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Nitrogen use efficiency of some maize hybrids

Hoda Kh. A. El-Mekser [1] and Shimaa A. Badawy [2]*
[1]*Maize Research Department, Field Crops Research Institute, Agriculture Research Center, Giza, Egypt.* [2]*Agronomy Department, Faculty of Agriculture, Kafrelsheikh University, Egypt. *e-mail: shamsbadawy2000@yahoo.com*

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Abstract
A two-year field experiment was conducted to study the effect of four rates of nitrogen fertilizer (0, 107, 214 and 321 kg N ha^{-1}) on six maize single crosses (SC 10, SC 125, SC 128, SC 162, SC 166 and SC 168) during 2011 and 2012 seasons. Results revealed that increasing N rates from 0 to 214 kg ha^{-1} was associated with a significant decrease in number of days to 50% tasseling and silking but increased plant height, ear height and grain yield. Further increase in N rate from 214 to 321 kg ha^{-1} did not significantly affect these traits. Hybrids SC 10 and SC 128 gave the highest yield. On the other hand, the interaction effect between hybrids and nitrogen was significant for plant height, ear height and grain yield in the second season. Nitrogen use efficiency for yield was higher at N application of 214 compared with 321 kg N ha^{-1}. At 214 kg N ha^{-1}, SC 10 and SC 128 had the highest N use efficiency in 2011, while SC 125 had the lowest N use efficiency. At the highest N rate (321 kg N ha^{-1}) SC 10 had the highest N use efficiency while SC 125 had the lowest N use efficiency in the second season. The increase in nitrogen rates was associated with a gradual decrease in nitrogen recovery (NRc) percent in both seasons. Increase in nitrogen rates was associated with a gradual decrease in partial factor productivity in both seasons.

Key words: Hybrids, nitrogen fertilizer, nitrogen application, *Zea mays*.

Introduction
Increasing maize production is essential to cover the gap between production and local consumption. This could be achieved through increasing productivity of the crop by growing high yielding cultivars and increasing cultivated area by the extension in the newly reclaimed lands, where poor organic matter and essential nutrient elements content is the main feature. Maximizing yield of the new maize hybrids requires an efficient fertilization program, which considers both macro- and micronutrients and determines the optimal nutrient levels. This mainly depends on soil type, cropping system, and the response of the new hybrids to each specific environment. Nitrogen fertilizer has been observed in maize as being the major mineral nutrient that becomes limiting to normal plant growth and high yield, especially for high extensive planting and deficiency of the organic manure in the soil. Nitrogen fertilizer application is one of the major factors that affect maize production and seed quality. In addition, it is also an important factor due to its essential role in encouraging photosynthetic and meristematic activities, as well as enhancing reproductive growth. Several investigators reported that increasing N rate significantly decreased number of days from planting to 50% tasseling and silking [5, 11]. In addition, previous studies showed positive response of maize plants to nitrogen fertilization either on growth or yield attributes [13, 17]. Moreover, Nofal and Hinar [14] found that increasing N rates up to 321 kg N ha^{-1} significantly decreased number of days to 50% tasseling and silking, while plant height and ear height were significantly increased. Raun and Johnson [16] reported that nitrogen use efficiency is variable with mean of only 33% of applied nitrogen recovered by cereal crops. Nitrogen use efficiency may be affected by crop species, soil type, and application rate of N fertilizer [4]. Nitrogen efficiency indices were significantly affected by N fertilizer rates [10]. Reduction of applied N fertilizer rate to an optimized level can reduce soil nitrate leaching[15]. Significant differences were detected among maize hybrids in terms of nitrogen use efficiency for yield [3]. The objectives of the current research were to evaluate the effects of N rates on yield and nitrogen use efficiency in maize.

Materials and Methods
A two year field experiment was carried out on sandy soil at Ismailia Agricultural Research station in 2011 and 2012 seasons to study the effect of N rates on growth and grain yield of some maize single crosses. Four treatments of N rates (0, 107, 214 and 321 kg N ha^{-1}) and six single crosses (SC 10, SC 125, SC 128, SC 162, SC 166 and SC 168) were used. Soil samples were taken from experimental site before planting and analyzed for some physical and chemical properties (Tables 1 and 2). Experimental design was split-plot with four replications arranged in RCBD. Nitrogen rates were randomly assigned to the main plots, while maize hybrids were arranged at random in the sub-plots. The sub-plots consisted of four rows, where the two middle rows were used for harvest. Rows were 6 m long and 70 cm apart and hills were spaced 25 cm along the row. Nitrogen was added in the form of ammonium nitrate (33.5% N) at eight equal doses. The first one was added after thinning (21 days from planting), and the rest was weekly added.

Table 1. Chemical analysis of the sandy soil at the experimental site in 2011 and 2012 seasons.

Chemical analysis	2011	2012
pH	7.80	8.10
Total N%	0.11	0.09
Available N (ug l^{-1})	17,300	20,100
Available K (ug l^{-1})	100,000	122,000
Available P (ug l^{-1})	8,400	10,000

Table 2. Physical properties of the soil at the experimental site in 2011 and 2012 seasons.

Physical properties	2011	2012
Sand %	64.20	65.40
Silt %	20.00	22.10
Clay %	15.10	12.90
Texture	Sandy loam	Sandy loam

Phosphorus and potassium were broadcasted at the rate of 30 kg P_2O_5 and 24 kg K_2O, respectively, for all plots before planting. Data recorded included number of days to 50% tasseling (DDT) and silking (DTS), plant height (PHT) and ear height (EHT) (cm), and grain yield (GY) t ha^{-1}. Ears were harvested from the two middle rows of each plot , weighed and about 5 kg seed $plot^{-1}$ taken for moisture and shelling percentage determination. Yield was adjusted to kg ha^{-1} at 15.5% moisture content. Nitrogen use efficiency (NUE), kg grain/ kg N applied, was calculated according to Craswell and Godwin [1] as follows:

NUE = Grain yield (f) - Grain yield (c), kg ha^{-1} / N fertilizer applied, kg ha^{-1}, where f = fertilized plots and c = non fertilized plots (control)

N recovery = N uptake by fertilized crop - N uptake by unfertilized crop / amount of N applied

Partial factor productivity = [Grain yield (t ha^{-1})/kg applied nitrogen] X 100

Analysis of variance was performed according to Steel and Torrie[18].

Results and Discussion

Effect of nitrogen fertilizer: Table 3 reveals that increasing nitrogen rates from zero to 107 and 214 kg ha^{-1} caused significant reduction in number of days from planting to 50% tasseling (66.8 to 64.9 and 69.2 to 64.6 days) and to 50% silking (70.9 to 67.3 and 78.2 to 66.6 days) in 2011 and 2012, respectively. Similar results were also obtained by Nofal and Hinar [14] and Faisal *et al.* [3], who found that increasing N rates from 0 to 107 kg ha^{-1} was associated with a significant decrease in number of days to 50% tasseling and silking. However, increasing N rate from 107 to 214 kg ha^{-1} did not significantly affect DDT or DTS.

Increasing N rate significantly increased plant and ear height in both seasons compared with the control. Table 3 reveals that increasing nitrogen rate from zero to 214 kg ha^{-1} caused significant increase in plant height from 241 to 275 cm and from 210 to 178 cm in 2011 and 2012, respectively, and in ear height from 108 to 126 cm and from 95 to 138 cm in 2011 and 2012, respectively. Increasing N fertilizer from zero to 107, 214 and 321 kg ha^{-1} significantly increased grain yield in 2011 and 2012 seasons, respectively.

These results clearly indicate the vital role of nitrogen in enhancing the meristematic activity and improved the vegetative growth of maize plants, which pushed the plants towards building sexual organs early and hastened the time of tasseling and silking, producing taller plants with higher ear height and higher grain yield per faddan. These results are in harmony with earlier results[3, 12, 13] that grain yield significantly increased as N rate increased.

Effect of hybrids: Significant differences were found among maize single crosses for all tested growth characteristics and grain yield (Table 4). Days from planting to 50% tasseling ranged from 67.2 to 64.1 and 67.1 to 64.8 days in 2011 and 2012 seasons, respectively. Number of days to 50% silking ranged from 69.9 to 67.1 and 71.2 to 68.4 days in 2011 and 2012 seasons, respectively. SC 125 was the earliest tasseling and silking hybrid, while SC 162 was the latest one in both seasons (Table 4). Plant height ranged from 270 to 249 cm in the first season and from 270 to 248 cm in the second season. Single cross 162 was the tallest hybrid in both seasons. In contrast, SC 168 had the shortest plants in 2011 but the differences among SC 168, SC 125 and SC 128 were not significant in the second season. Ear height ranged from 124 to 110 cm, from 133 to 114 cm for SC 162 and SC 125 in 2011 and 2012 season, respectively. SC 162 had the tallest plants and the highest ear height in both seasons. In contrast, SC 125 and SC 10 had the highest grain yield in both seasons. Similar findings were obtained by Hassan [7], Nofal and Mobarak [13], El-Mekser [2], Nofal *et al.* [12], Hefny and Aly [6] and Faisal *et al.*[3]. They recorded significant differences among different maize hybrids in growth and grain yield.

Interaction effect: Hybrid x nitrogen interaction was significant for PHT, EHT and GY in 2012 (Table 5). Single cross 162 was taller in plant height than SC 168 by 22 cm under non-fertilized plots, but the differences between these hybrids plant height were 26 and 21 cm at 107 and 214 kg N ha^{-1}, respectively. SC 128 gave the shortest ear height (92 cm) but the difference between SC 128 and

Table 3. Effect of nitrogen rate on DDT, DTS, PHT, EHT, and GY in 2011 and 2012 growing seasons.

N (kg ha^{-1})	DTT		DTS		PHT(cm)		EHT(cm)		GY(t ha^{-1})	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
0	66.8	69.2	70.9	78.2	241	210	108	95	3.379	1.909
107	66.1	66.3	68.6	69.0	253	259	113	120	5.732	5.096
214	64.9	64.6	67.3	66.6	270	277	123	137	7.819	6.942
321	65.3	64.8	67.3	66.7	275	278	126	138	8.079	8.829
LSD $_{0.05}$	1.2	1.6	1.9	1.8	18	18	11	14	1.246	0.776
CV%	1.9	1.8	2.1	1.9	5.7	5.2	8.7	9.3	17.47	11.28

Table 4. Differences among maize hybrids in DDT, DTS, PHT, EHT, and GY in 2011 and 2012 seasons.

Hybrid	DTT		DTS		PHT(cm)		EHT(cm)		GY(t ha^{-1})	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
SC 10	66.1	66.9	68.5	70.6	266	261	122	122	6.852	5.756
SC 125	64.1	64.8	67.1	68.4	256	249	110	114	5.679	5.712
SC 128	64.3	65.4	67.4	69.2	253	248	113	116	6.872	6.259
SC 162	67.2	67.1	69.9	71.2	270	270	124	133	6.342	5.342
SC 166	66.3	67.1	69.4	71.1	266	262	124	129	6.169	5.679
SC 168	66.6	66.2	68.8	70.2	249	248	114	122	5.599	5.412
$LSD_{0.05}$	0.9	0.8	1.0	1.0	10	9	7	8	0.773	0.453
CV%	1.9	1.8	2.1	1.9	5.7	5.2	8.7	9.3	17.47	11.28

Table 5. Hybrid x nitrogen interaction for plant height, ear height and grain yield in 2012 season.

Treatment		Plant height (cm)	Ear height (cm)	Grain yield (t ha^{-1})
N rate (kg ha^{-1})	Hybrid		2012	
0	SC 10	208	85	1.409
	SC 125	206	96	2.303
	SC 128	202	92	2.243
	SC 162	223	104	1.853
	SC 166	223	100	2.036
	SC 168	201	92	1.623
107	SC 10	266	121	5.279
	SC 125	252	106	5.099
	SC 128	264	120	5.876
	SC 162	280	127	4.329
	SC 166	257	122	4.999
	SC 168	238	126	4.992
214	SC 10	282	136	7.139
	SC 125	273	124	6.652
	SC 128	275	128	7.442
	SC 162	289	156	6.592
	SC 166	286	147	7.129
	SC 168	263	136	6.695
321	SC 10	287	146	9.682
	SC 125	288	139	7.462
	SC 128	251	115	10.198
	SC 162	289	152	8.595
	SC 166	281	142	8.682
	SC 168	268	135	8.339
$LSD_{0.05}$		18.94	16.15	0.906
CV%		5.2	9.3	11.28

SC 168 was not significant at non-fertilizer plots. The interaction effects of hybrids and nitrogen fertilizer on grain yield were also significant. The highest values were produced by 214 kg N ha^{-1} x SC 128 (7.442 t ha^{-1}) and 214 kg N ha^{-1} x SC 10 (7.139 t ha^{-1}) combination, while the lowest values were produced by 0 kg N ha^{-1} x SC 10 (1.409 t ha^{-1}) and 0 kg N ha^{-1} x SC 168 (1.623 t ha^{-1}) combinations (Table 5).These differences might be due to differences in nitrogen uptake by genotypes. These results were similar to those previously reported by Nofal and Mobarak [13] and Nofal *et al.* [12].

Nitrogen use efficiency for yield (NUEY): N use efficiency for yield (NUEY) at 107, 214 and 321 kg N ha^{-1} is shown in Table 6.

Table 6. Effect of nitrogen rate on NUEY averaged over all hybrid in 2011 and 2012 growing seasons.

N (kg ha^{-1})	NUEY (kg kg^{-1})	
	2011	2012
107	15.68	21.24
214	14.80	16.89
321	10.44	15.37
$LSD_{0.05}$	5.10	5.11
CV%	24.95	20.31

Results revealed that the highest NUE resulted from the lowest N rate (107 kg ha^{-1}) being 15.68 and 21.24 kg grains per kg of nitrogen in the first and second growing seasons, respectively, while applying 214 kg N ha^{-1} recorded 14.80 and 16.89 kg grains kg^{-1} N in 2011 and 2012, respectively. Results revealed also that applying the highest N rates (321 kg N ha^{-1}) led to a decrease in nitrogen use efficiency being 10.44 and 15.37 kg grains kg^{-1} N, respectively.

It could be concluded that the higher the N rate the lower the NUE. The results obtained earlier [10, 25] indicated that a decrease in NUE with increasing fertilizer rates is because yield rises less than the N supply in soil and fertilizer. Sowers *et al.* [19] and Zhao *et al.*[20] reported similar results and indicated that NUE decreased with increasing N rates. Kanampiu *et al.* [9] indicated that generally NUE decreases with increasing N fertilizer rate and nitrogen use efficiency decreases when N fertilizer rate increases. On the other hand, Campbell *et al.* [21] and Shafshak *et al.* [22] found that nitrogen use efficiency markedly increased due to the increase in nitrogen rates.

Nitrogen use efficiency for yield (NUEY) of maize hybrids: Differences among the tested hybrids concerning NUEY in 2011 and 2012 seasons are presented in Table 7. Significant differences were detected among maize hybrids in terms of NUEY averaged over 107, 214 and 321 kg N ha^{-1} in 2011 and 2012 seasons.

Table 7. Estimated NUEY for maize hybrid averaged over 107, 214 and 321 kg N ha^{-1} in 2011 and 2012 seasons.

Hybrid	NUEY (kg kg^{-1})	
	2011	2012
SC 10	18.73	20.55
SC 125	14.43	17.78
SC 128	9.71	17.61
SC 162	12.39	15.76
SC 166	13.98	17.18
SC 168	12.59	18.11
LSD 0.05	5.04	NS
CV%	24.95	20.31

Nitrogen recovery (NRc): Table 8 indicates that the increase in nitrogen rates was associated with a gradual decrease in NRc percent in both seasons with the exception in 2012 season when 321 kg N ha^{-1} was slightly higher than 107 kg N ha^{-1} but insignificantly.

In general, it can be concluded that the lower the applied nitrogen rate the higher the NRc or vice versa. In this respect, Gasser and Kalembasa [23], Mahgoub [24] and El-Mekser [2] showed that N recovery tended to decrease as fertilizer nitrogen increased. On the other hand, Shafshak *et al.* [22] reported that N recovery increased as N rate increased from 107 to 321 kg N ha^{-1}. Nofal [25] found that NRc was slightly recorded as N rate increased. Table 9 shows that NRc was not affected by hybrids in both seasons.

Table 8. Nitrogen recovery (NRc) as affected by nitrogen application in 2011 and 2012 growing seasons.

N (kg ha^{-1})	NRc	
	2011	2012
0	---------	---------
107	39.33	37.42
214	32.00	33.79
321	23.00	32.75
$LSD_{0.05}$	4.75	8.19
CV%	19.18	17.00

Table 9. Nitrogen recovery (NRc) as affected by hybrids in 2011 and 2012 seasons.

Hybrid	NRc	
	2011	2012
SC 10	34.17	37.83
SC 125	33.00	36.58
SC 128	29.92	32.25
SC 162	28.67	32.58
SC 166	31.50	34.92
SC 168	31.42	33.75
LSD 0.05	NS	NS
CV%	19.18	17.00

Partial factor productivity (PEP): Tables 10 and 11 indicate that the increase in nitrogen rate was associated with a gradual decrease in partial factor productivity in both seasons. SC 10 had the highest partial factor productivity in 2011 season but no significant differences were detected among maize hybrids in the second season.

Table 10. Partial factor productivity (PEP) as affected by nitrogen application in 2011 and 2012 growing seasons.

N (kg ha^{-1})	PEP	
	2011	2012
0	---------	--------
107	12.83	11.09
214	8.75	7.77
321	6.03	6.58
$LSD_{0.05}$	1.47	1.23
CV%	20.13	11.76

Table 11. Partial factor productivity (PEP) as affected by hybrids in 2011 and 2012 seasons.

Hybrid	PEP	
	2011	2012
SC 10	10.43	9.91
SC 125	9.74	8.81
SC 128	8.19	8.48
SC 162	9.24	7.83
SC 166	9.30	8.56
SC 168	8.32	8.30
LSD 0.05	1.52	NS
CV %	20.13	11.76

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