# Maize Yield and Nitrogen Use Efficiency Components in Relation to Nitrogen, Cultivars, and Biofertilizer

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## ABSTRACT

Applying soil N fertilizer is a crucial factor for maximizing maize (*Zea mays* L.) grain yield. Maize hybrids have been found to positively respond to high amounts of applied soil N; yet high-applied soil N amount results in reduced N use efficiency (NUE), develops more environmental problems, and augments grower economic inputs. One way to compensate for using excessive N fertilizers is to apply non-symbiotic seed-inoculated nitrogen fixers. Therefore, the main objective of this experiment is to study NUE and its components – nitrogen uptake efficiency ($N_{UPE}$) and nitrogen utilization efficiency ($N_{UTE}$)-- of three maize hybrids at different N levels, and bio fertilizer. A 2-yr field study was carried out at the Moshtohor Agricultural Experiment Center, Kalubia in 2001 and 2002 on clay soil with a pH 7.85 and 2.0 organic matter. Eighteen treatments were: 0, 60, and 120 kg N $f^{-1}$; three maize cultivars (C) – Single Cross 10 hybrid (SC), Three-Way Cross 310(WC), and Giza 2--; zero and bio fertilizer (BF). Treatments were arranged as a split plot design in four RCB. The N levels were the main plots, and factorial combinations of both cultivars and bio fertilizer were the subplots. The N rate varied in favor of the 120 kg N, in both years, for all yield components and grain yield. In addition, grain N uptake increased in the same trend and this was reflected in grain protein yield. However, grain NUE, as well as its components, $N_{UPE}$ and $N_{UTE}$, was inversely related to N rate. Maize SC 10 hybrid, on the other hand, out yielded both TWC 310 and Giza 2 for grain and protein; surpassed both for NUE and $N_{UPE}$. Addition of bio fertilizer did not cause any differences for all characters studied. Only in both years, the N x C interaction was quite different ($p<0.05$) for just 100-grain weight and grain yield. Both SC x 60- and x 120-kg N for either 100-grain weight or grain yield had the highest means in both years. By cutting N rate in half within each cultivar, grain yield relatively dropped by 31.5% for Giza 2 and by 32% for SC, and by 37% for TWC averaged over the two years. Within maize cultivar, the 0-N and the two N rates differed for grain protein content, yet within N rate, cultivars had similar response within 0-N but great variation occurred within either 60- or 120-kg N. Grain NUE negatively responded to N fertilizer rate in both years. Mean SC hybrid for NUE were 51.7, 34.5 compared to 43.5, 30.3 for Giza 2; and 37.0, 31.7 kg grain $kg^{-1}$N for TWC hybrid for 60- and 120-kg N, respectively. Despite both $N_{UPE}$ and $N_{UTE}$ mean values were negatively associated with N rate and this paralleled NUE mean value, $N_{UPE}$ seemed to have contributed relatively more to NUE than $N_{UTE}$.


Key words: Maize, *Zea mays* L., N fertilizer, bio fertilizer, grain N uptake, NUE, $N_{UPE}$, $N_{UTE}$.

## INTRODUCTION

In Egypt, maize growers have been concerned with using high grain yield hybrids. Since hybrids have been found either to vary in their N rate

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to maximize grain yield or to have the potential to respond more efficiently to high amounts of N fertilizer or both, growers have tended to apply more N fertilizer than needed. Nitrogen supply limits to a great extent, as indicated by Mulvaney (1992), the growth and productivity of non-leguminous crops more often than the supply of any other mineral nutrient. Jokela and Randal (1989) pointed out that response to fertilizer N by corn hybrids is affected by time of application, rates, plant densities, soil type, previous fertilizer N applications, and hybrid. Therefore, breeding corn hybrids at low N that can remove more N to grain and efficiently utilize this N would eventually lead to saving input costs. An additional way to minimize N fertilizer usage is to apply non-mineral N sources – organic manure, and biofertilizers.

Since fertilizer N contributes a major portion to soil available N, applying excessive amounts of N fertilizer has been so far of great concern to researchers particularly to cereal grain nitrogen use efficiency (NUE). Cereal NUE has been estimated to be 29% in developing countries and 42% in developed countries. The world cereal grain NUE has been estimated at 33% (Raun and Johnson, 1999). One reason for this quite low cereal NUE is related to excessive N losses under application of higher N fertilizer rates (Sowers et al., 1994). Soil N losses result from gaseous plant emission, soil denitrification, surface runoff, volatilization, and leaching (Mulvaney, 1992; Raun and Johnson, 1999). Mulvaney (1992) further added that the nature and extent of the N transformations in soils ultimately determine the fate of fertilizer N, its availability to crops, and its pollution potential. Therefore, NUE may be improved and soil N losses reduced due to synchronization of seasonal timing of N mineralization of organic amendments and maize (*Zea mays* L.) N uptake (Ma et al. (1999a).

The effects of many factors on NUE have been studied. Estimated values of NUE declined substantially as soil available N increased for maize (Schmidt et al., 1998; and Ma et al., 1999) and for wheat (*Triticum aestivum* L.) (Limon-Ortega et al., 2000). Raun and Johnson (1999) argued that cereal NUE is unlikely to be improved unless a systems approach is employed that uses high harvest index and improved NUE cultivars, incorporated $NH_4$-N fertilizer, application of prescribed rates consistent with in-field variability, low N rates applied at flowering, and forage production systems.

Raun and Johnson (1999) also owed mainly --NUE variations among corn hybrids under low N supply-- to differences in utilization of accumulated N especially before anthesis. Cereal plants release N from plant tissue as $NH_3$ following anthesis (Francis et al., 1993). They also added that in corn research 52% to 73% of the unaccounted N using $^{15}N$ was due to plant N losses. However, differences among corn hybrids for N uptake efficiency, rather than N utilization efficiency, (Dhugga and Waines, 1989; and Horst et al., 2003) paralleled differences in overall NUE (Ma et al., 1999). Moreover, nitrogen uptake dominated NUE since variations in total plant N paralleled variations in yield (Ma and Dwyer, 1998). Under three N levels, Presterl et al. (2002) for yield and NUE evaluated two sets of European maize hybrids, which had been developed under low- and high -N input. Low-N hybrids had higher N uptake at both low and medium N levels; yet, no differences in N utilization efficiency between hybrid types were observed. Low-N hybrids had also mean yield higher than those of high-N hybrids at low and high N supply. Maize varieties with improved NUE under low N conditions, as suggested by Presterl et al. (2003), can contribute to sustainable agriculture.

The NUE has been defined in various ways; however, these definitions are certainly based on the same notion which is how a crop plant transforms available soil N to economic yield (Moll et al, 1982; and Ma et al., 1999a). It is also calculated as [(total cereal N removed)- (available soil N+ N deposited in the rainfall)]/(fertilizer N applied to cereals)(Raun and Johnson, 1999). Liang and Machenzie (1998) defined NUE as total plant N divided by the amount of available soil N. This definition is in fact analogous to Moll et al.'s (1982) definition of nitrogen uptake efficiency—the per plant N per available soil N. Nitrogen utilization efficiency is defined as gram of yield per gram of plant total N. Both terms together comprise NUE (Moll et al., 1982; and Dhugga and Waines, 1989).

The variations in NUE definitions among researchers refer mainly to how they define N supply. Sowers et al. (1994) defined NUE as grain yield per just N fertilizer applied which makes other possible N sources nearly constant. However, from Raun and Johnson's (1999) definition, both soil N and rainfall N adjusted grain N uptake. In Limon-Ortega's (2000) N supply is the sum of applied fertilizer N plus total N uptake in zero-N applied plots in both straw and grain. On the other hand, Dhugga and Waines (1989) considered N supply as the residual soil N plus applied N. To Thomason et al. (2000) in both forage and grain production of winter wheat, N supply was merely N available in the soil. In pearl millet (*Pennisetum glaucum* (L.) R Br.), Maman et al. (1999) defined NUE as grain yield per N uptake in the aboveground biomass.

In addition to adopting the idea of improving cereal grain NUE through minimizing N fertilizer application and improving maize hybrid NUE, there has been a great interest in using other N soil sources. Such as organic manure (Ma et al., 1999 and 1999a), bio solids (Binder et al., 2002), and bio fertilizers (Atta Allah, 1998). These practices have the potential to diminish growers' input costs, soil N losses and environmental hazards.

Our objectives of this research were to (i) assess grain nitrogen use efficiency as well as grain yield and protein for three maize cultivars at three N fertilizer rates and biofertilizer, (ii) evaluate the relative contribution of efficiency of grain N uptake and of nitrogen utilization to NUE, and (iii) study bio fertilizer potential as an N source.

## MATERIALS AND METHODS

A two-year field study was carried out at Moshtohor Experiment Center, Kalubia, Zagazeeg University in 2001 and 2002 on a clay soil with a pH 7.85 and 2% organic matter. Eighteen treatments were arranged in factorial experement within split plot design with four replications.Three nitrogen fertilizer rates --0, 6o, and 120 kg fa $^{-1}$ — were the main plots, three corn (*Zea mays* L.) cultivars – Giza 2, SC10, and TWC 310—and two bio fertilizer – zero and added— were the subplots. These cultivars have been developed by the Maize Research Unit, the Agricultural Research Center (ARC), Giza, Egypt. Seeds were planted on 27 May in 2001 and 11 June in 2002 in 3.0m x 3.5m subplots. Seeds were put in 0.30-m intra-ridge distance in five 0.70-m ridges at a rate of 15 kg fa$^{-1}$. In both years Egyptian clover (*Trifolium alexandrinum* L.) was the preceding crop.

Two split doses of N fertilizer ($NH_4$ $No_3$, 33.5%) were applied just prior to Irrigation 1 and 2. Maize seeds, just before planting, were inoculated with a mixture of a non-symbiotic N fixing Cerialine and Fosfarine biofertilizer mixture at a rate of 0.50 kg inoculum 15.0 kg $^{-1}$ maize seeds. These bio fertilizers have been developed at ARC, Egypt. During the two years there was an infection in some plots with corn borers, so a 1.5 litre fa$^{-1}$ of Nuvacron (mono crotophos dimethyl 1-dimethyl-2-(methyl carbamoyl) vinyl phosphate 3- (dimethoxy phosphinoloxy)-N-ethyl isocrotonamide) was sprayed. Hand weeding and cultivation were occasionally performed when needed.

At about 85 days after planting (DAP), a 10-guarded plant random sample was used from within each subplot to measure plant height, ear height, stem diameter, green leaf plant $^{-1}$. At harvest, a 10-ear random sample was used to measure ear length, grain row $^{-1}$, ear diameter, row ear $^{-1}$, ear weight, grain weight ear $^{-1}$, 100-grain weight, and percent shelling. Grain yield fa $^{-1}$ was estimated on a whole-plot basis after it had been adjusted to a 155 g kg$^{-1}$ moisture content.

Grain N content was estimated by micro Kjeldahl procedure. Both grain N uptake (N removal) and protein concentration were determined as grain yield per unit area multiplied by percent grain N, and by N x 6.25, respectively (Lambert et al., 2001). Then grain protein per unit area was obtained as a product of grain protein concentration and grain yield per unit area. Grain nitrogen use efficiency (NUE) was calculated as NUE = (Grain yield/$N_{applied}$) (Sowers et al., 1994; Young et al., 1999). Components of NUE, Nitrogen uptake efficiency ($N_{UPE}$), and Nitrogen utilization efficiency ($N_{UTE}$), were calculated as a derivation of Moll et al.'s (1982): $N_{UPE}$ = (grain N uptake)/(N applied), and $N_{UTE}$ = (Grain yield)/ (grain N uptake).

Statistical analyses were performed using the SAS general linear model (GLM) procedure (SAS Inst., 1990). When first-order interaction(s) was/were significant, main effects are no longer independent. Hence, simple effects were examined since they were declared heterogeneous (Steel and Torrie, 1980, p. 346). Treatment means were compared on the basis of an F-protected ($P \leq 0.05$) least significant difference test.

## RESULTS AND DISCUSSION

1. Yield-related, and Yield Characters

Yield component trait means related to maize cultivar grain yield at N fertilizer rates and biofertilizer are shown in Table 1&2, along with F-test probabilities for main effects and interactions. In both study years, N fertilizer rate greatly varied ($p<0.005$) for four out of the six studied morphological traits (Table 1). These traits were plant height, ear height, ear length, and green leaf number plant $^{-1}$. For both stem and ear diameters, N rate just differed ($p<0.05$) in one year. For all traits, however, maize cultivars deviated ($p<0.05$) in Year 1 only, but bio fertilizer did not ($p>0.05$) except for leaf plant $^{-1}$ in Year 1.

For each N increment plant height, ear height, and ear length rose linearly in both years (Table 1). The positive change in ear height paralleled plant height as N fertilizer moved up. For the above three growth traits, both N rates differed from zero-N treatment and the 120 kg N averaged more than the 60 kg N. By increasing N rate up to 125 kg (Hassanein et al., 1997), and up to 150 kg (El-Gizawy, 2000), plant height increased; yet applying N from 30 up to 150 kg, plant height, ear height, and leaf number were not affected (Shafshak et al., 1995). In the latter study, means were averaged over different planting dates, which may have led to this result. Also, Aly et al. (1996) varying N rates from 90 to 120 kg did not cause any differences in growth traits; it is likely that putting N rates in the subplots may be the reason.

For maize cultivar in Year 1, differences between SC10 and TWC 310 were minor ($p<0.05$) for almost all traits in Table 1. However, both hybrids differed ($p<0.05$) from cv. Giza 2. The TWC 310 compared to Giza 2 had higher plants and ears, and greater stem diameter (Aly et al., 1996); and more leaf plant $^{-1}$ and ear length (Shafshak et al., 1995).

For grain yield as well as almost all yield-related characters (Table 2), N rate main effect differed ($p<0.05$) upward in favour of the 120 kg N vs. either 0-N or 60 kg. Nitrogen rate increased grain yield quadratically (Oikeh et al., 1998), but Ma et al. (1999, 1999a), in maize, did not find differences between 100 and 200 kg N ha$^{-1}$. Winter wheat grain and forage production responded similarly to N fertilization (Thomason et al., 2000). On pear millet, Maman et al. (1999) did find yield difference between 0 and 78 kg N ha$^{-1}$. Presterl et al. (2003) had a 37% yield reduction at 0-N compared to high N.

The SC 10 hybrid main effect differed ($p<0.05$) from both TWC 310 and Giza 2 for most yield–related and grain yield characters (Table 2). Row ear $^{-1}$ of SC 10 was lower than that of the other two cultivars. In Shafshak et al.'s (1995) study, Giza 2 had more ear row $^{-1}$ than TWC 310. No difference was found between SC10 and TWC 310 for grain row $^{-1}$ and percent shelling. Both TWC 310 and Giza 2 did not differ for both 100-grain weight and percent shelling (El-Habbak and Shams El-Din (1996). Grain yield of SC 10 hybrid outyielded that of TWC 310 and Giza 2 (Table 2) as also indicated by Abou-Grab et al. (1997). However, grain yield means of the same three cultivars were close ($p>0.05$) (El-Habbak, 1996). Both N rate and plant density main effects, in the latter study, have caused noticeable variations in mean grain yields. This may partially explain the non-significant differences among mean grain yields of the three cultivars.

Except for 100-grain weight and grain yield fa $^{-1}$, most first-order interactions were not significant for any particular trait in the two years

(Tables 1, 2). Oikeh et al. (1998) on maize found significant differences between N x C interaction for both traits; yet for grain yield, Maman et al. (1999) did not for just grain yield. The N x C interaction varied for leaf plant $^{-1}$ (p=0.04) in Year 1 (Table 1), for ear weight (p<0.001) in Year2, grain weight ear $^{-1}$ (p<0.001) in Year 2, grain row $^{-1}$ (p=0.03) in Year 1 (Table 2). The C x BF interaction was different for both stem diameter (p=0.04) and leaf plant $^{-1}$ (p=0.05) in Year 1(Table 1), and for percent shelling (p=0.03) in Year 1 (Table 2). The N x BF interaction was significant (p=0.03) for 100-grain weight in Year 1.

The significance of any particular interaction indicated dependence of the involved main effects. Means of the significant nitrogen x cultivar interaction are shown in Table 3. Within any maize cultivar for all four traits, nitrogen increment had a positive effect except for SC grain per row since its mean dropped by doubling N rate. All N rate means were higher than the 0-N (p<0.05), and almost all 120 kg N means were higher than that of 60 kg N within each cultivar. The SC hybrid responded positively more than either Giza 2 or TWC did to N rate for leaf plant $^{-1}$, ear weight, and grain weight ear $^{-1}$.

Explanation of the N x C interaction for grain yields fa $^{-1}$ (Table 4) is partially related to that of the yield component traits. Though not significant (p=0.06) (Table 2), the 2001 N x C interaction for grain weight ear $^{-1}$ means --for N rate within SC hybrid -- were in sharp positive order towards the 120 kg N and paralleled those of 2002 (Table 3). In addition, in 2001, difference among 100-grain weight means between both N rates within either SC or TWC hybrids was minor (p>0.05) (Table 4). However, by cutting N rate in half within each cultivar, grain yield fa $^{-1}$ (Table 4), relatively dropped by about 28% for Giza 2, 25% for SC, and 42% for TWC in Year 1; by 35%, 39%, and 32% in Year 2 in the same order.

Within Giza 2 in either year, the magnitude of the difference between 100-grain weight was quite similar for 60 and 120 kg N (Table 4) and so was the magnitude for grain weight ear $^{-1}$ in Year 2 (Table 3). This caused grain yield fa $^{-1}$ to rise for the same interaction effects. Within SC hybrid, the magnitude of the difference for 100-grain weight was low in Year 1 (32.5 g vs. 36.8 g) than it was in Year 2 (32.8 g vs. 36.1 g), which resulted in the 25% and 39% yield drop in the two years mentioned earlier. This indicated that variations between N rates within SC hybrid for grain yield fa $^{-1}$ was affected partially more by N x SC for average grain weight than it did by N x SC for grain row $^{-1}$, ear weight, or grain weight ear $^{-1}$. Within TWC hybrid, although the magnitude of the difference for 100-grain weight followed a similar pattern as that of within SC, the 60 kg N to120 kg N grain relative yield drop changed in opposite order in the two years (42% vs. 32%). Differences in each of ear weight, grain weight ear $^{-1}$ due to N rate within TWC, therefore, contributed relatively more to grain yield.

Moreover, the simple effects of the N x C interaction for either 100-grain weight or grain yield fa $^{-1}$ were examined (Tables 5 and 6) since they had been declared heterogeneous (Steel and Torrie, 1980 p.346). When N x C sliced by cultivar, differences between N rates within any of the three cultivars were high ($p<0.05$) (Table 5). On the other hand, when sliced by N rate, all differences were extremely high ($p<0.05$) for both traits; however, the only quite low ($p=0.09$) difference was that within 120 kg N for 100-grain weight in Year 2 (Table 6). This low difference can be depicted from Table 4 since mean differences between SC and TWC was less than the 5% LSD value.

Hence, variations in grain yield per unit area were quite dependent on the association between cultivars and applied N rate. A particular cultivar grain yield was heavily relied on the applied N fertilizer rate. Grain yield range had a positive trend towards the highest N rate for each cultivar. In addition, within any specific N rate, a wide range in grain yield among cultivars occurred. The SC hybrid grain yield responded relatively more to N increment compared to Giza 2 and TWC hybrid. Compared to SC and averaged over years, both Giza 2 and TWC mean grain yield were lower by about 20% and 17.5% at 0-N, 14% and 16% at 60-N, and 15.5% and 10% at 120 kg N. Relative yield reduction of either cultivars was nearly inversely related to N fertilizer supply. Presterl et al. (2002) found an 11.5% higher yield for low N-bred maize hybrids vs. high-N bred ones at lower N supply and by 5.4% at high N supply. Thus, SC hybrid seems to have the potential to respond positively to low- and medium-N supply compared to Giza 2 and TWC

## 2. Grain Protein Yield, and Grain Nitrogen Use efficiency (NUE)

### 2.1. Grain Protein Yield

Nitrogen rate was greatly differed ($p<0.001$) for both grain N uptake (grain N removal) and grain protein yield in both years (Table 7). Pearl millet panicle N increased by using 78 kg N ha $^{-1}$ vs. 0-N (Maman et al., 1999). Grain N uptake was linearly increased as N rate reached 120 kg, and so did grain protein yield in both years. The 120 kg N fa $^{-1}$ resulted in nearly twice as much grain N removal as that 60 kg (Table 7); this led to 76% and 97% grain protein content higher for the 120 kg N in both years, respectively. However, increasing N level increased grain protein quadratically for five maize cultivars (Oikeh et al., 1998). To depict a response curve to N rate depends to great extent on how many N rates are used. In our study, three N rates are not quite enough to establish a response function since it was not one of the objectives, but in Oikeh et al's (1998), they used four N rates which can determine the nature of the response.

Moreover, grain protein yield differed ($p<0.001$) (Table 7) among the three cultivars. Mean grain protein yield of SC10 surpassed ($p<0.05$) those of TWC 310 and Giza 2 yields in both years (Table 7). This was merely due to higher grain N uptake as well as greater grain yield of SC10 compared to the other two cultivars in both years. The SC10 had the highest grain content compared to Giza 2 and TWC310 (Abou-Grab et al., 1997). TWC 310 and Giza 2 protein yields were close in Year 1 ($p>0.05$); by about 13% relative margin in Year 2.

The N X C interaction just varied ($p=0.05$) in Year 1, but Oikeh et al. (1998) did not find it significant for grain protein concentration or yield. Within maize cultivars, the 0-N and the two N rates differed for grain protein content (Table 8), yet within N rate, cultivars had similar response within 0-N but great variation occurred within either 60- or 120-kg N ($p<0.05$) (Table 9). The SC x 60-kg N gave 284 kg $fa^{-1}$, and x 120-kg N gave 460 kg $fa^{-1}$grain protein yield.

2.2. Grain Nitrogen Use efficiency and Components

Grain nitrogen use efficiency (NUE) was affected --greatly ($p<0.001$) in Year 1 but barely ($p=0.052$) in Year 2-- by N fertilizer rate. Grain NUE negatively responded to N fertilizer rate in both years (Table 7) (Sowers et al., 1994; Schmidt et al., 1998; Ma et al., 1999; and Limon-Ortega et al., 2000). Sowers et al. (1994) concluded that application of high N rates may result in poor N uptake and low NUE due to excessive N losses. In neither year, N uptake efficiency was different among N rates ($p>0.05$); however, N utilization efficiency was sharply dropped by doubling N rate in both years, yet the difference was not significant in Year2 (Table 7). The 60 kg N had higher mean $N_{UTE}$ in both years compared to the 120-kg N. This agrees with Dhugga and Waines (1989) that there has been a gradual decrease in $N_{UTE}$ as N level increases.

Nitrogen use efficiency among cultivars varied greatly in both seasons ($p<0.001$) (Table 7). Compared to Giza 2 and TWC 310, SC10 had both a good potential to use N in grain more efficiently and a great N uptake efficiency, but all cultivars were similar ($p>0.05$) for $N_{UTE}$ in both years.

Difference, between 60- and 120-kg N within each cultivar, was significant ($p<0.05$) for NUE (Table 8). On the other hand variation among the three cultivars was high ($p=0.0001$) within only the 60-kg N (Table 9). Mean SC hybrid for NUE were 51.7, 34.5 compared to 43.5, 30.3 for Giza 2; and 37.0, 31.7 kg grain kg $^{-1}$N for TWC hybrid for 60- and 120-kg N, respectively. The SC hybrid, therefore, had higher NUE by a margin of 19% and 40% at 60 kg N, and by 14% and 9% at 120 kg N compared to Giza 2 and TWC hybrid, respectively.

When N x C interaction sliced by cultivar, N rates were different ($p=0.0001$) for grain N uptake for each cultivar (Table 8), and when sliced by nitrogen, maize cultivars were different at 60- ($p=0.0003$) and at 120-kg N ($p=0.0014$) (Table 9). At each N rate, mean SC for N uptake was the highest --25.3, 45.4, and 73.6 kg grain N fa $^{-1}$-- compared to those of Giza 2 and TWC.

The SC hybrid had higher N uptake at 120-kg N, but this did not result in corresponding higher N uptake efficiency for SC x 120-kg N, but it did for SC x 60-kg N as mentioned earlier. The high N fertilizer rate –120kg N—has confounded the high N uptake compared to the 60-kg N. Excessive gaseous N losses occur from flowering to maturity (Harper et al., 1987). Nitrogen loss is associated with high N rates may contribute to lowering both N uptake efficiency NUE (Sowers et al., 1994). Nitrogen uptake differences between hybrids reflect hybrid differences in the ability to take up N during grain filling. Selection of hybrids that maintain uptake capacity as late as possible in the season should be coupled with high levels of soil mineral N during grain filling period (Ma et al., 1999). The SC hybrid seemed to partition most of the absorbed N into the grain; this as suggested by (Dhugga and Waines, 1989) would minimize N loss from the soil and make more economic use of the absorbed N.

Components of NUE, N uptake efficiency ($N_{UPE}$) and N utilization efficiency ($N_{UTE}$), have been studied extensively (Moll et al., 1982; Dhugga and Waines, 1989; Ma et al., 1999 and 1999a; Horst et al., 2003). Both components can explain the relative contribution –for different hybrids at different N supply-- of each to nitrogen use efficiency of a particular crop plant. The N x C interaction in Year 1 was different ($p<0.05$)(Table 7). Both N rates differed ($p=0.0001$) only within either Giza 2 or SC for $N_{UPE}$ (Table 8), and cultivars varied ($p=0.0001$) within 60 kg N (Table 9). At 60 kg N, SC hybrid had $N_{UPE}$ equaled to 0.757kg grain N for every kg N applied and Giza 2 ranked second of 0.631.

Despite both $N_{UPE}$ and $N_{UTE}$ mean values were negatively associated with N rate (Table 7) and this paralleled NUE mean value, $N_{UPE}$ seemed to have contributed relatively more to NUE than $N_{UTE}$ (Dhugga and Waines, 1989; Ma and Dwyer, 1998; Ma et al., 1999; and Horst et al., 2003).

Therefore, improving nitrogen uptake efficiency of maize hybrids bred at low N supply can mainly improve their overall grain NUE. Also hybrids, which have high harvest index as well as high ability to utilize N before anthesis, can (Raun and Johnson, 1999). Hybrids with delayed senescence and enhanced root growth may also contribute to N efficiency (Horst et al., 2003). Nitrogen uptake at physiological maturity correlates well with grain yield (Katsvairo et al., 2003). Improving N uptake at this particular maturity stage would, on one hand, improve N uptake efficiency especially under low N, and hence improve overall NUE. On the other hand, this would lead to expecting high grain yield, which may improve $N_{UTE}$. In addition, Lambert et al. (2001) suggested that grain protein content can be used to estimate grain nitrogen uptake or removal by corn hybrids.

Concerning biofertilizer in this study, except for the 2001green leaf plant $^{-1}$(Table 1), neither studied character was affected ($p>0.05$) by applying the biofertilizer mixture (Tables 1&2&3). The cultivar by biofertilizer interaction was only effective ($p<0.05$) for both stem diameter and green leaf plant $^{-1}$ in 2001. Maize seed inoculation caused neither significant change in any of the studied characters (Hassanein et al., 1997) nor conclusive results, for grain yield and components, were reached during years of study (Atta Allah, 1998; and Mohamed, 1999).

## CONCLUSION

The hybrid Single Cross 10 seems to have a potential of a relatively high grain nitrogen use efficiency. It needs along with other maize hybrids further assessment of NUE, as well as uptake and utilization efficiency at different environmental conditions especially soil available nitrogen supply. In addition, breeding new maize hybrids for high NUE at low N supply would most likely lead to cutting down N fertilizer application. This can be achieved by selection for higher N utilization before anthesis at low N supply. Also selecting for enhanced root growth, high harvest index, and delayed senescence would positively contribute to higher N efficiency. Moreover, further research is needed concerning organic manure application to various maize hybrids as a way to reduce N losses; hence raise N efficiency.

Furthermore, applying biofertilizer to non-legume crops has been so far not promising. This raises many questions concerning proper biofertilizer rate per unit area, handling as well as proper application methods. More important are their chemical components, especially N content, which researchers should be aware of before applying.

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## محصول الذرة الشامية و مكونات كفاءة استخدام النيتروجين وعلاقتهم بالسماد النتروجيني و الأصناف و السماد الحيوي

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اقيمت تجربتان حقليتان بمزرعة كلية الزراعة بمشتهر جامعة الزقازيق (فرع بنها) لدراسة استجابة بعض اصناف الذرة الشامية( هجين فردي ١٠ ، هجين ثلاثي ٣١٠ ، جيزة ٢ ) للسماد النيتروجيني( بدون ، ٦٠ ، ١٢٠ كجم نتروجين/فدان) والسماد الحيوي ( بدون ، خليط من السيريالين و الفوسفارين) واثر ذلك علي المحصول ومكوناته وكفاءة استخدام النتروجين في عامي ٢٠٠٢/٢٠٠١ . وقد تم استخدام التجارب العاملية في القطع المنشقة مرة واحدة في اربعة مكررات ووضع السماد النيتروجيني في القطع الرئيسية وتبادل الاصناف والسماد الحيوي في القطع الشقية .

وكانت أهم النتائج كالتالي:

- ادي التسميد النيتروجيني بمعدل ١٢٠ كجم نتروجين/فدان الي زيادة معنوية لصفات النمو والمحصول ومكوناتة بينما ادي الي نقص معنوي لكفاءة استخدام النتروجين.
- تفوق الصنف هـ.ف ١٠ في صفات النمو والمحصول ومكوناتة وكفاءة استخدم النتروجين بالمقارنة باصناف هـ.ث ٣١٠ ، جيزة ٢ .
- كما لم يكن هناك تأثير يذكر للتسميد الحيوي علي أي من الصفات المدروسة.
- كان تفاعل النيتروجين كبيرا مع الأصناف لمحصول الحبوب ووزن ١٠٠ حبة ($p<0.05$) في العامين. فقد أعطي تفاعل الهجين الفردي مع كل من ٦٠ – أو ١٢٠- كجم آزوت للفدان أعلي متوسطات لمحصول الحبوب في العامين.
- أما كفاءة استخدام النيتروجين للحبوب فقد نقصت بزيادة التسميد النيتروجيني في العامين. و أعطي تفاعل الهجين الفردي مع كل من ٦٠ – أو ١٢٠- كجم نيتروجين للفدان ٥١.٧ ،٣٤.٥، مقابل ٤٣.٥، ٣٠.٣ لجيزة ٢ ، و ٣٧.٠، ٣١.٧ كجم حبوب لكل كجم آزوت للهجين الثلاثي.