Original Paper Open Access

Nitrogen use efficiency in corn (*Zea mays* L) genotypes under different conditions of nitrogen and seeding date

Edmar Vinícius de Carvalho[1]*, Flávio Sérgio Afférri[1], Joênes Muci Peluzio[1], Michel Antônio Dotto[1], Leandro Lopes Cancellier[2]

[1]Universidade Federal do Tocantins, Departamento de Fitotecnia, Gurupi-Tocantins-Brasil, 77404-970
[2]Universidade Federal de Lavras, Programa de Pós Graduação em Genética e Melhoramento de Plantas, Lavras-Minas Gerais-Brasil, 37200-000
*Corresponding author: E-mail: carvalho.ev@uft.edu.br

Abstract

Many factors can contribute the nitrogen use efficiency in corn (*Zea mays* L) genotypes, like weather and soil, for instance. This present study aimed to identify efficient genotype using nitrogen across three seeding date and two covered nitrogen level at Tocantins-Brazil, during the season 2009/2010. The assessment characteristic were through: ear of corn yield and grain yield (kg ha^{-1}), they were correct for 13% of humidity; agronomic nitrogen use efficiency (NUE_A), partial by Moll et al and Low N index by Fischer et al. It was done through analysis of variance, considering the fixed genotype effect and the other random. Significant genotype, seeding date, covered nitrogen level, genotype x seeding date and genotype x covered nitrogen level were observed for ear of corn yield, grain yield, NUE_A. The NUE_A was significantly lower at LN than at HN for all genotypes. At LN the genotypes showed an average of 206 kg of produced grains for each N kg applied (kg kg^{-1}). At HN they showed an average of 39 kg kg^{-1}. The genotypes GEN 03, GEN 10 and GEN 16 were the most efficient that used the nitrogen, in both assessments methods above. It could be concluded that the choice of the methodology may be function of the study purpose, nitrogen level or seeding date effect.

Keywords: *Zea mays*, mineral stress, sustainability, Tocantins, economy

Introduction

In the last decade, yield grains have been increasing. As corn, it have been associated with the increase of the nitrogen use (Hirel et al, 2001), which the majority of the farmers still believe that the high level can guarantee a safety harvest (Montemurro et al. 2006), and the nutrient used above is the most important in the vegetable development (Presterl et al, 2002).

On the other hand, there is a huge environmental impact caused by this kind of fertilizer, as in its manufacture as in its use. It is necessary to be conscious about the efficiency of it when using it, within the target productivity (Erley et al, 2005), this justify for the actual economic model in some productive areas that has the objective to make the production cheaper (Hirel et al, 2001).

Al-kaisi and Yin (2003) said that nowadays the levels of nitrogen fertilizer used in the corn crop can be involved with the aquifer contamination or any type of natural resource, decreasing its quality. And any kind of extra activities can help the nitrogen efficiency (Cüi et al, 2009), like using a narrow row spacing, decreasing the fertilizer through increasing of recovery efficiency (Barbieri et al, 2008), crop rotation and the use of organic fertilizer, as a partial substitution of mineral (Montemurro et al, 2006) and a selection of efficient genotype for this nutrient (Erley et al, 2005; Hirel et al, 2001).

The efficiency of low nitrogen utilization in cropping systems is related to a low cost that is connected with lower waste and lower environmental impact. This can be reached by breeding programs that can obtain more efficient genotype (Agrama et al, 1999). There is a chance to find efficient genotypes because of its variability in the crop corn (Paponov et al, 2005; Presterl et al, 2002), where some productive genotype can be find that they are efficient, in conditions of nitrogen stress (Cüi et al, 2009).

Weather and soil can contribute in the efficiency of nitrogen (N) use in corn genotypes (Muchow 1998; Presterl et al, 2002), thus, this study aimed to identify efficient genotype using nitrogen under different conditions of nitrogen and seeding date at Tocantins-Brazil, during the season 2009/2010.

Materials and Methods

The 21 genotypes were seeded in three dates, two at Gurupi-TO (11°43’S and 49°04’W, 280m asl), one on November 21th (GURUPI 01) and another on December 14th (GURUPI 02) in 2009, and another at Palmas-TO (10°45’S and 47°14’W, 220m asl), on December 3rd (PALMAS) at the same year, at Tocantins-Brazil. In each seeding date, were conducted experiments with two levels of covered nitrogen fertilization, one with 0 kg of N ha^{-1} (LN) and another with 144 (HN)

RECEIVED 05/25/2012

Table 1 - Estimated mean squares of 21 genotypes for the assess characteristic across three seeding date and two covered N levels.

Trait	Source of variation	21 Genotypes
Ear of Corn Yield	Genotype (G)	3,702,103**
	Seeding Date (S)	8,223,218**
	Covered Nitrogen Level (N)	196,000,000**
	G x S	2,729,408**
	G x N	4,013,192**
	Residue	735,934
Grain Yield	Genotype (G)	2,254,883**
	Seeding Date (S)	5,329,773**
	Covered Nitrogen Level (N)	155,000,000**
	G x S	1,509,295**
	G x N	1,382,460**
	Residue	339,835
Agronomic Nitrogen use efficiency	Genotype (G)	1,732**
	Seeding Date (S)	6,520**
	Covered Nitrogen Level (N)	1,757,174**
	G x S	1,278**
	G x N	1,515**
	Residue	281

Significant at **F = 0.01

kg of N ha^{-1} (ammonium sulphate – single application). The covered nitrogen fertilization (LN and HN) was done at 19, 23 and 14 days after seed, respectively, at this seeding date: GURUPI 01, GURUPI 02 and PALMAS. The soil of the fields of the experiment are Latosol dystrophic red yellow.

The seed fertilization was 600 kg NPK ha^{-1} of fertilizer 04-14-08 in each seeding date, and others crop treatments were performed, if necessary. The experimental design for each combination between seeding date and level of N covered was the completely randomized blocks with 21 treatments, two replications and two-row plots.

The assessment characteristics were through: ear of corn yield, only without straw, (kg ha^{-1}) and grain yield (kg ha^{-1}), they were correct by 13% of humidity; agronomic nitrogen use efficiency, partial by Moll et al (1982); and Low N Index, by Fischer et al (1983):

$$\text{Agronomic Nitrogen Use Efficiency} = Ya(x)/N(x)$$

where: Ya is the genotype yield "a" in the condition "x"; and N is the quantity of nitrogen applied in the condition "x".

$$\text{Low N index} = Ya(-N)/Ya(+N) \times Yx(-N)/Yx(+N)$$

where: Ya(-N) is the genotype yield "a" with low N; Ya(+N) is the genotype yield "a" with high N; Yx(-N) is the average yield of all genotypes with low N; and Yx(+N) is the average yield of all genotypes with high N.

For all characteristics, it was done analysis of variance, considering the fixed genotype effect and the other random, after it, it was used the Scott-Knott average test at 5%, and the Spearman correlation coefficient was used to correlate the assessment char-

Table 2 - Ear of corn yield (kg ha-1) in 21 corn genotypes at three seeding dates, GURUPI 01, GURUPI 02 and PALMAS, and two covered nitrogen levels, 0 kg ha^{-1} (LN) and 144 kg ha^{-1} (HN), during the season 2009/2010.

Genotype	Covered Nitrogen Level[1]		Seeding Date[2]		
	LN	HN	GURUPI 01	GURUPI 02	PALMAS
GEN 01	7,154 Ba	8,012 Ba	7,851 Ca	8,175 Aa	6,724 Bb
GEN 02	6,842 Bb	9,127 Aa	7,913 Ca	7,763 Aa	8,277 Aa
GEN 03	8,102 Aa	8,027 Ba	8,428 Ca	8,275 Aa	7,492 Ba
GEN 04	8,249 Ab	9,710 Aa	10,951 Aa	7,855 Ab	8,132 Ab
GEN 05	6,877 Bb	10,171 Aa	7,718 Cb	8,510 Ab	9,344 Aa
GEN 06	6,447 Bb	9,928 Aa	8,501 Ca	7,696 Aa	8,366 Aa
GEN 07	7,957 Aa	8,805 Ba	8,535 Ca	8,013 Aa	8,595 Aa
GEN 08	8,315 Ab	9,719 Aa	10,104 Aa	8,261 Ab	8,686 Ab
GEN 09	6,718 Bb	9,681 Aa	7,674 Ca	8,191 Aa	8,734 Aa
GEN 10	7,880 Ab	10,065 Aa	9,414 Ba	8,179 Aa	9,326 Aa
GEN 11	7,341 Ab	9,876 Aa	9,104 Ba	9,269 Aa	7,454 Bb
GEN 12	6,831 Bb	8,231 Ba	7,955 Ca	7,447 Aa	7,191 Ba
GEN 13	6,715 Bb	8,269 Ba	7,745 Cb	9,117 Aa	5,614 Cc
GEN 14	7,527 Ab	8,984 Aa	8,780 Ca	7,991 Aa	7,995 Aa
GEN 15	7,881 Aa	6,477 Cb	8,051 Ca	5,419 Bb	8,067 Aa
GEN 16	7,348 Ab	9,144 Aa	8,522 Ca	8,248 Aa	7,968 Aa
GEN 17	6,673 Bb	8,771 Ba	8,051 Ca	7,220 Aa	7,896 Aa
GEN 18	7,655 Ab	9,123 Aa	9,349 Ba	7,981 Ab	7,837 Ab
GEN 19	6,076 Bb	8,320 Ba	6,618 Ca	7,659 Aa	7,317 Ba
GEN 20	6,814 Bb	10,305 Aa	8,298 Ca	8,573 Aa	8,807 Aa
GEN 21	7,741 Ab	9,478 Aa	9,692 Ba	7,586 Ab	8,551 Ab
Mean	7,292 b	9,058 a	8,536 a	7,973 b	8,018 b

Averages followed by the same capital letters in the column and small letters in the line do not show any difference for the Scott-Knott test at 5%. [1]Combined average of three seeding dates. [2]Combined average of two covered nitrogen levels.

Table 3 - Grain yield (kg ha^{-1}) in 21 corn genotypes at three seeding dates, GURUPI 01, GURUPI 02 and PALMAS, and two covered nitrogen levels, 0 kg ha^{-1} (LN) and 144 kg ha^{-1} (HN), during the season 2009/2010.

Genotype	Covered Nitrogen Level^1		Seeding Date^2		
	LN	HN	GURUPI 01	GURUPI 02	PALMAS
GEN 01	4,022 Cb	5,528 Ca	4,810 Db	5,822 Aa	3,694 Dc
GEN 02	5,130 Ab	6,512 Ba	5,686 Ca	5,624 Aa	6,153 Aa
GEN 03	5,610 Aa	6,167 Ba	6,005 Ba	5,990 Aa	5,670 Ba
GEN 04	5,803 Ab	7,139 Aa	7,549 Aa	5,817 Ab	6,048 Ab
GEN 05	4,684 Bb	7,472 Aa	5,954 Ba	6,243 Aa	6,037 Aa
GEN 06	4,295 Cb	6,642 Aa	5,530 Ca	5,487 Ba	5,389 Ba
GEN 07	5,434 Ab	6,819 Aa	6,304 Ba	5,711 Aa	6,364 Aa
GEN 08	5,692 Ab	6,914 Aa	6,674 Aa	6,087 Aa	6,148 Aa
GEN 09	4,914 Bb	6,858 Aa	5,465 Ca	5,907 Aa	6,286 Aa
GEN 10	5,438 Aa	6,056 Ba	5,913 Ba	6,299 Aa	5,029 Bb
GEN 11	4,851 Bb	7,220 Aa	6,028 Bb	6,885 Aa	5,193 Bc
GEN 12	4,889 Bb	6,479 Ba	5,986 Ba	5,767 Aa	5,299 Ba
GEN 13	4,087 Cb	6,009 Ba	4,912 Da	6,657 Aa	3,574 Db
GEN 14	5,309 Ab	6,904 Aa	6,446 Ba	5,874 Aa	6,000 Aa
GEN 15	5,006 Aa	5,249 Ca	5,444 Ca	4,877 Ba	5,061 Ba
GEN 16	5,531 Aa	6,136 Ba	6,098 Ba	5,915 Aa	5,487 Ba
GEN 17	4,527 Bb	6,353 Ba	6,033 Ba	5,053 Bb	5,233 Bb
GEN 18	5,144 Ab	6,513 Ba	6,020 Ba	5,877 Aa	5,589 Ba
GEN 19	4,007 Cb	6,355 Ba	4,618 Db	5,842 Aa	5,083 Bb
GEN 20	4,673 Bb	7,037 Aa	5,295 Cb	6,017 Aa	6,254 Aa
GEN 21	4,622 Bb	6,278 Ba	6,785 Aa	5,098 Bb	4,468 Cb
Mean	4,936 b	6,507 a	5,883 a	5,850 a	5,431 b

Averages followed by the same capital letters in the column and small letters in the line do not show any difference for the Scott-Knott test at 5%. ^{1}Combined average of three seeding dates. ^{2}Combined average of two covered nitrogen levels.

acteristics in each level of nitrogen.

Results and Discussion

Significant differences were observed for ear of corn yield (EY), grain yield (GY) and Agronomic Nitrogen Use Efficiency (NUE$_A$) among genotype (G), seeding date (S), and covered nitrogen level (N), G x S interaction and G x N interaction (Table 1).

This evidences the genotype influence, seeding date, and covered nitrogen level in the assessment characteristics. This fact has been reported by other researchers as relation of genotype and nitrogen influences (Cüi et al, 2009) and genotype, environments and nitrogen levels influences (Prestel et al, 2002) about grain yield and nitrogen efficiency.

The genotypes GEN 01, GEN 03 and GEN 07, had similar values of EY at both covered nitrogen levels (Table 2). These genotypes produced 7,154 (GEN 01), 8,102 (GEN 03) and 7,957 (GEN07) kg ha^{-1} at LN and 8,012 (GEN 01), 8,027 (GEN 03) and 8,805 (GEN 07) kg ha^{-1} at HN. In other words, they produced the same quantity of EY independent of covered nitrogen level. At HN the genotypes GEN 01, GEN 03 and GEN 07 were classified in the second statistic group, and at LN the genotypes GEN 03 and GEN 07 were classified in the first statistic group of productive genotypes, as EY relation.

For other genotypes performance, the average EY was higher at the HN relative to LN. Similar results of this fact were also reported by Ferreira et al (2001) for different genotypes at Minas Gerais-Brazil.

The GEN 04 showed a higher EY at GURUPI 01 (10,951 kg ha^{-1}), the GEN 13 at GURUPI 02 (9,117 kg ha^{-1}) and the GEN 05 at PALMAS (9,344 kg ha^{-1}) when compared to the other genotypes (Table 2). The EY was significantly higher at GURUPI 01 (8,536 kg ha^{-1}) than at GURUPI 02 (7,973 kg ha^{-1}) and PALMAS (8,018kg ha^{-1}) for an average of all the genotypes. This second fact can be explained by the late seeding date in the last experiments, and according to Cancellier et al (2009) it can be associated with the frequent decrease of rain in this research region.

The genotypes GEN 03, GEN 10, GEN 15 and GEN 16 had similar values of GY at both covered nitrogen levels (Table 3). These genotypes produced 5,610 (GEN 03), 5,438 (GEN 10), 5,001 (GEN 15) and 5,531 (GEN 16) kg ha^{-1} at LN, and 6,157 (GEN 03), 6,056 (GEN 10), 5,249 (GEN 15) and 6,136 (GEN 16) kg ha^{-1} at HN (Table 3). They were classified in the first statistic group at LN, and in the second (GEN 03, GEN 10, GEN 16) and third (GEN 15) statistic group at HN. Indicating that, these genotypes were specific for the environment with nitrogen stress, and according to Paponov et al (2004), this fact can indicate the superiority of these genotypes in some adverse environments, which indirectly modify the nutritional availability for the plants. For other genotypes perfor-

Table 4 - Agronomic nitrogen use efficiency ($kg\ kg^{-1}$) in 21 corn genotypes at three seeding dates, GURUPI 01, GURUPI 02 and PALMAS, and two covered nitrogen levels, 0 $kg\ ha^{-1}$ (LN) and 144 $kg\ ha^{-1}$ (HN), during the season 2009/2010.

Genotype	Covered Nitrogen Level[1]		Seeding Date[2]		
	LN	HN	GURUPI 01	GURUPI 02	PALMAS
GEN 01	168 Da	33 b	114 Ca	119 Ba	68 Cb
GEN 02	214 Ba	39 b	123 Cb	113 Bb	144 Aa
GEN 03	234 Aa	37 b	145 Ba	139 Aa	122 Aa
GEN 04	242 Aa	43 b	180 Aa	125 Bb	122 Ab
GEN 05	195 Ca	45 b	143 Ba	126 Ba	91 Bb
GEN 06	179 Da	39 b	110 Ca	115 Ba	102 Ba
GEN 07	226 Aa	40 b	142 Ba	139 Aa	120 Aa
GEN 08	237 Aa	41 b	160 Aa	135 Ab	123 Ab
GEN 09	205 Ca	41 b	98 Db	126 Ba	144 Aa
GEN 10	227 Aa	36 b	134 Ba	140 Aa	120 Aa
GEN 11	202 Ca	43 b	130 Ba	137 Aa	100 Bb
GEN 12	204 Ca	39 b	121 Ca	129 Aa	114 Aa
GEN 13	170 Da	36 b	84 Db	147 Aa	78 Cb
GEN 14	221 Ba	41 b	152 Ba	129 Ab	113 Ab
GEN 15	209 Ba	31 b	129 Ba	104 Bb	127 Aa
GEN 16	230 Aa	36 b	135 Ba	144 Aa	121 Aa
GEN 17	189 Ca	38 b	124 Ca	112 Ba	104 Ba
GEN 18	215 Ba	39 b	126 Ca	131 Aa	123 Aa
GEN 19	167 Da	38 b	79 Db	120 Ba	109 Aa
GEN 20	195 Ca	42 b	116 Ca	121 Ba	118 Aa
GEN 21	193 Ca	38 b	143 Ba	110 Bb	92 Bb
Mean	206 a	39 b	128 a	127 a	112 b

Averages followed by the same capital letters in the column and small letters in the line do not show any difference for the Scott-Knott test at 5%. [1]Combined average of three seeding dates. [2]Combined average of two covered nitrogen levels.

mance, the average GY was higher at the HN relative to LN. Similar results of this fact were also reported by Barbieri et al (2008) and Montemurro et al (2006) for different genotypes.

The GEN 04 showed a higher GY at GURUPI 01 (7,549 $kg\ ha^{-1}$), the GEN 11 at GURUPI 02 (6,885 $kg\ ha^{-1}$) and the GEN 07 at PALMAS (6,364 $kg\ ha^{-1}$) when compared to the other genotypes (Table 3). The GY was significantly higher at GURUPI 01 than at GURUPI 02 and PALMAS for GEN 04; and significantly higher at GURUPI 02 than at GURUPI 01 and PALMAS for GEN 11. The results observed in this research were in agreement with Cancellier et al (2009), who found similar values at Tocantins-Brazil during the season 2007/2008, when these authors evaluated different genotypes of the ones of this study.

The NUE_A was significantly lower at LN than at HN for all genotypes (Table 4). At LN the genotypes showed an average of 206 kg of produced grains for each N kg applied ($kg\ kg^{-1}$). At HN they showed on average 39 $kg\ kg^{-1}$. Similar results of this fact were also reported by Barbieri et al (2008) evaluating different genotypes. This low NUE_A of genotypes at HN can be associated with other factors, for instance, the hydric availability on soil; according to Al-Kaisi and Yin (2003) the NUE_A can be lower at conditions of low hydric availability. Therefore, when the other factors affect the NUE_A, the visualization of difference among genotypes is hard, thus, the condition of nitrogen stress permits that the restriction effect about this nutrient, can be responsible for the performance of the genotypes. This fact can be observed through the difference among the genotypes in LN with regard to NUE_A, where the genotype GEN 04 was the most efficient, producing 242 $kg\ kg^{-1}$. At HN there was no significant difference among the genotype in relation to NUE_A.

The GEN 04 showed a higher NUEA at GURUPI 01 (180 $kg\ kg^{-1}$), the GEN 13 at GURUPI 02 (147 $kg\ kg^{-1}$) and the GEN 02 at PALMAS (144 $kg\ kg^{-1}$) when compared to the other genotypes (Table 4). The NUE_A was significantly lower at PALMAS than at GURUPI 01 and GURUPI 02 for an average of all the genotypes. This result agrees with Muchow (1998) that says that the nitrogen efficiency changes with the weather and soil conditions.

The NUE_A used in this research is very useful in the distinction of genotypes among different fertilization levels, which lots of articles were found about the efficiency of this nutrient, like Barbieri et al (2008), Erley et al (2005), and Kolchinski and Schouch (2003). However, the environment (or seeding date) can affect in the NUEA of genotypes, as related by Muchow (1998) and Presterl et al (2002), and the proposed index by Fisher et al (1983), can become more adequate in the comparison in which environment (or seeding date, in this case) some genotypes were more efficient.

Significant differences were found for Low N Index among genotype, seeding date and genotype x

Table 5 - Low N Index by Fisher et al (1983) in 21 corn genotypes at three seeding dates, GURUPI 01, GURUPI 02 and PALMAS, with two covered nitrogen levels, during the season 2009/2010.

Genotypes	GURUPI 01	GURUPI 02	PALMAS
GEN 01	0.766 Aa	0.536 Bb	0.416 Cb
GEN 02	0.613 Bb	0.518 Bb	0.738 Aa
GEN 03	0.812 Aa	0.732 Aa	0.602 Ba
GEN 04	0.779 Aa	0.600 Bb	0.519 Cb
GEN 05	0.793 Aa	0.522 Bb	0.266 Cc
GEN 06	0.517 Ca	0.577 Ba	0.448 Ca
GEN 07	0.680 Ba	0.832 Aa	0.441 Cb
GEN 08	0.804 Aa	0.647 Bb	0.503 Cb
GEN 09	0.402 Db	0.589 Ba	0.713 Aa
GEN 10	0.687 Ba	0.653 Ba	0.793 Aa
GEN 11	0.618 Ba	0.503 Ba	0.476 Ca
GEN 12	0.519 Ca	0.670 Ba	0.607 Ba
GEN 13	0.372 Db	0.647 Ba	0.624 Ba
GEN 14	0.767 Aa	0.632 Ba	0.435 Cb
GEN 15	0.785 Aa	0.588 Bb	0.897 Aa
GEN 16	0.647 Bb	0.835 Aa	0.648 Bb
GEN 17	0.557 Ca	0.654 Ba	0.493 Ca
GEN 18	0.565 Ca	0.665 Ba	0.638 Ba
GEN 19	0.349 Db	0.543 Ba	0.596 Ba
GEN 20	0.628 Ba	0.510 Ba	0.450 Ca
GEN 21	0.573 Ca	0.604 Ba	0.548 Ca
Mean	0.630 a	0.622 a	0.564 b
Mean Square	ENVIRONMENT**	GENOTYPES**	ENV vs. GEN**

Averages followed by the same capital letters in the column and small letters in the line do not show any difference for the Scott-Knott test at 5%. **Significant at F = 0.01.

seeding date interaction (Table 5). GEN 03, GEN 10, GEN 15 and GEN 16 showed higher values (0.715; 0.711; 0.757; 0.710) of index by Fisher et al (1983), indicating that these genotypes, in average, were the most efficient.

The Low N Index was significantly higher at GURUPI 01 than at GURUPI 02 and PALMAS for GEN 08, significantly higher at GURUPI 02 than at GURUPI 01 and PALMAS for GEN 16 and significantly higher at PALMAS than GURUPI 01 and GURUPI 02 for GEN 15.

All Spearman correlations among the assessment characteristic were positive and significant, except at HN, among the index by Fisher et al (1983) and the other characteristics (Table 6), indicating that the more productive genotypes (EY and GY) at HN were more efficient only through the partial index by Moll et al (1983). Montemurro et al (2006) and Prestel et al (2002) also found positive and significant correlation between the grain yield and NUE$_A$, and according to the last authors, it can be related with the calculation of the nutrient efficiency, which there is an autocorrelation among the varieties used in the formula.

At LN, the correlation among EY and GY and the indexes of nitrogen efficiency had high value, in both indexes. According to Chantachume et al (1996) the Low N Index is used to choose the adapted genotype in both conditions: stress and no-stress of nitrogen; but, in this research this index just had significant correlation with NUE$_A$ with the LN (Table 6). Indicating the adequacy of the Low N Index in the selection of efficient genotypes in the nitrogen stresses.

75% of genotypes using nitrogen were indicated through the method of Fisher et al (1983) as the most efficient; they also were classified as the most efficient partial by Moll et al (1982), and the opposite

Table 6 - Spearman correlation coefficients among ear of corn yield (EY), grain yield (GY), agronomic nitrogen use efficiency (NUEA) partial by Moll et al (1982) and Low N Index by Fisher et al (1983) in 21 corn genotypes at three seeding date, with two covered nitrogen levels, 0 kg ha^{-1} (LN) and 144 kg ha^{-1} (HN), during the season 2009/2010.

Characteristics	EY	GY	NUE$_A$	Low N Index
EY	-	^{2}0.803**	^{2}0.802**	^{2}0.811**
GY	^{1}0.662**	-	^{2}0.999**	^{2}0.810**
NUE$_A$	^{1}0.633**	^{1}0.992**	-	^{2}0.811**
Low N Index	^{1}-0.286	^{1}-0.359	^{1}-0.353	-

^{1}HN; ^{2}LN. Significant at **T = 0.01. Covered nitrogen level considers all seeding dates.

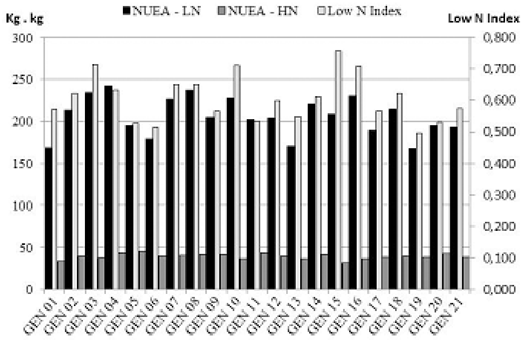

Figure 1 - Agronomy nitrogen use efficiency under low (0 kg ha^{-1}) and high nitrogen (144 kg ha^{-1}) in covered (NUE_A – LN and NUE_A – HN) and Low N index of 21 corn genotypes across in three seeding dates.

percent was just 43%. And this can indicate higher strictness in the methodology proposed by Fisher et al (1983) in this research, through the identification of the most efficient genotype.

Conclusions

It was concluded from this study that the genotypes GEN 03, GEN 10 and GEN16 were the most efficient that used the nitrogen in both assessments methods above, partial Moll et al (1982) and Fisher et al (1983) (Figure 1). The first method considers the yield in each nitrogen condition and the second consider two nitrogen conditions at the same time. Covered nitrogen level was 0 and 144 kg N ha^{-1}, and the seeding date interval among the three dates was ten days.

Based on the analysis of correlation, the methods used showed higher coefficient correlation in nitrogen stress. It could be concluded either that the method proposed by Fisher el al (1983) was more strict than the method proposed by Moll et al (1982), in the conditions of this research. Finally, the choice of the methodology may be function of the study purpose, nitrogen level or seeding date effect.

References

Agrama HAS, Zakaria AG, Sai FB, Tuinstra M, 1999. Identification of quantitative trait loci for nitrogen use efficiency in maize. Mol Breeding. 5: 187-195

Al-Kaisi MM, Yin X, 2003. Effects of Nitrogen Rate, Irrigation Rate, and Plant Population on Corn Yield and Water Use Efficiency. Agron J 95: 1475-1482

Barbieri PA, Echeverría HE, Rozas HRS, Andrade FH, 2008. Nitrogen Use Efficiency in Maize as Affected by Nitrogen Availability and Row Spacing. Agron J 100: 1094-1100

Cancellier LL, Afférri FS, Dotto MA, Cappellesso RB, Peluzio JM, Vaz-De-Melo A, 2009. Comportamento de cultivares de milho na região centro-sul do Estado do Tocantins, safra 2007/2008. Amazônia: Ci & Desenv 5: 73-92

Chantachume Y, Manupeerapan T, Grudloyma P, Tongchuay S, Noradechanon S, Kongtian D, Leon C, Lotrhop JE, 1996. Selection for Low N Tolerance in the Thai Maize Breeding Program. México, CIMMYT

Cui Z, Zhang F, Mi G, Chen F, Li F, Chen X, Li J, Shi L, 2009. Interaction between genotypic difference and nitrogen management strategy in determining nitrogen use efficiency of summer maize. Plant Soil 317: 267-276

Erley GS, Kaul H, Kruse M, Aufhammer W, 2005. Yield and nitrogen utilization efficiency of the pseudocereals amaranth, quinoa, and buckwheat under differing nitrogen fertilization. Eur J Agron 22: 95-100

Ferreira ACB, Araújo GAA, Pereira PRG, Cardoso AA, 2001. Características agronômicas e nutricionais do milho adubado com nitrogênio, molibdênio e zinco. Sci Agr 58: 131-138

Fischer KS, Johnson EC, Edmeads GO, 1983. Breeding and selection for drought in tropical maize. Mexico: CIMMYT.

Hirel B, Bertin P, Quilleré I, Bourdoncle W, Attagnant C, Dellay C, Gouy A, Cadiou S, Retailliau C, Falque M, Gallais A, 2001. Towards a Better Understanding of the Genetic and Physiological Basis for Nitrogen Use Efficiency in Maize. Plant Physiol 125: 1258-1270

Kolchinski EM, Schouch LOB, 2003. Eficiência no uso do nitrogênio por cultivares de aveia branca de acordo com a adubação nitrogenada. Rev Bras Cienc Solo 27: 1033-1038

Moll RH, Kamprath EJ, Jackson WA, 1982. Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. Agron J 74: 562-564

Montemurro F, Maiorana M, Ferri D, Convertini G, 2006. Nitrogen indicators, uptake and utilization efficiency in a maize and barley rotation cropped at different levels and sources of N fertilization. Field Crop Res 99: 114-124

Muchow, RC, 1998. Nitrogen utilization efficiency in maize and grain sorghum. Field Crop Res 56: 209-216

Paponov IA, Sambo P, Erley GS, Presterl T, Geiger HH, Engels C, 2005. Grain yield and kernel weight of two maize genotypes differing in nitrogen use efficiency at various levels of nitrogen and carbohydrate availability during flowering and grain filling. Plant Soil 272: 111-123

Presterl T, Groh S, Landbeck M, Seitz G, Schmidt W, Geiger HH, 2002. Nitrogen uptake and utilization efficiency of European maize hybrids developed under conditions of low and high nitrogen input. Plant Breed 121: 480-486