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TOLERANCE OF 28 MAIZE HYBRIDS AND POPULATIONS TO LOW-NITROGEN

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ABSTRACT

Breeding programs should pay more attention to develop hybrid maize of high nitrogen use efficiency. Therefore, the objectives of this investigation were to identify the genotypic differences among 28 maize hybrids and populations to low-N. The field work was carried out for two seasons (2009 and 2010) at the Agric. Res. Sta. of Fac. of Agric., Cairo Univ., Giza. Performance of maize genotypes varied with N level for all studied traits. Low-N caused significant reduction in grain yield/ plant (GYPP) by 52.89 and 44.38% in 2009 and 2010 seasons, respectively. Reduction in GYPP due to low-N was associated with reduction in yield components and all studied dry matter traits. On the contrary, low-N caused a significant enlargement in economic (NUE_e) and biological nitrogen use efficiency (NUE_b). Results indicated that SC 128, SC 3062, SC Ageeb and SC 101 were the highest N – efficient, while Tep-5 and DTP-1 (Cycle 7) were the lowest N - efficient in both seasons. Superiority of NUE_e for the highest over lowest N- efficient genotypes under low-N was 152.74 % in 2009 and 118.03 % in 2010 season. NUE_e showed highly significant and positive correlation coefficients (r_p) with GYPP, grain dry matter (GDM) and number of kernels/plant (KPP) under both N- levels in both seasons. Heritability in the broad- sense (h^2_b %) was generally high (> 80 %) for most studied traits. The highest (h^2_b %) estimates were shown by KPP in 2009 and NUE_e, GYPP and GDM in 2010 under both N-levels in both seasons. Expected genetic advance (GA) from selection was high for NUEe (> 43 %) under both N - levels in both seasons. The estimate of GA for most traits was higher under low- than under high - N in 2009 season, suggesting that low- N is preferred as selection environment for the improvement of low-N tolerance.

Key words: ***Zea mays, Dry matter, Heritability, Nitrogen use efficiency, NUE_e, NUE_b, Correlation, Selection gain.***

INTRODUCTION

Nitrogen is the most important nutritive element for the production of maize. One of the reasons responsible for low productivity of maize is using lower rates of nitrogen fertilizer than the recommended ones by Ministry of Agriculture. Most of Egyptian farmers use low-N fertilizer rates because of high price ratio between fertilizer and grain. Limited availability of N fertilizers, and low purchasing power of farmers, caused low nitrogen status of Egyptian soils. As a result, maize yield potentiality of the hybrid cultivars is not achieved.

Hybrid maize breeding programs in Egypt concentrated efforts in the last decades on developing high- yielding hybrids under high soil-N conditions i.e. hybrids of high N-response. Breeding programs should pay more attention to develop hybrid corn of high nitrogen use efficiency (NUE) under low-N, i.e. tolerant to low-N conditions, besides its high-N response under high-N conditions. Graham (1984) and Sattelmacher *et al* (1994), defined NUE as the ability of a genotype to produce superior grain yield under low soil N conditions in comparison with other genotypes. Genotypic differences in low-N tolerance among maize genotypes have been reported by Bruetsch and Estes (1976), Chevalier and Schrader (1977), Moll *et al* (1982), Hageman and Below (1984), Van Beem and Smith (1996), Akinotoye *et al* (1999), El-Moselhy (2000), Omoigui *et al* (2006), Al-Naggar *et al* (2008 and 2009) and Atta (2009). Therefore, low-N tolerance of maize could be improved via conventional breeding methods.

To start a successful breeding programme for improving low-N tolerance, available maize germplasm should be screened under low-N conditions to identify the best ones which could be used as parental materials for developing low-N tolerant single and three-way cross hybrids. Therefore the objectives of the present investigation were to examine the genotypic differences under low-N among 28 cultivars and populations of maize, identify the tolerant ones to low-N and estimate heritability and genetic selection gain for studied traits under high- and low-N.

MATERIALS AND METHODS

This study was carried out in the summer seasons of 2009 and 2010 at the Experimental Station of the Faculty of Agriculture, Cairo University, Giza, Egypt.

Plant materials

Twenty eight maize (Zea mays L.) single and 3-way cross hybrids and populations (Table 1) were kindly provided by Maize Res. Dept. of Agric. Res. Center (ARC), Pioneer Company, Fine Seed Company, Nile Seed Company and Agron. Dept. ,Fac. Agric., Cairo Univ., Egypt.

Experimental Procedure

Seeds of the 28 cultivars and populations of maize were sown under two nitrogen levels, i.e. high-N by adding 120 Kg N /fed in two equal doses in the form of urea (46.5 % N) before 1st and 2nd irrigations and low-N where no N fertilizer was applied. The previous crop was faba bean (*Vicia faba* L.) and Egyptian clover (*Trifolium alexandriunm* L.) in 2009 and 2010 season, respectively. Available soil nitrogen was analyzed immediately before sowing and found to be 94.78 and 100.8 Kg N /fed in 2009 and 2010 season, respectively. Available soil nitrogen was therefore 214.78 and 220.8 Kg N/fed in the high-N and 94.78 and 100.8 N Kg / fed in the low-N treatment in 2009 and 2010 season, respectively, i.e. 3.949 and 4.200 g / plant under low-N and 8.949 and 9.200 g / plant under high-N in 2009 and 2010 season, respectively. The soil of the experimental site was clayey

Table 1. Maize cultivars and populations used in this study.

Ser. No.	Genotype	Source	Genetic make up
1	S.C.10	ARC	Single cross
2	S.C.128	ARC	Single cross
3	S.C.155	ARC	Single cross
4	S.C.162	ARC	Single cross
5	S.C.124	ARC	Single cross
6	S.C.Ageeb	Fine Seed Co.	Single cross
7	S.C.101	Fine Seed Co.	Single cross
8	S.C.30 K-9	Pioneer Co.	Single cross
9	S.C.30 N-11	Pioneer Co.	Single cross
10	S.C.30 D-80	Pioneer Co.	Single cross
11	S.C.3062	Pioneer Co.	Single cross
12	S.C.30 K-8	Pioneer Co.	Single cross
13	T.W.C.352	ARC	Three-way cross
14	T.W.C.329	ARC	Three-way cross
15	T.W.C.324	ARC	Three-way cross
16	T.W.C.314	ARC	Three-way cross
17	T.W.C.321	ARC	Three-way cross
18	T.W.C.310	ARC	Three-way cross
19	T.W.C.323	ARC	Three-way cross
20	T.W.C Majed	Nile seed development Co.	Three-way cross
21	Cairo-1	Fac.Agric.,Cairo Univ.	Open-pollin. Pop.
22	Pop 59 E	ARC	Open-pollin. Pop.
23	AED	ARC	Open-pollin. Pop.
24	Pop local yellow	ARC	Open-pollin. Pop.
25	Pop-45	ARC	Open-pollin. Pop.
26	Com.21	ARC	Open-pollin. Pop.
27	Tep-5	CIMMYT (ARC)	Open-pollin. Pop.
28	DTP-1 (Cycle 7)	CIMMYT (ARC)	Open-pollin. Pop.

loam. A split-plot design with randomized complete blocks distribution in three replicates was used. Main plots were devoted to nitrogen levels (high-N and low-N). Sub-plots were assigned to the 28 genotypes. Each sub-plot consisted of two ridges of 3 m length and 0.7 m width, i.e. the experimental plot area was 4.2 m^2. Each main plot was surrounded with a wide ridge (1.5 m width) to avoid interference of the two N treatments. Sowing date was April 30 in the 1st season and April 4 in the 2nd one. Seeds over sown in hills at 25 cm apart, thereafter (before the 1st irrigation) were thinned to one plant/hill.

The following traits were measured: (1) number of kernels per plant (KPP), calculated by multiplying number of ears per plant by number of rows per ear by number of kernels per row, (2) 100-kernel weight (100KW) in g adjusted at 15.5% grain moisture, using shelled grains of each plot , and (3) grain yield per plant (GYPP) in g, estimated by dividing the grain yield per plot (adjusted at 15.5% grain moisture) on number of plants / plot at harvest.

At physiological maturity stage, three random plants were removed from each plot by cutting at the soil surface. The plants were bulked as one sample per plot and separated into leaf blades, stalks (including leaf sheathes + tassels) and grains. Samples were dried at 70 °C in a forced air to a constant weight and each part was weighed separately. The following traits were recorded: (1) leaf dry matter per plant (LDM) in g , (2) stalk dry matter per plant (SDM) in g , (3) grain dry matter per plant (GDM) in g , (4) total above ground dry matter / plant at maturity (TDM), (g); measured as follows: TDM = SDM + LDM + GDM , (5) economic nitrogen use efficiency (NUE_e) (g/g) calculated as follows: $NUE_e = GDM/N_s$, where N_s = available soil-N plant , and (6) biological nitrogen use efficiency (NUE_b) (g/g) at maturity calculated as follows: $NUE_b = TDM/N_s$ according to Moll *et al* (1982).

Biometrical analysis

Analysis of variance of the split plot design was computed according to Snedecor and Cochran (1989). Moreover, each main plot was analyzed separately as a randomized complete block design (RCBD) for the purpose of determining genetic parameters, i.e. under each environment (high- or low-N). Expected mean squares under a separate environment were estimated from ANOVA Table of RCBD according to Hallauer and Miranda (1988). LSD values were calculated to test the significance of differences between means according to Snedecor and Cochran (1989). Heritability (h^2_b %) in the broad sense for a separate environment was estimated using the following formula: $h^2_b \% = 100 \times (\delta^2_g / \delta^2_p)$ where δ^2_g = genetic variance, and δ^2_p = phenotypic variance. Phenotypic correlation coefficients (r_p) were calculated between NUE_e, NUE_b and other studied traits under each environment (high- or low-N) according to Singh and Chaudhary (2000) using the following formula: $r_p = \delta^2_{pxy} / (\delta^2_{px} \cdot \delta^2_{py})^{1/2}$ where: δ^2_{pxy} = the phenotypic covariance of the two traits, X and Y, δ^2_{px} and δ^2_{py}= the phenotypic variance of the two traits, X and Y, respectively. Expected genetic advance from direct selection for all studied traits under each environment was calculated according to Singh and Chaudhary (2000) as follows: $GA = 100\, k\, h_b^2\, \delta_p / x$ Where: x = general mean of the appropriate N level, δ_p = square root of the denominator of the appropriate heritability under N level, and k = selection differential (k = 1.76, for 10 % selection intensity, used in this study).

RESULTS AND DISCUSSION

Analysis of variance

Results of analysis of variance (not presented) showed that mean squares due to maize genotypes for all studied traits were highly significant in both 2009 and 2010 seasons. Mean squares due to nitrogen levels were highly significant for all studied traits in both seasons, indicating that low-N had a significant impact on all studied traits. Mean squares due to the first order interaction (genotypes × N-levels) were highly significant for all studied traits. Therefore, the performance of maize genotypes varies with N level for all studied traits, confirming previous investigators (Bruetsch and Estes 1976, Chevalier and Schrader 1977, Moll *et al* 1982, Hageman and Below1984, Van Beem and Smith 1996, El- Moselhy 2000, Omoigui *et al* 2006; Al-Naggar *et al* 2008 and 2009 and Atta 2009)

Effect of low-N

Mean grain yield / plant significantly decreased due to low- N by 52.89 % in 2009 and 44.38 % in 2010 (Table 2). Reduction in grain yield / plant due to low-N was associated with significant reduction in number of kernels / plant (37.75 and 36.78%) and 100 kernel weight (13.30 and 13.30 %) in 2009 and 2010 seasons, respectively. These results are in full agreement with those reported by Al-Naggar *et al* (2009). Moreover, low-N caused a highly significant reduction in all studied dry matter traits. This reduction was more pronounced in grain dry matter and less pronounced in leaf dry matter. In this respect, Sinclair and Horie (1989), Muchow and Sinclair (1994), Al-Naggar *et al* (2008 and 2009) and Atta (2009) found that low-N limits crop dry matter and grain yield potential.

On the contrary, low-N caused a significant enlargement in economic (NUE$_e$) and biological (NUE$_b$) nitrogen use efficiency traits; by 6.76 and 21.86 g/g for NUE$_e$ and 40.44 and 45.93 g/g for NUE$_b$ in 2009 and 2010 seasons, respectively (Table 2). Moreover, we believe that under low-N conditions, maize plants are forced to improve their N-uptake and N-translocation efficiencies, i.e. increase their NUE ability as means of coping with the N-stress conditions, though this increase differed from one genotype to another. In this respect, Anderson *et el* (1984), Pandey *et al* (2001),Al- Naggar *et al* (2008 and 2009) and Atta (2009), reported also that NUE increased as soil N-decreased.

Genotypic differences

Means of the 28 maize cultivars and populations showed a wide range for all studied traits under low- as well as high-N conditions (Table 2). The highest means of NUE$_e$ (19.21 and 20.83 g/g), grain dry matter (GDM) (75.85 and 87.50 g) and grain yield/plant (GYPP) (89.76 and 103.55 g) were achieved by the single cross SC 128 (developed by ARC) under low-N in 2009 and 2010 seasons, respectively. The same cross ranked 1st and 2nd under high-N conditions in 2009 and 2010 seasons, respectively. Under low-N conditions, SC 3062 (developed by Pioneer Co.), SC Ageeb and SC 101 (developed by Fine Seed Co.) ranked 2nd, 3rd and 4th in both

Table 2. Summary of means and ranges of studied maize traits under high- and low-N in 2009 and 2010 seasons.

Trait		2009 season			2010 season		
		High-N	low-N	R%	High-N	low-N	R%
KPP	Mean	555.35	345.69	37.75	647.16	409.13	36.78
(g)	Highest	697.59	544.32		1187.19	546.19	
	Lowest	372.01	114.39		429.26	237.12	
	LSD 0.05	G 57.50	G 63.83		G 74.69	G 48.97	
		N 45.49	G × N 64.34		N 44.32	G × N 62.68	
100KW	Mean	29.55	25.62	13.30	30.31	26.28	13.3
(g)	Highest	35.17	32.20		36.53	33.17	
	Lowest	23.50	19.53		24.50	20.20	
	LSD 0.05	G 0.264	G 1.689		G 0.756	G 1.051	
		N 0.229	G × N 0.324		N 0.657	G × N 0.93	
GYPP	Mean	117.54	55.37	52.89	119.59	66.51	44.38
(g)	Highest	164.12	89.76		166.69	103.55	
	Lowest	55.00	30.01		59.89	36.31	
	LSD 0.05	G 20.82	G 12.08		G 5.93	G 3.715	
		N 12.23	G × N 17.30		N 3.434	G × N 4.857	
GDM	Mean	99.32	46.79	52.89	101.01	56.20	44.36
(g)	Highest	138.68	75.85		140.85	87.50	
	Lowest	46.47	25.36		50.61	30.69	
	LSD 0.05	G 17.60	G 10.21		G 5.012	G 3.140	
		N 10.33	G × N 14.62		N 2.904	G × N 4.106	
SDM	Mean	85.87	58.82	31.50	88.96	62.03	30.27
(g)	Highest	128.20	107.10		138.16	108.24	
	Lowest	51.30	33.05		54.00	34.67	
	LSD 0.05	G 17.05	G 15.32		G 14.87	G 12.60	
		N 11.68	G × N 16.52		N 9.916	G × N 14.02	
LDM	Mean	50.31	40.32	19.86	51.63	42.66	17.37
(g)	Highest	59.66	49.69		60.44	51.58	
	Lowest	32.59	27.99		33.24	32.76	
	LSD 0.05	G 6.635	G 6.020		G 6.904	G 5.664	
		N 4.415	G × N 6.244		N 4.453	G × N 6.298	
TDM	Mean	235.49	145.93	38.03	241.60	160.93	33.39
(g)	Highest	319.88	209.49		339.45	225.01	
	Lowest	161.39	89.07		166.26	102.35	
	LSD 0.05	G 27.75	G 19.91		G 18.30	G 15.12	
		N 17.16	G × N 24.26		N 11.79	G × N 16.68	
NUEe	Mean	11.10	11.85	-6.76	10.98	13.38	-21.86
(g/g)	Highest	15.50	19.21		15.31	20.83	
	Lowest	5.19	6.42		5.50	7.31	
	LSD 0.05	G 1.964	G 2.588		G 0.545	G 0.748	
		N 1.678	G × N 2.373		N 0.458	G × N 0.6472	
NUEb	Mean	26.31	36.95	-40.44	26.26	38.32	-45.93
(g/g)	Highest	35.74	53.05		36.90	53.57	
	Lowest	18.03	22.55		18.07	24.37	
	LSD 0.05	G 3.102	G 5.043		G 1.989	G 3.601	
		N 3.055	G × N 4.321		N 2.097	G × N 2.966	

G = Genotypes, N = Nitrogen levels and R = Reduction%

seasons. These four cultivars were considered as the most tolerant genotypes to low-N in this experiment.

In contrast, Tep-5 and DTP-1 exotic populations were the lowest for NUE$_e$, GDM and GYPP under low-N in both seasons. In addition, Pop. 59E and American Early Dent (AED) in 2009 season and Pop. Local and the 3-way cross TWC 329 in 2010 were among the worst for the same traits under low-N. These genotypes were therefore considered as the most sensitive ones to low-N conditions.

Differences in tolerance of maize genotypes to low-N were also reported by several investigators (El-Moselhy 2000, Omoigui *et al* 2006, Al-Naggar *et al* 2008 and 2009 and Atta 2009).

It is worthy to note that SC 128 showed the highest means for NUE_e and grain yield/plant under both high- and low-N conditions, suggesting that this variety is tolerant to low-N and of high responsiveness to high-N environment. Identifying maize genotypes with specific adaptation to either low-N or high-N environments, which is of vital importance to maize breeder was also reported by Worku *et al* (2007) and Al-Naggar *et al* (2009).

Comparing maize genotypes in this study for tolerance to low-N, based on narrow *vs* broad base genetic background (Table 3), it is clear that , on average, narrow- genetic base genotypes (single crosses) were more tolerant to low-N than medium- and broad- genetic base genotypes (3-way crosses and populations, respectively) in both seasons. This might be attributed to the high nitrogen use efficiency traits of the newly developed high-yielding single crosses as compared to 3-way crosses and populations. These results are in agreement with those reported by Akinotoye *et al* (1999) and Worku *et al* (2007).

Table 3. Comparison of low-N tolerance among single and three-way crosses and populations for grain yield/plant (GYPP) and NUE_e in the two seasons.

Genotypes	2009 season		2010 season	
	GYPP (g/g)	NUE_e (g/g)	GYPP (g/g)	NUE_e (g/g)
		High-N		
Single crosses	**132.08**	**12.47**	**140.19**	**12.88**
Three-way crosses	**125.55**	**11.86**	**123.59**	**11.69**
Populations	**87.70**	**8.280**	**80.840**	**7.430**
		Low-N		
Single crosses	**66.43**	**14.21**	**80.94**	**16.28**
Three-way crosses	**50.61**	**10.83**	**60.30**	**12.13**
Populations	**43.55**	**9.320**	**51.06**	**13.38**

To describe the differences between low-N tolerant (T) and sensitive (S) genotypes, data were averaged for the groups of genotypes differing in their tolerance by definition, namely in grain yield under low-N stress and non-stress conditions (Table 4). The four highest tolerant genotypes to low-N were SC 128, SC 3062, SC Ageeb and SC 101 in both seasons while the four most sensitive ones were Tep 5, DTP-1, Pop 59 E and AED in 2009 and Tep-5, DTP-1 Pop-local and TWC 239 in 2010. Grain yield of tolerant (T) genotypes was greater than that of the sensitive (S) ones by 152.07% in

Table 4. Average performance of studied characters averaged over the four highest and four lowest NUE genotypes and superiority (%) of tolerant (T) over sensitive (S) genotypes under low-N in 2009 and 2010 season.

Characteristic	2009 season			2010 season		
	Tolerant (T)	Sensitive (S)	Superiority %	Tolerant (T)	Sensitive (S)	Superiority %
No. of genotypes	4	4		4	4	
GYPP	85.33	33.85	152.07	99.61	45.68	118.03
KPP	417.70	242.28	72.40	488.07	314.57	55.16
100KW	28.56	25.85	10.47	29.32	25.77	13.78
GDM	72.10	28.60	152.07	84.17	38.60	118.03
SDM	67.65	37.88	78.57	70.01	48.43	44.56
LDM	43.25	36.25	19.30	46.03	38.99	18.07
TDM	183.00	102.74	78.11	200.20	126.02	58.87
NUEe	18.26	7.24	152.07	20.04	9.19	118.03
NUEb	46.34	26.02	78.11	47.67	30.00	58.87

2009 and 118.03% in 2010 season. Superiority of tolerant over sensitive genotypes in grain yield was due to superiority in the two yield components, i.e number of kernels/plant and 100- kernel weight. Superiority of T over S genotypes in number of kernels/plant was more than six and four fold greater than such superiority in 100 kernel weight. Economic nitrogen efficiency of T was appreciably greater than that of S genotypes under low-N; with values comparable to that of grain yield/ plant.

The advantage of T over S in NUE_e would allow to expect greater biological nitrogen efficiency (NUE_b), GDM, stalk dry matter (SDM), leaf dry matter (LDM) and total dray matter (TDM). Consistent to expectation, significant higher values were exhibited in T than in S by about 78.11 and 58.87 % for NUE_b, 152.07 and 118.03 % for GDM, 78.57 and 44.56% for SDM, 19.30 and 18.07% for LDM and 78.11 and 58.87 % for TDM in 2009 and 2010 seasons, respectively. These results are in consistency with those, reported by Al-Naggar *et al* (2008 and 2009).

Trait interrelationships

Under low-N, results (Table 5) showed that NUE_e had a highly significant and very strong phenotypic association (r_p=1.00**) with GYPP and GDM traits in both seasons. This indicates that GYPP or GDM are very good selection criteria for economic nitrogen use efficiency, confirming results of Al- Naggar *et al* (2009). In this context, NUE_e had highly significant and positive correlation coefficients with number of kernels/ plant (0.62** and 0.65**) and total dry matter (0.70** and 0.67**) in 2009 and 2010 seasons, respectively. Similar trends were also obvious with respect of correlations between NUE_e and other studied traits under high-N in both seasons. Biological nitrogen use efficiency had a strong association with total dry matter (1.00** and 1.00**) and stalk dry matter (0.90** and 0.87**) in 2009 and 2010 seasons, respectively under low-N condition.

Table 5 . Phenotypic correlation coefficient (r_p) between NUE_e and NUE_b and other studied traits under high- and low-N conditions in 2009 and 2010 season (n=84).

Trait	NUE_e		NUE_b	
	High-N	Low-N	High-N	Low-N
		2009 season		
GYPP	1.00**	1.00**	0.79**	0.70**
KPP	0.32**	0.62**	0.17	0.42**
100 KW	0.47**	0.24*	0.54**	0.29**
GDM	1.00**	1.00**	0.79**	0.70**
SDM	0.17	0.35**	0.17	0.90**
LDM	0.22*	0.25*	0.62**	0.68**
TDM	0.79**	0.70**	1.00**	1.00**
		2010 season		
GYPP	1.00**	1.00**	0.80**	0.67**
KPP	0.46**	0.65**	0.37**	0.54**
100 KW	0.43**	0.34**	0.51**	0.36**
GDM	1.00**	1.00**	0.80**	0.67**
SDM	0.20	0.25*	0.72**	0.87**
LDM	0.13	0.21*	0.54**	0.67**
TDM	0.80**	0.67**	1.00**	1.00**

* and ** indicate significance at 0.05 and 0.01 probability levels, respectively.

Heritability and expected selection gain

Heritability in the broad- sense (h^2_b %) was generally high (above 80 %) for all studied traits, except for SDM and LDM under high- N in both seasons and TDM under low-N in 2009 season. Estimates of (h^2_b %) were > 99 % in 2009 for 100- kernel weight and > 98% for NUE_e, GYPP and GDM in 2010 under both high- and low-N levels.

Expected genetic advance (GA) from selection (Table 6) was high for NUE_e (> 43 %) in both seasons under both N- levels. A similar trend for GA was shown by GYPP and GDM. On the contrary, GA estimate was the lowest (from 15.48 to 21.84%) for 100 kernel weight under high- and low-N in both seasons.

The estimate of GA for most traits was higher under low-N than under high-N in 2009 season, but the opposite was true in 2010. Direct selection under low-N environment was recommended by several authors (Banziger *et al* 1999, Presterl *et al* 2003, Ajala *et al* 2007 and Al- Naggar *et al* 2008 and 2009) to ensure the preservation of alleles for low-N tolerance.

Table 6. Heritability in the broad sense (h^2_b) and expected genetic advance (GA) for all studied traits of maize genotypes evaluated under high and low - N conditions in 2009 and 2010 seasons.

Trait	2009 season		2010 season	
	h^2_b%	GA %	h^2_b%	GA %
		High-N		
KPP	83.55	22.94	90.87	37.33
100KW	99.75	19.10	97.99	18.53
GYPP	84.03	40.05	98.78	47.64
GDM	84.03	40.05	98.78	47.64
SDM	72.49	29.51	78.70	30.64
LDM	72.41	19.55	70.12	17.98
TDM	82.40	24.88	92.35	27.19
NUEe	84.02	40.05	98.77	47.65
NUEb	82.39	24.88	92.36	27.20
		Low-N		
KPP	84.46	42.54	87.56	31.94
100KW	99.57	21.84	95.98	20.59
GYPP	80.82	43.30	98.30	45.27
GDM	80.82	43.30	98.30	45.27
SDM	80.12	50.32	85.68	49.46
LDM	66.16	18.25	63.66	15.48
TDM	86.48	34.50	91.52	31.76
NUEe	80.82	43.30	98.30	45.27
NUEb	86.48	34.50	91.52	31.76

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تحمل ثمانية و عشرون هجيناً وعشيرة من الذرة الشامية للنيتروجين المنخفض

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في محاولة لاستنباط هجن من الذرة الشامية ذات كفاءة عالية في استخدام النيتروجين، كان الهدف من هذا البحث هو اختبار ثمانية وعشرون صنف وعشيرة من الذرة الشامية تحت مستوى منخفض من النيتروجين. وقد تم تنفيذ التجارب خلال موسمي ٢٠٠٩ و ٢٠١٠ بالمزرعة التجريبية لكلية الزراعة، جامعة القاهرة بالجيزة. وقد أظهرت النتائج اختلافاً واضحا في أداء التراكيب الوراثية للذرة باختلاف مستوى النيتروجين بالتربة لكل الصفات المدروسة. وقد سبب إجهاد نقص نيتروجين التربة نقصا معنويا في محصول حبوب النبات بمقدار ٥٢,٨٩، ٤٤,٣٨٪ في موسمي ٢٠٠٩ و ٢٠١٠ على التوالي. وكان هذا النقص مصحوباً بنقص في مكونات المحصول وكل صفات المادة الجافة المدروسة. وعلى العكس فقد سبب نقص النيتروجين في زيادة كبيرة في كل من الكفاءة الاقتصادية والبيولوجية لاستخدام النيتروجين وقد أبرزت النتائج تفوق الهجن الفردية هـ. ف أبيض جيزة ١٢٨ (مركز البحوث الزراعية) وهـ ف أصفر بيونير ٣٠٦٢ (شركة بيونير) و هـ ف أصفر عجيب و هـ ف أبيض ١٠١ (شركة فاين سيدز) في الكفاءة الاقتصادية لاستخدام النيتروجين بينما أظهرت العشائر المفتوحة التلقيح البيضاء Tep- 5 ، DTP-1 C7 أقل كفاءة في الموسمين. وكان التفوق في الكفاءة الاقتصادية لاستخدام النيتروجين في التراكيب الوراثية الأكثر كفاءة على التراكيب الأقل كفاءة مقداره ١٥٢,٧٤ ٪ موسم ٢٠٠٩ ، ١١٨,٠٣ ٪ موسم ٢٠١٠ تحت ظروف النيتروجين المنخفض. وقد أظهرت دراسة الارتباط أن الكفاءة الاقتصادية لاستخدام النيتروجين كانت مرتبطة ارتباطًا عالي المعنوية بمحصول حبوب النبات والوزن الجاف للحبوب وعدد الحبوب في النبات سواء تحت مستوى النيتروجين العالي أو المنخفض في كلا الموسمين. أظهرت كفاءة التوريث بالمعنى العام تحت كل من المستوى العالي والمنخفض للنيتروجين قيمًا مرتفعة (أعلى من ٨٠ ٪) لمعظم الصفات المدروسة وظهرت أعلى كفاءة توريث عامة في صفة عدد حبوب النبات في موسم ٢٠٠٩ وصفات الكفاءة الاقتصادية لاستخدام النيتروجين ومحصول حبوب النبات والوزن الجاف للحبوب في موسم ٢٠١٠ تحت كلا المستويين. كما أظهر التحسين المتوقع بالانتخاب قيمًا عالية (أكبر من ٤٣ ٪) للكفاءة الاقتصادية لاستخدام النيتروجين تحت كلا المستويين في كلا الموسمين. وقد كانت تقديرات التحسين المتوقع بالانتخاب لمعظم الصفات أعلى تحت ظروف النيتروجين المنخفض منها تحت ظروف النيتروجين المرتفع، بما قد يشير إلى أفضلية بيئة الانتخاب منخفضة النيتروجين لاستنباط تراكيب وراثية تتحمل ظروف النيتروجين المنخفض.