Investigation note

Evaluation of stover and grain in native corns in Guasave Sinaloa

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Abstract

Corn stover has always been used as a source of feed for cattle, goats, and sheep, although forage grasses have a series of benefits that increase the production of milk, meat and improve the reproductive efficiency of herds. The experiment was carried out with the objective of knowing the production of stover and grain yield in four native corns and two hybrids in Guasave, Sinaloa. Six genotypes of corn were used, four are native (yellow from Tlaxcala, blue from Oaxaca and red from Veracruz and white from Puebla) and two hybrids (4050 Dekalb® and Hipopótamo Asgrow®). The experimental design and treatments were established and analyzed in a completely randomized design with three repetitions, agronomic variables, grain yield and biomass were measured. An analysis of variance, Tukey's mean comparison test ($\alpha \leq 0.05$) were performed. The results show that the statistical parameters exhibit a wide diversity among the evaluated materials of native corns, in the values of the standard deviation in the agronomic attributes and biomass. The comparison of means of the variables shows that the white genotype produced the highest plant height, number of leaves, foliar area, total biomass and stover. White native corn obtained 44% more in stover production than the Hipopótamo hybrid. White corn generated the best characteristics for obtaining forage since it is a material of greater height, number of leaves, leaf area and total biomass, it also has the highest yield of the four native genotypes. The conclusion was that the genotype of white corn has the best characteristics for forage production.

Keywords: *Zea mays* L., biomass, native, stover, yield.

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Corn is the most produced cereal in the world and is used for human consumption, livestock feed and fuel (Gwirtz *et al*., 2014; Ranum *et al*., 2014). In Mexico, corn is of great importance, according to volume of production, uses and adaptability to different environmental conditions (Muñoz *et al*., 2013; Rocandio-Rodríguez *et al*., 2014). Sinaloa produces 64% of the total national volume, the National Institute of Forestry, Agricultural and Livestock Research (INIFAP, for its acronym in Spanish) reports that the harvest index is 0.45 with 26.24 tonnes of biomass per hectare, in a harvest of 11.76 tonnes of grain and 14.48 of stover (FIRA, 2019). Corn is produced under irrigation or rainfed conditions, where the state of Sinaloa stands out with the highest production in corn grain and stover (SIAP, 2018).

The stover reaches to represent 50% of the total aerial biomass of the plant (Tollenaar *et al*., 2006) and there is evidence that an improvement in its production capacity does not negatively affect grain yield, in addition to the fact that the production of stover is different among varieties (Lorenz *et al*., 2009). If it is considered that, among native corn populations, the phenotypic and genetic differences in agronomic attributes (Muñoz, 2005; Rocandio-Rodríguez *et al*., 2014) are common, it is inferred that it is possible to find materials that combine high yield of stover and grain (Dhugga, 2007).

The advantage of corn biomass over other energy plants is that it is produced after the grain harvest and does not require the use of a different zone for its development (Elizondo and Boschini, 2002). The management of corn stover becomes a problem for the farmer; who, after the harvest, is in the dilemma of incorporating the harvest residues through cultural work, recovering the straw and packing it for sale to the livestock sector, burning it to clean their land, which can cause serious damage to the soil; in addition to the loss of nitrogen that could be incorporated gradually. Although the burning of stover has already been penalized (Quintero and Moncada, 2008).

Stover has always been used as feed for cattle and sheep mainly, however, forage grasses have a series of benefits that increase milk and meat production, in addition, it tends to improve the reproductive efficiency of herds (Martínez and Leyva, 2014). According to this information, the objective is to know the production of stover and grain yield in four native corns and two hybrids in Guasave, Sinaloa.

The present research work was carried out during the months of December 2019 to April 2020, under irrigation conditions in the lot of the experimental field, located at the Higher Technological Institute of Guasave (ITGS, for its acronym in Spanish) in the municipality of Guasave, Sinaloa; located at coordinates 25° 52’ north latitude and 108° 37’ west longitude, at 15 masl.

The sowing was carried out on December 10, 2019, in soil with clayey texture. Six genotypes of corn were used, four are native (yellow from Tlaxcala, blue from Oaxaca and red from Veracruz and white from Puebla) and two hybrids (4050 from Dekalb® and Hipopótamo from Asgrow®), the latter used for the production of grain and stover (biomass).

Sowing was carried out in paired strips of 10 furrows of 20 m in length with a density of 87 000 plants per hectare and the separation between furrows of 0.76 m with 3 repetitions. The fertilization dose was 280-80-00, N-P-K ha^{-1}, half of N and all P was applied at the time of sowing and the other half of N was applied through the irrigation system in dosed form. The sources of fertilization urea and MAP which were applied before sowing and ammonium nitrate was used by the irrigation system. Six irrigations were applied (1 to settle and 5 supplemental) with an irrigation sheet of 43 cm through the drip irrigation system and for the control of weed plants, pre-emergent herbicide (Paraquat) was applied, two mechanical cultivations and a manual weeding were performed.

The experimental design and treatments were established and analyzed in a completely randomized design with three repetitions. Each experimental unit consisted of a 20 m furrow, having five furrows per each genotype. For the evaluation, 10 plants were taken by full competition per experimental unit, having a total of 30 plants harvested to estimate the evaluation of stover and grain yield.

Of which, five plants were used to obtain the variables of dry weight of stover and the other 25 plants were used for evaluation of agronomic variables, which were: plant height (m), which was measured from the base to the panicle, number of leaves per plant, stem diameter (mm) by means of a metallic vernier, leaf area (LA), it was obtained with a LI-COR 3100 leaf area meter (LI-COR, Lincoln, NE, USA) in cm^2 and to determine the yield, 100 grains of corn (g $plant^{-1}$) of the 25 ears were weighed with an Ohaus® compact digital balance (model CS 5000, China) and it is reported in t ha^{-1}, these were shelled to obtain the weight of the grain, adjusting the weight of the samples to 14% moisture (Rocandio-Rodríguez *et al*., 2014).

For stover (total biomass) (t ha^{-1}), the average of the five plants for each genotype per repetition was used and they were taken to the laboratory where they were separated into stem, leaves and ear, for drying, they were placed in previously identified paper bags in an oven (model 31480, Thelco, United States of America) with forced-air circulation at 70 ºC to constant weight and then the total stover was recorded with an Ohaus® compact digital scale (model CS 5000; China). The statistical package SAS 9.0 was used to perform an analysis of variance using the completely randomized design for the response variables, the multiple comparison of means test proposed by Tukey was also performed, with α= 0.05.

The results show that the statistical parameters show a wide diversity among the evaluated stovers of native corns (Table 1), this demonstrates the highest values both in the standard deviation and the least significant difference in the agronomic attributes, dry weight and yield, where the variables total biomass, weight of ear, stem, leaves, grain and stover in the genotypes evaluated are highlighted. Therefore, these variables are of great importance since the use of stover is dominant as a source of feed for livestock with more than 70% (Hellin *et al*., 2013) and thereby satisfying the demand for forage (Borja-Bravo *et al*., 2016).

Table 1. Estimated values of population parameters: mean, coefficient of variation (CV) and least significant difference (LSD) in six genotypes of corn in Guasave, Sinaloa, Mexico.

Variable	Mean	Standard deviation	Interval (min-max)	CV (%)	LSD
Plant height (m)	2.1	0.4	1.5-2.8	6.3	0.2
Number of leaves	13.2	1.7	11-17	5.7	1.3
Stem diameter (mm)	21.7	6.1	11-34	5.2	1.9
Leaf area (cm^{-2})	0.7	0.2	0.4-1.5	7.2	0.1
Dry stem weight (g $plant^{-1}$)	69.2	39.9	24-132	5.2	6.4

Variable	Mean	Standard deviation	Interval (min-max)	CV (%)	LSD
Dry leaf weight (g plant^{-1})	76.8	28.1	32-137	5.2	7.1
Dry ear weight (g plant^{-1})	189.7	65.1	108-326	4.7	15.1
Total biomass (g plant^{-1})	335.7	116.4	194-563	2.3	13.8
Weight of 100 grains (g plant^{-1})	38.7	13.3	25-63	3.7	2.6
Yield (t ha^{-1})	8.8	3.5	3.4-13	4.4	0.7
Stover (t ha^{-1})	9.7	3.8	3.6-15.1	4.4	0.7

In the analysis of variance for the six genotypes evaluated, they had significant differences ($p \leq 0.05$) in all the variables evaluated (Table 2), these results are similar to what Pecina-Martínez *et al*. (2011) report in number of grains per ear, which is an important indicator that must be considered for yield. The knowledge, conservation and use of this diversity is of scientific and economic interest. Scientific because it is necessary to document morphological and genetic variation, its relationship with the physical and biotic environment that surrounds it, as well as with the social determinant of its existence and evolution under domestication (Hernández and Esquivel, 2004) since Guasave, Sinaloa is considered the agricultural heart of Mexico.

Table 2. Sum of squares of the analysis of variance of the agronomic variables measured in six genotypes of corn in Guasave, Sinaloa, Mexico.

SV	DF	Plant height (m)	No. of leaves	Stem diameter (mm)	Leaf area (cm^2)	Weight of 100 grains (g)	Yield (t ha^{-1})
				Sum of squares			
Genotype	5	3.8**	85**	1 243**	1.4**	6 129**	430**
Error	30	0.5	17	38	0.08	64	4
Total	35	4.3	102	1 282	1.48	6 194	435

**= significant at probability levels of 0.05; SV= source of variation; DF= degrees of freedom.

The significances of the analyses of variance of native corn varieties indicate the response to the environment and the difference between measured variables that show the genetic expression of genotypes. In addition, it is important to have the variables of good quality such as: plant height, number of leaves, stem diameter and leaf area, since they will increase the production of biomass and that it will be reflected in the yield of stover and grain (Santiago-López *et al*., 2018). Although, Elizondo and Boschini (2002) indicated that any type of corn can be grown for forage, with the regional varieties being the best as they are mostly tall, compared to hybrids, which, being small in size, produce less amount of forage per unit area.

Statistical differences ($p \leq 0.05$) between genotypes indicate different productive potentials among them (Table 3). In this regard, there were native populations that exceeded or equaled in stover production to the commercial varieties recommended for the region, in this case not in yield, and according to Serratos (2009), in the American continent about 300 races were reported, the variation in Mexico represents 22.7% of the diversity of corn. This diversity is present even at the level of microregions, which he calls ethnophytogenetic pattern or varietal pattern (Muñoz, 2005).

Table 3. Sum of squares of the analysis of variance of yield variables measured in six genotypes of corn in Guasave, Sinaloa, Mexico.

SV	DF	Dry stem weight (g $plant^{-1}$)	Dry leaf weight (g $plant^{-1}$)	Ear weight (g $plant^{-1}$)	Total biomass (g $plant^{-1}$)	Stover (g $plant^{-1}$)
			Sum of squares			
Genotype	5	44 950**	27 285**	145 958**	472 979**	521**
Error	30	401	492	2452	1872	5
Total	35	45 352	27 777	148 411	474 746	526

**= significant at probability levels of 0.05; SV= source of variation; DF= degrees of freedom.

The results of Table 4, the white genotype produced the highest plant height, number of leaves and leaf area. This is similar to what was found by Camacho *et al*. (1995); Sánchez-Hernández *et al*. (2019), where they assured that the grain yield in corn increases as the total leaf area per plant increases. The plant height, number of leaves and stem diameter were different in all genotypes and ranged from 1.5 to 2.6 m in height, 12 and 17 leaves per plant, 1.2 and 3.1 cm stem diameter, respectively, these results are different from those reported by Rodríguez-Larramendi *et al*. (2016) in local genotypes from Chiapas, since these are adapted in their geographical area. However, the results obtained in this work are similar to those reported by Palemón-Alberto *et al*. (2019) in Iguala, Guerrero, where it fluctuated between 1.8 and 2.6 m in plant height. Being one of the main variables that indicate the selection indices of forage corn plants (Tucuch-Cauich *et al*., 2011).

Table 4. Agronomic variables of six genotypes of corn in Guasave, Sinaloa, Mexico.

Genotypes	Plant height (m)	No. of leaves	Stem diameter (cm)	Leaf area (cm^2)	Weight of 100 grains (g $plant^{-1}$)	Yield (t ha^{-1})
Red	1.9 c	13 bc	3.1 a	8 449 b	26 d	6.1 c
Yellow	1.5 d	12 c	1.8 d	4 274 c	26 d	8.6 d
Blue	1.9 c	13 bc	1.2 e	5 236 c	30 c	3.4 e
White	2.6 a	17 a	2.5 b	11 520 a	53 b	8.9 c
HD 4050	2.2 b	12 bc	2.0 d	8 797 b	59 a	13.5 a
Hipopótamo	2.1 b	14 b	2.2 c	8 806 b	50 b	12.5 b

Means with different letters indicate significant differences (α= 0.05).

This study found that white genotypes showed high yield compared to local genotypes, although, at present, local corn presents a high scientific interest from the point of view of its conservation, management, culture, commercialization, and improvement (Rodríguez-Larramendi *et al*., 2016). Because of this, it is of great importance to study the characteristics of native corn to include it as possible forage genotypes in the northern region of Sinaloa. Although, in this study, genotypes from other regions (Tlaxcala, Oaxaca, Puebla and Veracruz) were used to know their agronomic adaptation in the region of Guasave, Sinaloa.

However, this native corn is not regional and in yield, it does not exceed the hybrids used; however, the white variety from the state of Puebla is one of the genotypes used that produced greater production in yield and biomass. In a study carried out by Ángeles-Gaspar *et al*. (2010), in Puebla, they found that there is wide genetic diversity among local corn populations, to the extent that some of them exceed or equal in grain yield to commercial hybrids recommended for the region. Another way to increase yield and its components in native genotypes is to perform selection cycles as reported by López-Morales *et al*. (2020).

The comparison of means of the variables of dry weight (Table 5), the white genotype was better in all the variables measured. The results found in this analysis corroborated that the production of biomass per plant in local varieties is not uniform in all corns, hence the accumulation of biomass is an important factor in the selection of materials for forage, although the selection of corns is carried out based on grain yield (Peña *et al*., 2004; Sánchez and Hidalgo, 2018). As mentioned by Villegas *et al*. (2001), that the dry matter used for feed in livestock farming comes from four sources of supply: 29.8% is produced in ranges, 41.9% in meadows, 24% comes from agricultural residues and 4.3% is derived from forage crops, which shows the importance of the use of corn stover.

Table 5. Yield variables in six varieties of corn in Guasave, Sinaloa, Mexico.

Genotypes	Dry stem weight (g plant^{-1})	Dry leaf weight (g plant^{-1})	Ear weight (g plant^{-1})	Total biomass (g plant^{-1})	Stover (t ha^{-1})
Red	124 a	83 b	180 c	388 b	6.8 b
Yellow	28 e	34 e	135 d	198 d	9.5 f
Blue	39 d	62 b	111 e	213 d	3.7 e
White	106 b	125 a	308 a	541 a	14.8 a
HD 4050	45 d	71 c	220 b	337 c	13.7 d
Hipopótamo	70 c	84 b	181 c	236 c	9.8 c

Means with different letters indicate significant differences (α= 0.05).

White native corn surpassed the best hipopótamo hybrid in stover production by 44%, which proves to be a material with excellent characteristics for the production of biomass in livestock feed. Corn stover is the most abundant feed for ruminants during part of the year in many regions of Mexico, but its nutritional contribution is insufficient to maintain them (Guerra-Liera *et al*., 2017). According to Gasque (2008), he estimated that a bovine consumes an amount of stover per day equal to 3.2% of its live weight, which is equivalent to 14.4 kg, and it is estimated that 5 256 kg of stover is consumed per year.

Conclusions

The genotype of white corn has the best characteristics for the production of forage since it is a material of greater height, number of leaves, leaf area for obtaining forage (stover). The results obtained in local corns will serve as a reference for further studies in the adaptation of genotypes and their genetic improvement to produce forage and grain. It was also found that the white genotypes of corn produce more grain yield and stover since they are materials selected and improved for larger-scale production.

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