RIO CUARTO, ARGENTINA
Universidad Nacional de Río Cuarto

Quality and nutritional value of corn silage hybrids evaluated by multivariate analysis

ROSSI, EA; BONAMICO, NC; ORTIZ, ME and DI RENZO, MA.

Facultad de Agronomía y Veterinaria, Universidad Nacional de Río Cuarto, Agencia Nº 3, 5800 Río Cuarto, Argentina. e-mail: nbonamico@ayv.unrc.edu.ar

INTRODUCTION

Corn silage is a food with high energy and high yield/ha which has good palatability and consistency. Harvesting and storage are quick. Compared with other forage is has lower cost per ton of dry matter (Lauer, 2011).

Corn, for their content of readily fermentable carbohydrates is one of the most suitable crops for silage (Fregona *et al*., 2007, Huenting *et al*., 2012). Different corn hybrids differ regarding the variables associated with suitability for silage, so it is important to generate information on the performance of these (Mahanna, 2005).

When evaluating different genotypes for agronomic characteristics, it is interesting to interpret the similarity/dissimilarity between them. To this are effective and widely used multivariate analysis techniques that allow visualizing and interpreting graphs by ordering relations between genotypes (Balzarini *et al*., 2007; Bonamico *et al*., 2006; Ortolan *et al*., 2011).

Cluster analysis, often used as a screening method, could be used in order to meet the population genetic structure of different genotypes of maize hybrids. When multiple variables for each level of one or more factors that define the treatments studied, multivariate analysis of variance (MANOVA) was used to make simultaneous inferences about the effects of factor analysis model (Balzarini *et al*., 2008; Vega *et al*., 2011).

The aim of this study was to evaluate the quality and nutritional value of different corn silage hybrids in the Río Cuarto locality, Córdoba province, Argentina.

MATERIALS AND METHODS

The quality and nutritional value of silage were estimated in 28 corn silage hybrids from different seed companies based on field evaluations conducted at the Río Cuarto locality (Córdoba province; 33°10`25``S, 64°21`40``W) from the semiarid region of Argentina. A randomized complete block design with three reps was used to test the genotypes during a crop season (2012/2013) (Table 1). Plots consisted of four 6 m rows with 0.8 m between rows.

The traits were determined in the two central row, discarding the two border row. The plants were thinned to a distance of 0.15 m. This low planting density allowed the expression of morphological characteristics without substantial plan-to-plant competition. The planting date was the first week of December 2012. Variation of twelve traits were analyzed: fresh weight (FW), dry matter (DM), grain yield (GY), plant height (PH), spike insertion height (SH), leaf number (LN), crude protein (PC), acid detergent fiber (FDA), metabolic energy (ME), digestibility in vitro (DG), anthesis-silking interval (ASI) and days to flowering (DF).

The variables were analyzed with a multivariate approach such as cluster analysis. This method allows grouping the different genotypes using a set of variables. The formation of clusters was performed using average linkage (UPGMA) and the Euclidean distance. A multivariate analysis of variance (MANOVA) was applied to establish the order of the hybrids to simultaneously considering all the variables.

Table 1. Seed companies, name and cycle of corn hybrids evaluated in Rio Cuarto, Córdoba, during the season 2012/2013.

Seed Companies	Hybrid	Cycle	Seed Companies	Hybrid	Cycle
La Tijereta	LT 622VT3P	Temperate	Sem West	SW 194/12	Tropical
La Tijereta	LT 626VT3P	Temperate	Sem West	SW 276/12	Tropical
La Tijereta	LT 632MGRR2	Temperate	KWS	4360 ASG	Temperate
Monsanto	DK 747VT3P	Temperate	Nidera	AX 896MG	Temperate
Monsanto	DK 72-10VT3P	Temperate	Syngenta	NK 880TDMAX	Temperate
Monsanto	DK 190MGRR2	Temperate	Pannar	BG 7049H	Tropical
Monsanto	DK 747MGRR2	Temperate	Pannar	BG W618R	Temperate
Los Algarrobos	ZEA 3265	Temperate	Pannar	BG 6503H	Temperate
Los Algarrobos	APACHE	Temperate	Pannar	BG 6502HR	Temperate
Los Algarrobos	DELTA	Temperate	Criadero Ing. Falco	RIO QUINTO	Temperate
Sem West	SW 5147	Temperate	Criadero Ing. Falco	EXP HS SIL	Temperate
Sem West	SW 5148	Temperate	Pioneer	30F35HR	Tropical
Sem West	SW 5150	Temperate	Pioneer	P1845YR	Temperate
Sem West	SW 5130	Tropical	UNRC	EXP UNRC	Temperate

RESULTS

Graph generated from the cluster analysis is shown in Figure 1. Twelve measures variables were considered in the 28 corn silage hybrids evaluated in the Río Cuarto, Córdoba. This analysis defines three groups consisting of twenty two, five and one genotype, respectively. One group, comprising the by 30F35HR, BG 7049H, SW 276/12, SW 194/12 and SW 5130 genotypes, are characterized by their tropical cycle. Another group consisted of hybrid UNRC EXP. Genotypes of temperate cycle formed the third group. Cophenetic correlation coefficient was 0,89.

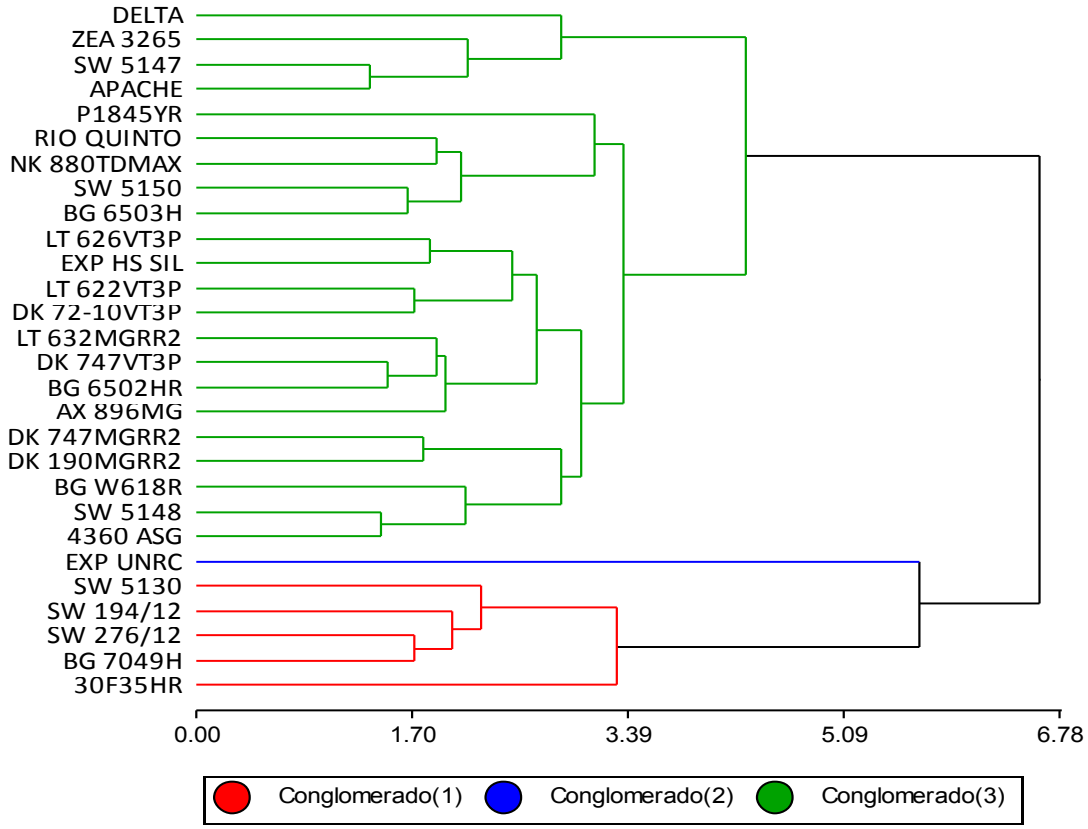

Figure 1. Dendrogram obtained by average linkage algorithm (UPGMA) and the Euclidean distance, with the variables related to quality and nutritional value of silage in 28 corn silage hybrids evaluated in the Río Cuarto, Córdoba, during the season 2012 / 2013.

The order of 28 corn hybrids that had statistically significant differences in the multivariate analysis of variance (MANOVA) is presented in Table 2. Jointly considering all the variables only RIO QUINTO genotype showed statistically significant differences ($p \leq 0,05$) compared to other hybrids. The average values of this genotype vary with respect to the overall mean depending on the variable analyzed. For dry matter, crude protein and digestibility, this cultivar recorded

below average values, while acid detergent fiber and grain yield were higher than the mean values. For the other variables, the values were similar to the average.

Table 2. Average of twelve traits related to quality and nutritional value of silage in 28 corn silage hybrids evaluated in the Rio Cuarto, Córdoba, during the season 2012/2013. These hybrids showed statistically significant differences in the MANOVA

HYBRID	FW	DM	GY	PH	SH	LN	PC	FDA	ME	DG	ASI	DF						
RIO QUINTO	54408	14758	7039	2,00	1,00	16	7,23	23,00	2,59	71,77	2,67	67	A					
DELTA	41300	12676	4245	1,87	0,83	14	8,49	19,30	2,68	74,33	4,00	64	B	H				
EXP UNRC	51675	13854	3866	2,00	1,03	15	8,05	26,0	2,51	69,70	1,67	62	B					
BG 7049H	67958	15633	6925	2,50	1,40	20	7,19	25,10	2,53	70,30	2,00	81	C	D				
30F35HR	57217	13198	4086	2,40	1,36	20	7,86	23,40	2,57	71,50	1,33	81	C					
SW 5130	66642	14580	6330	2,28	1,35	19	7,41	25,50	2,52	70,07	1,00	82	C					
SW 194/12	64217	15959	6000	2,47	1,52	19	7,44	23,60	2,57	71,43	1,00	80	D					
SW 276/12	68825	17622	6079	2,50	1,44	20	6,93	24,10	2,56	71,03	2,00	78	D					
LT 626VT3P	56300	18479	9567	2,22	0,91	14	7,41	17,90	2,71	75,37	3,67	64	E	F	I			
DK 747VT3P	51342	15275	7401	2,05	0,87	14	7,03	19,30	2,68	74,37	3,00	62	E	H	I	K		
EXP HS SIL	54250	18149	9043	2,00	0,87	14	7,18	17,90	2,72	75,37	2,33	61	E	I	K			
AX 896MG	45633	15729	8631	2,07	0,92	13	7,18	18,20	2,71	75,13	2,67	61	E	I	K			
DK 747MGRR2	53975	17239	6958	2,25	0,85	14	7,86	21,40	2,62	72,93	3,33	62	E	I				
DK 72-10VT3P	57642	17651	9248	2,23	0,93	13	6,83	19,70	2,67	74,13	3,33	61	E					
BG W618R	49700	16820	6419	2,10	0,89	14	7,31	20,40	2,65	73,60	3,67	64	F	G	H	I	J	K
BG 6502HR	48242	15756	7354	1,88	0,88	14	6,67	20,00	2,66	73,93	2,33	64	F	G	H	J	K	
P1845YR	57417	18632	8030	2,20	0,98	14	6,52	22,00	2,61	72,47	1,67	63	F	G	I	J	K	
BG 6502H	53758	15608	8455	1,93	0,88	14	6,79	22,30	2,6	72,30	3,00	64	F	G	J	K		
LT 622VT3P	57400	17359	8964	2,07	0,93	14	7,17	21,10	2,63	73,10	3,33	65	F	G	K			
4360 ASG	57950	15514	6990	2,10	0,95	14	6,77	20,60	2,64	73,47	4,67	66	F	G				
SW 5148	56167	15657	7094	2,15	0,93	15	7,33	20,90	2,64	73,27	5,33	66	F	G				
SW 5150	52825	15127	6766	1,87	0,83	14	7,08	21,20	2,63	73,07	3,33	64	G	H	J			
LT 632MGRR2	51358	17318	7487	2,17	0,92	15	6,98	19,50	2,67	74,30	2,00	62	H	I	K			
ZEA 3265	46477	13849	6081	1,95	0,87	14	7,21	22,10	2,61	72,43	4,00	63	H	J	K			
APACHE	45592	13238	5083	1,77	0,79	13	7,68	20,60	2,65	73,47	3,67	64	H	J	K			
DK 190MGRR2	56583	17730	7773	2,23	0,90	15	7,97	19,70	2,67	74,13	2,67	61	I	K				
NK 880TDMAX	54692	16128	7375	1,97	0,79	14	7,14	23,60	2,57	71,40	2,00	62	J	K				
SW 5147	47158	13925	4092	1,82	0,78	14	7,94	21,60	2,62	72,77	4,00	66	J					
Average	54525	15838	6906	2,11	0,99	15	7,31	21,43	2,62	72,90	2,85	66						
SE	864,12	246,05	193,20	0,02	0,02	0,26	0,09	0,34	0,01	0,23	0,14	0,75						

FW: fresh weight; DM: dry matter; GY: grain yield; PH: plant height; SH: spike insertion height; LN: leaf number; PC: crude protein; FDA: acid detergent fiber; ME: metabolic energy; DG: digestibility in vitro; ASI: anthesis-silking interval; DF: days to flowering. SE: Standar error

Significant differences (p > 0,05) between hybrids were indicated by different letters.

DISCUSSION

With cluster analysis it was possible to differentiate hybrids according to the length of the cycle. A group was constituted with the genotypes of tropical cycle and the other group with genotypes of temperate cycle. Cophenetic correlation coefficient obtained (0,89) indicated that distances in the dendrogram reflect the true distances between hybrids. These results were consistent with those observed by González Huerta et al. (2011) who evaluated twenty cultivars of maize in Mexico by fourteen agronomic traits. Cluster analysis differentiated a group with twenty short-cycle cultivars and another group with four long-season cultivars.

The multivariate analysis of variance (MANOVA) was a useful technique to help identify groups with statistically significant differences considering the twelve variables together in the twenty hybrids. Chiok and Chinte (2004) applied this type of analysis in a comparative experiment with six maize hybrids finding significant differences between genotypes. Further stated that this type of analysis will improve data interpretation. Vega et al. (2011) also applied the MANOVA to assess the variation in morphometric traits and germination from eight sources carob (*Prosopis alba* Griseb Fabaceae, Mimosoideae).

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