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Balanced Fertilization to Maximize Economic Yield of Corn under Calcareous Soil Conditions

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THIS study was carried out at El-Hamam, West Delta, Egypt, which was typically sandy loam soil. The experimental location was shaped so as two field experiments could be established both through two seasons (2005 and 2006). Corn var. Pioneer was the test crop in the two experiments. The aim of this study was approach a nutrient balance and attained maximum the yield of corn by applying NPK fertilizers to the soil. The obtained results show that the yield parameters of corn, nutrients concentration and uptake by plants were proportional to the rates of NPK during the 1st season. The compound treatment of 100N:50P_2O_5:80K_2O kg/fed surpassed other treatments in all studied corn parameters and produced 8.14 and 3.16 ton/fed of stalks and grains, respectively, in the 1st season. In the 2nd season, NPK rates were modified in a trial to approach a nutrient balance case. The optimum fertilizer treatment 90N:60P_2O_5 : 90K_2O kg/fed increased nutrients concentration and uptake, except for P, when compared with the $N_2P_3K_2$ 90N : 70P_2O_5:90K_2O treatment. This treatment gave 7.13 and 4.02 ton/fed of corn stalks and grains, respectively. Thus, decreasing N and increasing P and K rates in the 2nd season seemed to offer better nutrient balance to the grown plants and yield. Regression equations were established to help draw fertilizer recommendations for corn under calcareous soil conditions. The results assure that the 90N:60P_2O_5 : 90K_2O kg/fed treatment was the best fertilizer culmination for corn under El-Hamam soil conditions and the like ones.

Keywords: Corn, Sandy loam soil, Balanced NPK fertilizers.

Regarding the urgent need to meet food demand in Egypt, more desert soils whether sandy or sandy calcareous have to be brought into use. Such soils are typically characterized by being poor with respect to their physico- bio- chemical properties, and fertility status, as well.

Muhammad *et al.* (2004) reported that compound fertilizer level of 350N-200P_2O_5-275K_2O kg/ha produced the highest grain yield of corn (7.05 ton/ha). In their work, the treatment of 225N - 90P_2O_5-150K_2O kg/ha produced 7.84 and 8.41 ton/ha of corn grains grown in sandy and sandy loam soils, respectively. Manjunath *et al.* (2006) decided that corn grain yield increased proportionally to NPK rates. The results of Iqbal *et al.* (2006) revealed that corn crop grown in association with cowpea and supplied with fertilizers at 150N-

$100P_2O_5$-$100K_2O$ kg/ha produced the highest mixed forage yield of 58.62 ton/ha. In addition, the optimum grain yield (10.8 ton/ha) was obtained with the application 300 kg of each N, P_2O_5, K_2O/ha for sole maize. This treatment was remarkably higher than the control treatment by 46 % (Silwana *et al.*, 2007). On the same track, El-Hallof & Sarvari (2006) reported that the optimum fertilizer treatment was $120N:75P_2O_5:90K_2O$ kg/ha, which gave a yield of corn increasing an about 3-5 ton/ha. Bertic *et al.* (2006) assured that the optimum fertilizer treatment was to apply 120N : 200 P_2O_5 : $200K_2O$ kg/ha instead of 240N: $200P_2O_5$: $200K_2O$ kg/ha.

Concerning nutrients concentration and uptake in corn grains, Heckman *et al.* (2003) reported that the min. and max. nutrient concentration amounted to 10.2 and 12.9 g N /kg, 2.2 and 5.4 g P/kg, 3.1 and 6.2 g K/kg. Singh *et al.* (2007) reported that the highest N, P and K uptake values by grains were 106.91, 40.97 and 87.08 kg/ha, respectively. The objective of this study was to approach a nutrient balance case and reach a maximum yield of corn by applying the least amount of NPK fertilizers to the soil.

Material and Methods

Two successive years (2004 and 2005) completely randomized field experiments with three replications for each treatment was carried out in El-Hamam, (between the intersection of the longitude 30° 35' 58" N and the altitude 30° 16' 43" E). Some physico- chemical properties and available nutrients of the studied soils were reported in Table 1. The experimental field was flood irrigated of 15x5m dimensions for the experimental plots. Rows within the plots were spaced 50cm apart and plants were spaced 20cm apart in the row. Corn variety Pioneer was the test crop.

TABLE 1. Physico- chemical properties and available nutrients of the experimental soil*.

Depth cm	pH	E.C dS/m	OM	$CaCO_3$	Sand	Silt	Clay	C.E.C Cmol/kg	Texture
			%						
0-30	8.36	1.51	2.97	27.4	68.09	16.02	15.89	12.13	S.L
30-60	8.44	1.65	2.15	30.6	60.48	21.16	18.36	15.10	S.L

Soluble cations and anions in soil (mc/L)							
Depth	Na	K	Ca	Mg	HCO_3^{-1}	Cl^{-1}	SO_4^{-2}
0-30	3.87	0.58	4.90	5.75	0.80	9.67	4.63
30-60	4.56	0.60	5.39	5.95	0.85	10.44	5.21

Available nutrients in soil (µg/g)							
Depth	N	P	K	Fe	Mn	Zn	Cu
first season							
0-30	43.4	10.4	81	4.47	3.03	0.89	0.37
30-60	41.1	8.81	87.5	5.54	3.47	1.05	0.41
second season							
0-30	38.2	8.67	76.3	3.71	1.93	0.63	0.23
30-60	34.8	5.16	81.4	4.65	2.57	0.98	0.34

* Determine according to Page *et al.* (1982) and Klute (1984).

The experimental treatments were selected as follows: a control treatment, N_1P_1K, $N_1P_1K_2$, $N_1P_2K_1$, $N_1P_2K_2$, $N_1P_3K_1$, $N_1P_3K_2$, $N_2P_1K_1$, $N_2P_1K_2$, $N_2P_2K_1$, $N_2P_2K_2$, $N_2P_3K_1$, $N_2P_3K_2$ and the farmer (traditional) practice for comparison. Organic matter was incorporated into the surface soil layer of the soil at $15m^3$/fed during seedbed preparation. Nitrogen, P and K were applied to corn plants during the two seasons according to the following confounded fertilizer treatments (Table 2). All phosphorus amounts were added with the time of adding organic matter. Nitrogen and potassium fertilizers were split into three equal doses that were applied after 20, 40 and 60 days after sowing. Note worthy that, fertilizer amounts, to be applied, were aimed to fulfill just above the sufficient level of each nutrient in the studied soils. Consequently, Table 2 depicts the actually applied amounts that were input to the soil every season.

Plant samples were collected at three growth stages, 20, 40 days and at harvest. At the end of each experiment, the biological, grains, and stalks yields were recorded. Plant samples were analyzed for N, P and K after Cottenie *et al.*, (1982). Data were statistically analyzed according to Gomez & Gomez, (1984).

TABLE 2. Applied NPK rates to corn through the studied two seasons*.

Fertilizers	1st season	2nd season
Control	0	0
N_1	80	70
N_2	100	90
P_1	30	50
P_2	40	60
P_3	50	70
K_1	60	80
K_2	80	90
Farmer	N 33.5 kg/fed and P_2O_5 15.5kg/fed	

* As N, P_2O_5 and K_2O kg/fed.

Results and Discussion

After the application of different NPK treatments, the following exhibit will deal with the response of corn plants in the form of chemical composition (nutrient concentration), uptake, grains and stalks yields. So, the effect of enhanced fertility status of soil nutrients will be examined to furnish the fertilizer treatment design on the basis of sufficient level of each nutrient. The important role of the so-called balanced fertilization with macro-nutrients will be examined and reformulated in the second season.

Effect of fertilizer treatments on the yield of corn

Data shown in Table 3 present the affect of fertilizer treatments under study o yield of corn compared to the control treatment, all fertilizer treatments proved to be significantly higher. In the 1st season the superior fertilizer treatment was

($N_2P_3K_2$), *i.e.*, 100N, $50P_2O_5$ and $80K_2O$ kg/fed which produced 8.14 and 3.16 ton/fed of stalks and grains of corn, respectively. In the 2nd season, it become ($N_2P_2K_2$), *i.e.*, 90N, $60P_2O_5$ and $90K_2O$ kg/fed which achieved 7.13 and 4.02 ton/fed of stalks and grains. This can be attributed to modifying the fertilizer rates in sequence in the 2nd season by reduce applied N and raising both P and K in trial to approach a nutrient balance.

The above results agreed with those by Iqbal *et al.* (2006), Manjunath *et al.* (2006), Silwana *et al.* (2007) and Bertic *et al.* (2006) who showed that the optimum fertilizer treatment was 120N: $200P_2O$:$200K_2O$ kg/ha instead of 240N:$200P_2O$:$200K_2O$ kg/ha with sufficient available P and K.

TABLE 3. Effect of fertilizer treatments on the yields of corn.

Treatments	Bio.	Stalks	Grains	Bio.	Stalks	Grains
	ton/fed					
	First season			Second season		
Control	2.51	1.64	0.87	2.34	1.59	0.75
$N_1P_1K_1$	6.74	4.57	2.17	6.63	4.28	2.35
$N_1P_1K_2$	7.39	5.13	2.26	7.05	4.57	2.48
$N_1P_2K_1$	7.48	5.19	2.29	7.24	4.76	2.48
$N_1P_2K_2$	7.71	5.39	2.32	7.41	4.82	2.59
$N_1P_3K_1$	7.80	5.44	2.36	7.62	4.99	2.63
$N_1P_3K_2$	7.96	5.49	2.47	8.26	5.37	2.89
$N_2P_1K_1$	8.68	6.10	2.58	8.97	5.99	2.98
$N_2P_1K_2$	8.93	6.27	2.66	9.41	6.20	3.21
$N_2P_2K_1$	10.27	7.39	2.88	10.68	6.97	3.71
$N_2P_2K_2$	10.66	7.70	2.96	11.15	7.13	4.02
$N_2P_3K_1$	10.74	7.77	2.97	10.35	6.89	3.46
$N_2P_3K_2$	11.30	8.14	3.16	10.60	6.95	3.65
Farmer	5.64	3.88	1.76	5.35	3.72	1.63
LSD 0.05	0.78	0.59	0.19	0.76	0.55	0.21

Effect of fertilization treatments on the nutrients concentrations and uptake by corn

In the 1st season, increases in nutrients concentrations at different stages of corn growth took place in response to increased rates of NPK. Data in Table 4 revealed that the best fertilizer treatment in the 1st season was 100N:$50P_2O$:80 K_2Okg/ha. The latter treatment showed highest NPK concentrations in plant tissues during different stages of corn growth as compared with other treatments.

TABLE 4. Effect of fertilizer treatments on NPK concentration (%) of corn tissues at different stages of growth.

Fertilizer Treatments	N				P				K			
	Tasling	Silking	Stalks	Grains	Tasling	Silking	Stalks	Grains	Tasling	Silking	Stalks	Grains
First season												
Control	1.03	0.56	0.21	0.28	0.22	0.13	0.06	0.09	0.95	0.55	0.19	0.12
$N_1P_1K_1$	1.50	1.15	0.44	0.60	0.27	0.17	0.10	0.13	1.40	0.89	0.27	0.19
$N_1P_1K_2$	1.52	1.27	0.49	0.67	0.28	0.19	0.12	0.15	1.61	1.06	0.32	0.23
$N_1P_2K_1$	1.69	1.30	0.50	0.68	0.38	0.28	0.18	0.24	2.11	1.18	0.39	0.30
$N_1P_2K_2$	1.73	1.40	0.55	0.72	0.38	0.30	0.21	0.26	2.22	1.30	0.45	0.34
$N_1P_3K_1$	1.76	1.44	0.57	0.73	0.45	0.34	0.23	0.29	2.72	1.75	0.57	0.39
$N_1P_3K_2$	1.91	1.50	0.67	0.78	0.47	0.36	0.24	0.31	3.51	2.19	0.64	0.48
$N_2P_1K_1$	2.87	2.16	0.79	1.14	0.32	0.21	0.15	0.18	1.49	0.94	0.30	0.21
$N_2P_1K_2$	3.10	2.34	0.86	1.23	0.34	0.23	0.17	0.19	1.83	1.19	0.37	0.25
$N_2P_2K_1$	3.10	2.48	0.89	1.30	0.42	0.31	0.25	0.28	2.34	1.43	0.43	0.32
$N_2P_2K_2$	3.24	2.55	0.94	1.34	0.43	0.34	0.26	0.29	2.40	1.45	0.52	0.36
$N_2P_3K_1$	3.26	2.62	1.07	1.49	0.49	0.38	0.27	0.33	2.96	1.98	0.60	0.44
$N_2P_3K_2$	3.51	2.72	1.14	1.54	0.50	0.39	0.29	0.34	3.72	2.62	0.67	0.53
Farmer	1.39	1.19	0.37	0.52	0.24	0.18	0.09	0.12	1.17	0.74	0.24	0.15
LSD 0.05	0.02	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.05	0.04	0.02	0.03
Second season												
Control	0.88	0.55	0.19	0.24	0.20	0.11	0.05	0.08	0.81	0.47	0.17	0.10
$N_1P_1K_1$	1.40	1.07	0.42	0.59	0.40	0.30	0.16	0.22	1.57	0.92	0.34	0.21
$N_1P_1K_2$	1.50	1.24	0.47	0.66	0.44	0.32	0.17	0.24	1.86	1.40	0.44	0.31
$N_1P_2K_1$	1.62	1.30	0.48	0.68	0.64	0.43	0.26	0.31	2.52	1.54	0.49	0.34
$N_1P_2K_2$	1.65	1.35	0.53	0.71	0.67	0.45	0.28	0.33	2.88	1.68	0.51	0.38
$N_1P_3K_1$	1.74	1.40	0.55	0.78	0.71	0.49	0.32	0.38	3.59	2.44	0.65	0.53
$N_1P_3K_2$	1.91	1.46	0.62	0.85	0.74	0.52	0.34	0.39	4.40	2.98	0.66	0.57
$N_2P_1K_1$	2.71	2.05	0.77	1.08	0.47	0.34	0.20	0.25	1.82	1.03	0.38	0.25
$N_2P_1K_2$	2.83	2.20	0.83	1.17	0.49	0.36	0.21	0.27	2.18	1.55	0.46	0.32
$N_2P_2K_1$	3.02	2.53	1.01	1.35	0.73	0.48	0.30	0.35	3.89	2.82	0.68	0.57
$N_2P_2K_2$	3.20	2.63	1.08	1.40	0.75	0.51	0.31	0.37	4.70	3.47	0.74	0.65
$N_2P_3K_1$	2.92	2.26	0.89	1.24	0.79	0.59	0.35	0.43	2.66	2.09	0.51	0.38
$N_2P_3K_2$	2.97	2.48	0.96	1.30	0.80	0.59	0.37	0.44	3.05	2.11	0.56	0.45
Farmer	1.36	1.17	0.35	0.50	0.36	0.26	0.08	0.11	1.71	1.07	0.23	0.14
LSD 0.05	0.03	0.04	0.02	0.02	0.03	0.02	0.01	0.02	0.04	0.02	0.03	0.03

In the 2nd season, fertilizer combination was modified in a trial to achieve a nutrient balance, the superior fertilizer treatment ($N_2P_2K_2$), *i.e.*, 90N, $60P_2O_5$ and $90K_2O$ kg/fed proved to be the most effective for highest N and K tissue contents. This treatment assures that treatment ($N_2P_2K_2$), *i.e.*, 90N, $60P_2O_5$ and $90K_2O$ kg/fed was more balance than treatment ($N_2P_2K_2$), *i.e.*, 90N, $70P_2O_5$ and $90K_2O$ kg/fed (Table 4). Our results agree with those of Heckman *et al.* (2003), Sun (2005), Bertic *et al.* (2006) and Singh *et al.* (2007).

Data in Table 5 point to that NPK uptake at harvest stage of corn increased with increasing rates of NPK application in the 1st season.

In the 2nd season, after modified in fertilizer treatment, the superior fertilizer treatment ($N_2P_2K_2$), *i.e.*, 90N, 60P_2O_5 and 90K_2O kg/fed resulted in maximum for N and K uptake, after which no further significant enhancement in macronutrients uptake took place. It is obvious that the mentioned treatment could provide the plants with more balanced nutrients and occurrence the highest yield with best quality. Our findings agree with those by Heckman *et al.* (2003), Halevy1 *et al.* (2005), Bertic *et al.* (2006) and Singh *et al.* (2007) who decided that the total NPK content in the grains of corn increased with increasing NPK applications.

TABLE 5. Effect of fertilizer treatments on NPK uptake (kg/fed)at harvest stage of growth.

Treatments	N		P		K	
	Stalks	Grains	Stalks	Grains	Stalks	Grains
	Uptake (kg/fed)					
First season						
Control	3.4	2.4	1.0	0.8	3.1	1.0
$N_1P_1K_1$	20.1	13.0	4.6	2.8	12.3	4.1
$N_1P_1K_2$	25.1	15.1	6.2	3.4	16.4	5.2
$N_1P_2K_1$	26.0	15.6	9.3	5.5	20.2	6.9
$N_1P_2K_2$	29.6	16.7	11.3	6.0	24.3	7.9
$N_1P_3K_1$	31.0	17.2	12.5	6.8	31.0	9.2
$N_1P_3K_2$	36.8	19.3	13.2	7.7	35.1	11.9
$N_2P_1K_1$	48.2	29.4	9.2	4.6	18.3	5.4
$N_2P_1K_2$	33.9	32.7	10.7	5.1	23.2	6.7
$N_2P_2K_1$	65.8	37.4	18.5	8.1	31.8	9.2
$N_2P_2K_2$	72.4	39.7	20.0	8.6	40.0	10.7
$N_2P_3K_1$	83.1	44.3	21.0	9.8	46.6	13.1
$N_2P_3K_2$	92.8	48.7	23.6	10.7	54.5	16.7
Farmer	14.4	9.2	3.5	2.1	9.3	2.6
LSD 0.05	0.6	0.6	0.8	0.4	1.2	0.6
Second season						
Control	3.0	1.8	0.8	0.6	2.7	0.8
$N_1P_1K_1$	18.0	13.9	6.8	5.2	14.6	4.9
$N_1P_1K_2$	21.5	16.4	7.8	6.0	20.1	7.7
$N_1P_2K_1$	22.8	16.9	12.4	7.7	23.3	8.4
$N_1P_2K_2$	25.5	18.4	13.5	8.5	24.6	9.8
$N_1P_3K_1$	27.4	20.5	16.0	10.0	32.4	13.9
$N_1P_3K_2$	33.3	24.6	18.3	11.3	35.4	16.5
$N_2P_1K_1$	46.1	32.2	12.0	7.5	22.8	7.5
$N_2P_1K_2$	51.5	37.6	13.0	8.7	28.5	10.3
$N_2P_2K_1$	70.4	50.1	20.9	13.0	47.4	21.1
$N_2P_2K_2$	77.0	56.3	22.1	14.9	52.8	26.1
$N_2P_3K_1$	61.3	42.9	24.1	14.9	35.1	13.1
$N_2P_3K_2$	66.7	47.5	25.7	16.1	38.9	16.4
Farmer	13.0	8.2	3.0	1.8	8.6	2.3
LSD 0.05	0.5	0.9	0.6	0.3	0.1	0.2

Multiple regression equations and correlation coefficient between obtained yields (grains and stalks as ton/fed) and total N, P and K (available in soil + added as fertilizers kg/fed) of the superior treatment ($N_2P_2K_2$), *i.e.*, 90N-60P_2O_5-90K_2Okg/fed in second season are shown blow (Table 6).

TABLE 6. Regression equations of grains and stalks (ton/fed) of corn under superior treatment conditions at 2nd season.

Regression equations	R^2	Yield
Grains= 0.054+ 0.02*TotalN+ 0.003*TotalP+ 0.018*TotalK	0.998	4.02
Stalks =0.08+ 0.03*TotalN+ 0.011*TotalP + 0.034*TotalK	0.997	7.13

Finally, from the above results, it can be concluded that the best tool for fertilizer recommendation under the conditions of the study area was the use of multiple linear regression equations mentioned above to product the highest production. This emphasizes the importance of applying 90N-60P_2O_5-90K_2Okg/fed for optimum production of corn grains and stalks in sandy loam soil (calcareous soils). Such equations are possible to be use in other regions analogous in soil properties.

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التسميد المتوازن لانتاج اقصي محصول اقتصادى من الذرة الشامية تحت ظروف الاراضى الجيرية

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اقيمت هذه الدراسة فى منطقة الحمام غرب الدلتا بمصر والتى تمثل الاراضى الرملية الطميية ذات المحتوى المرتفع من كربونات الكالسيوم ولهذا الغرض اقيمت تجربتان حقليتان خلال موسمين ٢٠٠٥ و٢٠٠٦. وكانت الذرة الشامية صنف بيونيير هو المحصول الكشاف.

وتهدف الدراسة الى الوصول الى حالة الاتزان بين المغذيات وتحقيق اعلى انتاجية من محصول الذرة بأضافة اسمدة العناصر الكبرى NPK الى ارض الدراسة ويرى من النتائج ان القياسات المحصولية للذرة وتركيز المغذيات والممتص منها بواسطة النبات يزداد طرديا بزيادة معدلات اضافة العناصر الغذائية الكبرى خلال الموسم الاول حيث تفوقت المعاملة $100N:50P_2O_5:80K_2O$ kg/fed على المعاملات الاخرى فى جميع قياسات الذرة وانتجت 8.14 و 3.16 طن/فدان لقش وحبوب الذرة على التوالى. اما فى الموسم الثانى، فأن معدلات اضافة العناصرالغذائية الكبرى قد تم تعديلها فى محاولة للوصول الى حالة من الاتزان بين المغذيات. واكدت النتائج المتحصل عليها ان المعاملة $90N:60P_2O_5:90K_2O$ kg/fed احرزت زيادة عالية فى تركيزات العناصر الغذائية الكبرى والممتص منها ماعدا الفسفور عند المقارنة بالمعاملة $N_2P_3K_2$. هذة المعاملة اعطت 7.13 و4.02 طن/فدان لقش وحبوب الذرة على التوالى.

ويلاحظ من ذلك ان خفض معدلات النتروجين وزيادة معدلات الفسفور والبوتاسيوم ادت الى وجود حالة من التوازن الغذائى انعكست ايجابيا على المحصول ومحتواة من العناصر الغذائية. وتؤكد معادلات الانحدار والتى تستخدم للتنبؤ بالتوصيات السمادية ان المعاملة المتزنة$90N:60P_2O_5:90K_2O$ kg/fed هى الافضل للذرة تحت ظروف اراضى الحمام ويمكن تطبيقها فى حالة زراعة الذرة الشامية فى اراضى جيرية اخرى مماثلة.