

ISSN Online: 2156-8561 ISSN Print: 2156-8553

Balanced Fertilizer Use through Soil Testing Leads to Higher Yields and Nutrient Contents of Maize Grains

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How to cite this paper: El-Nasharty, A.B., El-Fouly, M.M. and El-Dahshouri, M.F. (2022) Balanced Fertilizer Use through Soil Testing Leads to Higher Yields and Nutrient Contents of Maize Grains. *Agricultural Sciences*, **13**, 1103-1116. https://doi.org/10.4236/as.2022.1310068

Received: August 13, 2022 Accepted: October 23, 2022 Published: October 26, 2022

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Abstract

Fertilizers use can be optimized through soil testing and leaf analysis. This paper deals with using soil analysis as a base for fertilizer use in maize. A field experiment was carried out in two summer seasons of 2013 and 2014 with maize (triple hybrid) in Oraby Village, Mariut sector, Alexandria, Egypt. Soil testing shows that soil was clay loam, with high Na and CaCO₃ contents with high pH, low organic matter, medium P and K and low micronutrient contents (Fe, Zn, Mn and Cu), seven treatments were designed. The most promising treatment was when P and K were increased and micronutrients were added based on soil testing. This treatment resulted in the highest yield with better grain contents of protein and nutrients which indicated that soil-test based on fertilizer use was superior. Soil analysis at the end of the experiment showed higher P and K contents. This approach could be adopted for regions with similar soil conditions in other parts of the world.

Keywords

Soil Testing, Macro & Micro Nutrients, Fertilizer Use, Maize

1. Introduction

Maize is considered one of the three most important crops in the world [1], with high yielding varieties, adaptable to grow across a range of agroecological zones and also multipurpose crop [2]. Regardless of maize's importance as a food security crop, there are many factors that obstruct the comprehension of the cereal crop's potential. Low soil fertility has been identified as a major factor in reducing crop yields [3].

Use of mineral fertilizers to enhance crop production is expensive. There are

many limiting factors affecting yield of maize grains; *i.e.* cultivation of enhanced varieties and little attention to balanced nutrient management [4] [5]. The absorption of nutrients by plants is affected as a result of the unbalanced supply of them, which leads to low crop yields [6] [7].

Fertilization by NPK in Egypt is characterized by the heavy use of N, high P and low K rates [8].

There is a report about increase in grain yield with increase in fertilizer use up to 120:26:50 kg NPK/ha [2], Also, [9] [10] confirmed the role of micronutrients nutrition in intensive cropping, and that maize is susceptible to micronutrients deficiency. It is recommended that supplying these nutrients should be considered to maintain higher yields and avoid consecutive depletion. In addition to soil applications nutrients, foliar application can reduce the period between the uptake and consumption of plants which is very important in stimulating plant growth during the growth phase [11]. Root development, as well as stem elongation and absorption of other elements, are affected by the shortage of nitrogen [12] [13].

In order to improve the profitability of the farmer under different soil and climatic conditions, information should be provided about the optimum dosing of the nutrients. To determine optimal fertilizer doses, it is better to use fertilizers based on studies of soil-crop behavior correlation, using a target yield approach to develop the relationship between crop yields on the one hand and soil testing and fertilizer inputs on the other hand [5] [14] [15].

Formulating recommendations for optimal fertilizers use for specific yields was reported by [16]. It has been modified to become an "objective performance model". In order to achieve a specific performance goal of the crop, a certain amount of nutrients must be applied to the crop. These nutritional requirements can be calculated taking into account the contribution of nutrients available from the original soil and the nutrients used in the fertilizer [17] [18] [19].

Due to insufficient nutritional balance and lack of nutrients, the objective of this study was to find out the effect of different NPK levels combined with micronutrients on yield and nutrient contents to determine the best fertilizer rates for production of maize crop.

2. Materials and Methods

The present study was carried out in a farmer's field at Oraby Village, Mariut sector, Alexandria, Egypt (located between latitude 30°58'47"N and longitude 29°48'38"E) during two summer seasons of 2013 and 2014. The objective was to study the effect of balanced NPK on the yield and its components of Maize (*Zea mays*, L.) based on soil testing. The agronomic practices were as shown in **Table** 1.

Treatments were as follows:

- 1) Control (without any fertilizers addition) (T₁).
- 2) Farmer's fertilization N: P_2O_5 : K_2O (120:31:0 kg/fed.) (T_2).

Table 1. Agronomic practices during summer seasons of 2013 and 2014.

Variable	season								
	2013	2014							
Variety	Triple hybrid 310 - V	Vatania white							
Organic matter added	20 m³/fed.*								
Sowing date	14 th July	21 th Ma	y						
Climatic condition	Average maximum t Average relative hun Monthly sunshine he	nidity (%)	26.5 - 29.7 66 - 71 316 - 363						
Sowing method	Afeer in hill on rows**								
Distance between rows	70 cm								
Weeding	by hoeing twice								
Irrigation times	at 15 days interval								
No. of irrigations/season	7 times								
Water quality	agricultural drainage	water							
Tasseling date	at 62 - 65 days								
Harvesting date	at 120 days								
Experimental design	Randomized Complete Block Design (RCBD) with four replicates. Plot area = 25 m^2 (5 m long and 5 m wide)								

^{*}Feddan = 4200 m^2 , **Sowing Maize grains on the dried soil before irrigation in shallow hills.

- 3) Recommended by Ministry of Agric. N:P₂O₅ (132:31 kg/fed.) (T₃)
- 4) Recommended by Ministry of Agric. N:K₂O (132:24 kg/fed.) (T₄)
- 5) Recommended by Ministry of Agric. N:P₂O₅: K_2O (132:31:24 kg/fed.) (T_5)
- 6) Based on soil testing $N:P_2O_5:K_2O$ (132:31:48 kg/fed.) (T_6)
- 7) Based on soil testing N:P₂O₅:K₂O (132:31:48 kg/fed.) + micronutrients foliar spray (T₇)

Changes in fertilizer doses were based on soil characteristics and contents of different nutrients.

Higher P_2O_5 than the recommended due to the high salinity and pH of soil which negatively affects the availability of P. Potassium (K) was increased due to the high fixation capacity of the soil (high silt and clay contents) and the high demand for K by Maize in short period. Micronutrients in soils were in the range of low to very low.

Irrigation water used in experiment was from drainage water and it has high salinity.

Nitrogen was added in the form of ammonium nitrate (33.5% N) in all treatments except farmer's treatment was urea (46% N), in three equal doses (at sowing—before the first and the second irrigations). Phosphorus and potassium were added in the form of triple super phosphate (37.5% P_2O_5) prior to sowing

and potassium sulfate (48% - 50% $\rm K_2O$) 21 days after sowing. Micronutrients were applied as foliar spray by using 1.5 g/L. water from EDTA chelated micronutrient compound (3% Fe:3% Zn:3% Mn). The plants were sprayed twice. The first spray was carried out with 300 L/fed. at 30 days from sowing and the second was with 400 L/fed. at 45 days from sowing.

Yield and yield components:-

At maturity, the plants were harvested five Ears from each plot from the four replications were taken randomly to determine the following paramiters

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    Ear length (cm)
    Bar diameter (cm)
    Number of rows/ear
    Ear weight (g)
    Grain yield/ear (g)
    Shelling percentage (%)
    Grain yield (ardab/fed.)
    (ardab = 140 kg, fed. = 4200 m²)
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Chemical analysis:

1) Soil testing

A representative soil sample was taken after soil preparation and before fertilization from the experimental site (0 - 30 cm depth). After harvest each season, soil samples were collected from plots of each treatment. Samples were air dried, ground in a wooden mortar and passed through a 2 mm pores sieve to be tested for physical and chemical characteristics (**Table 2**).

Table 2. Physical and chemical characteristics of soil (0 - 30 cm depth) before sowing during summer seasons of 2013-2014.

Variable	В	efore	Sowing	g	Methods used for sample preparation and analysis
	20	13	20	14	_
Sand %	3	1	30	0	
Silt %	39	9	4	1	
Clay %	30)	29	9	
Texture	Clay I	Loam	Clay I	Loam	measured by hydrometer method [20]
pН	8.4	Н	8.4	Н	measured by pH meter [21]
EC ds/m	4.1	vH	3.9	vH	measured by conductivity meter [21]
Calcium Carbonate %	27.3	Н	26.7	Н	measured by calcimeter [20]
Organic Matter %	1.9	L	1.7	L	determined by Walkly and Black method [22]
P	1.6	M	1.4	M	(NaHCO ₃ -Extractable) and measured using Spectrophotometer [23]
K (mg/100g soil)	26	M	23	M	(NH ₄ OAC-Extractable) and measured using Flame photometer [24]
Ca	595	vH	548	vH	}
Na	112	vH	116	vH	
Fe	5.30	L	5.12	L	(DTPA-Extractable) and measured using Atomic absorption [25]
Mn (ppm)	0.89	vL	0.89	vL	
Zn	0.78	L	0.76	L	
Cu	0.76	L	0.73	L	

vL = Very Low, L = Low, M = Moderate, H = High, vH = Very High [26].

2) Plant analysis

Five ear leaves and ears were randomly sampled from each plot at 75 and 115 days from planting, respectively were collected to be analyzed for macro and micronutrient contents. Ear leaves and grains were washed in sequence with tap water, 0.01 N HCl—acidified bi-distilled water and bi-distilled water, respectively, and then dried in a ventilated oven at 60° till constant weight was obtained.

The plant samples were ground in stainless steel mill with 0.5 mm sieve and kept for chemical analysis [24].

Protein: Calculated in grains as $(N \%) \times 6.25 [27]$.

3. Results and Discussion

Soil characterization and nutritional status:

Data in **Table 2**, shows that soil is clay loam. pH value in soil was more than 8.0. Meanwhile, value of electric conductivity was 3.9 and 4.1 dS/m. Also, calcium carbonate content in soil was 26.7 and 27.3%. So, soil of the experimental site is considered as highly calcareous saline. Organic matter percentage was 1.7% - 1.9%; such low content of organic matter would be attributed to the climatic conditions of the area which results in rapid decomposition of organic matter. On the other hand, soil fertility is an important factor, which determines the growth of plant. Soil fertility is determined by the presence or absence of nutrients; *i.e.* macro and micronutrients, which are required in minute for plant growth [7] [28]. Soil contents of macro and micronutrients revealed that available P and K were moderate, calcium and sodium were very high and the available Fe, Mn, Zn and Cu were low according to [26].

In general, under such unfavorable conditions and in soil which characterized as low fertile with high leaching rate through surface irrigation, the production of most crops uneconomic and farmers have to apply high rates of chemical fertilizers to maintain satisfactory yield [29] [30].

The soil data were evaluated using the criteria published by [26].

Changes in soil characteristics after

Data of macro and micronutrient contents in soil are shown in **Table 3** and **Table 4**, Values of available P and K contents in soil were moderate and may be attributed to silt and clay contents of soil. Available Na content was very high, values of DTPA extractable Fe, Mn, Zn, and Cu contents were very low as compared to critical values of [26]; such low content may be attributed also to lime induced condition, which reduces the availability of these micronutrients in soil. The above-mentioned soil characteristics reveal low supplying power of nutrients, especially micronutrients and K which may lead to imbalanced nutrition of plants grown on such soil. Generally, the overall fertility status at the experimental site was poor with most of the measured soil properties being lower than the critical values of nutrients required for crop growth according to the ratings by [31] and [26].

Table 3. Soil physico-chemical characteristics after harvest during summer season of 2013.

** • 11	After harvest													
Variable	*1	1	T,	2	Т	3	Т	4	T,	5	T	6	Т	7
Sand %	3	1	31	1	31		31		31	L	3	1 31		1
Silt %	39	9	43	3	38	38		41)	39	9	30	6
Clay %	30)	26	5	31		28		29)	30)	33	
Texture	Clay I	Loam	Clay I	Clay Loam		Loam	Clay Loam		Clay I	oam	Clay I	Loam	Clay I	Loam
PH	8.0	Н	8.2	8.2 H		Н	8.3	Н	8.4	Н	8.3	Н	8.5	Н
EC ds/m	5.4	vH	4.3	vH	4.1	vH	4.4	vH	4.2	vH	4.0	vH	3.9	vH
Calcium Carbonate %	27.6	Н	25.8	Н	27.2	Н	26.9	Н	26.7	Н	28.1	Н	27.2	Н
Organic Matter %	0.7	vL	1.7	L	2.0	L	1.5	L	2.1	M	2.4	M	2.7	M
P	0.9	L	1.1	L	1.4	M	1.0	L	1.9	M	2.1	M	2.3	M
K (mg/100g soil)	15	L	16	L	15	L	27	M	29	M	35	Н	39	Н
Ca	488	Н	520	vH	670	vH	569	vH	576	vH	669	vH	594	vH
Na	142	vH	130	vH	120	vH	134	vH	123	vH	121	vH	100	vH
Fe	3.66	vL	4.00	vL	5.90	L	5.00	L	4.61	vL	6.34	L	6.71	L
Mn (ppm)	0.80	vL	0.81	vL	0.60	vL	0.78	vL	0.83	vL	1.19	vL	1.23	vL
Zn	0.51	L	0.72	L	0.62	L	0.95	L	0.71	L	0.83	L	1.00	L
Cu	0.89	L	0.54	L	0.72	L	0.58	L	0.59	L	0.61	L	1.21	M

vL = Very Low, L = Low, M = Moderate, H = High, vH = Very High [26]; T₁ = (Control) T₂ = Farmer's fertilization; T₃ = NP, Ministry Agric; T₄ = NK, Ministry Agric; T₅ = NPK, Ministry Agric; T₆ = NPK soil test; T₇ = NPK soil test + micronutrients.

 Table 4. Soil physico-chemical characteristics after harvest during summer season of 2014.

Variable	After harvest													
v ariable	*T	1	Т	2	Т	3	T	4	Т	5	Т	6	Т	7
Sand %	30		29	9	30		30		28		31		3	1
Silt %	40		43	3	38		42		40		39	9		3
Clay %	30	30		3	32	2	28		32		30)	20	5
Texture	Clay I	Loam	Clay I	Loam	Clay I	Loam	Clay I	Loam	Clay I	Loam	Clay I	Loam	Clay I	Loam
pН	8.5	Н	8.3	Н	8.4	Н	8.4	Н	8.2	Н	8.2	Н	8.5	Н
EC ds/m	4.7	vH	4.1	vH	4.1	vH	4.3	vH	4.0	vH	3.9	vH	3.7	vH
Calcium Carbonate %	27.0	Н	25.4	Н	27.2	Н	27.0	Н	27.1	Н	27.0	Н	26.9	Н
Organic Matter %	0.8	vL	1.8	L	2.2	M	1.7	L	2.1	M	2.3	M	2.6	M
P	0.8	L	1.2	L	1.3	M	1.4	M	1.8	M	2.0	M	2.0	M
K (mg/100g soil)	17	L	18.0	L	16.0	L	26	M	27	M	32	Н	36	Н
Ca	479	H 505 vH		603	vH	579	vH	503	vH	669	vH	599	vH	

Con	tir	111	ьd
	··	ւս	cu

Na	144	vH	112	vH	110	vH	130	vH	118	vH	116	vH	96	vH
Fe	3.50	vL	3.91	vL	5.78	L	4.86	vL	4.48	L	6.10	L	6.61	L
Mn (ppm)	0.72	vL	0.78	vL	0.59	vL	0.79	vL	0.78	vL	1.15	vL	1.21	vL
Zn	0.49	L	0.68	L	0.57	L	0.82	L	0.67	L	0.78	L	1.15	L
Cu	0.80	L	0.53	L	0.68	L	0.57	L	0.54	L	0.61	L	1.20	M

vL = Very Low, L = Low, M = Moderate, H = High, vH = Very High [26]; T_1 = (Control) T_2 = Farmer's fertilization; T_3 = NP, Ministry Agric; T_4 = NK, Ministry Agric; T_5 = NPK, Ministry Agric; T_6 = NPK soil test; T_7 = NPK soil test + micronutrients.

Effect of different treatments on soil chemical analysis:

Phosphorous content in soil after harvest was decreased with treatments, where little amounts of phosphorus were added and increased by increasing its quantity [32]. Potassium showed a similar trend, while micronutrient contents were more or less not remarkably affected as micronutrients were applied through the leaves. Also, these results were essentially due to the treatment phosphorus was increased as the high salinity in soil and high pH decreases the availability of P in soils. Potassium was also increased due to its fixation on the clay and silt partials and the high demand of maize for potassium in a short period of its life cycle [33].

Yield and its components

There was significant response to NPK plus micronutrients foliar application (T_7) on grain yield and its components asserting the need for balanced NPK with foliar micronutrients of maize production (**Table 5** and **Table 6**).

The ear length increased due to adding, farmer's fertilization (T_2) and NPK plus micronutrients foliar application (T_7) during 2013 was 16% and 55%. While the increase in ear diameter was 9% and 50%. Comparable to the increase in number of rows/ear was 8% and 51% and for the ear weight it was 20% and 183%. Meanwhile the increase in 100-kernel weight was 8% and 40%. Also, shelling percentage was 3% and 10% compared with control treatment, respectively.

Grain yield /fed. was increased by applying farmer's fertilization and NPK plus foliar micronutrients were 24% and 211% compared with control treatment, respectively.

On the other hand, in the yield components, there were increases in ear length due to adding, farmer's fertilization and NPK plus micronutrients foliar application was 22% and 77%. While the increase in ear diameter was 7% and 33%. These results are consistent with those found by [34] who stated that the positive effect of micronutrient application on yield and yield components.

The increase of number of rows/ear was 6% and 35% and for the ear weight was 32% and 186%, respectively. Meanwhile, the increase in 100-kernel weight was 9% and 38%. Also, shelling percentage was increased by 3% and 9% compared with control treatment, respectively.

The same results were obtained by [35] reported increase in maize yield, accompanied with increased yield traits, which has been reported with nutrient application.

Table 5. Yield and its components of maize as affected by different levels of NPK and balanced fertilization during 2013 and 2014 seasons.

Treatment	Ea	ır lenş	gth (cn	n)	Ear	Ear diameter (cm)				Number of rows/ear				Ear weight (g)			
Treatment	2013	(%)	2014	(%)	2013	(%)	2014	(%)	2013	(%)	2014	(%)	2013	(%)	2014	(%)	
Control (T ₁)	12.3	100	11.5	100	2.96	100	3.47	100	9.3	100	11.3	100	60.0	100	56.0	100	
Farmer's fertilization (T ₂)	14.3	116	14.0	122	3.23	109	3.72	107	10.0	108	12.0	106	71.7	120	73.7	132	
NP, Ministry of Agric. (T ₃)	15.7	128	14.8	129	3.39	115	3.90	112	10.7	115	12.0	106	85.0	142	82.3	147	
NK, Ministry of Agric. (T ₄)	16.5	134	16.3	142	3.61	122	4.13	119	11.3	122	12.7	112	105.0	175	93.7	167	
NPK, Ministry of Agric. (T ₅)	17.2	140	16.8	146	3.82	129	4.29	124	12.0	129	13.3	118	133.3	222	101.0	180	
NPK soil testing (T ₆)	17.8	145	18.0	157	4.18	141	4.45	128	13.3	143	14.7	130	155.0	258	147.7	264	
NPK soil testing + micronutrients (T ₇)	19.0	154	20.3	177	4.45	151	4.61	133	14.0	151	15.3	135	170.0	283	160.3	286	
LSD (0.05)	1.0		0.6		0.10		0.12		1.7		1.9		11.2		11.4		

Table 6. Yield and its components of maize as affected by different levels of NPK and balanced fertilization during 2013 and 2014 seasons.

Treatment	Grain yield/ear (g)				100 - Kernel weight (g)				Shelling (%)				Grain yield (ardab/fed.)*			
	2013	(%)	2014	(%)	2013	(%)	2014	(%)	2013	(%)	2014	(%)	2013	(%)	2014	(%)
Control (T ₁)	46.0	100	42.6	100	14.53	100	13.93	100	76.67	100	76.00	100	7.36	100	6.80	100
Farmer's fertilization (T ₂)	56.9	124	57.5	135	15.73	108	15.20	109	79.33	103	78.00	103	9.10	124	9.19	135
NP, Ministry of Agric. (T ₃)	68.0	148	65.3	153	16.47	113	15.80	113	80.00	104	79.30	104	10.88	148	10.46	154
NK, Ministry of Agric. (T ₄)	85.4	186	74.6	175	17.3	119	16.83	121	81.33	106	79.70	105	13.67	186	11.94	176
NPK, Ministry of Agric. (T ₅)	109.8	239	81.8	192	18.17	125	17.47	125	82.30	107	81.00	107	17.57	239	13.09	193
NPK soil testing (T ₆)	129.2	281	121.1	284	18.93	130	18.60	134	83.35	109	82.00	108	20.66	281	19.37	285
NPK soil testing + micronutrients (T ₇)	142.8	310	132.6	311	20.30	140	19.20	138	84.00	110	82.70	109	22.85	310	21.22	312
LSD (0.05)	9.9		9.6		0.56		0.38		0.89		0.81		1.58		1.53	

 $(ardab = 140 \text{ kg, fed.} = 4200 \text{ m}^2).$

Grain yield/fed. was increased by applying farmer's fertilization and NPK plus foliar micronutrients 35% and 212% compared with control treatment, respectively. These results are in agreement with those obtained by [36] who reported that all yield attributes of the tested maize hybrids were significantly positively influenced by the NPK levels. Application of 125% recommended dose of fertilizer (200 kg N, 60 kg P and 60 kg K/ha) resulted in significant increase in all yield attributes over the control (-NPK) treatment. Similar trend was observed by [37] where the soil test crop response (STCR) targeted yield approach (90 q·ha⁻¹) with purely inorganic (47.35 q·ha⁻¹) fertilizer application has given significantly highest grain yield (47.35 q·ha⁻¹), whereas, highest stover yield was noticed with soil test laboratory (STL) approach (49.63 q·ha⁻¹).

The NPK based on soil testing (132 N, 31 P_2O_5 and 48 K_2O kg/fed.) plus foliar micronutrients was the most effective treatment in increasing the yield and yield components, while control treatment was the lowest one.

These results are in full agreement with those obtained by [5] [38] [39], and results mentioned by [40]. Thus, it might be concluded that balanced fertilization must be considered to obtain the highest possible yields especially under unsuitable conditions; through finding out the best fertilizer balance to produce the optimum yield [41].

Macro and micro-nutrient concentration in ear leaves and grains:

The data presented in Table 7 and Table 8 showed that, macro- and

Table 7. Nutrient contents in ear leaves of maize as affected by different levels of NPK and balanced fertilization during 2013 and 2014 seasons.

	1	1]	P	K			'e	Mn		Z	n
Treatment			(9	6)					(pp	m)		
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Control (T ₁)	1.7	1.3	0.17	0.13	1.5	1.8	65.0	71.1	27.00	25.00	13.67	12.30
Farmer's fertilization (T_2)	2.0	1.6	0.22	0.14	1.6	1.9	75.3	78.7	29.33	28.70	15.00	14.70
NP, Ministry of Agric. (T ₃)	2.2	1.8	0.24	0.18	1.7	1.9	80.7	79.3	30.32	31.00	16.00	16.30
NK, Ministry of Agric. (T ₄)	2.3	1.9	0.18	0.19	2.0	2.2	88.0	81.4	32.00	32.30	18.33	17.70
NPK, Ministry of Agric. (T ₅)	2.4	2.0	0.27	0.24	2.0	2.5	97.7	88.7	35.00	33.00	20.00	19.00
NPK soil testing (T ₆)	2.6	2.3	0.28	0.26	2.2	2.7	106.0	94.0	35.01	35.00	24.67	23.30
NPK soil testing + micronutrients (T_7)	2.6	2.4	0.30	0.27	2.4	2.8	112.7	101.7	38.00	37.40	27.67	25.70
LSD (0.05)	0.2	0.2	0.01	0.02	0.1	0.2	4.7	3.1	2.28	1.73	1.62	1.62

Table 8. Nutrient contents of maize grains as affected by different levels of NPK and balanced fertilization during 2013 and 2014 seasons.

	1	Ŋ	Pro	tein]	P]	K	F	e	M	[n	Z	Zn .
Treatment				(9	6)						(pp	m)		
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Control (T ₁)	1.20	1.18	7.48	7.40	0.20	0.16	0.33	0.30	10.7	15.3	11.00	9.30	17.33	20.00
Farmer's fertilization (T_2)	1.27	1.27	7.96	7.94	0.22	0.17	0.36	0.31	12.0	17.3	13.00	10.71	21.65	22.30
NP, Ministry of Agric. (T ₃)	1.31	1.33	8.17	8.34	0.33	0.20	0.39	0.35	14.3	19.7	13.33	11.32	22.67	23.70
NK, Ministry of Agric. (T ₄)	1.44	1.40	9.02	8.75	0.24	0.25	0.41	0.37	17.0	22.0	14.00	11.70	24.68	26.30
NPK, Ministry of Agric. (T ₅)	1.55	1.50	9.67	9.38	0.35	0.27	0.47	0.41	23.0	24.7	14.67	12.33	25.00	28.00
NPK soil testing (T ₆)	1.67	1.67	10.42	10.43	0.43	0.36	0.52	0.46	30.7	29.0	16.34	14.02	27.61	29.30
NPK soil testing + micronutrients (T_7)	1.78	1.72	11.15	10.73	0.53	0.42	0.61	0.52	38.0	37.7	17.67	16.41	31.30	36.00
LSD (0.05)	0.03	0.07	0.16	0.41	0.04	0.03	0.03	0.03	2.51	1.8	1.33	1.22	1.79	1.86

micro-nutrient contents in leaves and grains were significantly affected by different levels of NPK and balanced fertilization in both seasons. The highest content in ear leaves and grains was obtained with application of NPK plus micronutrients foliar application (T₇) compared with other treatments. These results are consistent with [5] indicating that the NPK dose based on soil testing plus spraying of micronutrients improving nutrient concentrations in maize leaves and also enhanced nutrients uptake which induced significant increase in grain yield as compared to other treatment in Maize grown in clay soils of Nile Delta.

These results might be attributed to soil characteristics as shown in **Table 3** and **Table 4** as clay loam texture. Also lime induced condition, which reduces the availability of these nutrients especially micronutrients and potassium which may lead to imbalanced nutrition of plants grown on such soil. So the best treatment was NPK (132 N:31 P_2O_5 :48 K_2O kg/fed.) based on soil testing plus foliar micronutrients (T_7). These results and others [5] show the importance of adjusting fertilizer application based on soil testing and target yield.

The same direction was found by [42] who found that the NPK dose considering soil testing plus spraying of micronutrients improved most of growth parameters, and enhanced nutrients uptake of wheat plants which induced significant increase in biological yield as compared to other treatments.

4. Conclusions

In general, results lead to the conclusion that the need for maintaining proper balance of nutrients when fertilization program is prepared especially for maize (probably other crops too) when grown on problematic soil such as calcareous and saline soils and/or irrigated with saline water.

Results lead also to the conclusion that application of fertilizer doses to a crop based on soil testing would help to realize greater response, as the nutrients are applied in proportion to the magnitude of the soil contents of a particular nutrient. In addition, the correction of the nutrient and other soil characteristics imbalance in soil would help to harness the synergistic effects of balanced fertilization.

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Acknowledgements

This study was conducted as a part of the Egypto-German project "Micronu-

trients and Other Plant Nutrition Problems in Egypt implemented by the National Research Centre (NRC) Fertilization Technology Department (coordinator Prof. Dr. M.M. El-Fouly) and the Plant Nutrition Chire Dep. for Plant Sciences, TU Munich (Prof. Dr. U. Schmidhalter). The project was supported by the Egyptian Academy of Scientific Research and Technology (ASRT) and the German Federal Ministry of Technical Cooperation (BMZ) through the German Agency for International Cooperation (GIZ). This work was partially supported by the International Plant Nutrition Institute (IPNI) USA.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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