0.993 SE% = 1.77

In the physiological maturity stage

[3] $y\hat{}_{grain}$ = 764.1608-0.0225(V)-0.0098(PLH) + 0.020(SpL) +0.0051(Gn ^{o}/Sp)* -0.0304(Gwt/sp)-0.0562(100wt/G)+ 0.0091(Sp/m^2)** - 0.0171(CI)*-0.5.1036 (LgS)* + 3.5988(AirMT)-0.0005(soil MT) + 0.00067(RH)

R^2 = 0.997 SE% = 1.15

[3] Skipping the 5th irrigation the addition of $MgCO_3$

Under the condition of skipping irrigation at grain milk stage and in addition to $MgCO_3$, either equation [1], [2] or [3] could be used to predict wheat yield. Moreover, the variety, number of spikes/ m^2 and length growth seasons in the two stages, while number spikes/ m^2 was found to be significant in the three stages. That could be attributed to under water stress and the addition $MgCO_3$, the role of mobilization from the stem became more pronounced in grain growth process.

In the tillering stage

[1] $y\hat{}_{grain}$ =17.69 – 0.1624(V)*-0.0023(PLH) + 0.0203(SpL) -0.0002(G/Sp)-0.099(Gwt/sp)+0.0586(100wt/G)+ 0.0078(Sp/m^2)** - 0.00005(CI)-0.106(LgS)* - 0.00001(AirMT)-0.00006(soil MT) - 0.00006(RH)

R^2 = 0.997 SE% = 0.89%

In the anthesis stage

[2] $\hat{y}_{grain}$ = 17.5420 -0.206(V)-0.0021(PLH + 0.0425(SpL) +0.0041(G/Sp)-0.1167(Gwt/sp)+0.1363(100wt/G)+ 0.0079(Sp/m^2)** - 0.00005(CI)-0.0748(LgS) - 4.2356(AirMT)-0.2849(soil MT) - 0.00007(RH)

R^2 = 0.998 SE% = 1.07%

In the physiological maturity stage

[3] $\hat{y}_{grain}$ = 17.6922 - 0.1624(V)*-0.0023(PLH) - 0.0203(SpL) +0.0002(G/Sp)-0.0994(Gwt/sp)+0.0586(100wt/G)+ 0.0078(Sp/m^2)** - 0.0005(CI)-0.106(LgS)* + 0.00003(AirMT)+0.0009(soil MT) - 0.00002(RH)

R^2 = 0.997 SE% = 0.89%

[4]Skipping irrigation at grain maturity stage

Either equation [1], [2] or [3] could be used to predict wheat yield. Under these conditions, it seemed that soil temperature and relative humidity in the anathesis stages could be an important predictor for wheat yield. Furthermore, variety and number of spikes/m^2 were found to be significant in the three stages (indicator of number of tillers/ m^2) and this could be an indicator of the role of soil temperature and relative humidity in the anathesis stage played in shoot apex growth. Furthermore, length growth season was found to be significant in the harvest stages. The sign air and soil temperature and relative humidity in the anathesis stag an indicator of their important role in yield prediction under this treatment.

In the tillering stage

[1] $\hat{y}_{grain}$ = -2.2558 – 0.1544(V)*-0.0007(PLH) - 0.0783(SpL) +0.0001(G/Sp)-0.4115(Gwt/sp)+0.6076(100wt/G)+ 0.0061(Sp/m^2)* + 0.0078(CI)+0.00001(LgS) - 0.000006(AirMT)+0.0345(soil MT) + 0.0253(RH)

R^2 = 0.992 SE% = 1.17

In the anthesis stage

[2] $\hat{y}_{grain}$ = 0.7693 – 0.1544(V)*+0.0007(PLH) - 0.0783(SpL) -0.0001(G/Sp)-0.4115(Gwt/sp)+0.6076(100wt/G)*+ 0.0061(Sp/m^2)** - 0.0078(CI)-0.00008(LgS) +0.00002 (AirMT)*-0.000002(soil MT)* + 0.000002(RH)*

R^2 = 0.992 SE% = 1.15

In the physiological maturity stage

[3] $\hat{y}_{grain}$ = -3.5153 -0.1417(V)*+0.0046(PLH) - 0.0895(SpL) -0017(G/Sp)-0.526(Gwt/sp)+0.983(100wt/G)+ 0.0042(Sp/m^2)* + 0.0124(CI)+0.94(LgS)* - 0.0633(AirMT)-0.1303(soil MT) - 0.00009(RH)

R^2 = 0.995 SE% = 1.17

[5]Skipping the 6th irrigation and the addition of $MgCO_3$

Similarly, either equation [1], [2] or [3] could be used to predict wheat yield. Regarding full regression model, for the studied stage, R^2 ranged between (0.992 and 0.998), SE% ranged between (0.52 and 0.62) for yield. The predictor coefficients in all equations are consistent, where the significant of variety, crop index and length of growth season in the three stages. The sign of air and soil temperature and relative humidity in the anthesis stag an indicator of their important role in yield prediction under this treatment.

In the tillering stage

[1] $\hat{y}_{grain} = -10.0457 - 0.4218(V)^{**} - 0.0032(PLH) - 0.0178(SpL) + 0.0011(G/Sp) + 0.0077(Gwt/sp) + 0.0331(100wt/G) + 0.0008(Sp/m^2) + 0.0235(CI)^{**} - 0.00003(LgS) + 0.5866(AirMT) + 0.0002(soil\ MT) + 0.029(RH)$

R^2 = 0.992 **SE%** = 0.62

In the anthesis stage

[2] $\hat{y}_{grain} = 2.3793 - 0.4158(V)^{**} - 0.00039(PLH) + 0.0181(SpL) + 0.0006(G/Sp) - 0.0133(Gwt/sp) + 0.0407(100wt/G) + 0.00008(Sp/m^2) + 0.023(CI)^{**} - 0.0000(LgS)^{**} - 0.00001(AirMT)^{**} - 0.000005(soil\ MT)^{**} + 0.00218(RH)^{**}$

R^2 = 0.997 **SE%** = 0.52

In the physiological maturity stage

[3] $\hat{y}_{grain} = 13.3798 - 0.4117(V)^{**} - 0.004(PLH) + 0.0175(SpL) + 0.001(G/Sp) - 0.0118(Gwt/sp) + 0.0358(100wt/G) + 0.001(Sp/m^2) + 0.0225(CI)^{**} - 0.0724(LgS) - 0.0346(AirMT) + 0.00007(soil\ MT) + 0.0017(RH)^{**}$

R^2 = 0.998 **SE%** = 0.62

[2] Prediction equations for straw and biological yield using air or soil temperature and relative humidity in the three stages

The trend of the relationship between weather parameters macro climatic factors, straw and biological yield under five treatments was similar to the one with grain yield. Regarding full regression model, for the studied stages, R^2 ranged between (0.618 and 0.755), SE% ranged between (4.67 and 5.72) for straw yield whereas R^2 was ranged between (0.602 and 0.714), SE% (5.3 and6.23) for biological yield. However, in most cases, relative humidity was better predictor of straw and biological yield in anathesis stage. We noticed form the prediction equation and multiple linear regressions that the most important macro and micro climatic factors were air and soil temperature, relative humidity, variety, irrigation and length of growth season.

[1] Straw yield

In the tillering stage

[1] $\hat{y}_{straw} = 6.1743 - 0.4256(V)^{**} - 0.0010(SoilMT) - 0.0378(RH)^{**}$

R^2 = 0.618 **SE%** =5.72

In the anathesis stage

[2] $\hat{y}_{straw} = -444.4732 - 0.3918(V)^{**} - 0.0071(Irr) + 3.203(LgS)^{**} - 1.2626(AirMT) + 0.0054(SoilMT) - 0.8168(RH)^{**}$

R^2 = 0.7547 **SE%** =4.67

In the harvest stage

[3] $\hat{y}_{straw} = 67.7098 - 0.4279(V)^{**} - 0.0473(Irr)^{**} - 0.4179(LgS) + 0.2671(AirMT) - 0.000001(SoilMT)^{**} - 0.0110(RH)$

R^2 = 0.6772 **SE%** =5.33

[2] Biological yield

In the tillering stage

[1] $\hat{y}_{bio} = 40.5715 - 0.7601(V)^{**} - 0.0866(Irr)^{**} - 0.2080(LgS)^{**} - 0.0002(AirMT)^{**} + 0.010(SoilMT) + 0.00002(RH)^{**}$

$R^2 = 0.612$ **SE%** =6.12

In the anathesis stage

[2] $\hat{y}_{bio} = -1017.5167 - 0.6769(V)^{**} - 0.00008(Irr) + 7.3080(LgS)^{**} - 2.9643(AirMT)^{**} + 0.0111(SoilMT) - 1.8195(RH)^{**}$

$R^2 = 0.71.40$ **SE%** =5.3

In the physiological maturity stage

[3] $\hat{y}_{bio} = 110.8035 - 0.74897(V)^{**} - 0.0879(Irr)^{**} - 0.6728(LgS) + 0.3524(AirMT) + 0.00003(SoilMT)^{**} + 0.000124(RH)$

$R^2 = 0.602$ **SE%** =6.23

CONCLUSION

Under scarce water supplies that Egypt will face in the near future, it may sometimes be advantageous to stress the crop to some degree. Water stress may reduce the crop yield to some extent but it will remain economically feasible, as long as the marginal benefit from reduced cost of water application is equal or greater than marginal cost of reduced yield. The amount of wheat yield reduction as a result of water stress is affected by genotype and the stage of grain development. Sakha 93 was more tolerant to water stress during grain growth stage than Giza 168. It could be concluded that under the conditions of Qalyoubia governorate, growing Sakha 93 could gave higher yield than Giza 168. Furthermore, it could also be concluded that saving irrigation water could be done if Sakha 93 was sown and sprayed with $MgCO_3$ and the last irrigation was skipped during grain maturity stage. However, it is advisable to skip irrigation during grain maturity stage instead of skipping irrigation during grain milk stage to reduce yield losses for both varieties. Either air temperature or soil temperature was found to be good predictor for wheat grain yield prediction.

REFERENCES

Draper, N.R. and Smith, H. (1987): Applied Regression Analysis. John Wilay and Sons, Inc. New York. pp. 397 - 402.

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

El-Kholy, M.A.; Ouda, S. A.; Gaballah, M.S. and Hozayn, M. (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.

Hanson, A.D. and Nelson, E.C. (1980): In The Biology of Crop Production, (ed). P. S. Carlson. New York Academic Press. USA.

Khater, A.N.; Abdel-Maksoud, H.H. and Eid, H.M. (1997): .Response of some wheat cultivars and their water relations to different irrigation levels in middle Delta . Egypt .J. Apple. Sci.,: 12(5) 142-158.

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

McMaster G.S. and Smika, D.E. (1988): Estimation and evaluation of winter wheat phenology in the Central Great Plains. Agric. For. Moteorol. 43:1-18.

McMaster G.S. and Wilhelm, W.W. (1998): Is soil temperature is better than air temperature in predicting winter wheat phenology. Agron. J. 90:602-607.

Sendecor, G.W. and Cochran, W.G.. (1988): Statistical Method. 7th Edition. Iowa State University Press. Ames, Iowa, USA.

Sofield, I. Evans, L.T. and Wardlaw, I.F. (1977): The effect of temperature and light on grain filling in wheat. R. Soc. N. Z. Bull. 12:909-915.

Wilhelm, W.W. and McMaster, G.S. (1995): The importance of phyllochron in studying the development of grasses. Crop Sci. 53:1-3.

التنبؤ بمحصول القمح تحت إجهاد الري في مرحلة نموالحبه في منطقة جنوب الدلتا

سامية جودة عطية محمد

المعمل المركزي لبحوث التصميم والتحليل الإحصائي – مركز البحوث الزراعيه – الجيزة – جمهورية مصر العربية.

أقيمت تجربتان حقليتان في محطة بحوث التجارب الزراعية – بنها- محافظة القليوبية في موسمين متتالين ٢٠٠٤/٢٠٠٥، ٢٠٠٥/٢٠٠٦ لدراسة تأثير بعض العوامل المناخية والبيئية الصغري وعمل معادلات التنبؤ بالمحصول ومكوناته لصنفين من القمح سخا ٩٣ وجيزة ١٦٨ وخمس مستويات من الري (المقارنه، تحريم رية في مرحلة النضج اللبني وتحريم رية في مرحلة النضج اللبني مع الرش بكربونات الماغنسيوم وتحريم رية في مرحلة النضج وتحريم رية في مرحلة النضج مع الرش بكربونات الماغنسيوم) . تم جمع بيانات الأرصاد الجوية وهي متوسط درجات حرارة الجو ومتوسط درجات حرارة التربة عند عمق ٢٠ سم ومتوسط درجات الرطوبة النسبية أيضا تحت ثلاث مراحل فينولوجية مختلفة، الأولي من الزراعة حتي التفريع والثانية من الزراعة حتي التزهير والثالثة من الزراعة حتي النضج الفسيولوجى وتم التحليل الإحصائي لكل من تحليل التباين – تحليل الإرتباط البسيط – إستخدام معادلات التنبؤ بالمحصول النموذج الكامل للإنحدار الخطى المتعدد. ولقد أظهرت الدراسة النتائج التالية:

- أظهرت النتائج وجود فروق معنوية بين الصنفين سخا ٩٣ وجيزة ١٦٨ وجميع الصفات تحت الدراسة ماعدا عدد السنابل في المتر المربع في السنة الثانية حيث كان الفرق غير معنوي.
- تشير النتائج أن معاملات الري كان لها تأثير معنوي علي كل الصفات تحت الدراسة في كلا الموسمين ماعدا وزن حبوب السنبلة في موسم النمو الثاني حيث

كانت غير معنوية وكذلك دليل المحصول ودليل الحصاد في كلا الموسمين علاوة على ذلك انخفضت كل الصفات تحت الدراسة في مرحلة الطور اللبني ومرحلة النضج نتيجة تحريم الرى، أظهرت النتائج أن الصنف سخا ٩٣ أكثر تحمل للإجهاد المائي عن جيزة ١٦٨.

- دلت النتائج أن أكثر المراحل انخفاضا لمحصول الحبوب نتيجة تحريم الرى كان في مرحلة النضج اللبني أكثر من مرحلة النضج الفسيولوجي في كلا الصنفين خلال موسمي النمو.
- وتشير النتائج أن إضافة كربونات الماغنسيوم أدت إلي تقليل النقص فى محصول الحبوب نتيجة تحريم الرى خصوصا بالنسبة للصنف جيزة ١٦٨.
- دلت نتائج تحليل الإرتباط البسيط علي وجود ارتباط سالب وعالي المعنوية بين محصول الحبوب وطول السنبلة وعدد حبوب السنبلة، بينما كان هناك ارتباط موجب وعالي المعنوية بين المحصول وعدد السنابل في المتر المربع ووزن مائة حبة تحت جميع معاملات الري.
- أظهرت معاملة الري المثلي (المقارنة) على وجود ارتباط موجب وعالي المعنوية بين طول النبات ومحصول القش بالفدان وكذلك ارتباط سالب مع محصول القش عند إضافة كربونات االماغنسيوم مع تحريم الرى.
- دلت أيضا نتائج الإرتباط البسيط والعوامل البيئية في مرحلة التفريع علي وجود ارتباط موجب وعالي المعنوية بين المحصول ومكوناته ومتوسط درجة الحرارة ودرجة حرارة التربة عند عمق ٢٠ سم، وكان هناك ارتباط سالب وعالي المعنوية بين المحصول ومكوناته ومتوسط الحرارة وحرارة التربة عند عمق ٢٠ سم في مرحلتي التزهير والنضج.
- أوضحت نتائج تحليل الإنحدار الكلي لمعادلات التنبؤ بالمحصول ومكوناته وذلك لجميع مستويات الري المختلفة لثلاث مراحل الفينولوجية أن مرحلة الري المثلي أعطت أعلي معامل التحديد ر٢ (٩٨,٩) وأقل خطا قياسي (٠,٨١%) وذلك في مرحلة التزهير.
- أظهرت نتائج تحليل الإنحدار الكلي لمعادلات التنبؤ بالمحصول ومكوناته وذلك لجميع مستويات الري المختلفة لثلاث مراحل الفينولوجية أن أعلي معامل التحديد (ر^{٢}) تقع ما بين (٩٦,٩ –٩٩,٨)، بينما كان الخطأ القياسي يقع مابين (٠,٥٢ %– ١,٧٧ %) وذلك في مرحلة التزهير أيضا .
- أوضحت نتائج تحليل الإنحدار الكلي للتنبؤ بمحصولي القش والبيولوجي أن العوامل المناخية الكبري والبيئية الصغري كان لها أعلي مساهمة في مرحلة التزهير.
- دلت الدراسة أن بعض العوامل المناخية الكبري والبيئية الصغري التي لها تأثير علي المحصول ومكوناته هي درجة الحرارة ودرجة حرارة التربة والرطوبة النسبية والأصناف وطول موسم النمو.