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PREDICTING WHEAT YIELD AT DELTA REGION UNDER DIFFERENT SOWING DATES USING HISTORICAL WEATHER DATA

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ABSTRACT

The objectives of this work are (i) to develop regression equations to predict wheat yield under different sowing dates using historical weather data at Delta region and (ii) to use the developed equations to predict wheat yield in the future. Data for mean temperature, solar radiation, and rain were collected for the period of (1975-2002) for Sakha, Kafer El-Sheakh Governorate (as a representative of Delta region). Wheat yield (Ardab/fed) was also collected for the Delta region for the same period from. The analysis was done in two directions. The first one, is to predict wheat yield under different sowing dates. The second one, is to predict wheat yield under different growth stages at these sowing dates. Weather parameters for twenty five years (1975-1999) were used to develop one prediction equation for each growth stage to predict wheat yield under the three sowing dates. In addition, weather parameters of 1999/00 season were used to predict wheat yield for the same year, then estimates were compared to actual yield and percent decrease in yield (PD%) was calculated. In addition, the yield of 2000/01 and 2001/02 were predicted using previous year weather parameters, and then estimates were compared to actual yields. Results indicated that, for sowing wheat on November, 15, any of the four studied stages was suitable to predict yield (PD% values were between 4.41- 7.55). Furthermore, the most suitable stage to predict wheat yield when sowing was done on December, 1, by the end of grain filling stage (PD% was 8.60%). Whereas, when sowing was done on December, 15, the most suitable stage was at the end of anthesis stage (PD% was 11.36%). Results also indicated that the lowest percent decrease was obtained for the growing season of 2001/02 when wheat was sown on November, 15 (2.55%) followed by the 2000/01 season at the same sowing date (7.46%). This is an indication that using previous year weather parameters to predict the following year yield was more accurate when wheat was sown at November, 15 Percent decrease in yield as a result of delayed sowing was found to be 3.37%. whereas the reduction was 8.24% when sowing was delayed until December, 15 Therefore, it is recommended to finish land preparation and wheat sowing not later than December, 1, or else yield reduction would occur

INTRODUCTION

Wheat yield is usually decreases when sowing is delayed. Wheat sown on optimum date usually meets suitable weather conditions throughout its growing season.

Weather parameters, such as temperature and solar radiation have great effect on wheat yield. Temperature is the primary factor driving wheat development (Wilhelm and McMaster, 1995), and consequently influences yield (McMaster, 1997). Number of tillers usually decreased when wheat plants were exposed to high temperature, which occurred when sowing is delayed (Friend 1965). In addition, temperature is the major variable controlling spikelet initiation and development rates (McMaster, 1997). At higher temperature, the duration of grain filling period was reduced (Sofield *et al.*, 1977) as well as growth rates with a net effect of lower final kernel weight (Bagga and Rawson 1977; McMaster, 1997).

Radiant energy level and temperature are the two factors that tend to fluctuate together, since surface temperature at any one location is largely influenced by the amount of solar radiation received (Gardner *et al.*, 1985). Therefore, both have direct effect on wheat growth and yield.

Delaying wheat sowing till December usually reduces yield as a result of exposure to high temperature, and causes reduction in season length (Eid *et al.*, 1997; El-Marsafawy *et al.*, 1998; Rayan *et al.*, 1999). Hence, accurate prediction of wheat yield is one of the ultimate goals of crop production.

The objectives of this work are (i) to develop regression equations to predict wheat yield under different sowing dates using historical weather data at Delta region (ii) to use the developed equations to predict wheat yield in future years.

MATERIALS AND METHODS

Data for mean temperature (Mtemp, °C), solar radiation (SR, cal/cm^2/day), and rain (mm) were collected[1] for the period of (1975-2002) for Sakha, Kafer El-Sheakh Governorate (as a representative of Delta region). Wheat yield (Ardab/fed) values were also collected for the Delta region[2] for the same period. The above mentioned weather parameters were used to predict wheat productivity, where a straight line was fitted to wheat yield as a function of weather parameters. The analysis was done in two directions. The first one, is to predict wheat yield under different sowing dates. The second one, is to predict wheat yield under different growth stages for these sowing dates. Three sowing dates were assumed (November, 15; December, 1; December, 15). Season length was assembly to be 175, 165, and 154 days for the above mentioned sowing dates

[1] Agriculture Extension Bulletin
[2] Agriculture Economics Bulletin

respectively as it was indicated by Eid *et al.*, (1999). For each sowing date, weather parameters of twenty five years (1975-1999) were used to develop one equation to predict wheat yield.

Furthermore, four growth stages (from planting to the end of tillering, from planting to the end of booting, from planting to the end of anthesis, and from planting to the end of grain filling) were studied. Tillering occurs about 45-50 days after planting and booting occurs about 80-85 days after planting. Anthesis takes about 5-10 days and grain filling period occurs about 85-95 days after planting. Mean temperature, mean solar radiation and mean rain were summed for each growth stage and throughout the growing season. Weather parameters for twenty five years (1975-1999) were used to develop one prediction equation for each growth stage to predict wheat yield.

Collected data was subject to multiple linear regression as outlined by Draper and Smith (1987). 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. R^2 is the amount of variability due to all independent variables, and SE% is a measurement of precision i.e. closeness of predicted and observed yield to each other.

In addition, weather parameters of 1999/00 season were used to predict wheat yield and then compared to actual yield of 1999/00. In addition, the yield of 2000/01 and 2001/02 were predicted using previous year weather parameters and then compared to actual yields. Percent reductions in yield were then calculated.

RESULTS AND DISCUSSION

Weather parameters calculations and actual wheat yield

Mean temperature, solar radiation, and rain were averaged for each growing stage under each sowing date from 1975-1999 (Table 1, 2, and 3).

Table (1): Mean temperature, solar radiation, and rain for four growing stages of wheat planted at November, 15 (average over 25 years)

Weather Parameters Growth stage	Mean Temperature (° C)	Solar Radiation (cal/cm²/day)	Rain (mm)
End of tillering	12.79	263.68	7.90
End of booting	13.27	292.13	10.06
End of anthesis	13.93	320.58	10.04
End of grain filling	13.98	336.81	6.70

Table (2): Mean temperature, solar radiation, and rain for four growing stages of wheat planted at December, 15 (average over 25 years)

Weather Parameters Growth stage	Mean Temperature (° C)	Solar Radiation (cal/cm^2/day)	Rain (mm)
End of tillering	13.89	256.19	7.38
End of booting	12.07	235.65	7.39
End of anthesis	14.82	309.22	10.05
End of grain filling	14.37	361.65	7.37

Table (3): Mean temperature, solar radiation, and rain for four growing stages of wheat planted at December, 15 (average over 25 years)

Weather Parameters Growth Stage	Mean Temperature (° C)	Solar Radiation (cal/cm^2/day)	Rain (mm)
End of tillering	14.25	273.32	8.57
End of booting	14.83	269.43	9.92
End of anthesis	14.43	302.68	12.71
End of grain filling	14.97	380.13	11.70

Actual wheat yield average over 25 years (1975-1999) and yield of 1999/00, 2000/01, and 2001/00 as were obtained from Agricultural Economics Bulletin are presented in Table (4).

Table (4): Actual wheat yield for Delta Region (Agricultural Economics Bulletin)

Year	Yield (Ardab/fed)
Average over 25 years (1975-1999)	12.96
1999/00	18.47
2000/01	18.57
2001/02	18.77

2. Predicting Wheat yield at different growth stages under different sowing dates:

2.1. Sowing at November, 15

Four equations for each growth stage were developed and used to predict wheat yield as follows:

- *From planting to the end of tillering:*

[1] Y`=90.04-1.97Mtemp**-0.09Rain**-0.16SR**

R^2= 0.8512 SE%= 10.10

- *From planting to the end of booting:*

[2] Y`=66.93-3.03Mtemp**-0.07Rain-0.03SR

R^2= 0.8024 SE% = 11.72

- *From planting to the end of anthesis:*
  [3] Y`= 52.69-2.46Mtemp**-0.06Rain-0.01SR
  R^2= 0.7443 SE%=13.27

- *From planting to the end of grain filling:*
  [4] Y`=36.58-2.22Mtemp**-0.04Rain+0.03SR
  R^2= 0.8613 SE%= 9.79

The highest R^2 and the lowest SE% were observed for equation [4]. Equations [1], [2], [3], and [4] were used to predict wheat yield in 1999/00 (Table 5). Results showed that, any of the four studied stages was suitable to predict wheat yield (percent decrease were between 4.41- 7.55 %). This could be an indication that sowing at November, 15 expose wheat plant to favorable weather conditions for growth and consequently increase yield.

2.2. Sowing at December, 1

Four equations for each growth stage were developed and used to predict wheat yield as follows:

- *From planting to the end of tillering:*
  [5] Y`=67.49-1.99Mtemp**-0.04Rain-0.15SR**
  R^2= 0.8226 SE%= 11.11

- *From planting to the end of booting:*
  [6] Y`=12.85-2.22Mtemp**+0.04Rain+0.12SR
  R^2= 0.7417 SE% = 13.34

- *From planting to the end of anthesis:*
  [7] Y`= 23.50-1.87Mtemp**+0.02Rain+0.06SR
  R^2= 0.7812 SE%=12.26

- *From planting to the end of grain filling:*
  [8] Y`=96.04-1.97Mtemp**-0.04Rain**-0.13SR**
  R^2= 0.8512 SE%= 10.10

The highest R^2 and the lowest SE% were observed for equation [8]. Equations [5], [6], [7], and [8] were used to predict wheat yield in 1999/00 (Table 5). Results in that table showed that the lowest percent decrease between predicted and actual wheat yield was obtained when wheat yield was predicted at the end of grain filling stage (PD = 8.60%). Therefore, that stage could be used to predict yield when wheat was sown in December, 1.

2.3. Sowing at December, 15

Four equations for each growth stage were developed and used to predict wheat yield as follows:

- *From planting to the end of tillering:*
  [9] Y`=57.08-2.22Mtemp**-0.03Rain-0.6SR
  R^2= 0.7690 SE%= 12.65

- *From planting to the end of booting:*
  [10] Y`=27.36-2.12Mtemp**+0.004Rain+0.04SR
  R^2= 0.7026 SE% = 13.42

- *From planting to the end of anthesis:*
  [11] Y`= 54.48-1.17Mtemp**-0.07Rain*-0.07SR**
  R^2= 0.8400 SE%=10.49

- *From planting to the end of grain filling:*
  [12] Y`= 59.22-2.82Mtemp**+0.04Rain-0.03SR
  R^2= 0.7380 SE%= 13.50

Table (5): Predicted wheat yield at four growth stages for wheat planted at three sowing dates in1999/00 growing season

Sowing Date / Growth Stage	November, 15		December, 1		December, 15	
	Predic-ted	PD %	Predic-ted	PD %	Predic-ted	PD %
End of tillering	17.65	4.41	16.10	12.77	14.91	19.23
End of booting	17.07	7.55	16.04	13.11	13.07	29.23
End of anthesis	17.33	6.15	16.19	12.33	16.37	11.36
End of grain filling	17.47	5.41	16.88	8.60	16.03	13.21

The highest R^2 and the lowest SE% were observed for equation [11]. Equations [9], [10], [11], and [12] were used to predict wheat yield in 1999/00 (Table 5). Results showed that the lowest percent decrease between actual and predicted wheat yield was obtained when wheat yield was predicted at the end of anthesis stage (PD = 11.36%). This could be attributed to the fact that anthesis is highly sensitive to high temperature (Saini and Aspinall, 1982). Therefore, when wheat was sown at December,15 its yield could be predicted as early as at the end of anthesis stage.

3. Predicting wheat yield using previous year weather parameters

Mean temperature, solar radiation, and rain for growing season of 1999/00 growing season were used to predict wheat yield in 2000/01, whereas the above mentioned weather parameters of growing season of 2000/01 were used to predict wheat yield of 2001/02 using equations [4], [8] and [12] (Table 6). Results in Table (6) showed that the lowest percent decrease (PD%) between actual and predicted wheat yield was obtained for the growing season of 2001/02 when wheat was sown at November,15 (2.55%) followed by growing season of 2000/01 at the same sowing date (7.46%). Larger decreases in yield were observed as a result of delay sowing, which could be an indication that using pervious year weather parameters to predict the following year wheat yield could be more accurate if it was done for wheat sown at November, 15.

Table (6): Predicted wheat yield using pervious year weather parameters

Season	2000/01		2001/02	
Sowing date	Predicted	PD%	Predicted	PD%
November, 15	17.18	7.46	18.29	2.55
December, 1	16.57	9.78	17.60	6.22
December, 15	16.97	14.01	16.00	14.75

4. Predicting wheat yield under different sowing dates at the end of grain filling period:

Equations [4], [8], [12] were used to predict wheat yield for the whole growing season (at the end of grain filling period) under the three sowing dates. Percent decrease in yield as a result of delay sowing was found to be 3.37%, whereas the reduction was 8.24% when sowing was delayed until December, 15 (Table 7). Eid *et al.* (1999), stated that delay sowing from November, 23 to December, 8 reduced yield by 1.57%, whereas the reduction was 4.76% when sowing was delayed until December, 23

Table (7): Predicted wheat yield under different sowing dates at Delta Region

Sowing Date	Predicted Yield (Ardab/fed)	Percent Decrease %
November, 15	17.47	0
December,1	16.88	3.37
December,15	15.43	8.24

CONCLUSION

Inexpensive, although accurate method to predict wheat yield could be accomplished by using historical weather data. Prediction equations were developed and used in this matter. Early prediction of wheat yield was attained by predicting wheat yield at different growth stages under different sowing dates. End of tillereing was the most suitable stage to predict yield when wheat was sown at November,15, whereas from planting to the end of grain filling was the suitable stage to predict yield when wheat was sown at December, 1. Furthermore, from planting to the end of anthesis was the stage to be used in predicting wheat sown at December, 15

In addition, early prediction of wheat yield was also attained by using pervious year weather parameters to predict the following year wheat yield.

The developed equations enable us to predict yield at different sowing dates to determine the reduction in yield as a result of delayed sowing. This could help farmers to determine which sowing date is more profitable for them.

Another set of equations could be developed to predict wheat yield under weather conditions of Middle Egypt and Upper Egypt.

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التنبؤ بمحصول القمح في منطقة الدلتا تحت مواعيد زراعه مختلفه باستخدام بيانات الارصاد الجويه

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القمح من اهم محاصيل الحبوب فى مصر وتأخير زراعته عن الميعاد المناسب يحدث نقص واضح فى المحصول. يهدف هذا البحث الى: (١) استخدام بيانات الارصاد الجويه لعمل معادلات انحدار للتنبؤ بمحصول القمح تحت عده مواعيد زراعه (٢) استخدام هذه المعادلات فى التنبؤ بمحصول القمح فى سنوات قادمه. تم جمع بيانات لمتوسط الحراره والاشعاع الشمسى والمطر في سخا - محافظه كفر الشيخ كممثل لمنطقة الدلتا في الفتره من ١٩٧٥-٢٠٠٢ وايضا تم جمع بيانات لانتاجية القمح فى تلك المنطقه للفتره السابقه. وتم عمل التحليل الاحصائى في اتجاهين: الأول هوالتنبؤ بمحصول القمح تحت عده مواعيد زراعة (١٥ نوفمبر، ١ ديسمبر، ١٥ ديسمبر) والثانى هوالتنبؤ بمحصول القمح فى أربعه مراحل نمو(من الزراعة حتى نهايه تكوين الاشطاء، من الزراعة حتى بداية تكوين الحبوب، من الزراعة حتى نهاية التزهير ومن الزراعة حتى نهاية امتلاء الحبوب) تحت مواعيد الزراعة السابقة. إستخدمت بيانات الأرصاد فى الفترة من ١٩٧٥ / ١٩٩٩ لعمل معادلة للتنبؤ فى كل مرحله نموولكل موعد زراعة. وتم أستخدام هده المعادلات مع بيانات الأرصاد لموسم نمو١٩٩٩ / ٢٠٠٠ للتنبؤ بالمحصول فى هذه السنه، ثم تم مقارنته بالمحصول الفعلى لنفس السنه وحساب نسبه النقص بين المحصول الفعلى والمتنبأ به . بالأضافة إلى ذلك تم أستخدام تلك المعادلات فى التنبؤ بمحصول القمح لسنة ٢٠٠١ بأستخدام بيانات الارصاد الجويه لموسم نمو١٩٩٩/ ٢٠٠٠ والتنبؤ بمحصول القمح لسنة ٢٠٠٢ بأستخدام بيانات الارصاد الجويه لموسم نمو٢٠٠١ / ٢٠٠٢ وتم مقارنه ذلك بالمحصول الفعلى وحساب نسبه النقص بين المحصول الفعلى والمتنبأ به. وقد اظهرت النتائج انه عند زراعه القمح فى ١٥ نوفمبر يمكن استخدام اى من مراحل النموالاربعه للتنبؤ بمحصول القمح حيث تراوحت نسبة النقص بين المحصول الفعلى والمتنبأ به ما بين ٤,٤١ -٧,٥٥ %. وعند زراعه القمح فى ١ ديسمبر كانت انسب مرحله للتنبؤ بالمحصول هى من الزراعه حتى نهاية امتلاء الحبوب (نسبة النقص بين المحصول الفعلى والمتنبأ به = ٨,٦ %). أما عند زراعة القمح فى ١٥ ديسمبر كانت مرحلة التزهير هى انسب مرحله للتنبؤ بالمحصول (نسبة النقص بين المحصول الفعلى والمتنبأ به = ١١,٣٦ %). وكانت أقل نسبة النقص بين المحصول الفعلى والمتنبأ به لسنة ٢٠٠٢ (٢,٥٥ %) يليها محصول سنة ٢٠٠١ (٦,٤٦ %) وهذا يدل على ان استخدام بيانات السنه السابقه للتنبؤ بمحصول السنه الحاليه يكون اكثر دقه عند زراعة القمح فى ١٥ نوفمبر وكانت نسبة النقص فى المحصول عند تأخير الزراعه من ١٥ نوفمبر الى ١ ديسمبر ٣,٣٧ % بينما كانت ٨,٢٤ % عند تأخير الزراعه من ١٥ نوفمبر الى ١٥ ديسمبر ولذلك من المهم ان يقوم المزارعون بالانتهاء من اعداد الارض للزراعه وعدم تأخير زراعة القمح بعد ١ ديسمبر حتى لا يحدث نقص كبير فى المحصول