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Silage Yield and Quality of Some Maize and Teosinte Genotypes and Their Hybrid

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Abstract: The objective of this research was to identify the potential of maize and teosinte genotypes for silage production. The genetic materials which used in this study were the maize hybrids; SC 10, SC 125, SC 130, SC 131, SC173 and SC 176 in addition to a local teosinte variety and SC 10 x local teosinte hybrid. These genetic materials were evaluated in field experiments during 2013 and 2014 summer seasons, at Giza Research Station, ARC, Egypt. The randomized complete block design with four replications was used. Morphological characters; plant height, number of stem plant^{-1}, stems diameter, number of leaves plant^{-1}, number of ears plant^{-1}, fresh and dry yield kg plant^{-1}, chemical composition and feeding value of silage were estimated for each genotype. Significant differences were observed among all genotypes. Local teosinte variety and the hybrid SC 10 X Local teosinte gave the highest values of plant height, tillering capacity plant^{-1}, number of leaves plant^{-1} and number of ears plant^{-1}. Also, the hybrid SC 10 x Local teosinte produced the highest total fresh and dry forage yields. With respect to chemical composition, feeding value and crude protein (CP) content was differed significantly among the tested genotypes. SC 10 x local teosinte hybrid gave the highest value (64.15%) of total digestible nutrient percentages (TDN %) without significant differences among the other genotypes. It is clear from the data that the evaluated genotypes especially SC 10 x local teosinte hybrid produced the highest yield and quality with suitable fermentation characteristics; yellowish green color and good smell silage.

Key words: Maize (*Zea mays* L.) · Teosinte *(Zea Mexicana* Schrad) · Nutritive value · Silage quality

INTRODUCTION

The production of forages in sufficient quantity and quality throughout the year becomes a necessity in all production systems that aim at higher productivity. Thus, ensilage has been used as an alternative in fodder preservation with view to greater productivity and animal performance. Therefore, the development of the Egyptian agriculture must move to a efficient and more demanded production systems to increase competitiveness and ensure sustainability. In this aspect, there is a need for investments and for the use of animals of higher genetic potential, which require a well-balanced diet of high nutritional value increases.

Maize is the most important silage plants in the world because of its high yield; high energy forage produced with lower labor and machinery requirements than other forage crops [1, 2]. Nussio *et al*. [3] reported that the large use of maize for silage making is mainly due to its chemical composition, which meets the requirements to making good silage combined with high productivity, low buffering power, adequate levels of soluble carbohydrates and attributes that allow the conservation of this roughage with quality. Also, maize is easy to cultivate, has high dry mass yield, is digestible, palatable to animals and has high nutritional value [4].

Therefore, preserving amounts of whole maize plants as silage may help to reduce feed shortage [5].There are many advantages for preserving whole maize plant as silage. Total digestible nutrients yield is about 50% more when maize is harvested as silage compared with harvesting as grain. Also, for maize silage made from the whole crop, more than 90% of the nutrients produced are saved [6].

However, there have been attempts to identify hybrids with better production potential and nutritional quality for silage, with good rate between stems, leaves and grains and high digestibility, since there is a high correlation between the nutritional value of a culture and its silage [7]. Gralak *et al.* [8] evaluated genetic divergence

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and combinatorial ability in 18 commercial corn hybrids that recommended for silage production and considered the agronomic and bromatological aspects of silage quality with the aim of selecting a germplasm for the synthesis of new base for production of silage with high nutritional value.

The higher proportion of grain in the material to be ensiled is desirable, for it contributes to the increase of the dry matter content of the silage, as far as there is no high proportion of straw and corn cob, which can reduce the effect of the ear in its quality [9]. Besides grain yield, it is also important to consider other hybrid qualities such as nutritional value, which is partly related to digestibility of the dry matter and the proportion of fibrous plant material (almost 60 % of the final volume of the silage) [8]. It is also necessary to consider other fractions of the plant, as the nutritional quality of the stem that has strong correlations with the nutritional quality of the whole plant [3]. The preservation of fodder silage is an anaerobic fermentative process, which converts soluble carbohydrates of the plant into organic acids by microbial activity. The silage quality depends on the efficiency of this process and the conditions that determine it, such as humidity, temperature, presence of oxygen, concentration of soluble carbohydrate and productive characteristics of the plant silage [10].

In Egypt, maize silage is the most common one used. The total planted area of maize crop was approximately 2.5 million feddans [11]. Importance of maize production is increasing year after year because of its value for silage production as well as grain production. Thus, the objective of this study was to evaluate production characteristics of eight genotypes (six maize SC hybrids, one local teosinte and its hybrid with maize (SC10)) and also their fermentation quality and the chemical composition of silages made of them.

MATERIALS AND METHODS

This current research was carried out at Giza Agricultural Research Station, ARC, Egypt, during 2013 and 2014 summer growing seasons to evaluate one local teosinte variety, one F_1 cross (maize x teosinte) and six maize single cross hybrids for fresh and dry silage yield and quality. A representative soil samples were collected from the top 20 cm layer in the experimental fields, air-dried and sieved through a 2 mm screen. The main physical and chemical properties (Table 1) were determined using the methods described by Piper [12] and Jackson [13].

Table 1: Some physical and chemical soil characteristics of the experimental soil.

Soil characteristics	Season 2013	Season 2014
Mechanical analysis		
Coarse sand %	6.54	7.12
Fine sand %	23.11	24.11
Silt%	34.23	33.31
Clay%	36.12	35.46
Textural class	Clay loam	Clay loam
Chemical analysis		
pH (suspension 1:2.5)	7.49	7.51
EC dS m^{-1}	2.30	242
Organic matter (%)	0.97	1.02
Available macronutrients (mg L^{-1})		
N	100.0	107.0
P	42.00	46.00
K	57.00	61.00

The materials which used in this study consisted of: a local teosinte variety (*Zea Mexicana* Schrad), one hybrid: (SC 10 x local teosinte) and white and yellow maize commercial hybrids (*Zea mays* L.) in Egypt, as shown in Table (2).

Table 2: Genotypes pedigree.

No.	Genotypes	Pedigree
1	Local teosinte	Damietta District
2	SC10 X Local teosinte	SC10 X Local teosinte
3	SC 10 (white)	(Sd 7 x Sd 63)
4	SC 125 (white)	Sd 7 x Gz 628
5	SC 130 (white)	Sk 12 x Sd 63
6	SC 131 (white)	SK 9 x SK 13
7	SC 173 (yellow)	Gz 647 x Gz 666
8	SC 176 (yellow)	Sk 10 x Sk 11

The preceding crop was faba bean in both seasons. The randomized complete block design with four replications was used. The experimental plot consisted of five rows each row of 6 m in length, 70 cm in width and hills spaced at 30 cm within the row. Planting dates were 20th and 24th of May in 2013 and 2014, respectively. All cultural practices for maize production were applied as recommended. Nitrogen fertilizer (120 kg N/fad) was added at three equal doses; just before the first, second and the third irrigations. At harvest, a random sample of ten guarded plants from each plot was used to estimate plant height (cm), number of stems $plant^{-1}$, stem diameter (cm), number of leaves $plant^{-1}$, number of ears $plant^{-1}$ and fresh and dry yield (kg) $plant^{-1}$. The first and fifth row in each plot were considered guarded rows, whereas all plants of the 2nd,$3^{rd}$and 4th rows were cut at soil surface and weighed at 105 days from planting.

Plants were chopped for making silage. Samples of 0.5 kg were taken from each hybrid to estimate dry matter (DM). Other samples were ensilaged in plastic bags (under anaerobic conditions) for 35 days. Silage samples of the second season only were used to determine crude protein (CP), crude fiber (CF), ether extract (EE) and ash, as well as the fermentation characters (pH), lactic acid, total volatile fatty acids (TVFAs) and nitrogen ammonia (Nh3-N% in total N) according to A.O.A.C [14]. Nitrogen free extract (NFE%) was estimated by using the following equations:

NFE% = 100 – (CP% + CF% + EE% + Ash%)

Digestible crude protein (DCP) and total digestible nutrients (TDN) were calculated according to equation of Church [15] as follows:

DCP = (CP X 0.929) - 3.48, TDN = 72.1 – (CF X 0.34).

The silage quality measurements had been done, *i.e.* acidity degree (pH), lactic acid of dry matter (%), volatile fatty acids (VFA%) and total concentration of NH_3-N %.

Statistical Analysis: Separate and combined analyses of variances were carried out according to Steel *et al.* [16], using the computer program PLABSTAT (Statistical Analysis of Plant Breeding Experiments) [17]. Before combined analysis, homogeneity test of variance was computed according to Bartlett [18].

RESULTS AND DISCUSSIONS

Morphological traits that can be measured easily could be used by plant breeder as selection criteria. Results presented in Table 3 showed that plant height, number of stems plant^{-1}, stem diameter, number of leaves plant^{-1} and number of ears plant^{-1} differed significantly among all genotypes. The highest value of plant height was observed in local teosinte (310.0 cm) followed by (SC10) X teosinte hybrid (302.0 cm), while the lowest one was recorded with white hybrid of maize SC131 (221.0 cm). The variation in plant height among different genotypes may be due to disparity in genetic makeup of these genotypes. Local teosinte gave the highest value of tillering capacity per plant (7.60) followed by (SC10) x teosinte hybrid (3.90). The maximum values of stem

Table 3: Mean performance of morphological characteristics of the eight genotyps (combined analysis across 2013 and 2014).

Genotype	Plant height (cm)	Stems plant^{-1}	Stem diameter (cm)	Leaves plant^{-1}	Ears plant^{-1}
Local teosinte	310	7.60	1.72	98.21	80.43
SC10 X Local teosinte	302	3.90	2.56	77.40	68.76
SC 125 (white)	224	1.00	2.43	15.67	1.25
SC 130 (white)	233	1.00	2.44	15.89	1.33
SC 131 (white)	221	1.00	2.41	15.33	1.22
SC 173 (yellow)	225	1.00	2.24	13.67	1.00
SC 176 (yellow)	250	1.00	2.12	15.44	1.17
Check (SC10)	262	1.00	2.66	15.91	1.68
Means	253.38	2.19	2.32	33.44	19.61
LSD0.05	12.82	0.45	0.14	7.33	11.01

Table 4: Mean fresh and dry yield of the eight genotypes at silage stage (combined analysis across 2013 and 2014).

Genotype	Fresh yield (ton fed^{-1})	*Relative yield %	Dry yield (ton fed^{-1})	*Relative yield %
Local teosinte	27.84	120.68	5.89	101.55
SC10 X Local teosinte	29.23	126.70	8.98	154.83
SC 125 (white)	19.76	85.65	4.96	85.52
SC 130 (white)	21.65	93.84	5.49	94.66
SC 131 (white)	17.98	77.94	4.52	77.93
SC 173 (yellow)	21.56	93.45	5.52	95.17
SC 176 (yellow)	22.43	97.23	5.62	96.90
Check (SC10)	23.07	100.00	5.80	100.00
Mean	22.94		5.85	
LSD 0.05	4.38		0.26	

*The relative fresh and dry yields were computed for each genotype as a percentage from the check (SC10)

diameter was observed for hybrid maize (SC 10) genotype (2.66 cm) followed by (SC10) x teosinte hybrid (2.56 cm). While the minimum stem diameter was recorded for local teosinte (1.72 cm). Local cv. of teosinte produced maximum number of leaves per plant (98.21) followed by (SC10) x teosinte hybrid (77.40), while minimum number of leaves per plant was observed for yellow SC173 (13.67). The highest number of ears per plant was observed for local cv. of teosinte (80.43) followed by (SC10) x teosinte hybrid (68.76); however, the maize hybrid SC173 gave the lowest number of ears per plant (1.00).

Performance of the tested genotypes for total fresh and dry forage yields and their relative yield to check variety (SC 10) across the two seasons are presented in Table (4).

Results in Table (4) showed significant differences among the genotypes for the total fresh and dry forage yields. The promising hybrid ((SC10) X Local teosinte hybrid) produced the highest total fresh and dry forage yields (29.23 and 8.98 ton fed^{-1}) and significantly exceeded the check variety SC10 by (26.70 and 54.83%), respectively. Meanwhile, SC 131 genotype produced the lowest total fresh and dry forage yields (17.98 and 4.52 ton fed^{-1}) and decreased compared with the check variety SC10 by (22.06 and 22.07 %), respectively. Bilgen *et al*. [19] indicated that, herbage yield of maize genotypes varied from 51.91 to 80.99 ton ha^{-1} and dry matter (%) from 23.2 to 26.3 and dry matter yield from 13.65 to 18.79 ton ha^{-1}. Moreover, Araujo *et al*. [20] reported that, knowledge of the dry matter content in the silage is important because based on it the calculation of the diet; since the feed consumption by animals is established in kg/dry matter/animal/day. Also, Melchinger *et al*. [21] reported that dry matter yield is a primary trait for selection of silage maize hybrids.

Data presented in Table (5) showed that crude protein content as a percentage (CP) was significantly different among the tested genotypes and ranged from 5.94% for (SC 173) to 8.14% for (SC10 X Local teosinte). Crude protein percentage was declined with increasing maturities as reported by Sheperd and Kung [22]. Similar results were obtained also by other authors Oliveira *et al*. [23], who found an average of 6.1 % protein in the silage assessed. Also, Pinto *et al*. [24] who evaluated silage production in maize cultivars found CP concentration between 7.1 and 8.8 %.Crude fiber (CF) content varied between 22.96 and 30.15% for the check variety SC10 and SC 173, respectively. Total ash percentage ranged from 6.45 to 8.35 % for SC 131 and SC 125, respectively. Ether extract (EE) percentage ranged from 1.75 to 2.76 % for SC 176 and SC 130, respectively. Means of nitrogen free extract (NFE) were significantly different among the eight tested genotypes and ranged from 54.85 to 58.96 for SC 173 and the check variety SC10, respectively. Regarding feeding values and digestible crude protein (DCP%) of the tested genotypes which ranged from 2.04 % to 4.08 % for SC 173 and SC10 X Local teosinte, respectively. The difference in DCP % may be due to differences in quantity and quality of crude protein in the tested genotypes. Differences among genotypes in total digestible nutrient percentages (TDN %) were not significant except between SC 173 and the other tested genotypes. Where the yellow maize SC 173 gave the lowest value of TDN % (61.85). On the other side, the hybrid Sc 10 x local teosinte gave the highest value (64.15%) without any significant differences among the other genotypes. In general, means of TDN% ranged from 61.85 to 64.15 for SC 173 and SC10 X Local teosinte, respectively. In this respect, Argillier *et al*. [25] confirmed that, silage digestibility is the most important aspect of nutritional quality because it is directly associated with an animal's ability to exploit feed.

Silage Quality: Concerning silage quality, data in Table (6) indicated that high quality silage with suitable fermentation characteristics yellowish green colour and good smell was observed. The pH values of the eight-tested silage samples ranged from 3.65 for the white maize SC 130 to 3.96 for the yellow maize SC 173, which were within the normal range of good quality silage.

These results are in agreement with those of Ghanem *et al.* [26] who reported that pH values ranged from 3.49 to 3.93 for five maize hybrids and Bendary *et al.* [27] who reported that pH values ranged from 3.74 to 4.18 for 10 hybrids and variety of maize. Lactic acid % was higher in the check variety (SC10) and SC10 X Local teosinte hybrid, which might be due to the presence of grains.

Our results are in agreement with Colenbrander *et al*. [28], who stated that whole maize plant contains high content of soluble carbohydrates, which are the main source of lactic acid production. Total VFA concentrations in all kinds of tested silage ranged from 1.48% (white maize SC 130) to 2.43 % (white maize SC 176 of DM), which revealed acceptable silage fermentation. Value of NH3-N concentration among silage of the different genotypes under study ranged from 4.18 (SC 10 x local teosinte genotype) to 6.37 (white maize SC 130). These results indicated good quality silage as stated by Mc Donald *et al.* [29] who reported that the concentration of NH_3-N of good quality silage being usually less than 10 % of total N.

Table 5: Silage chemical composition and feeding value of the eight genotypes (combined analysis across 2013 and 2014).

	Traits						
Genotype	CP %	CF %	Ash %	EE %	NFE %	DCP %	TDN %
Local teosinte	6.65	26.54	7.23	2.45	57.13	2.70	63.08
SC10 X Local teosinte	8.14	23.37	7.76	2.18	58.55	4.08	64.15
SC 125 (white)	6.22	24.54	8.35	1.98	58.91	2.30	63.76
SC 130 (white)	7.32	24.18	7.81	2.76	57.93	3.32	63.88
SC 131 (white)	7.58	25.06	6.45	2.66	58.25	3.56	63.58
SC 173 (yellow)	5.94	30.15	6.89	2.17	54.85	2.04	61.85
SC 176 (yellow)	6.78	27.38	8.12	1.75	55.97	2.82	62.79
Check (SC10)	8.07	22.96	7.96	2.05	58.96	4.02	64.29
Mean	7.09	25.52	7.57	2.25	57.57	3.11	63.42
LSD 0.05	0.63	1.88	0.52	0.23	1.39	0.49	1.02

CP %: Crude protein%, CF%: Crude fiber %, EE%: Ether extract %, NFE%: Nitrogen free extract %, DCP%: Digestible crude protein % and TDN%: Total digestible nutrients %.

Table 6: Silage quality characters of the eight genotypes (combined analysis across 2013 and 2014).

	Traits			
Genotype	pH	Lactic Acid % of DM	VFA%	NH_3-N % total
Local teosinte	3.82	3.85	1.78	4.74
SC10 X Local teosinte	3.77	5.14	2.32	4.18
SC 125 (white)	3.86	4.32	1.52	4.87
SC 130 (white)	3.65	4.32	1.48	6.37
SC 131 (white)	3.67	4.75	1.60	5.10
SC 173 (yellow)	3.96	4.83	1.68	4.85
SC 176 (yellow)	3.73	3.96	2.43	5.64
Check (SC10)	3.81	5.19	1.79	4.42
Mean	3.78	4.55	1.83	5.02

pH: Acidity degree, VFA%: Volatile fatty acids % and NH_3-N % total: Total concentration of NH_3-N %.

We may conclude from the data of the study that, the evaluated genotypes presented similar fermentative, nutritional and production characteristics and are recommended for silage composition especially, SC10 x teosinte hybrid. In that context, Commercial maize hybrids are an important source of alleles for good quality characters where they are important for improving various traits related to quality of silage. Thus, developing more genetic combinations between maize hybrids and teosinte may be recommended to result in genotypes with high yield and high silage quality.

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