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ECONOMIC EVALUATION OF NITROGEN RESPONSE CURVE IN MAIZE

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By

Sh. A. Mansour , S.K. A.Ismail* I. Kh. Abbas and S. M. H. Ali Eissa ****

Maize Research Department, Field Crops Research Institute, Agriculture Research Center, Giza.
**Agronomy Department, Faculty of Agriculture, Fayoum University.*
*** Center Laboratory for Design & Statistical Analysis Research,*
Agriculture Research Center, Giza, Egypt.

ABSTRACT

Three field experiments were carried out at Sids Agricultural Research Station, Agricultural Research Center (ARC) during the seasons 2010, 2011 and 2012. The objectives of this study were to: 1) Evaluate the nitrogen levels effects (0, 30, 60, 90, 120 and 150 Kg N/fed) on grain yield (ard/fed) of Single Cross 10 (S.C 10), 2) Determine the response of grain yield to N fertilizer, and 3) Estimate the economic of N rate in maize. The highest grain yield (ard/fed) was produced by supplying 150 Kg N/fed in the three seasons. Quadratic model was the best of the tested models for describing the relationship between grain yields of maize hybrid (S.C 10) to N fertilizer. The economic optimum N rates (121.053, 120.645 and 120.129 Kg N/fed) were produced by adding (24.77, 21.69 and 25.17 ard/fed), respectively, and the net return (£.E 4780.61, 5682.78 and 6795.9/fed) in the three seasons, respectively.

Key words: *economic evaluation, nitrogen response curve, maize.*

1. INTRODUCTION

The economic optimum fertilizer rate is essential to maximize profitability and minimize potential negative environmental impacts of nitrogen fertilizer use. Decisions regarding the optimum rate of fertilizer require fitting some type of model to the data on yield collected when several fertilizer rates are applied. Cerrato and Blackmer (1990) fitted five response models namely: linear plus plateau, quadratic, quadratic plus plateau, exponential and square root to maize yield data in the USA. They found that quadratic plus plateau model was the best described response of maize yield to nitrogen fertilizer. Economic optimum rate of N fertilizer was 184 kg N ha^{-1}. Using quadratic response functions and a 1:10 N fertilizer : maize price ratio, Oberle and Keeney (1990) reported economic optimum N rates between 160 and 210 lb/acre on irrigated sandy soils and between 90 and 150 lb/acre on fine textured soils. In Wisconsin, USA, the N fertilizer rate required to maximize net return with maize was 160 to 170 lb/acre in high –yielding and low–yielding years (Vanotti and Bundy, 1994). Schlegel *et al*. (1996) demonstrated that in Kansas, USA, the economic optimum N rate for irrigated continuous maize was about 160 lb/acre. Response of maize grain yield to N fertilization under different plant densities was studied by El-Douby, *et al*. (2001). They found that the relation between grain yield and N fertilizer was described by the quadratic model.

Yield of maize is the integrated effect of many variables that affect plant growth during the season. Growth analysis and relative contribution studies may help in interpreting the results and perhaps lead the breeder to get better cultivars and good evaluation for the agricultural practices.

The objectives of this study were (i) Investigate the effect of N fertilizer on grain yield (ard/fed) to determine the response degree of grain yield to N fertilizer, (ii) Calculate the economic optimum N rates for maize yield. The techniques utilized include fitting polynomial curves and performing economic analysis of the response curves.

2. MATERIALS AND METHODS

The experiments were carried out to study the effect of six nitrogen fertilizer levels (0, 30, 60, 90, 120 and 150 kg N/fed) on maize grain yield of cultivar Single Cross 10 (S.C 10), to determine the degree of yield response to nitrogen fertilization as well as to estimate the economic optimum N rate. Three field experiments were conducted at Sids Agricultural Research Station, Agricultural

Research Center (ARC) in 2010, 2011 and 2012 seasons.

The experimental treatments were arranged in four replicates in a randomized complete block design. Plots consisted of five ridges, 3 m long and 70 cm apart. Planting was done in hills spaced 25 cm along the ridge. Plot area was 3X3.5 (10.5 m2). At harvest time, grain yield (ard./fed) was estimated on the basis of plot area (10.5 m2) and was adjusted to 15.5 % moisture content. Mechanical and chemical analysis of the soil at the experimental sites Jackosn (1973) are presented in Table (1). All cultural practices were applied as recommended.

2.1. Statistical analysis

Analysis of variance for a randomized complete block design was done according to (Gomez and Gomez, 1984) and **(**Draper and Smith, 1981) to the data of grain yield. Three response models were fitted to the grain yield data for the tested cultivar during the first, the second and the third seasons according to Neter *et al.* (1990) and Steel and Torrie (1980).

2.2. Nitrogen response curve Models

To describe maize grain yield response to N fertilizer, four statistical models (linear, quadratic, exponential, and square root) were fitted to the data using the regression curve procedure of the SPSS software. Economically optimum N rates (EONR) for the four models were computed for grain yields. The EONR (kg N fed) is defined as the rate of N application where £. E.1 of additional N fertilizer returned £. E. 1 of maize, and it describes the minimum rate of N application required to maximize economic return. This analysis assumes that N fertilizer costs are the only variable costs and that all other costs are fixed. The EONR 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 maize for the four tested models (Dustin *et al*., 2004).

For the four statistical models, Y is the grain yield in ard/fed, N is the N fertilization rate in kg N fed, and a, b, and c are parameter estimates using the regression curve procedure (Gilles Bélanger *et al*., 2000).

The linear model is

$$Y = a + bN$$

The quadratic model is

$$Y = a + bN + cN2$$

The square root model is Y = a + bN1/2

The exponential model is Y = e (a+bN)

The coefficients of determination (R^2), standard error of estimate (SE) and significance of the model were the bases considered comparing among the above mentioned response models. The significant model that had the highest (R^2) and the lowest SE was the best model for describing the relationship between grain yield and N fertilization.

Economically Optimum Nitrogen Rate and Yield at Economically Optimum Nitrogen Rate (EONR) were calculated for N rate and the yield response to N was calculated for all treatments. If the yield did not significantly increase with N application, the EONR was set at zero. If the yield curve function fitted a simple linear model, the EONR was the maximum N rate used (in this case

Table (1): Mechanical and chemical analysis of the soil at the experimental sites during the three seasons.

Properties	2010	2011	2012
Sand %	22.19	14.42	19.68
Silt %	32.60	28.58	34.6
Clay %	49.25	57.00	43.78
Texture	Clay	Clay	Clay
pH1:2.5	8.15	8.10	8.20
O.M %	2.04	2.02	2.04
CEC m.e./100 g soil	36.0	36.20	36.0
Total N %	0.180	0.156	0.157
NH4 ppm	5.70	5.90	15.20
NO2 ppm	0.11	0.32	0.23
NO3 ppm	20.20	15.13	19.30
Available (p) ppm	15.20	12.30	9.25
Available (k) m.e./100 g soil	0.91	0.91	0.90

Table (2): Costs and returns of maize production under N nitrogen treatments (£ E./fed).

Production Activity	2010	2011	2012
Land preparation	90	110	120
Seeding& planting	93	115	200
Irrigation	120	240	240
Fertilization	480	640	640
Weeding	280	350	350
Pest Control	20	30	30
Harvesting	225	350	350
Transportation	60	80	80
Other Expenses	60	80	80
Total without Rent	1428	1995	2090
Rent	1000	1666.67	1333.33
Total Cost	2428	3661.67	3423.33
Yield (ard/fed.)	24.2	21.8	26.0
The price of maize	£ E 193/ard	£ E 262/ard	£ E 270/ard
Main crop value	4670.6	5711.6	7020
Secondary crop value	190	200	200
Total Revenue	4860.6	5911.6	7220
Net Return	2397.86	2049.93	3596.67

120 kg N fed). If the yield curve function fitted a quadratic model, the EONR was calculated by setting the derivative of the gross return function in the following equation:

Net return= (a+ b x N rate + c x N rate^2) x (P_c – P_n) x N rate

Equal to zero. The gross return was calculated using this equation, where b0, b1, and b2 are intercept, linear, and quadratic parameters, respectively; pc is the price of maize; and pn is the cost of N. The prices of maize were (£ E 240/ard, 160/ard and 140/ard) in the three seasons, respectively. The prices of N fertilizer per kilogram were (£ E 4/kg and 5.3/kg) at the time of the experiment. The detailed costs of the inputs and other farm operations are presented in Table (2). Gross return comparison was made between EONR and a uniform N rate recommendation made by the University of Minnesota (Mamo *et al.*, 2003).

3. RESULTS AND DISCUSSION

3.1. Effects of nitrogen fertilizer on grain yield

The results of nitrogen fertilizer rates on grain yield ard/fed in maize single cross hybrid (S.C.10) are presented in Table (3). Grain yield (ard/fed) was significantly affected by N rates in the three seasons of the study.

These results indicated clearly that nitrogen levels had a significant effect on grain yield (ard /fed) in all the studied seasons. Application of 30, 60, 90, 120 and 150 kg N/fed increased grain yield /fed by 28.57 %, 50.99 %, 60.32, 70.79 and 88.26 % in the first season, 59.24%, 104.18%, 140.46, 164.29 and 206.42% in the second season and 28.96%, 67.19%, 78.23, 102.12 and 125.74 in the third season compared to the check treatment, respectively. The highest grain yield (30.39, 31.50 and 35.18 ard/fed) was obtained by using 150 kg N/fed, while the lowest grain yield of (16.14, 10.28 and 15.58 ard/fed was produced at the check treatment (zero nitrogen fertilizer) in all seasons, respectively. Also, the result of gross income was the same results of nitrogen fertilizer rates on grain yield ard/fed.

3.2. Benefit cost ratio analysis

Using the benefit cost ratio allows researchers to make decisions on the negatives and positives of investing in different nitrogen fertilizer rates. In other words, using benefit cost ratio analysis allows an entity to decide whether or not the benefits of a given nitrogen fertilizer rate outweigh the actual costs compared with the zero nitrogen fertilizer rate.

The results clearly indicated that the application of 30, 60, 90, 120 and 150 kg N/fed realized (1.409, 1.674, 1.691, 1.726, 1.863 and 1.582) in the first season 2010, (-0.177, 0.005, 0.130, 0.187, 0.319 and 0.021) in the second season 2011, in 2012 (-0.044, 0.175, 0.192, 0.288, 0.375 and 0.145).

3.3. Analysis of N response curve

Linear, quadratic, exponential and square root models were fitted to the grain yield data for the tested maize cultivar in the three seasons, respectively. Three bases were considered to compare among the four models *i. e* coefficient of determination (R^2), estimate standard error (SE) and the significance of the model. The significant model which had highest R^2 and lowest SE was the best model fitted to the yield data.

Table (4) shows the coefficient of determination (R^2), the standard error of estimate (SE) and the calculated F value of the four models to study the response of maize grain yield to N fertilizer during 2010, 2011 and 2012 seasons. Results clearly indicate that the best value of coefficient of determination, R^2, was in favor of quadratic model for the tested cultivar in the three seasons of the study. The values of R^2 of quadratic model were 93.4 %, 91.8% and 84.3 % in the three seasons, respectively. The second degree model had a standard error of estimate less than those of linear, exponential and square root models. Moreover, quadratic model had a significant calculated F value for the tested cultivar in the three seasons.

Therefore, the quadratic model was the best of the response models tested for describing the response of grain yield of maize cultivar S. C. 10 nitrogen fertilizer, (Table 4 and Figs 1 and 2). These results are similar to those obtained by Schlegel *et al.* (1996) and El–Douby *et al.* (2001) who reported that the relation between grain yield of maize and N fertilizer followed the quadratic model.

Maximum nitrogen rates estimated by the quadratic equation were 121.053, 120.645 and

Table (3): Effect of nitrogen fertilizer rates on grain yield (ard/fed) of maize cultivar(S.C.10) in 2010, 2011 and 2012 seasons.

Year	Characters	0	30	60	90	120	150	Mean
Nitrogen rates (N kg /fed) 2010	Yield (ard/fed)	16.144 A	20.756 B	24.377 C	25.882 CD	27.573 D	30.392 E	24.187
	%		28.57	50.99	60.32	70.79	88.26	49.83
	Gross income	3115.7 A	4005.9 B	4704.8 C	4995.2 CD	5321.7 D	5865.6 E	4668.2
	%		28.57	51.00	60.32	70.81	88.25	49.83
	Profit	1167.7	1937.9	2516.8	2687.2	2893.7	3317.6	2420.2
	Total cost	1948.0	2068.0	2188.0	2308.0	2428.0	2548.0	2248.0
	Benefit cost ratio	0.599	0.937	1.150	1.164	1.192	1.302	1.057
Nitrogen rates (N kg /fed) 2011	Yield (ard/fed)	10.280 A	16.37 B	20.99 C	24.72 D	27.17 D	31.500 E	21.84
	%		59.24	104.18	140.46	164.29	206.42	112.45
	Gross income	2693.3 A	4288.4 B	5501.6 C	6476.6 D	7118.5 D	8254.2 E	5722.1
	%		59.23	104.27	140.48	164.32	206.48	112.46
	Profit	-328.4	1106.8	2159.9	2974.9	3456.8	4432.5	2300.4
	Total cost	3021.7	3181.6	3341.7	3501.7	3661.7	3821.7	3421.7
	Benefit cost ratio	-0.109	0.348	0.646	0.849	0.944	1.160	0.639
Nitrogen rates (N kg /fed) 2012	Yield (ard/fed)	15.587 A	20.10 A	26.06 B	27.78 BC	31.503 CD	35.186 D	26.04
	%		28.96	67.19	78.23	102.12	125.74	67.06
	Gross income	4208.5 A	5428.1 A	7034.9 B	7499.9 B	8505.9 BC	9500.3 D	7029.6
	%		28.98	67.16	78.21	102.11	125.74	67.03
	Profit	1425.2	2484.8	3931.6	4236.6	5082.6	5917	3846.3
	Total cost	2783.3	2943.3	3103.3	3263.3	3423.3	3583.3	3183.3
	Benefit cost ratio	0.512	0.844	1.267	1.298	1.485	1.651	1.176

***LSD value at 1%**

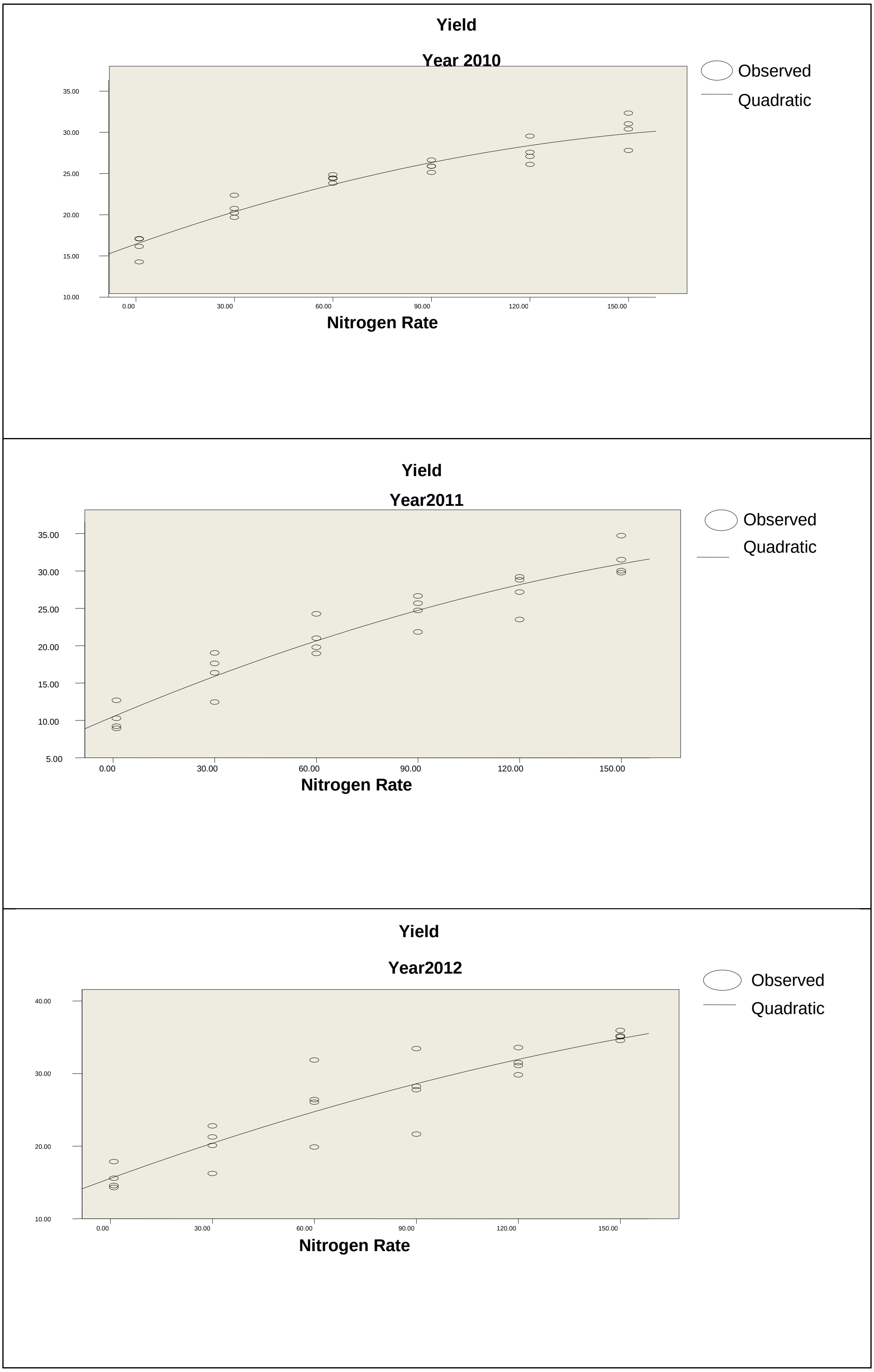

Fig. (1): Nitrogen response curves

Table (4): Coefficient values of determination (R^2), standard error of estimate (SE) and calculated F value for models describing the relationship between N rate and grain yield of maize cultivars in 2010, 2011 and 2012 seasons.

Year	Cultivars Models	Regression equations	R^2 %	S.E.	F (cal)	P
2010	Linear	Y=17.53+ 0.0887 N	91.0	1.495	221.9	0.00
	Quadratic	Y=16.537+0.138N-0.00057N**2	93.4	1.308	148.9	0.00
	Square root	Y=14.55+1.23 N^0.5	93.8	1.537	332.8	0.00
	Exponential	Y = 17.687 +0.004 exp(N)	87.2	0.080	149.5	0.00
2011	Linear	Y=11.679+0.135 N	90.7	2.327	213.6	0.00
	Quadratic	Y=10.638+0.187N-0.000775N**2	91.8	2.231	117.6	0.00
	Square root	Y==7.35+1.85 N^0.5	90.6	5.417	213.4	0.00
	Exponential	Y = 12.072 +0.007 exp(N)	84.7	0.159	122.1	0.00
2012	Linear	Y=16.470+0.12754N	83.6	3.019	112.4	0.00
	Quadratic	Y=15.692+0.1665N-0.0006937N**2	84.3	3.027	56.35	0.00
	Square root	Y==12.51+1.73 N^0.5	82.3	9.863	102.3	0.00
	Exponential	Y = 16.824 +0.005 exp(N)	81.5	0.134	96.81	0.00

120.129 kg N/fed in the three seasons, respectively. (Table 5). The results showed that cultivar S.C.10 out yielded in the three seasons at the maximum level of fertilizer nitrogen recording 24.89, 21.92 and 25.69 ard/fed in the three seasons, respectively.

3.5. Economic analysis

The results in Table (6) show the economic analysis of nitrogen fertilizer. In the first season, the optimum nitrogen rate was 106.433 kg N/fed. Grain yield produced by supplying the optimum N dose was 24.77 ard/fed giving return equals to £ E 4780.61/fed. In the second season , adding the optimum N rate 101.53 kg N/fed gave grain yield of 21.69 ard/fed and return equal to £ E 5682.78/fed. In the third season optimum N dose was 92.84 kg/fed gave grain yield 25.17 ard/fed giving return equals to £ E 6795.9/fed. Similar results were obtained by Cerrato and Blackmar (1990), Oberle and Keeney (1990), Vanotti and Bundy (1994), Schlegel *et al*. (1996) and William *et al*. (2004).

Price of nitrogen = £ E 4/kg-2010 and £ E 5.3/kg for 2011 and 2012.

Price of maize grain = £ E 193/ard -2010, 262/ard-2011 and 270/ard-2012.

Table (5): Quadratic regression equations, maximum nitrogen rate and grain yield at the maximum nitrogen rate for maize cultivars in the 2010, 2011 and 2012 seasons.

Seasons	Regression equations	Maximum N rate (kg/fed)	Yield at the maximum N rate (kg/fed)
2010	Y=16.537+0.138N-0.00057N**2	121.053	24.89
2011	Y=10.638+0.187N-0.000775N**2	120.645	21.92
2012	Y=15.692+0.1665N-.0006937N**2	120.129	25.69

Table(6): Economic analysis of nitrogen fertilization for maize cultivars in 2010, 2011 and 2012 seasons.

Seasons	Optimum N rate (kg /fed)	Yield at the optimum N rate (ard/fed)	Net return (£ E /fed)
2010	106.433	24.77	4780.61
2011	101.530	21.69	5682.78
2012	92.840	25.17	6795.9

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تقييم اقتصادي لمنحنيات استجابة الذرة الشامية للتسميد الآزوتي

شابون عبدالعزيز منصور - سمير كامل علي اسماعيل* - ايمان خليل عباس- سعيد محمد حسين عيسي ****

قسم بحوث الذرة الشامية - معهد المحاصيل الحقلية - مركز البحوث الزراعية- الجيزة.

* قسم المحاصيل - كلية الزراعة - جامعة الفيوم .

**المعمل المركزي لبحوث التصميم والتحليل الإحصائي ، مركز البحوث الزراعية – الجيزة- مصر.

ملخص

أقيمت ثلاث تجارب حقلية في محطة البحوث الزراعية بسدس – مركز البحوث الزراعية خلال المواسم (2010و2011 و 2012) بهدف دراسة :-

1- تقييم تأثير معدلات السماد الآزوتي (صفر- 30-60-90- 120- 150 كم أزوت/فدان) على محصول حبوب الذرة الشامية هجين فردى 10 .

2- تحديد انسب درجة لهذة العلاقة بين محصول الحبوب و السماد الآزوتي.

3- تقدير المعدل الاقتصادي الأمثل للسماد الآزوتي.

أوضحت النتائج أن أعلى محصول حبوب للفدان تحقق نتيجة التسميد بمعدل 150 كجم أزوت/فدان. وأن العلاقة بين التسميد الآزوتي و محصول حبوب الذرة الشامية تتبع الدرجة الثانية حيث كان منحنى الدرجة الثانية أفضل المنحنيات لوصف هذه العلاقة.

كان المعدل الاقتصادي الأمثل للسماد الآزوتي هو (121.053، 120.645 و 120.129 كم أزوت/فدان) فى المواسم الثلاث على الترتيب. كما بلغ محصول الحبوب على أساس المعدل الاقتصادي الأمثل للسماد الآزوتي 24.77 و 21.69 و 25.17 إردب/فدان فى المواسم الثلاث على الترتيب . وصل الدخل 4780.61 و 5682.78 و 6795.90 جنيها/فدان فى المواسم الثلاث على الترتيب.