Annals of Agric. Sc., Moshtohor,
Vol. 33(2):525-544, 1995.

STEPWIES REGRESSION AND RESPONSE CURVE ANALYSIS FOR IMPORTANT YIELD FACTORS IN MAIZE

BY

Shafshak, S.E.*; Abd El-Halim, A.A.; Rosenberger, J.L.***; Saad, A.M.M.* and Ahmed, F.A.****

* Agron. Dept., Fac. of Agric., Moshtohor, Zagazig Univ., Egypt.
** Central Laboratory for Design and Statistical Analysis Res., Agric. Res. Center.
*** Stat. Dept. Pennsylvania State University, USA.

ABSTRACT

Two field experiments were conducted at the Research and Experimental Center of Moshtohor, Faculty of Agriculture in 1991 and 1992 seasons. Three planting dates [early (May 1st), intermediate (June 1st) and late (July 1st)], two maize varieties (Giza 2 and T.W.C. 310) and five nitrogen fertlizer levels (30, 60, 90, 120 and 150 kg N/fed.) were evaluated. Strip plot design with three replications in first season and four in the second one for each planting date was used. Varieties were randomly assigned in the vertical strips and nitrogen fertilizer levels in the horizontal strips. Combined analysis over both years was made for the three planting dates of single experiments for each season separately. The obtained results can be summarized as follows:

Response curve analysis:

In first season, data of May planting showed that the best model fitted to the yield data of variety Giza 2 was quadratic plus plateau model, whereas linear plus plateau model fit well to the yield of T.W.C. 310 variety. In June and July planting, the best model was linear plus plateau for the two tested varieties.

In second season, the best model fitted to the yield data was linear plus plateau model for the two varieties in May planting and also for Giza 2 variety in June planting. The quadratic model fit well to the yield of T.W.C 310 variety in June planting and also for both varieties in July planting.

Stepwise regression analysis:

The results indicated that 68.75% of the total variation in the yield could be linearly related to the studied variables. 66.99% of the total yield variation could be attributed to the variables included into the model and 1.76% could be due to the eliminated variables.

The variables included to the model could be arranged, according to their relative importance measured by partial R^2, in a descending order as

follows: years, first planting date (May 1st), second planting date (June 1st), shelling percentage, ear length, weight of 100 kernels, plant height, nitrogen fertilization and varieties.

INTRODUCTION

Yield is a very complex attribute. It is a final outcome of a number of components. Hence, it is necessary to detect the variables having the greatest influence on the yield and its relative contributions to variation in the yield.

Several investigators studied the relationship between maize yield and its components by using some statistical procedures, namely, factor analysis, stepwise regression analysis, path coefficient analysis and multiple linear regression. Leaf area accounted for 68.41% of the variation in grain yield (El-Kalla and El-Rayes, 1984). Number of leaves/plant and weight of 100 kernels accounted for 91.64% of the total variation in grain yield in variety S.C. 10, also the two characters were the most contributors in Giza 2 variety. Ear length, plant height, shelling percentage, leaf area index and ear diameter accounted for 93.77% of the total variation of the grain yield of variety T.W.C. 310. Similar results were obtained by Mohamed and Sedhom (1993) who found that number of rows/ear, weight of 100 kernels and number of grains/ear were the major contributors to seed yield variation.

This study aims to determine a prediction model for yield and the significant variables as well as to calculate the relative contributions of these variables.

MATERIALS AND METHODS

Two field experiments were conducted at the Research and Experimental Center of the Faculty of Agriculture at Moshtohor, Zagazig University, Egypt in the 1991 and 1992 seasons. The experimental treatments were as follows:

1- Three planting dates, i.e. early (May 1st), intermediate (June 1st) and late (July 1st).
2- Two maize varieties, i.e. Giza 2 and Three Way Cross 310 (T.W.C. 310).
3- Five nitrogen fertilizer levels, i.e. 30, 60, 90, 120 and 150 kg N/fed.

The experimental design used was strip plot design for each planting date, as a single experiment, with three replications in the first season and four in the second one. Varieties were randomly assigned to the vertical strips and the nitrogen fertilizer levels were also randomely assigned to the horozintal strips. Each plot consisted of five rows of 3 m length and 70 cm apart. Seeds were sown in rows, plant hills were 25 cm apart. Ammonium nitrate (33.5%) as nitrogen source was applied in two equal doses before the first and second irrigations at the above stated rates of nitrogen. Irrigation was provided every 15 days. Data were collected on five plants selected randomly from the three guarded rows, the selected plants were labelled for collecting data on the following characters:

Growth characters were number of leaves/plant, leaf area of topmost ear, leaf area index, plant height, ear height and stem diameter.

Ear characters were ear length, ear diameter, number of rows per ear and number of kernels/row.

Yield and related characters were grain yield/fed., grain yield/plant, shelling percentage and weight of 100 kernels.

Statistical analysis:

Response curve analysis:

Three response models, namely, linear plus plateau, quadratic plus plateau and quadratic were fitted to the data for both varieties (Giza 2 and T.W.C. 310) in the three planting dates during 1991 and 1992 seasons by using the SAS non linear procedure (NLIN) according to SAS (1985). The procedure allows a general class of models to be fit in an interative procedure that procedues the least sum of squares.

The linear plus plateau model is given by using the following formulas:

$Y = a + bx$ .... (1) if $x < x_0$

$Y = p$ if $x \geq x_0$

The quadratic plus plateau model is specified by using the following equation:

$Y = a + bx + cx^2$ ...(2) if $x < x_0$

$Y = p$ if $x \geq x_0$

The quadratic polynomial model is estimated by using the following formula:

$Y = a + bx + cx^2$ ......(3)

where: Y: is the grain yield per feddan in kgs.

a: is the intercept.

b: is the linear coefficient.

x: is the level of nitrogen fertilizer applied in kg/fed.

c: is the quadratic coefficient.

x_0: is the critical level of nitrogen fertilizer, which corresponds to the intersection of the linear response and the plateau lines (equation 1), while in equation 2 x_0 is the critical level of nitrogen fertilizer, which corresponds to the intersection of the quadratic response and plateau lines, and is a parameter estimated from the data in both equations.

p: (in both equations 1 & 2) is plateau yield for $x > x_0$ and also a parameter estimated from the data. And the model is constrained such that $a + bx_0 = p$(equ. 1) while, in equation 2 the model is constrained such that $a + bx_0 + cx_0^2 = p$

For the linear plus plateau and quadratic plus plateau models, the plateau yields were considered to be maximum yields. For the quadratic model, predicted maximum yields were obtained by equating the first derivative of the response equation to zero, solving for x, substituting the value of x into the response equation, and solving for Y.

Comparisons among the models, linear plus plateau, quadartic plus plateau and quadratic, were based on the mean square error (MSE). The model which had the least mean square error was considered to be the best model fitted to the yield data.

Stepwise regression:

Stepwise multiple linear regression aims to determine the variables accounting for the majority of the total yield variability. This approach computes a sequence of regression equations. The criterion for accepting or removing an independent variable can be stated equivalently in terms of error sum of squares reduction, coefficient of partial correlation, or F* statistic. Stepwise regression was conducted as described by Draper and smith (1981).

The regression analysis using stepwise procedure. was applied to the data over both seasons including the plant characteristics mentioned before over all three dates of planting over both Giza 2 and T.W.C. 310 maize varieties, and over the five levels of nitrogen fertilizer used in this study. The dependent variable was grain yield/fed. and the predictor variables were the plant characteristics, namely, grain yield/plant, number of leaves/plant, leaf area of the topmost ear, leaf area index, plant height, ear height, stem diameter, ear length, ear diameter, number of rows/ear, number of kernels/row, shelling percentage and weight of 100 kernels and years, planting date, variety and fertilization.

Data were subjected to analysis in the Statistics Department at Pennsylvania State University. U.S.A.

RESULTS AND DISCUSSION

A. Response curve analysis:

Profitability of maize production is affected by selecting the appropriate level of nitrogen fertilizer. Decisions concerning optimal levels of fertilization involve fitting some types of continuous response model to the yield response data collected when several levels of fertilizer are applied. Comparisons among the response functions. linear plus plateau. quadratic and quadratic plus plateau were based on the mean square error. The model with least mean square error was considered to be the best model fitted to the yield data.

Mean square error for the three models for grain yield/fed. of maize varieties, Giza 2 and T.W.C. 310, planted in May, June and July during the 1991 and 1992 seasons are presented in Table (1). The regression equations are shown in Table 2 and the curves are given in Figures (1-12).

In the 1991 season, data for May planting indicate clearly that the best model fitted to the grain yield of variety Giza 2 was quadratic plus plateau, the mean square error for this model was less than those of the other two models. The nitrogen fertilizer rate was 90 kg/fed. at the point of the plateau (Fig. 1). This result is in agreement with that obtained by Fox and Piekielek (1983 and 1990) and Cerrato and Blackmer (1990), who found that the quadratic plus plateau model was the best of the response models tested for describing maize grain yield response to nitrogen fertilization. They conclude that the quadratic plus plateau model worked well for describing response of grain yield/fed. to nitrogen fertilization. The plateau yield was similar to maximum yield, 3334.9 kg/fed.

For June planting, it is clear from Table (1) that the least mean square error was for the linear plus plateau model for both tested varieties, Giza 2 and T.W.C. 310. Figures 3 and 4 show that the optimum rate of nitrogen fertilization, according to the linear plus plateau model, was 110 kg N/fed. The optimum is the lowest N rate which gives the maximum response, i.e. the join point of the plateau. Similarly, the linear plus plateau model was the best model fitted to the yield data of variety Giza 2 in the July planting. Mean square error for this model was 196.826 while it was 205.798 and 197.010 for quadratic and quadratic plus plateau models, respectively (Table 1). It can be seen from Figure (5) that the optimum rate of nitrogen fertilizer was 110 kg/fed. The results of June and July plantings in the 1991 season are in line with that obtained by Anderson and Nelson (1975). They fitted linear plus plateau, quadratic and square root models to the yield of maize in North Carolina, U.S.A. and found that the linear plus plateau model was the best model compared with quadratic and square root models.

The estimated model for T.W.C. 310 variety planted in July 1991 is not presented, since the best fitting model is a quadratic with a positive coefficient on the quadratic term, (which corresponds to a minimum). Therefore, the nearest sensible model would be simply a plateau, at the average of all treatments (Fig. 6).

In second season, the grain yield response to N fertilization was linear plus plateau and quadratic. In May planting, data presented in Table (1) clearly

Table 2 : Regression equations of maize varieties planted in May, June and July during 1991 and 1992 seasons.

Planting dates	Varieties	Regression equations	X_o	Models
		1991		
May	Giza 2	$Y = 1191.27 + 47.040\ X - 0.2581\ X^2$	91	Quadratic + plateau
	T.W.C 310	$Y = 2778.00 + 0.560\ X$	60	Linear + plateau
June	Giza 2	$Y = 1930.00 + 4.657\ X$	110	Linear + plateau
	T.W.C 310	$Y = 1660.60 + 9.751\ X$	110	Linear + plateau
July	Giza 2	$Y = 1795.00 + 0.418\ X$	110	Linear + plateau
	T.W.C 310	$Y = 2273.00 - 20.200\ X + 0.11\ X^2$		Non - estimable
		1992		
May	Giza 2	$Y = 1378.00 + 4.500\ X$	60	Linear + plateau
	T.W.C 310	$Y = 1102.00 + 11.900\ X$	60	Linear + plateau
June	Giza 2	$Y = 657.00 + 14.200\ X$	60	Linear + plateau
	T.W.C 310	$Y = 825.00 + 18.300\ X - 0.0736\ X^2$	124	Quadratic
July	Giza 2	$Y = 352.00 + 12.200\ X - 0.0331\ X^2$	150	Quadratic
	T.W.C 310	$Y = 586.00 + 7.500\ X - 0.0014\ X^2$	150	Quadratic

indicate that linear plus plateau model was the best model among the three models fitted to the data of grain yield for both tested varieties. The optimum rate of nitrogen fertilizer was 60 kg/fed. for both varieties (Figures 7 and 8). This result is in harmony with that obtained by Anderson and Nelson (1975), who reported that the linear plus plateau model was the best model compared with quadratic and square root models.

In the June 1992 planting, the values of mean square error of T.W.C. 310 variety were 196,247, 188,600 and 189,498 for linear plus plateau, quadratic and quadratic plus plateau models, respectively, (Table 1). These values indicate clearly that the quadratic model was the best model fitted to the data of grain yield of T.W.C. 310 variety since it had the least mean square error (Fig. 10). The maximum rate of fertilizer nitrogen was 124 kg/fed. and it produced maximum grain yield which was 1960.61 kg/fed.

In the July 1992 planting, the best model fitted to the data of grain yield of both tested varieties was the quadratic model. Its mean square error was less than those of the other two models, linear plus plateau and quadratic plus plateau (Table 1 and Figures 11 & 12).

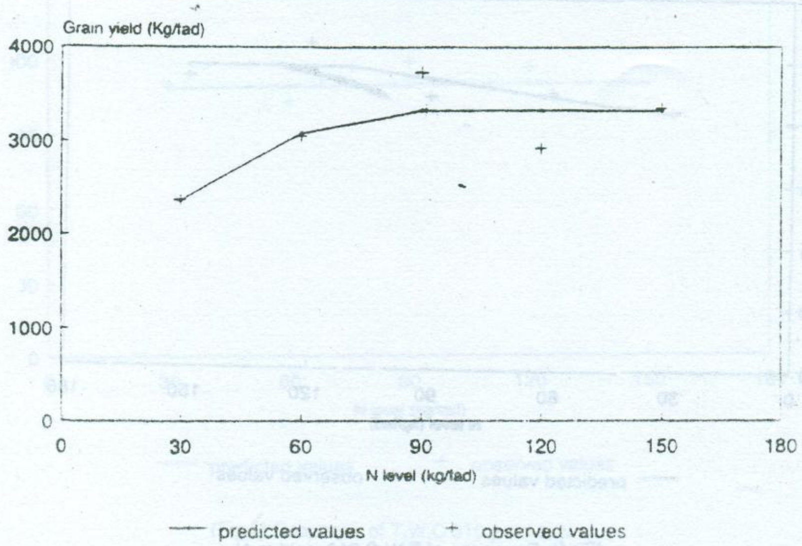
The two results of June and July plantings in the 1992 season, are in line with that reported by Engelstad and Parks (1971), Awasthi and Tewari (1976), Balko and Russell (1980), Singh *et al.*, (1980) and Nimje and Seth (1988) who demonstrated that the quadratic model was well fitted to the data of maize yield.

Concerning yield data of T.W.C. 310 variety planted in May 1991 season (Figure 2) and of Giza 2 variety planted in June 1992 season (Figure 9), although the quadratic plus plateau model has the minimum mean square error of these data, this model was not estimable since the join point was estimated to be less than 60 kg N/fed. (in order to fit a quadratic equation, at least three points of support are required). Thus, the linear plus plateau model was used, which is estimable with a join point less than 60.

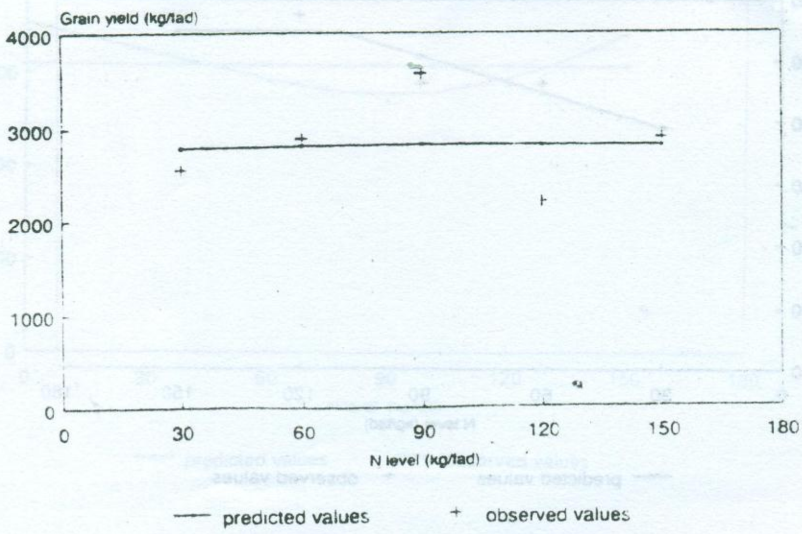
Stepwise regression analysis:

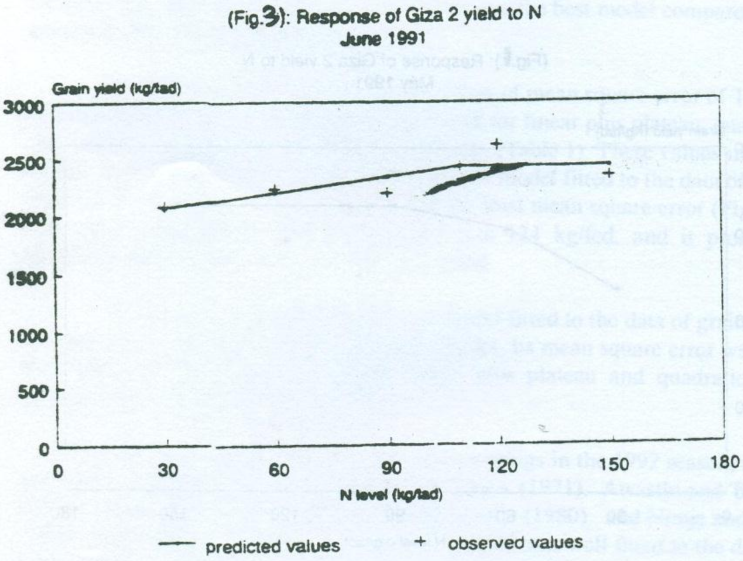
Variable explaining maize grain yield are presented in Table (3). This data indicate that 8 of the 17 variables were accepted as significantly contributing to variation in maize grain yield, also, showed that 68.75% of the total variation in the yield could be linearly related to the studied variables 66.99% of the total yield variation could be attributed to the variables included into the model and 1.76% could be due to the eliminated variables. The highest value of R^2 were for years and planting dates indicating the magnitude of the environmental conditions in maize production.

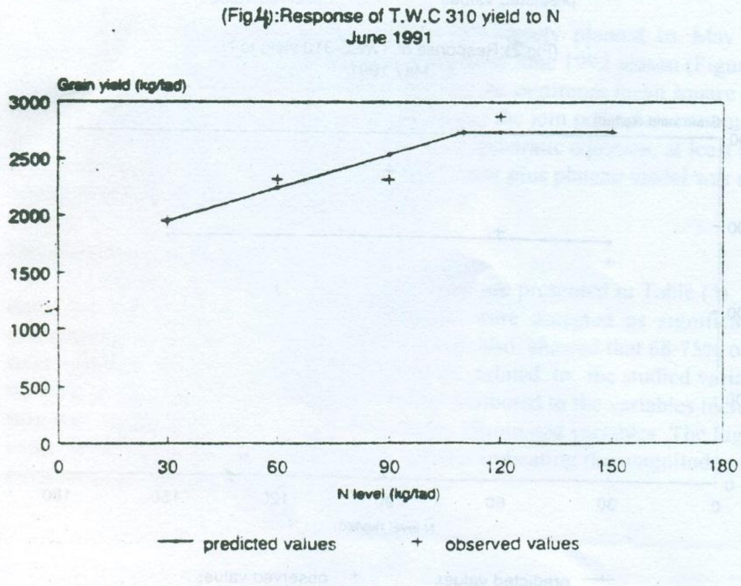
(Fig.1): Response of Giza 2 yield to N
May 1991



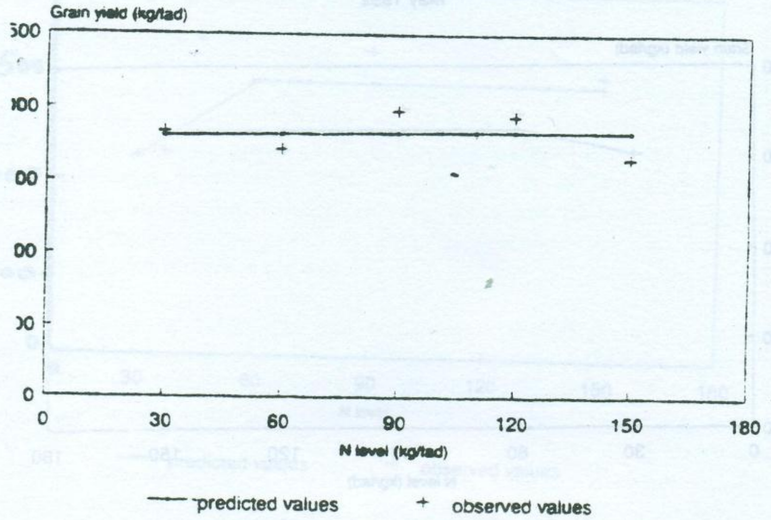
(Fig.2):Response of T.W.C 310 yield to N
May 1991



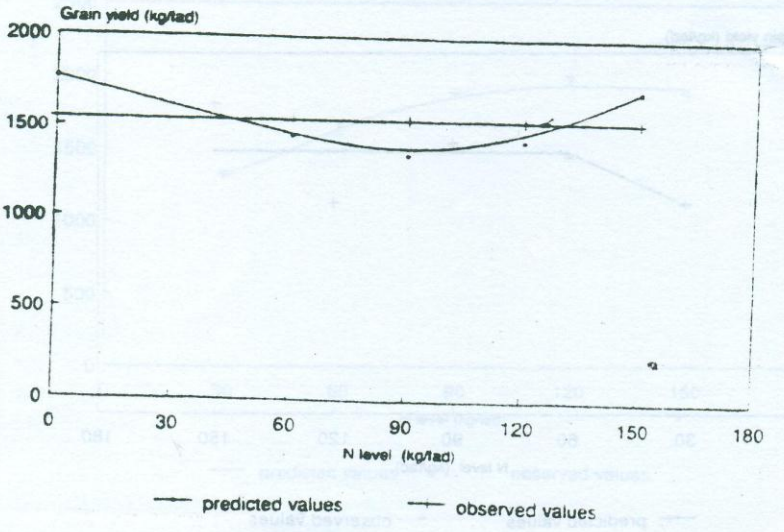

(Fig.3): Response of Giza 2 yield to N
June 1991
Grain yield (kg/fad)
3000
2500
2000
1500
1000
500
0
0
30
60
90
120
150
180
N level (kg/fad)
predicted values
observed values


(Fig.4):Response of T.W.C 310 yield to N
June 1991
Grain yield (kg/fad)
3000
2500
2000
1500
1000
500
0
0
30
60
90
120
150
180
N level (kg/fad)
predicted values
observed values

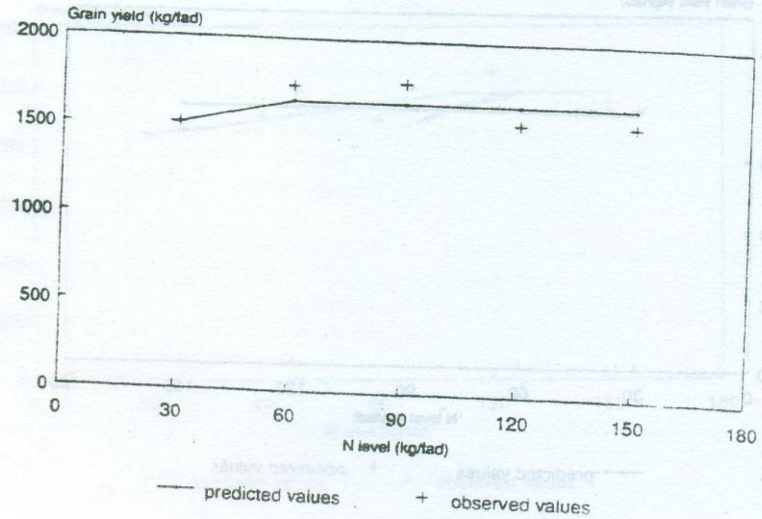
(Fig. 5): Response of Giza 2 yield to N
July 1991



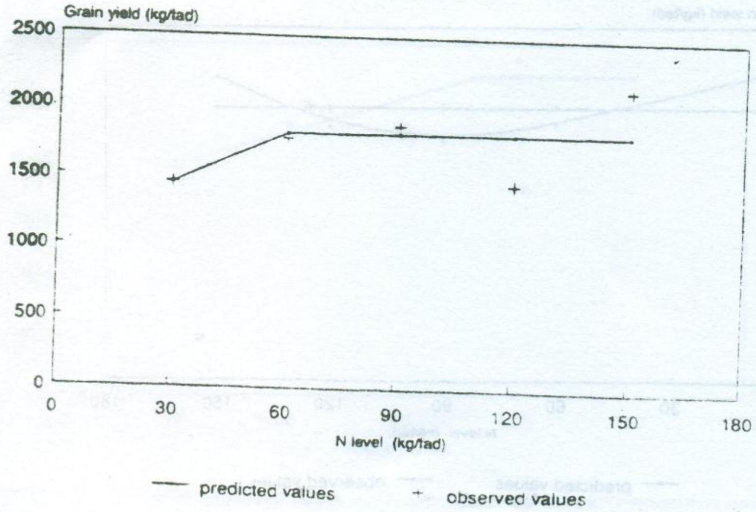
(Fig.6): Response of T.W.C 310 yield to N
July 1991



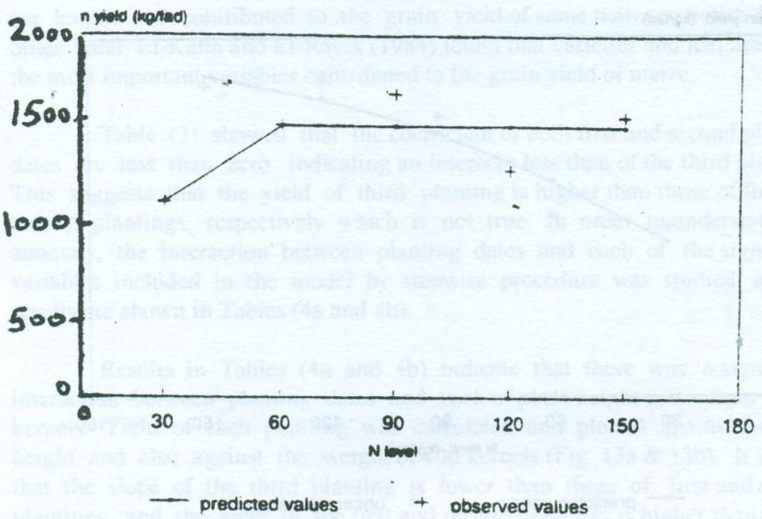
(Fig. 7): Response of Giza 2 yield to N
May 1992



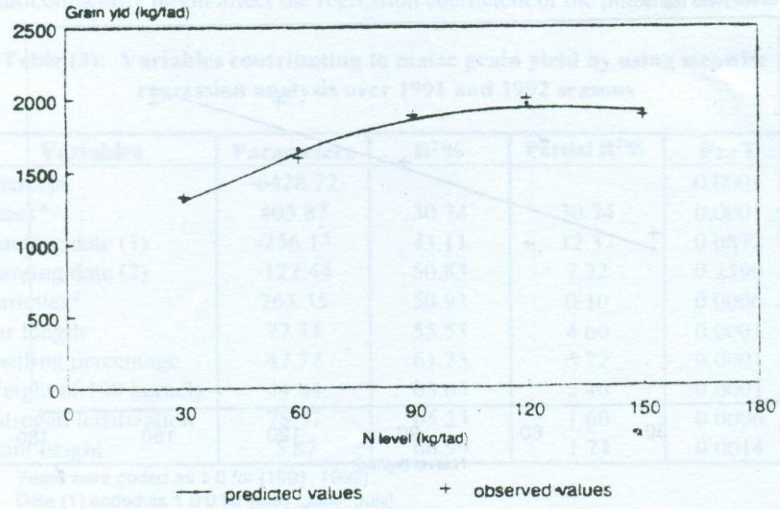
(Fig. 8):Response ofT.W.C 310 yield to N
May 1992



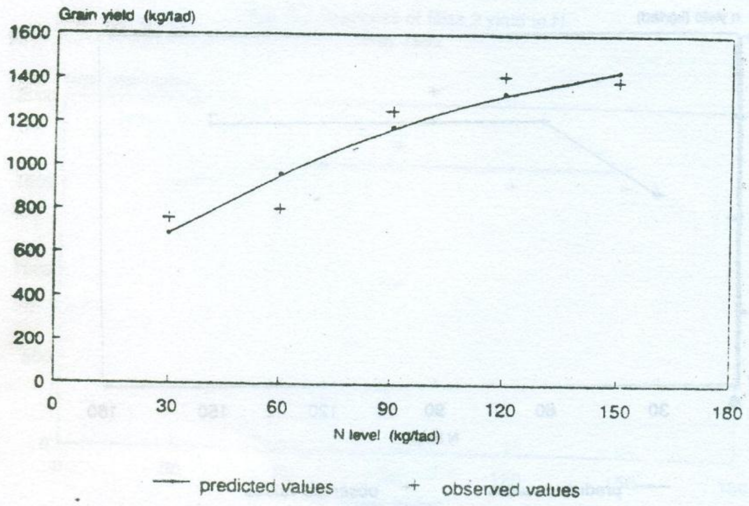
(Fig. 9): Response of Giza 2 yield to N
June 1992



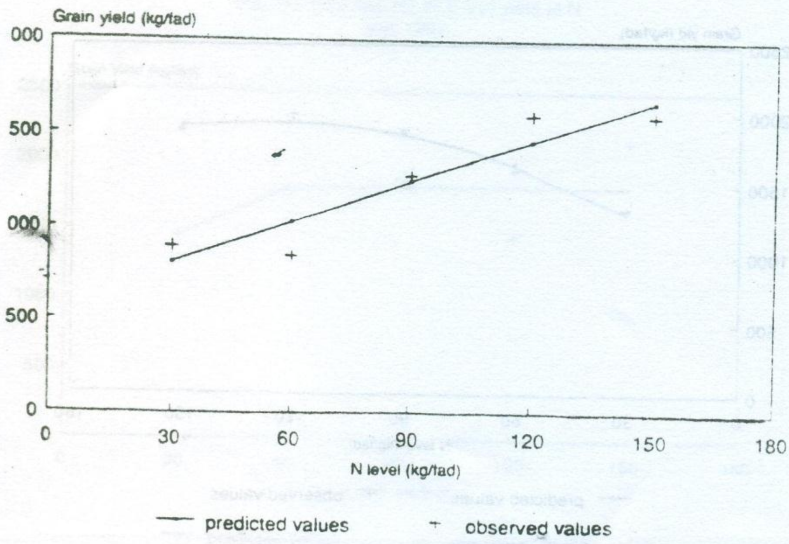
(Fig. 10): Response of T.W.C 310 yield to N
June 1992



(Fig. 11):Response of Giza 2 yield to N
July 1992



(Fig. 12):Response of T.W.C 310 yield to N
July 1992



According to their relative importance as measured by the partial R^2, the variables included in the model could be arranged in a descending order as follows: years, first planting date, second planting date, shelling percentage, ear length, weight of 100 kernels, plant height, nitrogen fertilization and varieties. These results are in rough agreement with that obtained by Ashmawy (1989), who reported that plant height, weight of 100 kernals, shelling percentage and ear length had contributed to the grain yield of some maize varieties. On the other hand, El-Kalla and El-Rayes (1984) found that varieties and leaf area were the most important variables contributed to the grain yield of maize.

Table (3) showed that the coefficient of both first and second planting dates are less than zero indicating an intercept less than of the third planting. This suggests that the yield of third planting is higher than those of first and second plantings, respectively which is not true. In order to understand this anomaly, the interaction between planting dates and each of the significant variables included in the model by stepwise procedure was studied and the results are shown in Tables (4a and 4b).

Results in Tables (4a and 4b) indicate that there was a significant interaction between planting dates and each of plant height and weight of 100 kernels. Yield of each planting was calculated and plotted against the plant height and also against the weight of 100 kernels (Fig. 13a & 13b). It is clear that the slope of the third planting is lower than those of first and second plantings, and the yield of the first and second plantings is higher than that of the third planting. The reason for this case is probably due to the correlation between the independent variables and the dependent variable, the grain yield, and/or the correlation between the independent variables themselves and this multicollinearity might affect the regression coefficient of the planting dates.

Table (3): Variables contributing to maize grain yield by using stepwise regression analysis over 1991 and 1992 seasons

Variables	Parameters	R^2%	Partial R^2%	Pr>T
Intercept	-6428.72			0.0001
Years*	405.87	30.74	30.74	0.0001
Planting date (1)	-256.13	43.11	12.37	0.0872
Planting date (2)	-122.44	50.83	7.72	0.2590
Varieties*	263.35	50.93	0.10	0.0006
Ear length	77.31	55.53	4.60	0.0001
Shelling percentage	47.72	61.25	5.72	0.0001
Weight of 100 kernels	44.04	63.65	2.40	0.0001
Nitrogen fertilization	78.77	65.25	1.60	0.0006
Plant height	5.87	66.99	1.74	0.0014

- Years were coded as 1 0 for (1991, 1992).
- Date (1) coded as 1 0 0 for (May, June, July).
- Date (2) coded as 0 1 0 for (May, June, July).
- Varieties coded as 1 0 for (Giza 2, T.W.C 310)
- R^2 for accepted variables = 66.99%
- R^2 for eliminated variables = 1.76%.
- R^2 for all studied variables = 68.75%

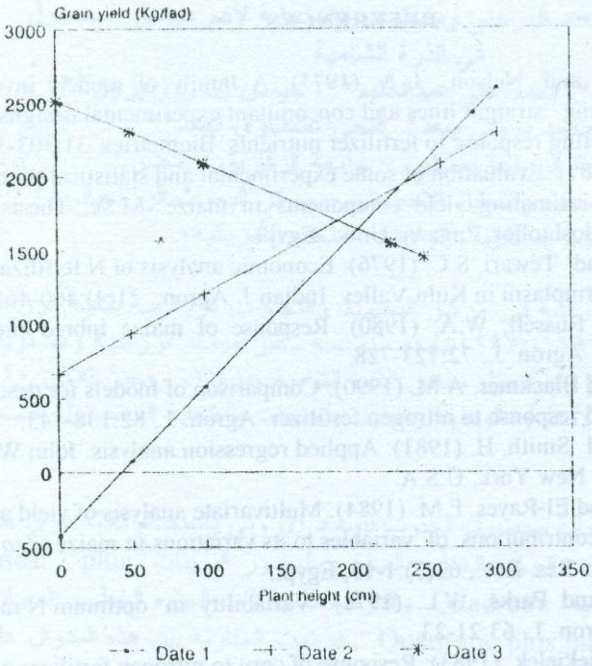
Table (4a): Variables contributing to maize grain yield by using stepwise regression analysis over 1991 and 1992 seasons

Variables	Parameters	Pr>T
Intercept	-3197.7789	0.0157
Years	395.9526	0.0001
Planting date (1)	-3630.9815	0.0004
Planting date (2)	-2250.0965	0.0310
Varieties	220.8399	0.0038
Nitrogen fertilizer	73.0261	0.0013
Ear length	72.9694	0.0001
Shelling percentage	34.9823	0.0020
Weight of 100 kernels	45.4153	0.0001
Plant height X date (1)	10.0683	0.0001
Plant height X date (2)	5.4342	0.0319
Plant height X date (3)	-4.1808	0.2640

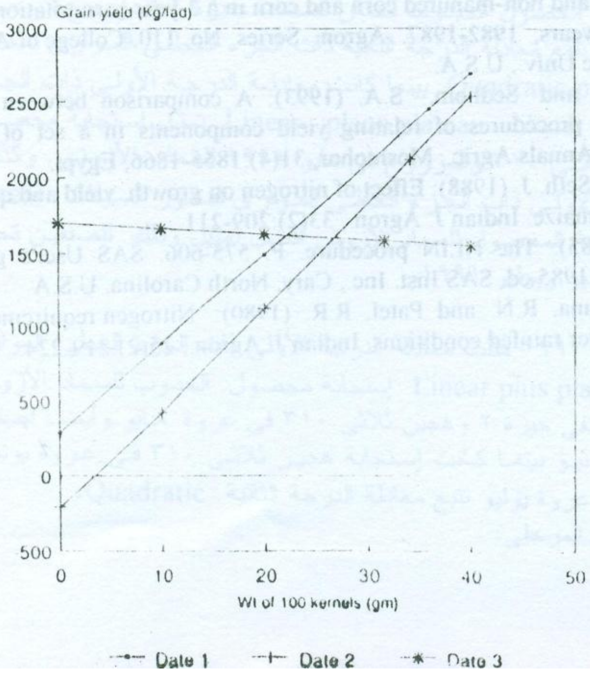
Table (4b): Variables contributing to maize grain yield by using stepwise regression analysis over 1991 and 1992 seasons

Variables	Parameters	Pr>T
Intercept	-4481.5684	0.0001
Years	490.5358	0.0001
Planting date (1)	-2287.6387	0.0067
Planting date (2)	-2507.5645	0.0021
Varieties	280.4783	0.0002
Nitrogen fertilizer	81.0255	0.0003
Ear length	5.2290	0.0044
Shelling percentage	84.8486	0.0001
Weight of 100 kernels	40.8341	0.0002
Plant height X date (1)	60.2459	0.0013
Plant height X date (2)	70.7504	0.0001
Plant height X date (3)	-3.7952	0.8347

(Fig.13-a): Grain yield at three dates
at different heights of plant



(Fig.13-b): Grain yield in three dates
at different Wt of 100 kernels



REFERENCES

Anderson, R.L. and Nelson, L.A. (1975): A family of models involving intersecting straight lines and concomitant experimental designs useful in evaluating response to fertilizer nutrients. Biometrics, 31:303-318.

Ashmawy, F. (1989): Evaluation of some experimental and statistical procedures used in estimating yield components in maize. M.Sc. Thesis, Fac. Agric., Moshtohor, Zagazig Univ., Egypt.

Awasthi, O.P. and Tewari, S.C. (1976): Economic analysis of N fertilization of maize germplasm in Kulu Valley. Indian J. Agron., 21(4):460-465.

Balko, L.G. and Russell, W.A. (1980): Response of maize inbred lines to N fertilizer. Agron. J., 72:723-728.

Cerrato, M.E. and Blackmer, A.M. (1990): Comparison of models for describing corn yield response to nitrogen fertilizer. Agron. J., 82:138-143.

Draper, N.R. and Smith, H. (1981): Applied regression analysis. John Wiley & Sons Inc. New York, U.S.A.

El-Kalla, S.E. and El-Rayes, F.M. (1984): Multivariate analysis of yield and the relative contributions of variables to its variations in maize (*Zea mays*, L.). Agric. Res. Rev., 62(7):1-13, Egypt.

Engelsted, O.P. and Parks, W.L. (1971): Variability in optimum N rates for Corn. Agron. J., 63:21-23.

Fox, R.H. and Piekielek (1983): Response of corn to nitrogen fertilizer and the prediction of soil nitrogen availability with chemical tests in Pennsylvania. Bull. No. 843, College of Agric., Penn State Univ., U.S.A.

Fox, R.H. and Piekielek (1990): Long-term nitrogen fertilization of continuous manured and non-manured corn and corn in a 3-year corn rotation: The first six years, 1982-1987. Agron. Series No. 110, College of Agric., Penn State Univ., U.S.A.

Mohamed, M.K. and Sedhom, S.A. (1993): A comparison between four statistical procedures of relating yield components in a set of corn varieties. Annals Agric., Moshtohor, 31(4):1855-1866, Egypt.

Nimje, P.M. and Seth, J. (1988): Effect of nitrogen on growth, yield and quality of winter maize. Indian J. Agron., 33(2):209-211.

SAS Institute (1985): The NLIN procedure. P. 575-606. SAS User's guide: Statistics, 1985 ed. SAS Inst. Inc., Cary, North Carolina, U.S.A.

Singh, S.N.; Sharma, R.N. and Patel, R.R. (1980): Nitrogen requirement of maize under rainfed conditions. Indian J. Agron., 25(2):219-224.

تحليل الأنحدار المتعدد المرحلى ومنحنيات الإستجابة لأهم عوامل المحصول فى الذرة الشامية

صلاح الدين شفشق *، أحمد على عبدالحليم **، جيمس ل. روزنبرجز ***،
عدلى محمد مرسى سعد* فتحى عشماوى أحمد**
* قسم المحاصيل - كلية الزراعة بمشتهر - جامعة الزقازيق - مصر.
** المعمل المركزى للتصميم والتحليل الاحصائى - مركز البحوث الزراعية.
*** قسم الاحصاء - جامعة بنسلفانيا - الولايات المتحده الأمريكيه.

أجريت هذه الدراسة فى مركز البحوث والتجارب الزراعية بكلية الزراعة بمشتهر فى موسمى ١٩٩١، ١٩٩٢ بهدف دراسة تأثير ميعاد الزراعة ومستويات السماد الأزوتى على نمو ومحصول صنفى الذرة الشامية جيزة ٢، وهجين ثلاثى ٣١٠. وأستخدم لذلك تحليل الأنحدار المتعدد وتحليل منحنيات إستجابة المحصول للسماد الأزوتى.

تم دراسة إستجابة محصول الحبوب للسماد الأزوتى بإستخدام ثلاثة دوال هى دوال الدرجة الأولى ذات الجزء الخطى الموازى لمحور السينات Linear plus plateau والدرجة الثانية Quadratic والدرجة الثانية ذات الجزء الخطى الموازى لمحور السينات Quadratic plus plateau وقد تمت المقارنة بين هذه الدوال على أساس مقدار الخطأ فالدالة ذات الخطأ الأقل أعتبرت أفضل الدوال لدراسة إستجابة المحصول للسماد الأزوتى. وأمكن تلخيص النتائج فيما يلى:
تحليل منحنيات الأستجابة للأزوت:

كانت إستجابة محصول الحبوب للفدان لصنف جيزة ٢ المزروع فى مايو ١٩٩١ للسماد الأزوتى تتبع معادلة الدرجة الثانية ذات الجزء الخطى الموازى لمحور السينات Quadratic plus plateau بينما كانت معادلة الدرجة الأولى ذات الجزء الخطى الموازى لمحور السينات Linear plaus plateau تمثل إستجابة محصول حبوب الصنف هجين ثلاثى ٣١٠ والمزروع فى مايو ١٩٩١ للسماد الأزوتى. وكذلك مثلت معادلة الدرجة الأولى ذات الجزء الخطى الموازى لمحور السينات Linear plus plateau إستجابة المحصول للسماد الأزوتى أفضل تمثيل وذلك للصنفين تحت الدراسة فى عروتى يونيو ويوليو ١٩٩١م.

أما فى موسم ١٩٩٢ مثلت معادلة الدرجة الأولى ذات الجزء الخطى الموازى لمحور السينات Linear plus plateau إستجابة محصول الحبوب للسماد الأزوتى أفضل تمثيل وذلك لصنفى جيزة ٢ وهجين ثلاثى ٣١٠ فى عروة مايو وأيضا لصنف جيزة ٢ فى عروة يونيو بينما كانت إستجابة هجين ثلاثى ٣١٠ فى عروة يونيو وإستجابة الصنفين فى عروة يوليو تتبع معادلة الدرجة الثانية Quadratic.
تحليل الأنحدار المتعدد المرحلى:

أوضحت النتائج أن الصفات تحت الدراسة وهى عدد الأوراق للنبات، ومساحة ورقة الكوز العلوى، دليل مساحة الأوراق، إرتفاع النبات، إرتفاع الكوز، سمك الساق، طول الكوز، قطر الكوز، عدد صفوف الكوز، معدل التفريط، ووزن الـ ١٠٠ حبة، محصول الحبوب للنبات بالإضافة إلى السنوات، ميعاد الزراعة، الأصناف، مستويات السماد الأزوتى تسهم بحوالى ٦٨,٧٥٪ من تباين المحصول وأن ٦٦,٩٩٪ من التباين الكلى يرجع إلى العوامل التى تضمنها نموذج الأنحدار المتعدد المرحلى وهى السنوات، ميعاد الزراعة الزراعة الأول والثانى، الأصناف، طول الكوز، معدل التفريط، وزن الـ ١٠٠ حبة، التسميد الأزوتى، إرتفاع النبات وأسهمت العوامل التى لم يتضمنها هذا النموذج بنحو ١,٦٧٪ من التباين الكلى.

كما يمكن ترتيب العوامل التى تضمنها نموذج الأنحدار المتعدد المرحلى ترتيبا تنازليا وذلك حسب قيمة معاملة التحديد الجزئى على النحو التالى: السنوات – ميعاد الزراعة المبكر (أول مايو) – ميعاد الزراعة المتوسط (أول يونيو) – معدل التفريط – طول الكوز –وزن الـ ١٠٠ حبة – إرتفاع النبات – التسميد الأزوتى – الأصناف.