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

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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 $CaCO_3$ 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) ($T_1$).

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 - Watania white | |
| Organic matter added | 20 $m^3$/fed.* | |
| Sowing date | 14th July | 21th May |
| Climatic condition | Average maximum temperature ˚C<br>Average relative humidity (%)<br>Monthly sunshine hours | 26.5 - 29.7<br>66 - 71<br>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. $N:P_2O_5$ (132:31 kg/fed.) ($T_3$)

4) Recommended by Ministry of Agric. $N:K_2O$ (132:24 kg/fed.) ($T_4$)

5) Recommended by Ministry of Agric. $N:P_2O_5:K_2O$ (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 $N:P_2O_5:K_2O$ (132:31:48 kg/fed.) + micronutrients foliar spray ($T_7$)

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% $K_2O$) 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

- Ear length (cm) - Ear diameter (cm)
- Number of rows/ear - Ear weight (g)
- Grain yield/ear (g) - 100-kernel weight (g)
- Shelling percentage (%) - Grain yield (ardab/fed.)

(ardab = 140 kg, fed. = 4200 $m^2$)

**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 | Before Sowing | | | | Methods used for sample preparation and analysis |
|---|---|---|---|---|---|
| | 2013 | | 2014 | | |
| Sand % | 31 | | 30 | | |
| Silt % | 39 | | 41 | | |
| Clay % | 30 | | 29 | | |
| Texture | Clay Loam | | Clay Loam | | measured by hydrometer method [20] |
| pH | 8.4 | H | 8.4 | H | measured by pH meter [21] |
| EC ds/m | 4.1 | vH | 3.9 | vH | measured by conductivity meter [21] |
| Calcium Carbonate % | 27.3 | H | 26.7 | H | 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 | ($NH_4OAC$-Extractable) and measured using Flame photometer [24] (K, Ca, Na) |
| 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$^{\circ}$ 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 %) × 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.

| Variable | After harvest | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *$T_1$ | | $T_2$ | | $T_3$ | | $T_4$ | | $T_5$ | | $T_6$ | | $T_7$ | |
| Sand % | 31 | | 31 | | 31 | | 31 | | 31 | | 31 | | 31 | |
| Silt % | 39 | | 43 | | 38 | | 41 | | 40 | | 39 | | 36 | |
| Clay % | 30 | | 26 | | 31 | | 28 | | 29 | | 30 | | 33 | |
| Texture | Clay Loam | | Clay Loam | | Clay Loam | | Clay Loam | | Clay Loam | | Clay Loam | | Clay Loam | |
| PH | 8.0 | H | 8.2 | H | 8.5 | H | 8.3 | H | 8.4 | H | 8.3 | H | 8.5 | H |
| 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 | H | 25.8 | H | 27.2 | H | 26.9 | H | 26.7 | H | 28.1 | H | 27.2 | H |
| 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 | H | 39 | H |
| Ca | 488 | H | 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]; *$T_1$ = (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.

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

| Variable | After harvest | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *$T_1$ | | $T_2$ | | $T_3$ | | $T_4$ | | $T_5$ | | $T_6$ | | $T_7$ | |
| Sand % | 30 | | 29 | | 30 | | 30 | | 28 | | 31 | | 31 | |
| Silt % | 40 | | 43 | | 38 | | 42 | | 40 | | 39 | | 43 | |
| Clay % | 30 | | 28 | | 32 | | 28 | | 32 | | 30 | | 26 | |
| Texture | Clay Loam | | Clay Loam | | Clay Loam | | Clay Loam | | Clay Loam | | Clay Loam | | Clay Loam | |
| pH | 8.5 | H | 8.3 | H | 8.4 | H | 8.4 | H | 8.2 | H | 8.2 | H | 8.5 | H |
| 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 | H | 25.4 | H | 27.2 | H | 27.0 | H | 27.1 | H | 27.0 | H | 26.9 | H |
| 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 | H | 36 | H |
| Ca | 479 | H | 505 | vH | 603 | vH | 579 | vH | 503 | vH | 669 | vH | 599 | vH |

Continued

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | Ear length (cm) | | | | Ear diameter (cm) | | | | Number of rows/ear | | | | Ear weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 kg, fed. = 4200 $m^2$).

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 $q \cdot ha^{-1}$) with purely inorganic (47.35 $q \cdot ha^{-1}$) fertilizer application has given significantly highest grain yield (47.35 $q \cdot ha^{-1}$), whereas, highest stover yield was noticed with soil test laboratory (STL) approach (49.63 $q \cdot ha^{-1}$).

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.

| Treatment | N | | P | | K | | Fe | | Mn | | Zn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (%) | | | | | | (ppm) | | | | | |
| | 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.

| Treatment | N | | Protein | | P | | K | | Fe | | Mn | | Zn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (%) | | | | | | | | (ppm) | | | | | |
| | 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 ($T_7$) 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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## Conflicts of Interest

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

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