Effect of Different Levels of NPK and Micronutrients Fertilization on Yield and Nutrient Uptake of Maize Plants

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Abstract: Field experiments were carried out in Kafer El Kadera village at El–Monofia governorate- Egypt which located at the middle of Delta, during three summer seasons of 2009, 2010 and 2011 to explore the effects of different NPK treatments on growth, yield and nutrients uptake of maize plant (*Zea mays*, L.) var.30K8, grown on an irrigated silty clay loam under a wheat-maize cropping system. Six NPK combinations were tested in the first season, while one more treatment was added in the second and third seasons as control treatment. The obtained results indicated that the NPK dose based on soil testing plus spraying of micronutrients, improved all growth parameters, ear characteristics and resulted in improving nutrient concentrations in maize leaves and also enhanced nutrients uptake which induced significant increase in grain yield as compared to other treatments.

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1. Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in Egypt. It is mainly used to overcome the increasing requirement for human consumption and animal and poultry feed as well as many industrial purposes. Cultivation of improved varieties, nutrient depletion, and little attention to balanced nutrient management are limiting factors of maize production. In this concern, **Taha, 1996** mentioned that the NPK ratios in Egypt are 1:0.19:0.05 as compared with 1:0.58:0.54 in the developed countries. Also, from the data in **FAO Fertilizer Yearbook (1995, 2003),** it can be concluded that the NPK fertilization in Egypt is characterized by the heavy use of N, high P and low K rates. In Egypt, the ratio between K/N is lower than the ratio in global fertilizer use **(El- Fouly *et al*., 1987).** Great efforts have been done by Egyptian scientists to improve maize productivity **(Fawzi, 1988, Fawzi, *et al*., 1997, Zeidan *et al*., 2006).** Also, responses of maize to NPK fertilization were shown by **Rastija *et al*., (2006).** In addition to NPK soil application, micronutrients can be used as foliar application. In this concern, balanced nutrition leads to efficiency increment of all nutrients applied and, thus decrease the amounts of fertilizers used. Concerning the NPK balanced fertilization and micronutrients to maximize maize yield, the results obtained by **El-Fouly (1984)** were confirmed the important role of balanced fertilization.

Also, **El-Fouly, *et al*., (1981) and Firgany, *et al*., (1983)** confirmed the role of micronutrients nutrition in intensive cropping, and that maize is susceptible to zinc deficiency. It is recommended that supplying these nutrients should be considered to prevent successive depletion.

Therefore the present work was carried out to investigate the effect of different NPK levels in combination with micronutrients on yield and nutrient uptake of maize plants.

2. Materials and Methods:

Three field experiments were conducted in Kafer El Kadera village, El–Monofia governorate, Egypt, during the three summer seasons of 2009, 2010 and 2011 using maize (*Zae maize* var.30K8). The field experiments were conducted on the same soil and the same experimental unites of the studied treatments. All agronomic practices were done as usual. Before maize planting in every season, soil samples were taken from every treatment to test physical and chemical properties. (Tables 1, 2).

Maize grains were sowing in 6 June 2009, 2010 and 2011 and harvested in 25 August.

The studied treatments were as follow:

T0 = control (without any fertilizers addition)

T1 = NPK added by the farmer i.e. 80 kg N + 50 kg P_2O_5 + 0 kg K_2O/ feddan.

T2 = The recommended NPK by MoA i.e. 120 kg N + 60 kg P_2O_5 + 48 kg K_2O/ feddan.

T3 = The recommended NPK by MoA i.e. 120 kg N + 60 kg P_2O_5 + 0 kg K_2O / feddan.

T4 = The recommended NPK by MoA i.e. 120 kg N + 0 kg P_2O_5 + 48 kg K_2O. / feddan.

T5 = NPK based on soil testing i.e. 125 kg N + 65 kg P_2O_5 + 80 kg K_2O. / feddan.

T6 = NPK based on soil testing + one time micronutrients foliar spray.

NPK were applied to the soil at 30 days after sowing as ammonium nitrate 33.5%N, single superphosphate 15.5%P_2O_5, and potassium sulphate

48% K_2O). Micronutrients used as a foliar application at 45 days after sowing using chelated micronutrient compound (3% Fe: 3% Zn: 3% Mn) at rate of 1.5 g/l. water. Grain yield and yield components were measured at physiological maturity. The uptake of grain nutrients was calculated.

At harvest, ten individual plants were chosen at random to determine: Plant height, number of leaves /plant, ear length, number of rows/ear, number of grains/ear, chilling%, grain yield/plant, 100-grain weight. Ear leaves, were collected from all treatments to determine macro-and micro-nutrients. Grain yield (ton/ha) was calculated based on total grain per plot.

Chemical analysis:

Soil testing:

Soil samples were analyzed for texture with a hydrometer **(Bouyoucos, 1954),** for pH and electric conductivity (EC) using water extract method (1 soil: 2.5 water) method, **(Jackson, 1973),** total calcium carbonate ($CaCO_3$%) by calcimeter method as described by **(Alison and Moodle, 1965)**. Organic matter (O.M%) content according to **Walkley and Black, (1934)** using potassium dichromate **(Chapman and Pratt, 1978)**. Phosphorus was extracted using sodium bicarbonate **(Olsen *et al*., 1954).**

Potassium, calcium, Magnesium and sodium were extracted using ammonium acetate **(Jackson, 1973).** Iron, manganese, zinc and copper were extracted using DPTA **(Lindsay and Norvell, 1978).**

Plant analysis:

The plant material was digested using an acid mixture consisting of nitric, perchloric and sulfuric acids in the ratio of 8:1:1 (v/v), respectively **(Chapman and Pratt, 1978).** Nitrogen (N) was determined in the dry plant material using the boric acid modification described by **Ma and Zuazage, 1942**, and distillation was done using a Buechi 320-N_2-distillation unit. Phosphorus was photometrically determined using the molybdate vanadate method according to **Jackson, 1973**

Potassium, calcium and sodium were determined using flame photometer (Genway). Mg, Fe, Mn, Zn and Cu were determined using the Atomic absorption spectrophotometer (Perkin Elemer 1100 B).

The soil data were evaluated using the criteria published by **(Ankerman & Large, 1974,** as well **as Silvertooth 2001),** whereas the leaf analysis data were evaluated according to the criteria reported by **(Jones *et al*., 1991)** in Plant Analysis Handbook.

Statistical analysis:

The obtained data were subjected to the analysis of variance of randomized complete block design (*RCBD*), Every treatment was repeated four times, according to **Snedecor and Cochran,1990** where the means of different treatments were compared using the least significant difference (L.S.D) test at 5% probability level.

3. Results and Discussion

Soil testing: the results in Tables 1 and 2 summarized the physical and chemical characteristics of the soil where, experiments were done. The soil was silty clay loam in texture, alkaline in reaction. The total $CaCO_3$ content tended to be low and O.M and EC were medium (Table 1). According to the tentative values of available nutrient concentration by Ankerman and Large (1974), Silvertooth (2001) data presented in Table 2 showed that soil had medium N, Mg, and Fe, had high K, Ca and Cu, while, P, Mn and Zn ranged between medium and high content. Na was between low and medium. Data in Table 2 showed that the content of N, P and K increased due to both NPK based on soil testing and NPK based to soil testing + micronutrients treatments, Also, Mn and Zn increased with NPK based to soil testing + micronutrients treatment.

Table 1: Soil characters before sowing

Character	Values
Sand %	30.80
Silt %	28.00
Clay %	41.20
Soil Texture	S.C.L
pH (1:2.5)	8.68 VH
E.C dS/m (1:2.5)	0.35 M
$CaCO_3$ %	1.90 L
O.M %	2.20 M

L = Low M = Medium H = High VH = Very high

Yield and its components

Data presented in Table (3) indicated that number of leaves /plant, ear length, number of rows /ear, grains number/row, 100-grains weight, grains yield /plant and yield ton/ha were significantly increased by the different studied treatments.

Treated maize with N 125, P_2O_5 65 K_2O 80 based on soil testing plus micronutrients foliar spray gave significant increments in number of leaves/plant, ear length (cm), number of rows/ear, grains number/row, chilling (%), 100 grains weight (g), grain yield/plant (g), yield/ton/ha, followed by the NPK treatment which based on soil testing (N 125, P_2O_5 65 K_2O 80).These increments may be due to the role of micronutrients which were not available due to high soil reaction (pH). Also, most values of manganese and zinc in the ear leaves were found at in the beginning of the normal range levels, in this respect **Bergmann**

(1972) mentioned that the nutrient contents should lie as far as possible in the middle or even better in the upper half of the satisfactory or optimal range. For example, manganese acting as an activator of the dehydrogenases, transferases, hydroxylases, and decarboxylases involved in respiration, amino acid, lignin and hormone synthesis **(Burnell, 1988)** Also, zinc functions as a part or cofactor for several enzymes especially carbonic anhydrase, which has an important direct role in photosynthetic incorporation of CO_2 **(Zubay, 1983 and Keys & Parry, 1990).**

On the other hand, control and farmer's fertilizer were the lowest one. Maize treated with recommended N 120, P_2O_5 60, K_2O 48, according to Ministry of Agric. surpassed the treatments of N 120, P_2O_5 60 and N120, K_2O 48.

In general, grain yields of maize were high, Grain yields of maize significantly increased to level of 161% and 104% in the second and third season due to NPK based on soil testing + micronutrients application; respectively, as compared to control.

Table 2: Mean of soil nutrient concentrations during the three seasons (2009-2011)

Treatment / Nutrient	Control	Farmer's fertilizer	NPK Minstry. Agric.	NP Minstry. Agric.	NK Minstry. Agric.	NPK soil testing	NPK soil testing + micronutrients
				mg/kg			
N	1119M	1092M	1085M	1129M	1070M	1214M	1217M
P	21.9 M	25.3M	22.5M	24.8M	23.2M	30H	30.6H
K	355H	324H	363H	353H	349H	387H	404H
Ca	5100H	5035H	5660H	5069H	5366H	4960H	4894H
Mg	1687M	1761M	1739M	1679M	1683M	1718M	1706M
Na	234L	298M	281M	234L	247L	300M	243L
Fe	14.3M	16.0M	15.5M	15.3M	15.1M	13.2M	14.5M
Mn	11.9M	14.2H	13.9H	12.9H	11.6M	12.3M	14.6H
Zn	2.24 M	2.61M	2.39M	2.07M	2.18M	2.95M	3.04H
Cu	3.05VH	3.24VH	2.66VH	2.48H	2.60VH	2.45H	2.69VH

L = Low M = Medium H = High VH = Very high

Table (3) Yield and its components of maize as affected by different levels of NPK and balanced fertilization

Treatment	Number of leaves/plant	Ear length (cm)	Number of rows/ear	Grains number /row	Chilling (%)	100 grains weight (g)	Grain yield/plant (g)	Yield/ton/ ha
				First season				
Farmer's Fertilizer	13.06	16.38	13.37	42.00	76.68	30.18	178.28	10.34
NPK, Ministry.Agric.	14.87	21.11	14.53	50.88	87.35	30.89	206.08	11.93
NP, Ministry. Agric.	14.51	20.18	14.35	45.75	81.50	30.26	196.03	11.43
NK, Ministry. Agric.	14.38	18.12	13.75	48.20	81.10	30.78	204.58	11.87
NPK soil testing	14.43	21.18	14.87	51.38	87.53	33.14	218.98	12.35
NPK soil testing+micronutrients	15.63	23.75	15.75	55.50	90.87	33.30	229.58	13.26
LSD (5%)	0.77	1.28	0.83	4.41	5.52	0.74	11.21	1.11
				Second season				
Control	10.25	16.00	10.25	40.50	59.98	23.40	86.73	4.77
Farmer's Fertilizer	10.50	19.25	10.75	44.75	63.75	28.51	166.63	7.76
NPK, Ministry. Agric.	10.75	20.00	12.00	46.00	74.50	29.70	189.40	10.23
NP, Ministry. Agric.	12.50	19.25	10.75	42.25	66.83	30.40	174.60	9.53
NK, Ministry. Agric.	11.50	20.75	12.00	45.50	70.75	31.35	177.85	9.81
NPK soil testing	14.50	22.63	12.75	49.25	76.75	31.59	203.15	11.17
NPK soil testing+micronutrients	16.00	23.25	13.75	51.50	78.20	33.53	215.83	12.47
LSD (5%)	1.97	2.38	0.89	5.19	5.30	1.78	25.58	1.41
				Third season				
Control	11.75	19.75	9.5	35.25	65.03	24.98	126.4	6.31
Farmer'sFertilizer	13.13	22.43	10.5	41.75	71.95	29.18	178.9	8.95
NPK, MoA	16.25	25.70	12.5	51.50	79.05	34.95	226.8	11.37
NP, MoA	15.25	24.88	11.0	50.00	74.13	32.62	217.4	10.87
NK, MoA	14.50	24.15	11.5	46.50	75.75	34.47	220.5	11.03
NPK soil testing	16.25	26.43	12.5	54.00	80.38	35.65	229.6	11.50
NPK soil testing+micronutrients	16.73	27.75	13.5	56.50	82.90	37.68	256.6	12.85
LSD (5%)	1.24	1.33	1.82	4.67	1.72	1.25	8.89	0.45

Ear leaf nutrient contents

Results in Table (4) showed that in the first season, treatments of NPK based on soil testing and NPK based on soil testing + micronutrients gave the highest significant increase for all nutrients as compared with the farmer's fertilizer. The treatment NPK based on soil testing + micronutrients surpassed the treatment of NPK based on soil testing. On the other hand, in the second season the improvement was noticed only with P, K, Ca, Fe, Mn and Cu as compared with control. In third season, the two treatments of NPK based on soil testing and NPK soil testing + micronutrients gave the highest significant increases for most of nutrients as compared with the control. From the above mentioned results it could be concluded that the treatment of NPK based on soil testing plus foliar application of micronutrients resulted in improving nutrient concentrations in maize leaves.

Table (4) Nutrient contents in ear leaves of maize as affected by different levels of NPK and balanced fertilization

Treatment	%						ppm			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
First season										
Farmer's Fertilizer	2.10L	0.23L	2.24M	0.21L	0.52H	0.04	465H	25.0M	28.3M	12.5M
NPK, Ministry. Agric	2.61L	0.26M	2.39H	0.28M	0.73H	0.04	586H	35.3M	24.5M	12.8M
NP, Ministry. Agric.	2.54L	0.28M	2.35H	0.26M	0.65H	0.04	557H	28.8M	29.0M	13.8M
NK, Ministry. Agric.	2.46L	0.29M	2.35H	0.27M	0.68H	0.04	576H	38.3m	31.5M	14.0M
NPK soil testing	3.21M	0.35M	2.65H	0.33M	0.75H	0.05	643H	59.5M	45.0M	14.5M
NPK soil testing+ micronutrients	3.18M	0.34M	2.75H	0.34M	0.83H	0.05	653H	65.0M	54.0M	14.8M
LSD 5%	0.23	0.03	0.34	0.04	0.07	0.01	29	6.2	3.4	1.0
Second season										
Control	2.76M	0.28M	1.16L	0.18L	0.18M	0.09	285H	27.0M	78H	25H
Farmer's Fertilizer	2.54L	0.30M	1.16L	0.18L	0.18M	0.10	328H	27.7M	84H	27H
NPK, Ministry. Agric	2.64L	0.26M	1.22L	0.18L	0.18M	0.10	314H	33.7M	64H	27H
NP, Ministry. Agric.	2.75M	0.30M	1.19L	0.18L	0.17M	0.10	369H	22.3M	71H	21H
NK, Ministry. Agric.	3.07M	0.31M	1.19L	0.18L	0.18M	0.09	335H	37.0M	79H	23H
NPK soil testing	2.49L	0.31M	1.28L	0.19L	0.18M	0.08	433H	40.3M	73H	30H
NPK soil testing+ micronutrients	2.58L	0.30M	1.24L	0.20L	0.18M	0.10	537H	47.7M	76H	28H
LSD 5%	N.S	0.03	N.S	N.S	N.S	N.S	121	7.6	N.S	4.0
Third season										
Control	2.48L	0.33M	4.83H	0.45M	0.71H	0.31	422H	40M	45M	19M
Farmer's Fertilizer	2.35L	0.33M	3.41H	0.43M	0.87H	0.31	561H	36M	58M	16M
NPK, MoA	2.67L	0.33M	3.53H	0.46M	0.81H	0.27	576H	45M	50M	15M
NP, MoA	2.30L	0.31M	2.49H	0.48M	0.90H	0.29	433H	48M	41M	16M
NK, MoA	2.47L	0.30M	3.23H	0.38M	0.69H	0.28	302H	41M	44M	16M
NPK soil testing	2.86M	0.29M	2.88H	0.44M	0.99H	0.38	526H	56M	52M	15M
NPK soil testing + micronutrients	2.62L	0.30M	2.11M	0.54M	0.88H	0.28	497H	40M	34M	16M
LSD 5%	0.29	N.S	1.39	N.S	N.S	0.04	70	N.S	11	2.37

VL = very low, L = Low, M = Moderate, H = High

Uptake of Nutrients by grains:

Results in Table (5) showed that in the first season there is different significant between the treatments on N, Mg, Mn, Zn and Cu uptake. However, in the second season there is different significant effect between all the treatments and the treatment of NPK based on soil testing + micronutrient foliar spray.

Results also, showed that in third season there is different significant effect among most of all the treatments and the treatment of NPK based on soil testing plus micronutrient foliar spray, the uptake of N, P, K, Fe, Mn and Zn in the second season were 240, 96, 119, 167, 147 and 106 %, respectively and in the third season were 110, 76, 164, 96, 71and 58% as compared with control. **Abou El-Nour, 2002** stated that foliar application of nutrient is partially overcoming the negative effect of stress conditions influencing root growth and absorption capacity, **Abdalla and Mobarke, 1992** came to the same conclusion.

Table (5) Nutrient uptake in grains of maize as affected by different levels of NPK and balanced fertilization

Treatment	Kg/ha						g/ha			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
First season										
Farmer's Fertilizer	146.6	33.6	24.8	27.8	70.7	21.7	1942	152.3	574	36
NPK, Ministry. Agric	122.3	30.9	27.1	28.1	85.4	27.1	1714	173.7	828	21
NP, Ministry. Agric.	116.1	30.9	24.5	18.3	77.4	24.3	1680	169.0	714	14
NK, Ministry. Agric.	279.7	32.8	26.9	35.7	76.9	25.0	1909	183	833	26
NPK soil testing	141.6	40.7	30.9	21.7	93.5	26.2	2318	200	883	76
NPK soil testing + micronutrients	198.3	40.0	32.1	34.7	88.8	28.6	1568	219	945	126
LSD 5%	69.3	N.S	N.S	N.S	14.5	4.0	N.S	33	198	48
Second season										
Control	58.0	13.8	23.5	14.3	21.6	4.9	826	116	294	30
Farmer's Fertilizer	84.1	15.5	29.0	69.9	35.7	11.9	1216	168	399	49
NPK, Ministry. Agric	127.9	22.5	38.2	24.9	46.4	13.6	1313	222	624	79
NP, Ministry. Agric.	158.5	19.1	29.2	22.9	42.2	11.4	1493	242	556	64
NK, Ministry. Agric.	134.3	21.6	48.4	27.0	44.1	15.0	1667	229	575	62
NPK soil testing	174.3	22.7	48.0	38.4	49.2	17.5	1695	223	588	74
NPK soil testing + micronutrients	197.0	27.0	51.5	59.4	55.7	13.7	2203	287	607	100
LSD 5%	45.1	0.64	0.94	19.9	1.2	0.8	86.0	17	20	14
Third season										
Control	81.4	17.0	31.6	40.4	13.2	5.0	479	248	128	71
Farmer's Fertilizer	106.5	27.7	42.1	56.4	24.2	7.1	662	329	226	96
NPK, MoA	141.1	25.0	55.7	73.9	25.0	9.1	853	372	182	103
NP, MoA	98.9	25.0	57.6	68.5	25.0	8.7	783	355	188	101
NK, MoA	82.7	16.6	63.9	66.1	25.4	9.9	827	342	143	103
NPK soil testing	81.6	20.7	71.3	67.9	36.8	10.3	828	330	195	100
NPK soil testing + micronutrients	170.9	30.0	83.5	74.5	39.8	11.6	938	424	202	119
LSD 5%	6.73	3.37	14.0	5.0	5.6	1.50	24	32	42	11

From aforementioned results, it could be noticed that increasing nutrient concentrations in maize leaves as well as nutrient uptake by grains resulted in increasing grain yield by 161% and 104% in the second and third season respectively, as compared to control due to NPK based on soil testing + micronutrients application; Such a response indicated that NPK plus micronutrients was necessary for the plant to express its yield potential. This might be returned to increasing of plant physiological processes which led to more nutrient absorbance by roots **(Amberger, 1980 and Hahr, 1987).** Such results are extension to that mentioned by **Mobarak and Abdalla, 1992**. Thus, it might be concluded that balanced fertilization is a must to consider; especially under unsuitable conditions; through finding out the best fertilizer balance to produce the optimum yield. **(Singh, and Sarkar 2001).**

Conclusion

Based on three years average, it is concluded from this study that, under balanced fertilization, the treatment of NPK based on soil testing plus micronutrient foliar spray was the best for leaves nutrient contents and grain nutrients uptake, yield and its components of maize plants. Therefore on the basis of these results it could be concluded that 300, 150, 190 kg ha^{-1} was the best NPK levels in this study.

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