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ASSESMENT OF CORN (*ZEA MAYS* L.) GENOTYPES IN RELATION TO NITROGEN FERTILIZATION UNDER IRRIGATED CROPPING CONDITIONS IN TURKEY

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Abstract

Efficient nitrogen (N) fertilizer management in crop production is based on supplying adequate amounts of the nutrient for optimum economic yield, while minimizing losses to the environment. Exploiting genotypic differences in N use is an additional consideration in achieving nutrient-use efficiency. Thus, in order to identify N-efficient corn genotypes, we established N-response field trials at 2 locations (University Research Farm, and Cutaem) for 2 years (1999, 2000) in the Cukurova region of Turkey. Ten corn genotypes, commonly grown in the region, were fertilized with N at application rates of 160, 240, 320 and 400kg N ha^{-1}. The optimum N fertilizer rate was probably in the 160-240kg N ha^{-1} rate based on response data. There were no significant or consistent differences between genotypes and N application for grain yield and N uptake. The average agronomic efficiency ranged between 20 to 65% across the genotypes and decreased with increasing N application rates. The pattern was similar for other efficiency indices with decreases with applied N, but little or no genotype differences. It is apparent that the genotypes used were bred for N as well as yield. There was little evidence of differences between genotypes or their response to N. Thus, while genotypic selection of corn can be one of the suitable potential N management practices in the Mediterranean region where genetic diversity exists, it is not appropriate considering genotypes are homogenous with respect to N use.

Introduction

Nitrogen is the main driver of world food production, and N fertilizers dominate the fertilizer trade in both developed and developing countries. Comprehensive reviews, such as that of Schepers and Raun, (2008), attest to the indispensability of N for the major non-legumunious crops, especially cereals such as wheat (*Triticum aestivum*), rice (*Oryza sativa*), and corn (*Zea mays*). Environmental and health implications of inappropriate or excessive N fertilizer use are also current concerns (Mosier *et al*., 2004). The key concept in reconciling adequate and economic crop yields with minimum losses of N from the plant system is *N-fertilizer use efficiency* (Khaliq *et al*., 2009; Raun & Johnson, 1999). Though this concept is not new (Keeney, 1982), its urgency has never been greater. The process of N loss that leads to inefficient N use by crops are well understood and documented, e.g., denitrification and ammonia volatilization (Harrison & Webb, 2001), leaching and runoff (Aulakh & Mahli, 2005). The accumulated knowledge from such studies has also led to improved fertilizer and crop management to minimize such losses (Ladha *et al*., 2005).

Central to improved N fertilizer use has been the concept of “efficiency” which has been varying definitions and interpretations depending on the perspective considered. In that context, Dobermann (2005) described partial factor productivity of applied, agronomic efficiency, crop recovery efficiency and physiological or utilization efficiency. The commonly observed phenomenon that N efficiency decreases with increasing fertilizer application rates (Jokela & Randall, 1989; Sabata & Mason, 1992) only highlight the challenge to scientists to minimize N loss while attaining maximum economic crop yields.

While most of the new knowledge of N has emanated in developed countries, and more recently in China, lesser developed areas of the world such as the Mediterranean region have gained considerable momentum in the past few decades as agriculture expanded along with fertilizer N use. Following initial perspectives of N in the region (Harmsen, 1984), a recent comprehensive review (Ryan *et al*., 2009) reveals much research that has been conducted in countries of the region to further the quest of achieving greater N-use efficiency, particularly in minimizing volatile loss of ammonia (NH_3) from applied urea, the dominant fertilizer source of N (Monem *et al*., 2010).

While precedence has been given to management of N-fertilizer use for efficiency, exploitation of genetic differences between crop cultivars is another approach in the scientists’ arsenal to combat N loss, which in many field situations can amount to half or more of the N fertilizer applied to the crop. While various studies indicated increased N-use efficiency under irrigation (Garabet *et al*., 1998), there has been limited emphasis on varietal selection based on responses to N, despite the fact that considerable genetic variation exists in crops with respect to yield parameters (Turi *et al*., 2007) and N uptake and physiological utilization (Kamprath *et al*., 1982; Dobermann, 2005).

As a major world cereal, corn or maize (*Zea maize* L.) has been shown to exhibit considerable genetic variability with respect to N use. Cui *et al*., (2009) showed wide differences between 2 hybrid maize varieties in China, with 1 having a higher grain yield potential with lower fertilizer N applied. Similarly, field trials in Nebraska, USA, showed differences within 12 corn hybrids with respect to N and water stress (O'Neill *et al*., 2004). An earlier North Carolina study (Anderson *et al*., 1985) showed that prolific corn genotypes had higher utilization efficiency than semi-prolific ones at all fertility levels, but showed a greater decrease in utilization efficiency as N fertilizer levels increased.

As corn is a crop of increasing significance in Turkey, and given the fact that genetic differences in corn varieties with respect to N response do exist, our aim in this 2-year field study from the Mediterranean coast of Turkey was to test corn varieties with respect to N efficiency and thus add a potentially valuable component to overall crop breeding strategies.

Materials and Methods

Location: Field trials were conducted with corn at two experimental sites in Cukurova region (Adana, Turkey) for 2 years (1999, 2000). The experimental soils were a loamy, smectitic, calcareous, thermic Vertic Xerofluvent (Cukurova University Research Farm) and Entic Chromoxerert (Cutaem). Selected physical and chemical properties of the soils are presented in Table 1. Generally, the soils were: clay loam texture, alkaline pH, low organic matter content, high $CaCO_3$. Mineral N in the profile (0-90cm) varied from 50 to 100kg ha^{-1} for the Farm and Cutaem sites. Levels of plant available P were marginal; but as P was not a variable in the trial, adequate P fertilizer was applied as a blanket dressing.

Table 1. Soil properties at the 2 experimental locations, with mineral nitrogen in both years*.

Depth (cm)	Texture	pH	$CaCO_3$ (%)	Organic matter	Mineral N (kg ha^{-1}) 1999	Mineral N (kg ha^{-1}) 2000
University Farm						
0-30	Clay loam	7.7	35	0.74	51.5	35.2
30-60	Clay loam	7.7	30	0.50	40.8	33.8
60-90	Clay loam	7.7	41	0.46	23.8	37.2
Cutaem						
0-30	Clay loam	7.7	25	1.87	48.8	24.1
30-60	Silty clay loam	7.5	21	1.19	46.6	18.7
60-90	Silty clay loam	7.9	16	1.06	33.7	N.M.

N.M. = not measured

*From the incubation study in the laboratory, mineralization rate in the surface horizon for 125 days were 72kg Nmin ha^{-1} in University Farm and 62kg Nmin ha^{-1} in Cutaem.

Treatments and growth conditions: Ten corn genotypes commonly grown in the Mediterranean coast of Turkey (P3394, C6127, LG60, TTM815, Dracma, XL72AA, P3163, LG2777, DK626 and P3335) were planted manually in late June to early July, based on the climatic conditions of that specific year. These single cross genotypes were released between 1985-2001 and classified as high yielding ones. Fertilizer N was applied as ammonium nitrate at application rates of 160, 240, 320 and 400kg N ha^{-1} which were the main plots, while genotypes were the subplots. All the plots received 80kg K ha^{-1} as K_2SO_4 and 35kg P ha^{-1} as triple superphosphate in both years in order to eliminate any deficiency of those elements; both elements were applied at planting. The experiments were arranged in a split-plot design with four replications. For the N treatments, half of each application rate was applied at planting as a band close to the seed with a combine drill and the other half was added by broadcasting when the plants were about 50cm high. The plot dimensions were 5 x 2.8m, having inter-row spacing of 20cm and row spacing of 70cm. Plants were irrigated periodically as needed about every 10 to 15 days to eliminate any growth restrictions due to drought. The average annual rainfall was 511mm (1999) and 706mm (2000) in comparison to the long-term average of 575cm.

Soil, leaf and grains sampling and analysis: Prior to the experiment, soil samples were taken from 0 to 30, 30 to 60 and 60 to 90cm depths, and analyzed for the selected physical and chemical soil properties using standard procedures (Page *et al*., 1982). Soil mineral N (NH_4^+ + NO_3^-) was determined (Fabig *et al*., 1978) at the effective rooting depth (0 to 90cm). Mineralized N or mineralization potential was determined based on an incubation study with extraction after intervals of 15 days over a period of 125 days. Extractable soil P was determined based on the standard Olsen procedure and measured using the Murphy & Riley (1962) procedure.

Representative leaf samples from 10 randomly selected plants in each plot were collected at silking stage (Jones & Steyn, 1973). The samples were washed with deionized water, dried at 60°C for 72h, and ground using a silica grinder to pass a 0.5mm sieve. Total tissue N was determined based on the Kjeldahl procedure (Bremner, 1965). Plants were harvested about 125 days after planting. Ears from each plot were manually harvested for determination of grain yield, (including the cobs). Representative grain subsamples were dried at 60°C for dry matter determination and then ground to pass a 0.5mm sieve. Grain was analyzed for N in the same manner as the leaf samples. Soil, plant and grain data were statistically analyzed using MSTAT computer program.

Nitrogen efficiency: While N-use efficiency (NUE) in its strictest sense was not possible to calculate in the absence of non-fertilized control, other measures of efficiencies were employed (Moll *et al*., 1982; Kamprath *et al*., 1982; Moll *et al*., 1987). Thus, in this study, we considered NUE in terms of grain produced per unit of N supplied (*Gw/Ns*). Variation in N uptake was considered in terms of two primary components following Kamprath *et al*. (1982), i.e., N uptake per unit of N applied (*Nt/Ns*) and utilization efficiency defined as grain produced per unit of N uptake or total plant N (*Gw/Nt*).

Results

The response of the 10 corn varieties to a range of N application rates (from sub-optimum to presumed excess) is presented for the 2 loactions for 2 year (Table 2). Surprisingly, location had a major effect on crop response, but neither N nor genotype, or their interaction, were significant at the University Farm location.

However, at the second site (Cutaem), the N effect was highly significant ($p \leq 0.001$), while the genotype effect was significant at the $p \leq 0.05$ level. As with the Farm site, the Cutaem site showed no significant interaction between applied N and genotypes. The pattern with respect to crop response was similar in the second year (2000), with no significant effects at the first location and both N and varieties being significant at the second site.

As the main factors, N and genotypes, were significant at the Cutaem site, the mean effects are highlighted. Thus, as N application increased from 160 to 400kg N ha^{-1}, the mean corn yields increased slightly, i.e., by 8, 18, an 22% in 1999 and by 4, 14 and 6% in 2000. Mean yields of the genotypes ranged from 10.8 Mg ha^{-1} for C6127 to 13.3 Mg ha^{-1} for P32K61. However, in the second year (2000), the order of genotype yields differed from the first year, with differences between genotypes being less pronounced (Table 2).

When grain N uptake by the 10 corn genotypes was considered (Table 3), the results were different from yields, with only N having a significant effect at the University Farm site. Thus, as N application increased (160, 240, 320 and 400 kg N ha^{-1}), grain N uptake increased up to the 320kg N ha^{-1} rate. In contrast, there were no significant effects of N or genotypes, or their interactions observed at the Cutaem location in 1999. The response pattern was again influenced by location in the second year, with only N again being significant at the Farm site at this location (grain N uptake consistently increased with applied N, i.e. 146, 179, 182, and 231 kg N ha^{-1}). However, both N and genotypes and their interaction were highly significant at the Cutaem site. Reflecting the significant interaction of N and genotypes, N uptake in some genotypes increased consistently with added N (XL72AA), while in others it was highest at the 160kg N ha^{-1} rate (DK623, LG60, P3335, TTM815), with some being highest at the 240kg ha-^{1} N rate (DRACMA). Despite the significant effects, the uptake patterns varied among the genotypes at the each N application level.

Table 2. Yield response (Mg ha^{-1}) of 10 corn varieties to varying N fertilizer application rates at 2 locations in 1999 and 2000.

Genotypes	University Farm					Cutaem				
	N application rates (kg N ha^{-1})									
	160	240	320	400	Mean	160	240	320	400	Mean
	1999									
C6127	8.2	10.4	10.2	10.8	9.9	9.9	10.0	11.3	12.1	10.8
DK 626	7.3	10.2	11.5	10.0	9.8	9.3	10.1	13.1	13.1	11.4
XL 72AA	9.2	10.8	9.3	10.0	9.8	11.3	11.0	12.7	12.2	11.8
DK 623	9.7	11.3	10.7	10.3	10.5	11.3	11.7	12.6	12.4	12.0
DRACMA	9.8	10.7	10.6	10.6	10.4	11.3	12.8	11.5	12.4	12.0
LG 60	8.8	10.7	11.1	9.7	10.1	10.0	11.3	11.9	12.6	11.5
P32K61	8.3	9.3	10.6	10.8	9.8	10.9	13.1	15.2	14.1	13.3
P 3335	9.1	9.1	9.6	10.6	9.6	11.3	10.7	12.2	14.2	12.1
P 3394	10.5	10.1	8.8	11.8	10.3	10.7	11.6	11.8	13.2	11.8
TTM 815	10.5	10.9	10.6	11.1	10.8	10.2	11.2	12.8	12.4	11.7
Mean	9.1	10.4	10.3	10.6		10.6	11.4	12.5	12.9	
F Test	N, G, NxG = NS					N=***, G=**, NxG=NS				
	2000									
C 6127	9.5	10.3	11.0	10.9	10.4	10.1	9.2	11.0	10.9	10.3
DK 626	8.1	11.4	11.0	11.5	10.5	11.1	10.8	12.3	11.5	11.4
XL 72AA	9.5	10.6	11.0	10.7	10.5	8.9	8.2	10.3	10.7	9.5
DK 623	7.8	8.9	9.8	10.2	9.2	10.2	9.7	10.0	10.2	10.0
DRACMA	9.1	10.3	10.3	10.0	9.9	10.8	12.2	11.9	10.0	11.2
LG 60	9.6	10.6	12.1	11.8	11.0	9.9	10.6	10.4	11.8	10.7
P32K61	8.3	9.7	9.9	10.8	9.7	10.8	12.6	13.0	10.8	11.8
P 3335	8.1	7.0	9.2	9.9	8.6	11.2	12.1	13.4	9.9	11.7
P 3394	10.2	10.3	10.9	10.8	10.6	10.0	10.9	11.9	10.8	10.9
TTM 815	9.9	11.6	12.0	11.9	11.4	10.3	10.8	12.6	11.9	11.4
Mean	9.0	10.1	10.7	10.9		10.3	10.7	11.7	10.9	
F Test	N, G, NxG = NS					N=***, G=**, NxG=NS				

, *, NS denotes significance of 5%, 1%, and non-significance, respectively.

Table 3. Grain N uptake (kg N ha-1) of ten corn varieties to varying N fertilizer application rates at two locations in 1999 and 2000.

Genotypes	University farm					Cutaem				
	N application rates (kg N ha^{-1})									
	160	240	320	400	Mean	160	240	320	400	Mean
	1999									
C 6127	180	263	230	267	235	177	215	222	186	200
DK 626	191	255	318	202	242	149	262	196	223	208
XL 72AA	182	189	336	261	242	182	259	193	210	211
DK 623	170	176	308	197	213	111	260	231	182	196
DRACMA	195	183	241	187	202	266	256	287	243	263
LG 60	171	258	306	281	254	188	145	216	228	194
P32K61	292	214	269	211	247	264	251	207	260	246
P 3335	169	165	212	175	180	168	257	175	259	215
P 3394	222	270	197	250	235	215	212	196	207	208
TTM 815	283	238	294	218	258	277	253	187	373	273
Mean	206	221	271	225		200	237	211	237	
F Test	N=**, G, NxG = NS					N, G, NxG=NS				
	2000									
C 6127	125	176	204	245	188	390	207	436	497	383
DK 626	160	137	165	179	160	374	522	350	533	445
XL 72AA	204	188	189	264	211	230	343	357	409	335
DK 623	133	171	167	438	227	385	508	319	332	386
DRACMA	161	209	167	241	195	285	355	410	289	335
LG 60	173	188	188	202	188	252	545	402	385	396
P32K61	121	149	145	189	151	227	368	331	379	326
P 3335	85	167	172	133	139	243	476	350	388	364
P 3394	155	166	202	218	185	339	523	411	429	426
TTM 815	144	241	222	204	203	179	534	328	327	342
Mean	146	179	182	231		290	438	369	397	
F Test	N=**, G, NxG = NS					N=***, G=***, NxG=***				

, *, NS denote significance of 5%, 1% and non-significant, respectively.

Table 4. Nitrogen use efficiency (kg grain per kg N applied) of corn genotypes in relation to N fertilizer application rates.

Genotypes	University Farm					Cutaem				
	N application rates (kg N ha^{-1})									
	160	240	320	400	Mean	160	240	320	400	Mean
	1999									
C6127	51.3	43.3	31.9	27.0	38.4	61.9	41.7	35.3	30.3	42.3
DK 626	45.6	42.5	35.9	25.0	37.3	58.1	42.1	40.9	32.8	43.5
XL 72AA	57.5	45.0	29.1	25.0	39.1	70.6	45.8	39.7	30.5	46.7
DK 623	60.6	47.1	33.4	25.8	41.7	70.6	48.8	39.4	31.0	47.4
DRACMA	61.3	44.6	33.1	26.5	41.4	70.6	53.3	35.9	31.0	47.7
LG 60	55.0	44.6	34.7	24.3	39.6	62.5	47.1	37.2	31.5	44.6
P32K61	51.9	38.8	33.1	27.0	37.7	68.1	54.6	47.5	35.3	51.4
P 3335	56.9	37.9	30.0	26.5	37.8	70.6	44.6	38.1	35.5	47.2
P 3394	65.6	42.1	27.5	29.5	41.2	66.9	48.3	36.9	33.0	46.3
TTM 815	65.6	45.4	33.1	27.8	43.0	63.8	46.7	40.0	31.0	45.4
Mean	57.1	43.1	32.2	26.4		66.4	47.3	39.1	32.2	
F Test	N=**, G, NxG = NS					N, G, NxG=NS				
	2000									
C 6127	59.4	42.9	34.4	27.3	41.0	63.1	38.3	34.4	27.3	40.8
DK 626	50.6	47.5	34.4	28.8	40.3	69.4	45.0	38.4	28.8	45.4
XL 72AA	59.4	44.2	34.4	26.8	41.2	55.6	34.2	32.2	26.8	37.2
DK 623	48.8	37.1	30.6	25.5	35.5	63.8	40.4	31.3	25.5	40.2
DRACMA	56.9	42.9	32.2	25.0	39.2	67.5	50.8	37.2	25.0	45.1
LG 60	60.0	44.2	37.8	29.5	42.9	61.9	44.2	32.5	29.5	42.0
P32K61	51.9	40.4	30.9	27.0	37.6	67.5	52.5	40.6	27.0	46.9
P 3335	50.6	29.2	28.8	24.8	33.3	70.0	50.4	41.9	24.8	46.8
P 3394	63.8	42.9	34.1	27.0	41.9	62.5	45.4	37.2	27.0	43.0
TTM 815	61.9	48.3	37.5	29.8	44.4	64.4	45.0	39.4	29.8	44.6
Mean	56.3	42.0	33.5	27.1		64.6	44.6	36.5	27.1	
F Test	N=**, G, NxG = NS					N=***, G=***, NxG=***				

, *, NS denote significance of 5%, 1% and non-significance, respectively.

Nitrogen use efficiency is the grain yield of corn divided by the respective N application.

Nitrogen-use efficiency, in terms of grain per kg N applied, showed variation with location and years (Table 4). In 1999, the only significant effect was with N at the Farm site, with consistent decreases in use efficiency (57.1, 43.1, 32.2 and 26.4kg kg^{-1} N) as the application rate increased. A similar pattern of decrease occurred at the Farm site in the second year. Again, as noted for yield and N uptake, the main effects and interactions were only significant at the Cutaem site in the second year.

The general pattern observed was a decrease in efficiency with increasing N application to an extent that depended on the genotype. When N uptake efficiency was expressed by grain uptake over the respective N application, significant effects paralleled those for nitrogen uptake efficiency (Table 5). Thus, only N was significant at the University Farm site in 1999 and in 2000, while all factors were significant at the Cutaem site in the second year. The general observation was one of decreasing values with increasing applied N levels.

Table 5. Nitrogen uptake efficiency (kg grain N uptake per kg N applied) of corn genotypes at varing N application rates at the two locations (1999 and 2000).

Genotypes	University Farm					Cutaem				
	N application rates (kg N ha^{-1})									
	160	240	320	400	Mean	160	240	320	400	Mean
	1999									
C 6127	1.1	1.1	0.7	0.7	0.9	1.1	0.9	0.7	0.5	0.8
DK 626	1.2	1.1	1.0	0.5	0.9	0.9	1.1	0.6	0.6	0.8
XL 72AA	1.1	0.8	1.1	0.7	0.9	1.1	1.1	0.6	0.5	0.8
DK 623	1.1	0.7	1.0	0.5	0.8	0.7	1.1	0.7	0.5	0.7
DRACMA	1.2	0.8	0.8	0.5	0.8	1.7	1.1	0.9	0.6	1.1
LG 60	1.1	1.1	1.0	0.7	1.0	1.2	0.6	0.7	0.6	0.8
P32K61	1.8	0.9	0.8	0.5	1.0	1.7	1.0	0.6	0.7	1.0
P 3335	1.1	0.7	0.7	0.4	0.7	1.1	1.1	0.5	0.6	0.8
P 3394	1.4	1.1	0.6	0.6	0.9	1.3	0.9	0.6	0.5	0.8
TTM 815	1.8	1.0	0.9	0.5	1.1	1.7	1.1	0.6	0.9	1.1
Mean	1.3	0.9	0.8	0.6		1.2	1.0	0.7	0.6	
F Test	N=**, G, NxG = NS					N, G, NxG=NS				
	2000									
C 6127	0.8	0.7	0.6	0.6	0.7	2.4	0.9	1.4	1.1	1.4
DK 626	1.0	0.6	0.5	0.4	0.6	2.3	2.2	1.1	0.9	1.6
XL 72AA	1.3	0.8	0.6	0.7	0.8	1.4	1.4	1.1	0.9	1.2
DK 623	0.8	0.7	0.5	1.1	0.8	2.4	2.1	1.0	0.8	1.6
DRACMA	1.0	0.9	0.5	0.6	0.8	1.8	1.5	1.3	1.0	1.4
LG 60	1.1	0.8	0.6	0.5	0.7	1.6	2.3	1.3	1.0	1.5
P32K61	0.8	0.6	0.5	0.5	0.6	1.4	1.5	1.0	0.8	1.2
P 3335	0.5	0.7	0.5	0.3	0.5	1.5	2.0	1.1	0.9	1.4
P 3394	1.0	0.7	0.6	0.5	0.7	2.1	2.2	1.3	1.0	1.7
TTM 815	0.9	1.0	0.7	0.5	0.8	1.1	2.2	1.0	0.8	1.3
Mean	0.9	0.7	0.6	0.6		1.8	1.8	1.2	0.9	
F Test	N=**, G, NxG = NS					N=***, G=***, NxG=***				

, *, NS denote significance of 5%, 1% and non-significance, respectively.

Nitrogen uptake efficiency is the grain N uptake of corn divided by the respective N application.

As with previous measurements of efficiency, a similar pattern of significance emerged when N utilization efficiency was considered (Table 6). Where N was significant (University Farm), by comparison with the lowest N application rate (160 kgN ha^{-1}), with increasing N application rates, the pattern was inconsistent in 1999, but tended to decrease in 2000. Similarly, despite significant main effects and their interaction, the changes in utilization efficiency with increasing applied N varied with the genotype, but the trend was a decrease with applied N fertilizer rates.

Discussion

The concept of fertilizer best management practices underpinned this 2-year field study involving N fertilization of corn genotypes in the corn-producing Mediterranean coastal region of Turkey. The minimum N application rate adopted here was based on local experience of what was adequate to produced acceptable crop yields. The rationale for including much higher application rates was to establish if such N amounts were surplus to requirements, resulting in an economic waste of fertilizer with negative impact on the environment due to the excess N. Implicit in the selection of a range of corn genotypes was that a differential response to applied N would occur. As corn genotypes exhibit genetic diversity in many traits related to yield (Turi *et al*., 2007; D'Andrea *et al*., 2006; Rafiq *et al*., 2010), especially N response (Cui *et al*., 2009), it was speculated that such diversity could be manipulated in breeding programs for crop improvement. We further assumed that the genotypes would reflect a range of responses to N as was shown by Korkmaz *et al*., (2009) for responses of corn genotypes to P fertilizer.

Table 6. Nitrogen utilization efficiency (kg grain yield per kg grain N uptake) of corn genotypes at varing N application rates at 2 locations in 1999 and 2000.

Genotypes	University farm					Cutaem				
	N application rates (kg N ha^{-1})									
	160	240	320	400	Mean	160	240	320	400	Mean
	1999									
C 6127	45.6	39.5	44.3	40.4	42.5	55.9	46.5	50.9	65.1	54.6
DK 626	38.2	40.0	36.2	49.5	41.0	62.4	38.5	66.8	58.7	56.6
XL 72AA	50.5	57.1	27.7	38.3	43.4	62.1	42.5	65.8	58.1	57.1
DK 623	57.1	64.2	34.7	52.3	52.1	101.8	45.0	54.5	68.1	67.4
DRACMA	50.3	58.5	44.0	56.7	52.3	42.5	50.0	40.1	51.0	45.9
LG 60	51.5	41.5	36.3	34.5	40.9	53.2	77.9	55.1	55.3	60.4
P32K61	28.4	43.5	39.4	51.2	40.6	41.3	52.2	73.4	54.2	55.3
P 3335	53.8	55.2	45.3	60.6	53.7	67.3	41.6	69.7	54.8	58.4
P 3394	47.3	37.4	44.7	47.2	44.1	49.8	54.7	60.2	63.8	57.1
TTM 815	37.1	45.8	36.1	50.9	42.5	36.8	44.3	68.4	33.2	45.7
Mean	46.0	48.3	38.9	48.2		57.3	49.3	60.5	56.2	
F Test	N=**, G, NxG = NS					N, G, NxG=NS				
	2000									
C 6127	76.0	58.5	53.9	44.5	58.2	25.9	44.4	25.2	21.9	29.4
DK 626	50.6	83.2	66.7	64.2	66.2	29.7	20.7	35.1	21.6	26.8
XL 72AA	46.6	56.4	58.2	40.5	50.4	38.7	23.9	28.9	26.2	29.4
DK 623	58.6	52.0	58.7	23.3	48.2	26.5	19.1	31.3	30.7	26.9
DRACMA	56.5	49.3	61.7	41.5	52.2	37.9	34.4	29.0	34.6	34.0
LG 60	55.5	56.4	64.4	58.4	58.7	39.3	19.4	25.9	30.6	28.8
P32K61	68.6	65.1	68.3	57.1	64.8	47.6	34.2	39.3	28.5	37.4
P 3335	95.3	41.9	53.5	74.4	66.3	46.1	25.4	38.3	25.5	33.8
P 3394	65.8	62.0	54.0	49.5	57.8	29.5	20.8	29.0	25.2	26.1
TTM 815	68.8	48.1	54.1	58.3	57.3	57.5	20.2	38.4	36.4	38.1
Mean	64.2	57.3	59.3	51.2		37.9	26.3	32.0	28.1	
F Test	N=**, G, NxG = NS					N=***, G=***, NxG=***				

+; **, ***, NS denote significance of 5%, 1% and non significant, respectively.
Nitrogen utilization efficiency is the grain yield of corn divided by the respective N uptake by grain.

Despite our expectations, data on yields were inconsistent with location and cropping season. The absence of any response at the University Farm location suggests that the lowest application rate (160kg N ha^{-1}) was generally adequate for maximum yields, with higher amounts of N applied being a waste of resources and a cause of environmental pollution (Cui *et al*., 2008). The small increase with applied N at the second site are probably attributed to lower mineral N and lower mineralization potential at that site compared to the Farm site. That no interactions occurred between applied N and genotypes in terms of yield is probably due to genetic uniformity. Only at the Cutaem site was the NxG interaction significant for N uptake and than only in 2000. Most probably, breeding for N response was also incorporated into the development of those genotypes. As shown by Anderson *et al*., (1985), corn genotypes bred for yield are collectively different in terms of N response than less productive genotypes.

While not having in unfertilized control was a limitation in assessing NUE, that constraint was dictated by practical on-farm conditions as yield without applied N would have been small and unharvestable. However, we assessed NUE using the accepted partial factor productivity of applied N (PFP_N), or kg of harvestable product per unit of N applied (Dobermann, 2005). This approach is important for farmers as it describes the use efficiency of both native or indigenous N and applied fertilizer N. Increasing native N and increasing the efficiency of applied N are equally important to improving PFP_N values, which normally range from 40-70kg grain per kg N (Dobermann, 2005). Our PFP_N values (Table 4) all fell within this range and consistently decreased, reflecting the limited responses with increasing N applied. Using a similar approach, Kamprath *et al*., (1982) noted PFP_N values of 101, 41 and 25 for N application rates of 56, 168 and 280 kg ha^{-1} for corn hybrids. The high values reflect either low N supply or an efficiently managed system (Dobermann, 2005). As with yield and N uptake, our PFN_N as an index of NUE indicated little evidence of interactions between applied N and genotypes.

As efficiency of N use by cereal genotypes can be described by several other indices (Kamprath *et al*., 1982; Moll *et al*., 1987; Dobermann, 2005), we used some of these to describe N efficiency. Using total N uptake per unit N applied or Nt/Ns (Table 5), our data correspond with values observed by Kamprath *et al*., (1982) showing consistent decreases with added N (1.8-0.6), but again showing no consistent differential effect of genotypes. Nitrogen utilization efficiency, or total corn grain weight / N uptake (Table 6) was not as consistent in relation to N response as previous indices, but in accord with those indices there was no consistent genotype interaction. Notwithstanding the validity of the efficiency indices used the more conventional NUE indices (Dobermann, 2005) of agronomic efficiency (AE_N), crop recovery efficiency (BE_N), and physiological efficiency (PE_N) could not be applied due to the absence on unfertilized control.

In summary, this field study of N-fertilized corn genotypes in the southern coastal region of Turkey indicated the maximum fertilization rate should not exceed 160-240kg N ha^{-1}. Using crop yields, N uptake, and various indices of NUE, there was little to indicate any differential response to N fertilization. Thus, with respect to N response, the 10 genotypes were genetically similar. Nevertheless, only crop response trials in the field can reliably assessed the N response patterns types. Part of the variation in the data may be explained by inherent drawbacks in field experimentation involving due to sampling variability arising from the plant size.

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