Introduction of tropical maize genotypes to increase silage production in the central area of Santa Fe, Argentina

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ABSTRACT

Some temperate areas of the world behave as sub-tropical due to greenhouse effect and the global warming. Therefore, more temperate genotypes show an important decrease in yield and dry matter production as consequence of heat stress. The objective of this work was to evaluate the behavior of tropical maize genotypes under these climatic conditions and the feasibility of its utilization for silage production. Fifteen commercial hybrids were evaluated, five temperate and ten tropical, for fresh and dry matter production, grain yield, harvest index, plant and ear height, dry matter digestibility and crude protein in a field trail. Tropical genotypes showed a good behavior for all traits, inclusively those related with forage quality. Results attested that it is possible to increase silage production under these climatic conditions by introducing tropical genotypes into plant breeding programs.

KEY WORDS: *Zea mays*, heat stress, silage, exotic genotypes.

INTRODUCTION

The central area of Santa Fe is considered one of the most important regions for milk production in Argentina, where animal feed is based mainly on grazing alfalfa and maize silage (Castignani et al., 1996; Thomas et al.,1999). In the last decades, the increase in the warming of the earth atmosphere due to the greenhouse effect produced mainly by air contaminants, caused climatic alterations in many agricultural regions (Taiz and Zeiger, 1998). The central area of Santa Fe, as others in the planet, has shown a gradual increase in the incidence of hotter summers. Although maize is classified in the limit between mesophile and termophile plants because of its tropical origin, sometimes some genotypes show severe damage due to heat stress, specially those developed for temperate areas. Productivity of susceptible genotypes under high temperatures has had an significant decrease in growth as result of alterations in the kinetics of the enzymes and in the permeability of the plasma membrane (Hopkins, 1998).

Genetic improvement was proved to be a useful approach to increase maize yield. It allows the selection for heat stress since genetic variability is available. When variability is small, plant breeders may utilize exotic germplasm as gene source. According to Santos (1985) populations, landraces, hybrids and inbreds lines, selected under different environmental conditions, may be considered exotic germplasms. These sources could be used in plant breeding programs by introgressive mating with an adapted germplasm followed by recurrent selection (Hallauer and Miranda, 1988). In the literature, several authors reported on the utilization of exotic germplasm and the best proportion in introgressive mating (Crossa and Gardner, 1987; Albrecht and Dudley, 1987; Bridgeds and Gardner, 1987). Thus, Miranda Filho (1992), Nass (1992) and Regitano Neto et al. (1997) reported on the utilization of exotic germplasm in maize.

The objective of this study was to compare, under field conditions, a set of tropical and temperate hybrids, and to evaluate the possibility of introducing a tropical germplasm into maize breeding program by introgressive crosses.

MATERIAL AND METHODS

Fifteen maize hybrids were tested in a field trial (Table 1). Five of these were temperate commercial hybrids, largely utilized in the region for silage production (1 to 5) and 10 tropical provided by ESALQ-USP maize breeding program (6 to 15). The temperate hybrids were used as checks.

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Table 1. Set of 14 commercial hybrids used in the field trial. Temperate (1 to 5) and tropical (6 to15) groups.

Number	Hybrid	Number	Hybrid	Number	Hybrid
1	DK 765	6	NK AVANT	11	MASTER
2	DK 664	7	DK 834	12	MITLA 9560
3	TITANIUM I1	8	DK 834	13	ZENECA 8410
4	TITANIUM F5	9	NK HERCULES	14	DINA D 170
5	DK 696	10	AGX 7393	15	AG 6018

The trial was carried out in the experimental field of the National Litoral University at the city of Esperanza, province of Santa Fe, Argentina, located at 31^{o} south and 61^{o} west of latitude and longitude, respectively. The experimental design used was a randomized complete block design with three replications. Hybrids were sowed in the spring of 2000 in plots with four rows, 4 m long and spaced 0.70 m apart, with 80 plants each (71,400 plants ha^{-1}). It was fertilized with 60 kg ha^{-1} of calcium phosphate at sowing and the same proportion of urea at six leaves (V6) phenological stage (Bleiholder et al., 1992). Weed control was performed using 4 L ha^{-1} of Gliphosate twenty days before sowing and 2 L ha^{-1} of atrazine at the sowing time.

The following variables were analyzed: dry matter percentage (DM), fresh (FMP) and dry matter production (DMP), yield (Y), harvest index (HI), plant (PH) and ear height (EH), dry matter digestibility (DMD) and crude protein (CP).

At the grain black layer stage of maturity, whole-plants of 1.42 m from the two internal rows of the plot were sampled by cutting them 5 cm above the ground. They were weighted to obtain the FMP. Afterwards, the samples were dried in stove at 65 ^{o}C to obtain the DMP. Collected plants were harvested by hand, and grain weight was corrected to a standard 14% of moisture to assess Y. HI was calculated by using the equation proposed by Donald and Hambling, (1976).

Plant and ear height were measured for the distance between the ground and the first branch of the tassel and the first ear respectively . For the DMD determination, four plants of each hybrid were randomly chosen and dried in stove at 65 ^{o}C and fine grounded (Cherney et al., 1996). Nylon bags were filled with 5 g of each sample and placed into the rumen of fistulated steer for 48 h. After this period, samples were pulled to the rumen, washed with tap water and dried at 65 ^{o}C for 24 h. Digestibility of each sample was calculated by the difference between initial and final dry weight and CP was measured by the micro-Kjeldhal procedure.

Univariate data analysis was performed using the ANOVA procedure and for multivariate ones, a PC-ORD software was used to carry out a principal components analysis.

RESULTS AND DISCUSSION

Significant hybrid differences (P<0.05) were found for dry matter production (table 2), varying from the lowest DM production of 16.39 T ha-1 (hybrid 2) to the highest of 25.86 T ha-1 (hybrid 10). However, the group of tropical hybrids showed higher FMP mean (52.79 T ha^{-1}) than temperate one (43.97 T ha^{-1}), and only two temperate -3 and 1- were listed in the top ten.

Dry matter production (Table 2) showed cultivar differences (P<0.05) varying among the lowest DM production of 16.39 T ha^{-1} by the hybrid 2 and the highest 25.86 T ha^{-1} presented by the hybrid 10. As emphasized by the FMP, the tropical group showed the best productivity when compared with the temperate ones. Tropical hybrids showed a group's mean of 22.64 T ha^{-1} contrasting with the temperate mean of 19.12 T ha^{-1} , evidencing an increase in productivity of 18.4 %. DM values for temperate hybrids observed in this study appear to be similar to those observed under similar environmental conditions by Marano et al. (1996), were DMP values varied among 17 to 20 T ha^{-1}.

No significant differences (P>0.05) among genotypes were observed for Y; however, they were found for FMP and DMP, where both groups showed similar Y average values of 10.70 T ha^{-1} and 10.55 T ha^{-1} for temperate and tropical hybrids, respectively. These values appear to be analogous to those reported by Fossati (2000, 2001) for temperate hybrids and by Fontanetto et al. (1998) for tropical ones.

When DMP and Y were compared, an important

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difference appeared among the groups. While in the temperate hybrids, grain production was induced during dry matter partition, in the tropical hybrids the main destination of the products of photosynthesis was towards stem and leaf production. According to Table 2, hybrids showed significant differences (P<0.01) with values varying between 0.23 (hybrid 14) to 0.54 (hybrid 2).

In the first case, the behavior of hybrid 14 was characteristic of an exotic, non adapted germplasm. This genotype, and in a smaller proportion hybrids 10 and 13, accumulated dry matter during the vegetative period and destined it principally to the production of structural organs with the consequent loss of grain yield. On the other hand, hybrid 2 and the others that showed high HI values (higher than 0.45) indicated that an intense dry matter partition to ear occurred during the grain filling period. The values reported in this study were consistent with those observed by Andrade et al. (1996)

Although some differences were appointed between both groups, the main differences between temperate and tropical hybrids were observed both in plant and ear height. Varietal differences (P<0.01) were observed for both traits (Table 2) and tropical hybrids showed highest plant height - i.e. hybrid 14 showed PH higher than 3.00 m - while the PH mean of temperate hybrid was lower than 2,00 m. This value of PH for temperate was similar to those reported under similar conditions (Fossati ,2000, 2001). Usually, PH and EH are considered positively associated traits. In the present study ,this tendency was confirmed and tropical hybrids showed the highest values of EH. For all tropical hybrids, EH was higher than 1 m (Table 2), specially for hybrids 10, 13, 14 and 15 that showed a EH higher than 1.30 m. This situation is very undesirable due to problems that could be associated principally with mechanical harvesting.

For quality traits, no significant differences (P>0.05) among the genotypes were observed for DM (Table 3) as result of the previous sampling process carried out to establish the optimal moment to harvest. Genotypes showed a range of DM varying between 45.1% (maximum) for the hybrid 6 and 39.5% (minimum) for hybrid 14; these values are consistent with those reported by Hunt et al. (1992) and Johnson et al. (1999).

Ruminal *in situ* fermentability (DMD) of whole plant samples (Table 3) showed no varietal differences (P>0.05). All genotypes tested showed good quality, varying between 65.87% for the hybrid 5 to 58.5% for hybrid 14. This behavior could be explained by the differences of HI (Table 2) showed

Table 2. Means of agronomic traits for temperate (1 to 5) and tropical (6 to 15) hybrids: Fresh (FMP) and Dry matter (DMP) production, Yield (Y), Harvest index (HI), Plant (PH) and ear (EH) height.

Hybrid	FMP ^{NS} T ha^{-1}	DMP $^{1/}$ T ha^{-1}	Y ^{NS} T ha^{-1}	HI $^{2/}$ %	PH $^{2/}$ m	EH $^{2/}$ m
1	49.46 ^{ABCD}	21.91 ^{AB}	12.56 ^{AB}	0.51 ^{A}	1.74 ^{I}	1.01 ^{FG}
2	39.38 ^{D}	16.39 ^{B}	9.80 ^{AB}	0.54 ^{A}	1.88 ^{HI}	0.93 ^{G}
3	50.15 ^{ABCD}	21.31 ^{AB}	11.55 ^{AB}	0.49 ^{ABC}	1.87 ^{HI}	0.82 ^{H}
4	40.93 B^{CD}	17.85 ^{B}	9.50 ^{AB}	0.48 ^{ABC}	1.96 ^{H}	0.93 ^{G}
5	40.47 ^{CD}	18.13 ^{B}	10.11 ^{AB}	0.50 ^{AB}	1.88 ^{HI}	0.80 ^{H}
6	55.22 ^{ABC}	24.91 ^{A}	13.29 ^{A}	0.48 ^{ABC}	2.15 ^{G}	1.09 ^{FG}
7	52.42 ^{ABCD}	22.65 ^{AB}	9.81 ^{AB}	0.39 ^{D}	2.24 ^{FG}	1.26 ^{CD}
8	51.02 ^{ABCD}	20.51 ^{AB}	11.80 ^{AB}	0.52 ^{A}	2.21 ^{FG}	1.28 ^{CD}
9	55.44 ^{ABC}	24.84 ^{A}	11.87 ^{AB}	0.42 ^{BCD}	2.29 ^{EFG}	1.26 ^{CD}
10	59.32 ^{A}	25.86 ^{A}	10.34 ^{AB}	0.36 ^{D}	2.40 ^{DEF}	1.37 ^{BC}
11	45.38 ^{ABCD}	19.45 ^{AB}	8.46 ^{B}	0.39 ^{D}	2.54 ^{CD}	1.19 ^{CD}
12	50.08 ^{ABCD}	22.19 ^{AB}	12.43 ^{AB}	0.40 ^{CD}	2.44 ^{DE}	1.18 ^{DE}
13	49.23 ^{ABCD}	22.15 ^{AB}	8.83 ^{AB}	0.35 ^{D}	2.67 ^{C}	1.36 ^{BC}
14	54.04 ^{ABCD}	21.34 ^{AB}	8.87 ^{AB}	0.23 ^{E}	3.26 ^{A}	1.63 ^{A}
15	55.77 ^{AB}	22.48 ^{AB}	9.83 ^{AB}	0.50 ^{AB}	2.87 ^{B}	1.41 ^{B}
C.V.	15.35	15.21	22.56	10.59	14.47	15.33

Significance levels: NS = non significant (p> 0.05); ($^{1/}$) = P< 0.05; ($^{2/}$) = p < 0.01.
Duncan's Test. Means with the same letter are not significantly different.

in the different genotypes discussed above. Hybrid 14 showed the lowest percentage of DMD by two main conditions that affect the fermentability into the rumen. Vatikonda and Hunter (1983) expressed that grain yield and the stove fiber content affect *in situ* digestibility. In this case, the hybrids that showed the worst fermentation in rumen presented both low grain production and the lowest biomass partition due to the higher incidence of stover in the dry matter partition (Table 2) presented by these genotypes. In the last decades, the best hybrid for yield was considered the best for silage production as well , based on the fact that a major grain proportion could be related with a fast rumen degradability (Vatikonda and Hunter, 1983). Nevertheless, at the present time, the degradability of the fibrous portion of the plant is considered, together with grain yield, the most important factor of dry matter digestibility. An increase in the quality of one of these traits could be neutralized by the decrease in the other, according to Wolf et al. (1993) and in contradiction with Johnson et al. (1985) who reported no correlation between fiber percentage in the stover and grain yield.

Table 3. Means of quality traits for temperate (1 to 5) and tropical (6 to 15) hybrids: Dry matter (DM), "in situ" digestibility of dry matter (DMD) and crude protein (CP) [1/].

Hybrid	DM [NS] (%)	DMD [NS] (%)	CP [NS] (%)
1	44.3 [AB]	62.90 [AB]	8.53 [AB]
2	41.0 [B]	62.83 [AB]	8.40 [B]
3	42.5 [AB]	65.27 [A]	8.53 [AB]
4	43.6 [AB]	65.37 [A]	9.01 [A]
5	44.8 [AB]	65.87 [A]	8.67 [AB]
6	45.1 [AB]	64.01 [AB]	8.57 [AB]
7	43.2 [AB]	62.80 [AB]	8.70 [AB]
8	40.2 [AB]	63.47 [AB]	8.70 [AB]
9	44.8 [AB]	63.33 [AB]	8.63 [AB]
10	43.6 [AB]	63.37 [AB]	8.27 [AB]
11	42.9 [AB]	65.35 [A]	8.53 [AB]
12	44.3 [AB]	65.70 [A]	8.33 [AB]
13	45.1 [AB]	61.67 [AB]	8.27 [AB]
14	44.8 [AB]	58.50 [B]	7.83 [B]
15	40.3 [A]	63.43 [AB]	8.10 [AB]
C.V. %	16.86	14.93	13.17

[1/] Significance levels: NS = non significant (p> 0.05); ([1/]) = P< 0.05; ([2/]) = p < 0.01; Duncan's Test. Means with the same letter are not significantly different.

The values of DMD observed in this work were analogous with those reported for whole-plant ruminal degradability for temperate (Carrete et al., 2000) and tropical genotypes (Penati, 1995; Oliveira et al., 1997; Silva et al., 1997).

Whole-plant CP content (Table 3) of the fifteen hybrids did not differ (P>0.05) and showed good values varying among 8,5 and 9 %. These value were closely related with those reported by PROPECO (1996), Daccord et al. (1996) and Coors et al.(1997). As discussed for DMD, the small differences observed could be explained by the different participation of grain and fibrous portion in the dry matter partition.

When all variables were analyzed together, the ordination performed by principal component analysis (PCA) showed that data distribution was linked with the origin of the genotypes. This analysis showed that the variables EH, PH, HI and CP were the most important in the treatment distribution axes and that the principal component 1 (PC1) explains more than 50% of the variability (Figure 1).

In general, the PCA analysis allowed placing the treatments (hybrids) around three main groups: The first group was composed only by hybrid 14 that show a characteristic behavior of tropical genotype. The second group (intermediate) includes the other nine tropical hybrids and the temperate 1 and 3. The third group (temperate) was composed by the hybrids 2, 4 and 5. The PCA analysis confirmed the results obtained by the univariate analysis where hybrid 14 showed the most contrasting behavior. Meanwhile, hybrids 2, 4 and 5 were typical temperate and temperate hybrids 3 and 1 showed an intermediate behavior very close to the intermediate tropical group especially with hybrids 6, 8 and 11.

CONCLUSIONS

Our results show that tropical genotypes, especially hybrids 9 and 10, were highly productive, had quality and an important adaptability to the environmental conditions. All tropical genotypes tested, with exception of the hybrid 14, that showed poor agronomic performance, could be used to increase maize silage production in the central area of Santa Fe, Argentina. These tropical germplasm tested in this trial could be incorporated by introgressive crosses into the plant breeding program.

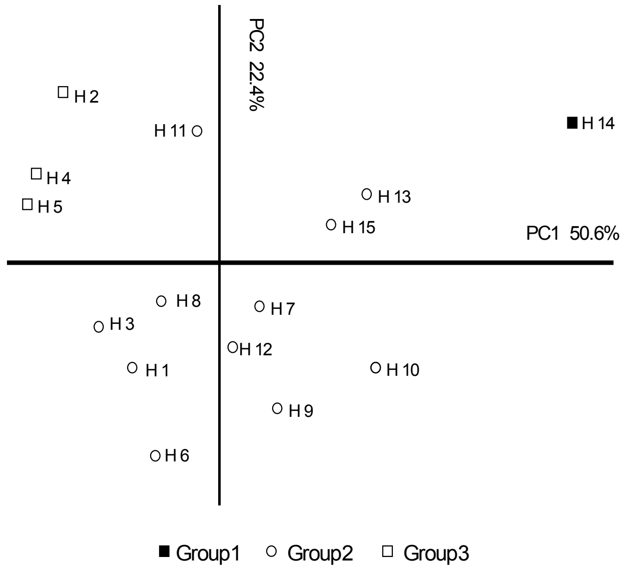

Figure 1. PCA analysis for the agronomic and quality parameters evaluated in the temperate (H1 to H5) and tropical (H6 to H15) groups of hybrids.

RESUMO

Introdução de Genótipos de Milho Tropical Para Aumentar a Produção de Silagem na Região do Centro de Santa Fe, Argentina

Como conseqüência do aquecimento global, muitas regiões temperadas do mundo começaram a se comportar como subtropicais e os genótipos considerados adaptados, a apresentar diminuições importantes em rendimento e produção de matéria seca devido ao estresse térmico. O objetivo deste trabalho foi avaliar o comportamento de genótipos de milho tropicais sob essas condições ambientais e a possibilidade de sua utilização para a produção de silagem. Quinze híbridos comerciais, cinco temperados e dez tropicais, foram avaliados num experimento de campo para produção de matéria verde e seca, rendimento, índice de colheita, altura de plantas e espigas, digestibilidade e proteína total. Os genótipos tropicais apresentaram um bom comportamento para todos os caracteres avaliados inclusive para aqueles relacionados à qualidade da forragem. Esses resultados permitem concluir que é possível aumentar a produtividade de milho para silagem para essas condições ambientais através da introdução de genótipos tropicais no programa de melhoramento genético.

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Received: August 19, 2002;

Accepted: October 29, 2002.

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