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SOME MODELS OF PREDICTED EQUATIONS OF MAIZE RESPONSE YIELD TO FERTILIZER APPLICATIONS

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ABSTRACT

Two field trials were conducted at Giza Research Station, with split plot design with three replicates during the two successive summer seasons in 2012 and 2013. The aim of this study was to find out the effect of cotingen for covering seed by four treatments (zero, 7.5, 15 and 22.5 g kg^{-1} grain) and six nitrogen fertilizer levels (control, 30, 60, 90, 120 and 150 kg fed.$^{-1}$) on maize yield and yield attributes of single cross 10 cultivar. Stepwise multiple linear regression analysis was used to determine the importance of yield components and to predict the yield under different levels of nitrogen and cotingen rates. Nitrogen levels exhibited significant effect for all studied traits, while cotingen were significant for100-kernels weight; shelling% and grain yield traits only. The interaction between cotingen and Nitrogen was significant for row per ear, shelling% and grain yield. Meanwhile, stepwise linear regression analysis showed that 100-kernels weight, number of kernels per row and shelling% were the most important contributing traits to yield (R^2 = 82.11%).

The nitrogen rates for maximum yield derived from the four statistical models (linear, logarithmic, quadratic, and exponential) describing the response of yield, using the R^2statistic to select a model**,** which shows how each of the models fits the data. The quadratic model best described the yield responses observed in this study. Further confirms the role of nitrogen and cotingen fertilizers in increasing yield production in maize. The 5th N rate under 3rdcotingen (120 Kg fed^{-1} + 22.5 and 15g kg^{-1} grain) produced the highest yield being 34.70 and 34.65 ard. fed^{-1} over all treatments. This is very close to recommendations. The 4th N (90Kg fed^{-1}) rate under any cotingen level produced higher yield than any nitrogen rate only. Economically, considering optimum N fertilization rate, 105.18 Kg fed^{-1} nitrogen and 22.5 g kg^{-1} grain cotingen was the most reasonable level. This is considerably below the current recommendation. Therefore, results confirmed that higher cotingen treatment decreased the optimal nitrogen and increased the yield.

INTRODUCTION

Corn (*Zea maize* L.) is one of the most important cereal crops grown principally during the summer season in Egypt. Maize grain is used for both human consumption and poultry feed. The local production of the crop is not sufficient to meet the continuous increase of consumption. Therefore, attempts to increase maize production are of great importance.

Such attempts could be achieved through horizontal and vertical expansions. Intensive farming practices that aims to produce higher yield, require extensive use of agro-chemicals which are costly and create environmental pollutions **(Kozdro et al 2004).** Nitrogen is required in large quantities for plants to grow and is mainly provided in the form of synthetic chemical fertilizers.

Recommendations for fertilization of crops are derived from field studies in which crop yield and quality responses to a range of fertilizer rates are measured. Responses are often modeled to determine optimum fertilizer rate. Today, the relationship of nutrient management to environmental pollution also is an important aspect of any fertilization recommendation. There are many mathematical models for fitting crop response data. The research

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seeks to find a model that describes the data well and aids in defining reasonable fertilization recommendations that result in optimum crop yield and quality without risking over fertilization **(Marvi, 2008**).

In a study using stepwise regression under normal condition grain depth, grain number per row and plant height consider useful selection criteria of increasing in grain yield, stepwise regression indicated that row number per ear and 1000-grain weight was the most suitable inputs to the statistical model **(Shoae Hosseini et al 2008**).

Several different response models have been used to identify economic optimum rates of N fertilization, and many researchers have noted that these models often disagree when identifying these rates (**Nelson et al 1985; Blackmer and Meisinger, 1990**)

A standardized procedure for selecting one model over others has not been adopted, however. Moreover, the importance of the disagreements among models when identifying economic optimum rates of fertilization has received little attention in recent discussions evaluating tradeoffs between the profitability and the environmental costs of crop production and decisions concerning optimal rates of fertilization usually are based on the use of a model with little or no discussion of why this model was selected over other models.

The effect of N fertilizer on the yield of agricultural crops can be studied using N response functions. Such functions are usually fitted to the data from N rate trials by regression. The available function types used for modeling purposes in the course of this discussion are for example, quadratic (**Lambert et al 2002 and Hernandez and Mulla, 2008**) or the linear functions (**Wagner, 1999**) and the Mitscherlich, which is a kind of exponential model **(Lark and Wheeler, 2003**). Other researchers had additionally investigated the quadratic model **(Cerrato and Blackmer, 1990**) and even more complicated models **(Colwell, 1994)**. On the basis of the assessed production functions, expost analyses were carried out for the economically optimum N application. Meanwhile, cotingen treatments may improve the provided faster germination, better leaf growth and plant growth, then increase yield.

Our objective was to compare and evaluate four statistical models (linear, logarithmic, quadratic and exponential) describing the response of grain yield to N fertilizer application under cotingen treatments. More specifically, we focused on fitting each model to data collected from six N rates under four cotingen treatments and selecting the best model on the bases of comparing coefficients of determination (R^2). Therefore, calculated economic optimum N rates were estimated and trends in differences between measured and calculated data. Then, alternative recommended level was determined.

MATERIALS AND METHODS

Field Experiments

Two field experiments were carried out during the two successive seasons (2012 and 2013) at the experimental farm of Giza Research Station to study the effect of N and bio-fertilizer (Cotingen) rates on growth, yield and quality of corn **(*Zea mays* L.)** single cross 10 (S.C.10).

Some physical and chemical analysis of the used soil is presented in **Table (1)**. Each experiment included twenty four treatments. Cotingen treatments were seed covering at four bio-fertilization rates (non fertilized, 7.5, 15 and 22.5 g kg^{-1} grain). Nitrogen treatments were ammonium nitrate broadcast and incorporated into the soil at six N- fertilization levels (non fertilized, 30, 60, 90, 120 and 150 kg N $fed.^{-1}$). All plants in the 2^{nd} and 3^{rd} rows are harvested and adjusted to 15.5% moisture. All recommended cultural operations were carried as usual in both seasons (phosphorus at a rate of 30 Kg P_2O_5 fed^{-1} in the form of superphosphate (15 % P_2O_5) and Potassium at a rate of 24 Kg K_2O per fed. in the form of potassium sulphate (48 % K_2O) were added before planting). Soil samples at (0-30cm depth) were taken from the experimental site before planting for physical and chemical analysis according to **Page et al (1982)**.

Experimental treatments were arranged in a split plot design with three replications in both seasons. Cotingen rates were arranged in the main plots, while Nitrogen rates were randomly allocated to the sub plots. The area of each plot was 1/400 feddan, including 5 rows, three meters long and 70 cm wide. In both seasons, grains of maize (*Zea mays* L.) single cross 10 were sown on 15^{th} and 20^{th} June in the both seasons, respectively.

At harvest time after 120 days from planting, three medium rows were taken from each plot in which grain yield was determined on the basis of 15.5 % moisture and the following data were recorded: number of ears per plant, ear length (cm),

Table 1. Some physical and chemical analysis of the experimental soil over two seasons

Soil characters	Physical analysis	Soil characters	Chemical analysis
Corse sand %	25.1	PH (1-2.5 suspension)	8.3
Fine sand	-	Ec (m mohs cn^{-1})	2. 3
Silt%	31.5	OM%	1.8
Clay%	45.8	Available N ppm	33.8
Soil texture	clay	Available P ppm	15.5
		Available K ppm	119

number of rows per ear, number of kernels per row, 100-kernel weight (gm), ear weight (gm), ear kernel weight (gm), yield per feddan (ard fed^{-1}) and shelling%.

Statistical analysis and Model Description

Analysis of variance of the two growing seasons was carried out according to the procedure out lined by **Gomez and Gomez (1984)**.

Correlations among different maize traits and stepwise multiple linear regression procedure was used according to **Draper and Smith (1966)** to determine the variable accounting for the majority of total yield variability.

Four statistical models (linear, logarithmic, quadratic and exponential) describing the response of (Y) yield ard fed^{-1} to (N) fertilization rate in kg fed^{-1}, were fit to the data from each year.

-The linear model is defined by this equation (1):

$$Y = a + bN$$

-The logarithmic model is defined by equation (2):

$$Y = a + b\ln(N)$$

-The quadratic model is defined by equation (3):

$$Y = a + bN + cN^2$$

-The exponential model (i.e., the Mitscherlich model) is defined by equation (4):

$$Y = a\ exp^{(bN)}$$

Where; *a*, *b*, and *c* are parameter estimates (*a* = intercept parameter, *b*= linear response coefficient; *c* = quadratic response coefficient (**Overman et al 1994**).

The coefficients of determination (R^2) were computed from the analysis of variance: R^2 = 1 - (residual SS/corrected total SS), where SS is the sum of squares. The SEs of total and marketable yields for the models was calculated according to the equation (5):

$$SE = [\frac{\sum (Y_{meas} - Y_{calc})^2}{n-3}]^{1/2}$$

Where Y_{meas}: is the measured yield, Y_{calc}: is the calculated yield, and n: is the number of observations. The analysis of residuals (measured yields - calculated yields).

The economically optimum fertilizer (N_{opt}) was calculated. The N_{opt} (kg N fed^{-1}) is defined as the rate of N application where £1 of additional N fertilizer returned £1 of maize grain yield, and it describes the minimum rate of N application required to maximize economic return (**Colwell, 1994**). This analysis assumes that fertilizer N costs are the only variable costs and that all other costs are fixed. The N_{opt} was calculated by setting the first derivative of the N response curve equal to the ratio between the cost of fertilizer and the price of grain yield for the selected models.

RESULTS AND DISCUSSION

Data in **Table (2)** showed the effect of Cotingen and Nitrogen levels on the studied traits of maize during the two seasons. Mean performance revealed significant differences between Cotingen treatments for 100-kernel weight, shelling% and yield (ard fed^{-1}) traits. The 3rd cotingen rate recorded highest value for 100-kernel weight, shelling% and yield.

In addition, Nitrogen fertilizer had highly significant differences for all traits, which demonstrated an existence of high effect of different N fertilizer levels. Yield revealed highest value under 5th nitrogen level.

The results in this experiment was in agreement with the results of other researchers such as **Sadeghi and Bahrani (2002)** and **Ibrahim et al (2014)**, who indicated that applying more nitrogen rate in corn increased all characters and yield.

In terms of the interaction between cotingen treatments and N fertilizer levels, there were significant differences for row per ear, shelling % and yield (ard fed^{-1}) traits over the two seasons (not shown).

Table 2. Effect of different cotingen treatments and nitrogen levels on different traits of maize over the two seasons of 2012 and 2013

Fertilizer	Rate	E/p	El	R/e	K/r	100k	Ew	Kw	Sh%	Yield
Cotingen	0	1.08	22.09	12.36	44.93	38.56	265.82	213.82	79.78	25.03
	7.5	1.11	22.82	12.55	44.68	39.61	268.35	213.20	80.00	27.33
	15	1.17	22.69	12.20	43.30	40.50	258.40	212.12	81.99	28.98
	22.5	1.07	22.99	12.27	44.57	40.31	267.46	216.80	81.24	28.71
LSD		NS	NS	NS	NS	2.68	NS	NS	2.49	2.53
Nitrogen	0	1.01	20.62	11.68	40.13	35.98	219.46	177.17	78.56	17.63
	30	1.02	21.69	12.06	43.13	37.79	242.98	198.03	79.47	23.89
	60	1.06	22.37	12.29	44.01	38.29	258.83	209.53	80.14	28.42
	90	1.22	23.38	12.59	45.72	40.57	272.08	221.95	81.20	31.22
	120	1.17	23.72	12.67	46.53	42.03	291.53	233.80	81.96	32.29
	150	1.17	24.12	12.79	46.70	43.82	305.16	243.43	83.18	31.64
LSD		8.42	2.16	0.40	3.15	2.07	30.77	25.02	1.50	1.68

Number of ear per plant (E/p), ear length (El),number of row per ear (R/e), number of kernels per row (K/r),100- kernel weight (Hkw), ear weight (Ew), kernel weight (Kw), shelling ratio (Sh%) and yield (Y)**.**

The interaction between cotingen treatments and nitrogen fertilizer rates had significant effect on maize yield. Mean performance showed significant variation with the different fertilizer rates used. Data revealed that the lowest yield was obtained at zero nitrogen and cotingen (control) fertilizer rates (**Table 3**).The 4^{th} N (90Kg fed^{-1}) rate under any cotingen level produced higher yield (30.25, 31.40 and 32.64 ard fed^{-1}) than any nitrogen rate only (15.89, 22.96, 25.23, 27.22, 29.53 and 29.34 ard fed^{-1}). The increase in the yield following the addition of N compared to control gave the highest values. In respect to nitrogen, significant differences were detected for all levels, which demonstrated an existence of high effect of different treatments. The results were in agreement with the results of other researchers such as **Ghasemi-pirbalouti et al (2002**)**, Sadeghi and Bahrani (2002)** and **Ibrahim et al (2014**), who reported that applying more nitrogen rate in maize, increased yield and its components.

Correlation studies

The estimates of simple correlation coefficients for all comparisons among the studied traits are presented in **Table (4)**. The maximum correlation coefficient value was detected between ear weight and kernel weight (0.812^{**}). Grain yield had a positive and significant correlation with all traits. The 100-kernal weight revealed highest correlation coefficient value with grain yield (0.714^{**}).In the same context, grain yield exhibited high correlation coefficient values with each of shelling % (0.652^{**}), number of kernel per row (0.640^{**})**,**kernel weight (0.628^{**}),number of row per ear (0.621^{**}),ear weight (0.608^{**}),ear length (0.553^{**}) and number of ear per plant (0.405^{**})**.**These results are in line with those confirmed by **Khazaei et al (2010), Khodarahmpour and Hamidi (2012), Zamaninejad et al (2013) and Ibrahim et al (2014)**.

Stepwise regression analysis

The obtained results of stepwise multiple regression analysis (**Table 5**) showed that 82.11%, while adjusted R^2 = 80.89% of total variation in yield could be explained by100-kernels weight, number of kernels per row and Shelling %. **Khazaei et al (2010), Zamaninejad et al (2013) and Ibrahim et al (2014)** reported that number of kernels per row and1000-kernels weight were useful for the determination of an increase in yield. Stepwise regression results for maize yield indicated that the best prediction equation for yield (Ŷ) is formulated as follows:

$$\hat{Y} = -99.04 + 0.63^{*}\ Hkw + 0.95^{**}\ K/r + 0.74^{*}\ Sh\%.$$

Hence, it could be concluded that selection based on these traits, 100-kernels weight, number of kernels per row and shelling % is a more appropriate.

Table 3. Effect of the interaction between cotingen (C) treatments and nitrogen (N) levels on grain yield trait over two seasons 2012 and 2013

Fertilizer rate	N_1(0)	N_2 (30)	N_3 (60)	N_4 (90)	N_5 (120)	N_6 (150)	Mean
C_1 (0)	15.89	22.96	25.23	27.22	29.53	29.34	25.03[c]
C_2 (7.5)	16.57	25.8	28.56	30.25	31.06	31.76	27.33[b]
C_3 (15)	17.31	27.69	28.86	31.40	34.65	33.96	28.98[a]
C_4 (22.5)	17.17	26.80	28.72	32.64	34.70	32.25	28.72[a]
Mean	16.74 [f]	25.81 [e]	27.84 [d]	30.38 [c]	32.48 [a]	31.83 [b]	34.64

The same letters in mean column (C levels) or mean row (N levels), on the basis of Duncan test have no significant differences at 5% level.

Table 4. Correlation coefficients between all possible pair's combination of studied traits in *Zea mays* L. under cotingen and nitrogen rates

Trait	E/p	El	R/e	K/r	Hkw	Ew	Kw	Sh%
El	0.301**							
R/e	0.254**	0.482**						
K/r	0.305**	0.526**	0.530**					
100k	0.347**	0.518**	0.623**	0.550**				
Ew	0.239**	0.537**	0.638**	0.748**	0.732**			
Kw	0.294**	0.497**	0.587**	0.649**	0.724**	0.812**		
Sh%	0.357**	0.446**	0.337**	0.491**	0.695**	0.506**	0.491**	
Yield	0.405**	0.553**	0.621**	0.640**	0.714**	0.608**	0.628**	0.652**

Number of ear per plant (E/p), ear length (El), number of row per ear (R/e), number of kernels per row (K/r), 100-kernel weight (Hkw), ear weight (Ew), kernel weight (Kw), shelling ratio (Sh%) and yield (Y).

*, ** and ns indicates significant, highly significant and insignificant at the 0.05 and 0.01 level of probability.

Table 5. Stepwise regression between yield and related traits in maize

Independent variable	intercept	Regression coefficient			Accumulative partial R- Sq%	Std of estimate
		b1	b2	b3		
100-kernels weight	- 40.71	1.72**			73.74	2.93
kernels per row	- 55.72	1.15**	0.85**		80.43	2.56
Shelling %	- 99.04	0.63*	0.95*	0.74*	82.11	2.48

*and ** Significant at 5% and 1% of probability levels. **Adjusted R^2 = 80.89%.**

These findings are in accordance with the results obtained by **Khodarahmpour and Hamidi (2012), Zamaninejad et al (2013) and Ibrahim et al (2014)** who reported that some of these traits were useful for the determination of an increase in yield.

- Response of maize yield to fertilizer supply

Models of maize Response to Nitrogen

With the exception of some treatments, the majority of the data fitted the models fairly well as indicated by regression (R^2) values. Based on that, the N rates for maximum yield derived from some response models**,** regardless cotingen rates (with very low R^2 and insignificant models). The amount of fertilizers obtained for maximum yield differed between the responses models used. Several response models may produce any significant results when the data was evaluated, especially in cotingen treatments.

Although many mathematical functions could be chosen for this purpose, we have chosen the best fitted equation. The yield responded significantly in accordance with the 4 response models with increasing N. Because there is little biological basis for selecting one model over other, (**Nelson et al 1985**), R^2statistic usually is used to justify the use of a particular model. The limitation of using R^2statistic and standard error to select a model is further illustrated in (**Table 6**)**,** which shows how each of the models fits the data. The maximum regression (R^2) values by the response models were in the order: Quadratic (87.60) > Logarithmic (85.20) > Linear (72.80) > Exponential (69.40). This shows that, the Quadratic model tended to give higher maximum and best model compared to others (**Cerrato and Blackmer 1990**in maize**, Sadeghi 2008** in Lettuce and Spinach**, and Hartinee et al 2010** in rice) followed by Logarithmic and Linear response models.

The lines in **Figure (1)** are drawn from four fitted equations (Quadratic, Logarithmic, Linear and Exponential); the curves are. The model describes the pattern in the data rather well. This figure shows that some models fit the response data with less systematic bias than others and suggest that the Quadratic model fit well **(Cerrato and Blackmer 1990)**. The Quadratic model offers a useful tool for evaluation of maize response to applied N. Parameters a, b and c in Eq. [3] could be estimated from data by nonlinear regression.

Rates of nitrogen and cotingen fertilization for maximum yield

Figure (2 a, b and c) show the quadratic response curve at rates of N fertilization. This model often identified corresponded yield under four cotingen treatments. This figure also shows a tendency for the quadratic model to overestimate the slope of the response curve of N fertilization at lower rates of cotingen (each line) slightly less than higher rates. Indicating that, the effect of cotingen treatments with N fertilization were significant, especially cotingen treatment 3 and 4 (15 and 22.5 g kg^{-1} grain). Meanwhile, the differences between treatment 3 and 4 were insignificant. Hence, treatment 3 (15 g kg^{-1} grain) was the best one. In addition to Quadratic predicted equations describing maize grain yields response to nitrogen rates under four cotingen treatments (as a linear).

Finally, a comment on the issue of validation: It is believed that the extended quadratic model has been clearly validated as a useful mathematical description of yield response to applied nitrogen (**Cerrato and Blackmer (1990)**.

Optimum N fertilizer rate

Economically optimum N fertilizer rates (N_{opt}) for the selected quadratic model were computed for yield within each cotingen level. The N_{opt} for the quadratic model was computed for grain yield (from **Table 6 and Fig. 2**).

The quadratic model offers a useful tool for evaluation of maize response to applied N. Parameters a, b and c in **Eq. [3]** can be estimated from data by nonlinear regression. The N_{opt} (kg N fed^{-1}) is defined as the rate of N application, and it describes the minimum rate of N application required to maximize economic return. A summary of critical values of quadratic model were calculated, optimal N and peak N values is listed in **Table (7)**.

According the quadratic model under four cotingen (C) fertilizers rates **(Fig. 2)** as follows:

$$\hat{Y}_{C1\ (0)} = 16.524+0.1923N-0.0007N^2.$$

$$\hat{Y}_{C2\ (7.5)} = 17.66+0.238N-0.0009N^2.$$

$$\hat{Y}_{C3\ (15)} = 18.56+0.2415N-0.001N^2.$$

$$\hat{Y}_{C4\ (22.5)} = 17.79+0.2763N-0.0012N^2.$$

Fertilization rates of N_{peak} may be optimal for production because of diminishing returns obtained as N approaches N_{peak}. Therefore, optimum applied N rates would tend to be below N_{peak}. Then,

Table 6. Coefficient of determination (R^2 values) for five models describing maize grain yields response to nitrogen rates

Model	R^2	SE	Equation
Quadratic	87.60	2.10	$\hat{Y} = 17.616 + 0.238N - 0.001N^2$
Logarithmic	85.20	2.25	$\hat{Y} = 20.89 + 2.039 \ln(N)$
Linear	72.80	3.05	$\hat{Y} = 20.51 + 0.093N$
Exponential	69.40	0.14	$\hat{Y} = 20.186 \exp^{(0.004N)}$

$\hat{Y}$ = is the yield (ard fed^{-1}), N= is the Nitrogen fertilization rate (kg fed^{-1}), and ln = the natural logarithm.

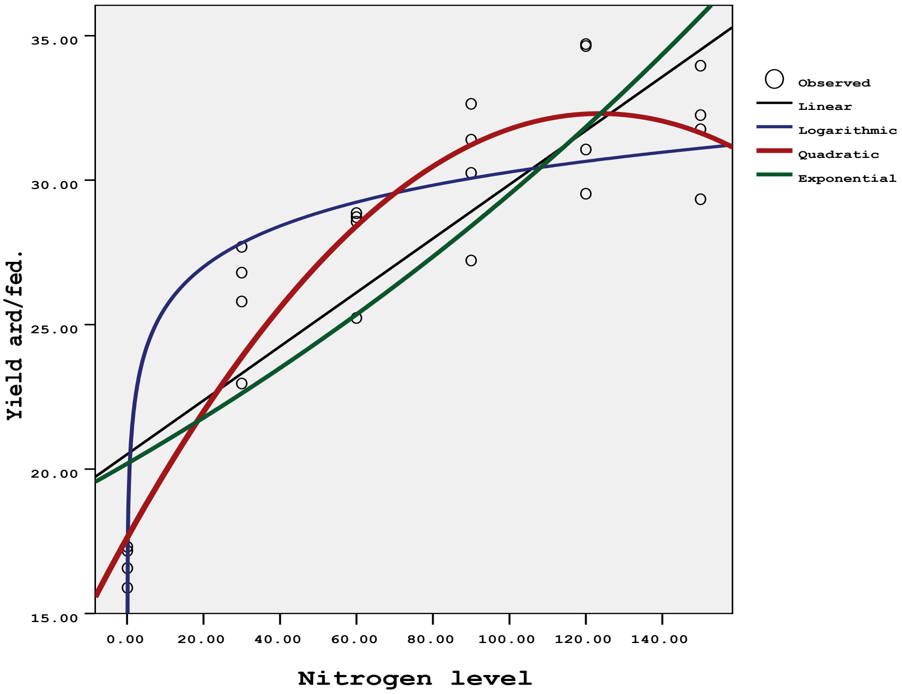
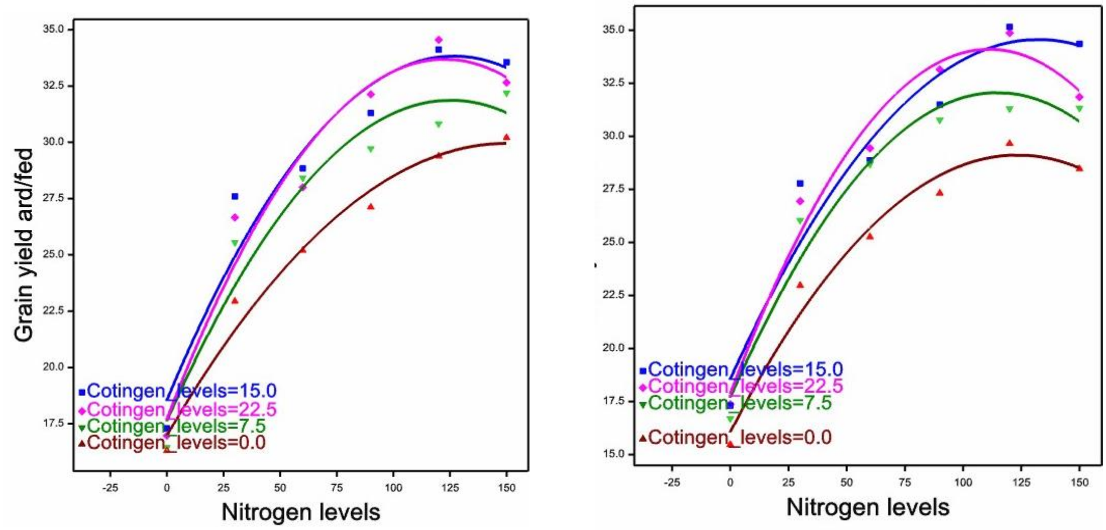
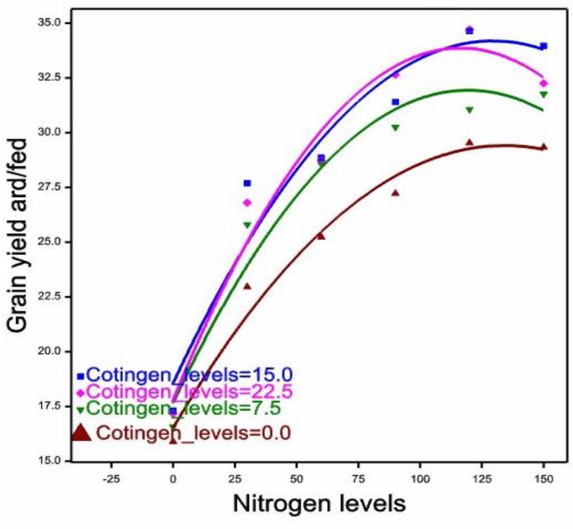


Fig.1. Example of maize yield response to N fertilization, indicating how each of the best four models fits the data.

according to results fertilization rates of $\mathbf{N_{opt}}$ optimum applied N rates was below $\mathbf{N_{peak}}$ (i.e., 120.30 < 137.36, 118.96 < 132.22, 108.81 < 120.75 and 105.18 < 115.13) for each cotingen level, respectively (**Colwell 1994**, **Marvi 2008**).

Results revealed decreasing $\mathbf{N_{peak}}$ and $\mathbf{N_{opt}}$ by increasing cotingen level. $\mathbf{N_{peak}}$ in comparison with $\mathbf{N_{opt}}$ values revealed $\mathbf{N_{opt}}$ value recorded (120.30, 118.96, 108.81 and 105.18 kg fed^{-1}) for the cotingen level (0.0, 7.5, 15.0 and 22.5 g kg^{-1} grain), respectively. The 5^{th} N rate under 3^{rd}cotingen (120 Kg fed^{-1} +15g kg^{-1} grain) recorded the highest yield 34.11 ard fed^{-1} over all treatments. $\mathbf{N_{opt}}$ was 108.81 Kg fed^{-1} for 3^{rd} cotingen level (15.0g kg^{-1} grain). Meanwhile, $\mathbf{N_{opt}}$ rate under 4^{th}cotingen (22.5 g kg^{-1} grain) was 105.18 Kg fed^{-1}. From analysis of the field studies, N appears to give the most reasonable level for a nitrogen fertilizer recommendation, viz. 105.18 Kg fed^{-1} nitrogen under (22.5 g kg^{-1} grain) cotingen. This is considerably below the current recommendation of 120 Kg fed^{-1}. The profit of the N fertilizer rate was calculated only with negligence cotingen, in view fewness the cotingen price. The most profitable N fertilizer rate was calculated by subtracting N costs from the gross profit. Results in **Table (7)** revealed that N rate under 4^{th}cotingen level (105.18 Kg fed^{-1} + 22.5 g kg^{-1} grain) was the most profit. Therefore, N 105.18 Kg fed^{-1} rate under 4^{th}cotingen was the most reasonable level and alternative recommendation.





Combined (c)

$\hat{Y}_{C\,(0)} = 16.524+0.1923N-0.0007N^{2}$. R^2= 96.30 Se= 0.985

$\hat{Y}_{C\,(7.5)} = 17.66+0.238N-0.0009N^{2}$ R^2= 93.10 Se= 1.50

$\hat{Y}_{C\,(15)} = 18.56+0.2415N-0.001N^{2}$. R^2= 90.20 Se= 1.98

$\hat{Y}_{C\,(22.5)} = 17.79+0.2763N-0.0012N^{2}$. R^2= 94.60 Se= 1.47

Fig. 2. Yield response curve to N fertilization, indicating how each line fits the data. The data correspond to total yield under four Cotingen treatments (C_0, $C_{7.5}$, C_{15} and $C_{22.5}$).

Table 7. Response of maize yield to nitrogen under four cotingen fertilizers rates (C_0, $C_{7.5}$, C_{15} and $C_{22.5}$)

Fertilizer rate	C1 (0)	C2 (7.5)	C3 (15)	C4 (22.5)	Observed mean
N_1(0)	16.52	17.66	18.56	17.79	17.63
N_2 (30)	21.65	23.93	24.97	25.01	23.89
N_3 (60)	25.48	28.40	29.69	30.09	28.42
N_4 (90)	28.02	31.07	32.74	33.04	31.22
N_5 (120)	29.27	31.94	34.11	33.84	32.29
N_6 (150)	29.23	31.00	33.80	32.51	31.64
Mean	25.03	27.33	28.98	28.71	27.51
N_{peak}	***137.36***	***132.22***	***120.75***	***115.13***	118.65
Y_{peak}	29.73	33.39	33.14	33.69	31.71
N_{opt}	***120.30***	***118.96***	***108.81***	***105.18***	106.71
Y_{opt}	29.53	33.24	33.00	33.58	31.57
Profit	**4665.02**	**5319.87**	**5320.28**	**5436.95**	**5078.81**

Means within a row followed by the same letters are not significantly different at 5% level by LSD.

N fertilizer (ammonium nitrate 33.5%) price: 4.179£ kg^{-1}, the yield product price=175£ ard^{-1} and Cp=0.0239.

N_{opt}: optimum nitrogen rate = (CP - b)/2c, N_{peak}: Peak nitrogen rate = $b_q/2c_q$, Y_{peak}: Peak production = $a_q+b_q/2N_{peak}$

CONCLUSION

The results of this study clearly indicate that the reason for selecting one model over others deserves more attention than it has received in the past when making decisions concerning amounts of fertilizer required for profitable crop production. These decisions could relate to selection of the most profitable rate of fertilization on a field scale or to weighing the costs (environmental as well as economic) and benefits of N fertilization on a regional or national scale. The quadratic model best described the yield responses observed in this study. Further confirms the role of nitrogen and cotingen fertilizers in increasing growth and yield in maize production. The 4th N (90Kg fed^{-1}) rate under any cotingen level produced higher yield than any nitrogen rate only. **N_{opt}** rate under 4thcotingen level was the most profit. Therefore, **N_{opt}** 105.18 Kg fed^{-1} rate under 22.5 g kg^{-1} grain cotingen was the most reasonable level and alternative recommendation. This **N_{opt}** rate was considerably below the current recommendation of 120 Kg fed^{-1}.

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