Article

Productivity of fodder maize genotypes under organic fertilization and physical-chemical soil properties

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Abstract

The Lagunera region is the main region of dairy cattle exploitation in the whole country, a process that demands large quantities of forage of the highest quality. Therefore, the objective of this work was to evaluate the forage production on dry basis of three forage corn hybrids, using different amounts of vermicompost and bovine manure for fertilization, as well as to evaluate the effect of these treatments on the physico-chemical properties ground. Under organic fertilization, HT 6806Y, ABT hybrids were tested; DAS2306, from Dow Agrosciences and RX717, from Asgrow. The experiment was established in the Faculty of Agriculture and Zootechnics of the Juarez University of the state of Durango. A randomized blocks design was used in split plots, with three repetitions. The experiment was carried out in the spring-summer cycle of 2014. In the comparison analysis of means the hybrid HT6806Y proved to be superior ($p \leq 0.05$) with a production of 69.91 t ha^{-1} of green forage, under the treatment T3 (160 t ha^{-1} of solarized manure with 3 t ha^{-1} of vermicompost); on the other hand, the three hybrids showed a good response to organic fertilization, since they all obtained acceptable productions of dry matter of 25.89 t ha^{-1} (HT6806Y), 26.04 t ha^{-1} (RX717) and 25.33 t ha^{-1} (DAS2306). The mixtures of nitrogen sources tested in this study turned out to be a good alternative that competes with the synthetic sources of nitrogen, improving some variables of yield and quality of the forages.

Keywords: manure, corn hybrids, vermicompost.

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Introduction

The Lagunera region is the main region of cattle bovine milk production in the whole country (Ramírez *et al*., 2016), therefore, it is the area that requires the most forage. In the region, there are more than 400 thousand dairy cows, which produce approximately 925 000 tonnes of dry manure per year, with an average of 1.6% nitrogen (N) (Magri and Teira-Esmatges, 2015; Ramírez *et al*., 2016), which provides 14 800 tons of nitrogen (N) per year. The use of these organic waste is increasingly important as rational recycling of nutrients, helps plant growth and return to the soil the elements extracted during the production process (Zhao *et al*., 2014).

Among the forages that are most consumed and produced in the region is corn, it is the second important crop in the Comarca Lagunera after alfalfa, with 32 491 ha (SIAP, 2012) and occupies approximately 36% of the surface planted at the national level (SIAP, 2014). On the other hand, the constant growth of the number of head of cattle in the region, demand the increase in the production of fodder maize and raises the need to identify materials with good forage characteristics, so among the selection criteria to identify suitable hybrids, is that which presents high grain yield, productivity and high forage quality (Sánchez *et al*., 2011).

In addition, livestock activity generates large amounts of manure with nutritional potential, which can be used to make a sustainable production system, however, it is important to carry out local studies on N mineralization of manure, to estimate the manure doses of manure precise way (Flores *et al*., 2009; Azeez and Van Averbeke, 2010). Therefore, the objective of this work was to evaluate the forage production on dry basis and the protein content of three fodder corn hybrids, using different amounts of vermicompost and bovine manure for fertilization, as well as to evaluate the effect of these treatments in the physical-chemical properties of the soil.

Materials and methods

Study site

The present work was carried out during the spring-summer cycle of 2014 in the experimental field of the Faculty of Agriculture and Zootechnics of the Juárez University of the state of Durango (UJED), located at 25° 46' 56" north latitude and 103° 21' 02" west longitude, at a height of 1 110 meters above sea level, with arid climate and deficient rainfall in all seasons. The average temperature fluctuates between 18 and 22 °C, with maximum and minimum temperatures of 48 °C and -8 °C.

Establishment of the experiment

Fodder corn hybrids, HT6806Y (Agribiotech), DAS2306 (Dow Agrosciences) and Rx717 (Asgrow) were used. The plots were 8 m^2, with distance between rows of 0.65 m and between plants of 0.15 m. The sowing was carried out in dry, on April 14, 2014, two seeds were placed per hit, and thinning was carried out a week after emergence of seedlings leaving a population of 102 500 plants ha^{-1}. The experiment was conducted with irrigation by strip and was established under a randomized blocks design in divided plots, with three repetitions.

Organic treatments

The treatments evaluated were the following: T1) 0 t ha^{-1} of solarized manure + 3 t ha^{-1} of vermicompost; T2) 80 t ha^{-1} of solarized manure + 3 t ha^{-1} of vermicompost; T3) 160 t ha^{-1} of solarized manure + 3 t ha^{-1} of vermicompost; T4) 0 t ha^{-1} of solarized manure + 0 t ha^{-1} of vermicompost; T5) 80 t ha^{-1} of solarized manure + 0 t ha^{-1} of vermicompost; T6) 160 t ha^{-1} of solarized manure + 0 t ha^{-1} of vermicompost. The treatments were manually distributed and incorporated with a harrowing step 45 days before sowing to stabilize moisture and allow the mineralization process.

Materials used in the treatments

The vermicompost was acquired from the Technological Institute of Torreon (ITT) and for its production was used California red worm (*Eisenia foetida*), bovine manure and remains of leaves of trees, fruits and vegetables; the bovine manure that was solarized was obtained from the stable The Espada (Fco I. Madero, Coahuila). For the solarization process, the manure was covered with transparent plastic without albedo and with a thickness of 100 µm, during the months of january and february, the maximum temperature reached in the solarization pile was 65 °C.

Sampling

To analyze forage quality, the harvest of each hybrid was made when reaching ¾ of milk line in the cob, which, in each hybrid was different, reached RX-717 110 days after sowing, HT-6806Y to 109 days after sowing and DAS-2306 to 114 days after sowing. To determine the forage production in green per hectare, the plants established in 1.3 m^2 of useful plot were harvested and weighed in a clock scale (THOR, Mod. Balanzon, minimum division 25 g). Of the plants harvested to determine green forage yield, three complete plants were taken, cut with scissors and dried in an oven at 80 °C for 24 h, to determine dry matter and crude protein. The evaluated variables were: green forage yield (FV), dry forage yield (FS), plant height (AP), stem diameter (DT), number of internodes (NE), cob width (AM), length of cob (LM), rows by cob (NHM) and raw protein of forage (PC), which, was determined by the technique of NOM-F-068-S-1980.

Two soil samples were taken, one at 45 days after applying the treatments and before sowing, and another at the end of the experiment, both at two depths (0-15, 15-30 cm), to observe changes in the physical-chemical properties of soil. The variables that were evaluated in the soil samples were: organic matter (%) (MO), pH, CE (dS m^{-1}) and nitrates (ppm) (NO_3) were determined according to the norm NOM-021-SEMARNAT-2000. The homocedasticity of the data was tested with the Bartlett test (Little and Hills, 1989), the data of the variables were subjected to analysis of variance, comparison of means with DMS and Pearson correlation and analyzed with the statistical program SAS version 9.22 (SAS, 2010).

Results and discussion

The analysis of variance showed significant differences (Table 1, $p \leq 0.05$) in the treatments (Trat), for the variables: green fodder (FV), dry fodder (FS), plant height (AP), cob width (AM)), length of cob (LM) and number of rows per cob (NHM), which suggests different effects of the treatments.

Highly significant differences ($p \leq 0.01$) were also observed for stem diameter (DT). In the hybrid variation factor (Hib), highly significant differences ($p \leq 0.01$) were observed for the variables plant height (AP), stem diameter (DT), number of internodes (NE), length of cob (LM) and number of rows per corn (NHM); and significant differences ($p \leq 0.05$) in the variables of green forage (FV), cob width (AM) and crude protein (PC). The significant differences observed in the plant variables related to the production of forage (Table 1) show the effect of the treatments as well as the genetic differences between the evaluated hybrids, noting that organic fertilization is an alternative of agricultural production at the same time that a sustainable use of manure is made (Annicchiarico *et al.*, 2011).

Table 1. Analysis of variance for corn forage variables under manure and vermicompost treatments.

FVar	FV	FS	AP	DT	NE	AM	LM	NHM	PC
Rep	673.46*	127.6*	0.01*	0.03*	0.68*	0.17*	2.16*	0.74*	0.42
Trat	158.6*	10.98	0.03*	0.17**	0.38	0.06*	2.01*	0.51*	2.53*
Hybrid	562.13*	2.48	1.61**	0.43**	27.46**	0.42*	136.2**	1.35**	5.57*
Trat x Hib	48.48	8.54	0.01	0.05*	0.39	0.07	1.28	1.17*	0.6
Error	89.54	12.9	0.01	0.02	0.64	0.05	0.65	0.51	0.73
CV	14.6	13.9	4.7	5.5	5.6	4.5	4.2	4.7	9.8

FV= green fodder; FS= dry fodder; AP= plant height; DT= stem diameter; NE= number of internodes; AM= cob width; LM= length of ear; NHM= number of rows per ear; PC= crude protein; *= $p < 0.05$, **= $p < 0.01$. The mean squares and their significance are shown.

Regarding the soil variables of the initial sampling (Table 2), the organic matter (MO1) and electrical conductivity (CE1, CE2) showed highly significant differences ($p \leq 0.01$) in the treatment variation factor (Trat), while the organic matter (MO2) and pH (pH1 and pH2) showed significant differences ($p \leq 0.05$). No significant differences were observed for nitrates.

Table 2. Analysis of variance for initial sampling of the physical-chemical variables of the soil under treatments of manure and vermicompost.

FVar	MO1	MO2	pH1	pH2	CE1	CE2	$NO_3$1	$NO_3$2
Rep	0.24	0.05	0.003	0.01	0.02	0.05	0.05	0.08
Trat	2.8**	0.63*	0.01*	0.001*	14.71**	10.78**	1.63	0.2
Error	0.16	0.12	0.003	0.003	0.73	0.58	0.32	0.07
CV	13	12.2	0.7	0.7	17.2	14	14	15

MO1= organic matter; pH1= hydrogen potential; CE1= electrical conductivity; $NO_3$1= nitrates at the depth of 0-15 cm; MO2= organic matter; pH2= hydrogen potential; CE2= electrical conductivity; $NO_3$2 = nitrates at depth of 15-30 cm; *= $p < 0.05$; **= $p < 0.01$. The mean squares and their significance are shown.

In the analysis of variance of the final physical-chemical variables of soil (Table 3) significant differences ($p \leq 0.05$) were observed for the treatments in the variables MO3, pH3, pH4 and highly significant differences ($p \leq 0.01$) for CE3, CE4, $NO_3$3, $NO_3$4.

Table 3. Analysis of variance for final sampling in the physical-chemical variables of the soil under treatments of manure and vermicompost.

FVar	MO3	MO4	pH3	pH4	CE3	CE4	$NO_3$3	$NO_3$4
Rep	0.002	0.03	0.02	0.01	0.58	0.04	21.13	91.8
Trat	1.49*	0.1	0.01*	0.04*	3.14**	1.64**	97.77**	289**
Error	0.12	0.07	0.01	0.01	0.29	0.21	11.92	17.45
CV	12.9	11.3	1.4	1.4	21.1	12.3	15.9	16.9

MO3= organic matter; pH3= hydrogen potential; CE3= electrical conductivity; $NO_3$3= nitrates at the depth of 0-15 cm; MO4= organic matter; pH4= hydrogen potential; CE4= electrical conductivity; $NO_3$4= nitrates in the depth of 15-30 cm; *= $p< 0.05$; **= $p< 0.01$. The mean squares and their significance are shown.

In the comparison of treatment means for the forage variables (Table 4), green tilapia stood out, treatments T3 and T6, with 70 t ha^{-1} and 68 t ha^{-1}, respectively. In stem diameter (DT) the best treatments were T2, T3, T5 and T6, with a value between 2.6-2.7 cm. The T3 treatment exceeded the others in plant height (AP), with a value of 2.9 m; in cob width (AM), treatments T2, T6 and T3 stood out, with values 5.2, 5.1 and 5.1 cm, respectively; in the length of cob (LM), the best treatments were T2, T3, T1 and T6, with 19.6, 19.5, 19.3 and 19.1 cm, respectively; the highest number of rows per cob (NHM) was observed in the T6 treatment with a value of 15.6 cm.

Table 4. Comparison of means for forage variables in forage corn hybrids treated with manure and vermicompost.

Trat	FV	FS	PC	DT	AP	NE	AM	LM	NHM
T1	64 b	25.9 a	8.8 a	2.5 b	2.8 b	14 a	4.9 c	19.3 a	14.8 b
T2	61 c	25.8 a	8.6 a	2.7 a	2.8 b	14.1 a	5.2 a	19.6 a	15.3 b
T3	70 a	26.8 a	9 a	2.6 a	2.9 a	14.4 a	5.1 b	19.6 a	15.2 b
T4	59 c	23.7 a	8.4 a	2.4 b	2.8 b	14 a	4.9 c	18.3 b	15.1 b
T5	65 b	25.8 a	8.8 a	2.7 a	2.7 c	14.1 a	5 c	18.9 b	14.8 b
T6	68 a	26.6 a	8.8 a	2.7 a	2.8 b	14.4 a	5.1 b	19.1 a	15.6 a
DMS	3	3.4	0.8	0.1	0.1	0.7	0.2	0.7	0.6

T1= 3 t ha^{-1} of vermicompost, without solarized manure; T2= 80 t ha^{-1} of solarized manure with 3 t ha^{-1} of vermicompost; T3= 160 t ha^{-1} of solarized manure with 3 t ha^{-1} of vermicompost; T4= witness; T5= 80 t ha^{-1} of solarized manure; T6= 160 t ha^{-1} of solarized manure; FV= green fodder; FS= dry fodder; PC= crude protein; DT= stem diameter; AP= plant height; NE= number of internodes; AM= cob width; LM= length of ear; NHM= number of rows per ear. Within columns, means with equal letters are not statistically different (DMS $p\leq 0.05$).

The observed values for green forage were higher than the regional average of 47.8 t ha^{-1} (SIAP, 2014), and although there were no significant differences in dry forage, all treatments exceeded that reported by Salazar *et al*. (2007) who obtained 23.6 t ha^{-1} with 160 t ha^{-1} of cattle manure. In the crude protein (PC) variable there were no statistically significant differences between treatments, and the values obtained were similar to the highest values reported by Tadeo-Robledo *et al*. (2012)

but lower than the national average reported by Nuñez (2006) of 10.3%. The decrease in crude protein content could be the result of the loss of leaf biomass coupled with a higher proportion of stem in the total biomass, which are deficient in crude protein content (Tariq *et al*., 2011).

Regarding the comparison of means of the physico-chemical variables at the beginning of the experiment (Table 5), in the organic matter at the two depths the best contents were observed in the treatment T6 and T3, and the lowest values in the control T4 which is corresponding to the amounts of manure applied. Regarding pH, no significant differences were observed and the average value was 7.7. Regarding the CE, the highest values were observed in the treatments T3 and T6, and the lowest in the treatment T4, which are consistent with the applied doses of manure and vermicompost in each treatment and are a reflection of the addition of nutrients and salts in applied organic matter (Carmo *et al*., 2016). Regarding nitrates, they were considered statistically equal in all treatments in the initial sampling.

Table 5. Comparison of means for the initial sampling in the physical-chemical variables of the soil treated with manure and vermicompost.

Trat	MO1 (%)	MO2 (%)	pH1	pH2	CE1 (dS m^{-1})	CE2 (dS m^{-1})	$NO_3$1 (ppm)	$NO_3$2 (ppm)
T1	2.9 c	2.9 b	7.8 a	7.7 a	4 c	4.9 b	31.4 a	42 a
T2	3.1 b	2.6 b	7.7 b	7.7 a	4.2 c	4.9 b	33.2 a	38.9 a
T3	2.9 c	3.2 a	7.7 b	7.7 a	6 b	6.5 a	35 a	39.1 a
T4	2.6 c	2.6 b	7.7 b	7.7 a	3.8 c	4.2 b	32 a	38.7 a
T5	3.1 b	2.8 b	7.7 b	7.7 a	4.7 c	5 b	30.3 a	39 a
T6	4.2 a	3.1 a	7.7 b	7.7 a	7.1 a	7 a	33.4 a	40.6 a
DMS	0.3	0.3	0.05	0.05	0.8	0.7	1	0.9

T1= 3 t ha^{-1} of vermicompost, without solarized manure; T2= 80 t ha^{-1} of solarized manure with 3 t ha^{-1} of vermicompost; T3= 160 t ha^{-1} of solarized manure with 3 t ha^{-1} of vermicompost; T4= witness; T5= 80 t ha^{-1} of solarized manure; T6= 160 t ha^{-1} of solarized manure. MO1= organic matter; pH1= hydrogen potential; CE1= electrical conductivity; $NO_3$1= nitrates at the depth of 0-15 cm; MO2= organic matter; pH2= hydrogen potential; CE2= electrical conductivity; $NO_3$2= nitrates at a depth of 15-30 cm. Within columns, means with equal letters are not statistically different (DMS $p \leq 0.05$).

In relation to the comparison of means of the physico-chemical variables at the end of the experiment (Table 6), only in the organic matter and in the depth of 0-15, the mean values presented significant differences being the treatments T3 and T6 where they observed the highest values. In relation to the pH there was a slight increase in the two depths with respect to the initial values, being the highest value of 7.9. In relation to the CE, a decrease of the salts with respect to the initial content was observed, and the highest value was 4.2 dS m^{-1} in the depth of 15 -30, observing the highest values in the treatments with the highest dose of manure (T3 and T6), as well as a slight increase in CE in the treatments that had vermicompost, but within the range tolerated by the corn crop (Khorasani *et al*., 2012). Likewise, a tendency of increase in the amount of nitrates was observed, as the manure dose increased in the treatments, with the best treatments being T3 and T6.

Table 6. Comparison of means for the final sampling in the physical-chemical variables of the soil treated with manure and vermicompost.

Trat	MO3 (%)	MO4 (%)	pH3	pH 4	CE 3 (dS m^{-1})	CE 4 (dS m^{-1})	$NO_3$3 (ppm)	$NO_3$4 (ppm)
T1	2.2 c	2.5 a	7.7 a	7.7 c	2.5 c	3.7 b	20 c	21.4 c
T2	2.8 b	2.4 a	7.8 a	7.6 c	2.6.c	3.8 b	22.8 b	26.4 b
T3	3.2 a	2.5 a	7.8 a	7.7 c	3.4 a	4.2 a	25.4 a	27.9 b
T4	2.2 c	2.3 a	7.8 a	7.7 c	1.8 d	3.1 c	16.3 c	15.6 d
T5	2.7 b	2.3 a	7.8 a	7.8 a	2.1 d	3.4 b	21.5 b	24.7 c
T6	2.9 b	2.5 a	7.8 a	7.9 b	3 b	4.2 a	24.7 b	32.1 a
DMS	0.3	0.2	0.1	0.1	0.5	0.4	3.3	4

T1= 3 t ha^{-1} of vermicompost, without solarized manure; T2= 80 t ha^{-1} of solarized manure with 3 t ha^{-1} of vermicompost; T3= 160 t ha^{-1} of solarized manure with 3 t ha^{-1} of vermicompost; T4= witness; T5= 80 t ha^{-1} of solarized manure; T6= 160 t ha^{-1} of solarized manure. MO3= organic matter; pH3= hydrogen potential; CE3= electrical conductivity; $NO_3$3= nitrates at the depth of 0-15 cm; MO4= organic matter; pH4= hydrogen potential; CE4= electrical conductivity; $NO_3$4= nitrates at a depth of 15-30 cm. Within columns, means with equal letters are not statistically different (DMS $p \leq 0.05$).

All the treatments that took manure and vermicompost (except T4) generated changes in the physical-chemical properties of the soil. The T6 treatment initially gave a value of 4.2%, while the T3 treatment was better in the depth of 15-30 (MO2) with a value of 3.2%, being these two strata (0-15, 15-30 cm) the most important for root exploration and where most of the absorption of nutrients occurs (Andrades and Martínez, 2014). For the variable electrical conductivity (CE1, CE2, CE3, CE4) all the treatments generated changes in the amount of soluble salts in the soil, and the highest values were observed in the initial sampling, which could have damaged the absorption of nutrients in solution (Carmo *et al.*, 2016).

In the variable nitrates the values were higher in the initial sampling in the depth 15-30 cm (NO32), highlighting the T6 treatment with 32.1 ppm, a value lower than that reported by Salazar *et al*. (2007), who report a value of 70 ppm for the same treatment and at the same depth; in the depth of 0-15 cm ($NO_3$1) the T3 treatment stood out with a value of 25.4 ppm, also lower than that reported by Salazar *et al*. (2007), for the same treatment and depth. This could be due to factors such as moisture content, microbial activity, temperature and the state of the manure, which accelerate or delay the availability of nutrients (Trejo *et al*., 2013).

In relation to the agronomic behavior of the hybrids (Table 7), green hybrid forage was better HT-6806Y with 69.9 t ha^{-1}, in plant height, the hybrid DAS-2306, with 3.14 m, and in diameter Stem (DT), the hybrid RX-717 stood out with a value of 2.75 cm, this being a variable directly related to the production of green forage, as mentioned by Wong-Romero *et al*. (2006), who indicate that the weight of corn with totomoxtle and the weight of stems with spikes, are the most important for green forage yield.

In the raw protein variable, hybrids RX-717 and HT-6806Y stood out, with 9.1 and 8.9% respectively, which are within the range (7.5-10.3%) reported by Jurado *et al*. (2014) for commercial hybrids, and those who mention that since the production of dry matter and forage quality of maize have a direct effect on the milk ha^{-1} production potential, these factors should be taken into account in the selection of hybrids of corn for forage production. The percentage of crude protein is an important variable to determine the quality of the forage (Lauer *et al*., 2001; Saha *et al*., 2017) and this content depends on the genetic potential of the hybrid or variety, and agronomic management (Silva *et al*., 2005).

Table 7. Comparison of means for variables between fodder maize genotypes treated with manure and vermicompost.

Genotypes	FV ($t\ ha^{-1}$)	FS ($t\ ha^{-1}$)	AP (m)	DT (cm)	NE	PC (%)	AM (cm)	LM (cm)	NHM
HT-6806Y	69.9 a	25.8 a	2.5 c	2.4 c	13.5 b	8.9 a	4.8 b	20.2 b	14.8 b
RX-717	64.8 a	26 a	2.6 b	2.7 a	13.4 b	9.1 a	5.1 a	21.1 a	15.4 a
DAS-2306	58.8 b	25.3 a	3.1 a	2.5 b	15.6 a	8 b	5.1 a	16 c	15.3 a
DMS	6	2.4	0.08	0.09	0.5	0.5	0.1	0.5	0.4

FV= green fodder; FS= dry fodder; AP= plant height; DT= stem diameter; NE= number of internodes; PC= crude protein; A = cob width; LM= length of ear; NHM= number of rows per ear. Within columns, means with equal letters are not statistically different (DMS $p< 0.05$).

The variables width of cob (AM), cob length (LM), and number of rows per cob (NHM) are characteristics of maize hybrids with high yield and quality of forage and are components of the characteristic called cob percentage, considered as one of the quality attributes of fodder corn as it contributes to the net energy of lactation (Núñez *et al*., 2010). In the variable width of cob (AM), the hybrid RX-717 stood out, as in the variable length of cob (LM) and number of rows per cob (NHM), which makes this hybrid a good candidate to be followed exploiting commercially, since although there were no statistical differences in dry forage, it was the one with the highest production; In addition, the values observed in dry forage in this work exceeded the values mentioned by Jurado *et al*. (2014) for the state of Chihuahua.

On the other hand, the identification of outstanding genotypes with high nutritional value of forage is an important aspect in terms of feeding requirements of livestock (Lauer *et al*., 2001), in this case the best hybrid was RX-717 since it excelled in dry forage, crude protein, plant height, stem diameter, width and length of cob, and number of rows per cob.

The correlations between plant variables (Table 8) show positive and highly significant correlation, between raw protein with cob length; This correlation is important since the cob stores a large amount of protein and energy that contributes to improve the quality of the forage (Sánchez *et al*., 2013) and it was in the hybrid RX-717 that the highest values of cob length and crude protein were observed similarly, the crude protein variable correlated positively with the number of internodes, which means more leaves and therefore more protein, since the leaves provide important values of protein to the forage (Hassan, 2011). The variable of green forage strongly correlated with the variable length of cob, there was also a positive and highly significant correlation between cob width and stem diameter.

Table 8. Phenotypic correlations of plant maize hybrid variables treated with manure and vermicompost.

	FV	FS	AP	DT	NE	AM	LM	NHM	PC
FV	1	0.7065 <0.0001	-0.2516 0.0664	0.0696 0.617	-0.3068 0.024	0.0849 0.5415	0.3714 0.0057	-0.1438 0.2993	0.0492 0.7236
FS		1	-0.0181 0.8962	0.0605 0.6638	-0.1113 0.4227	-0.0783 0.5734	0.0974 0.4835	-0.08 0.5649	-0.202 0.1428
AP			1	0.0425 0.7602	0.7304 <0.0001	0.1929 0.1621	-0.7166 <0.0001	0.126 0.3639	-0.3151 0.0203
DT				1	0.1760 0.2029	0.6064 <0.0001	0.1759 0.2031	0.1089 0.433	0.1777 0.1986
NE					1	0.2653 0.0525	-0.7084 <0.0001	0.0991 0.4757	0.4381 0.0009
AM						1	-0.0201 0.885	0.4936 0.0001	0.0303 0.8274
LM							1	-0.0594 0.6691	0.4591 0.0005
NHM								1	0.0432 0.7562
PC									1

FV= green fodder; FS= dry fodder; AP= plant height; DT= stem diameter; NE= number of internodes; AM= cob width; LM= length of ear; NHM= number of rows per ear; PC= crude protein.

Although none of the hybrids used showed remarkable superiority in the production of green matter and dry matter, they exceeded the national average yield (47.61 t ha^{-1}) in green fodder under irrigation (SIAP, 2014) and considering that they stood out significantly in some variables that are directly related to production and quality, they can be recommended for future experiments. In addition, the hybrid RX717 proved to be better in the production of cobs, both in length and in diameter, which determine the yield and quality of forage.

Conclusions

Manure is a good source of nutrients and can be combined with other sources of nitrogen, to improve plant nutrition and therefore improve some of the variables that directly influence the performance and quality of forages. The T3 treatment with 160 t ha^{-1} of solarized manure + 3 t ha^{-1} of vermicompost was where the highest production of green fodder, dry fodder and protein content was obtained, surpassing the T6 treatment of only 160 t ha^{-1} of solarized manure, so the positive effect of the addition of vermicompost is deduced. Although it is known that soil fertility is a determinant of crop productivity, the genotype of the cultivar used is also determinant to achieve high yields of forage and good quality, as an efficient cultivar in the use of nitrogen can still have acceptable yields with low doses of nitrogen.

In this work no differences were observed in the production of dry forage, but in raw protein content, and in green forage, the yields were very similar among the hybrids evaluated, which denotes the genetic potential of the three hybrids, in particular the Hybrid RX-717 that excelled in forage quality characteristics. The correlations found, indicate that cultivars with high production of green forage tend to have high yields of dry forage, and that high values of crude protein content will be associated with high values of cob length.

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Cited literature

Andrades, M. y Martínez, M. E. 2014. Fertilidad del suelo y parámetros que la definen. 3ra. edición. Universidad de la Rioja. Servicio de publicaciones. ISBN 978-84-695-9286-1. 4 p.

Annicchiarico, G.; Caternolo, G.; Rossi, E. and Martiniello, P. 2011. Effect of manure *vs* fertilizer inputs on productivity of forage crop models. Int. J. Environ. Res. Public Health. 8(6):1893-1913.

Azeez, J. O. and Van Averbeke, W. 2010. Nitrogen mineralization potential of three animal manures applied on a sandy clay loam soil. Bio. Technol. 101(14):5645-5651.

Carmo, D. L.; Lima, L. B. and Silva, C. A. 2016. Soil fertility and electrical conductivity affected by organic waste rates and nutrient inputs. Rev Bras Cienc Solo. 40(1): e0150152.

Flores, J. P.; Corral, D. B.; Figueroa, U.; Mauricio, L. y Sotomayor, V. 2009. Nitrógeno mineralizable de estiércol bovino lechero en suelos agrícolas del norte de México. *In*: agricultura orgánica. (Comp.). Orona, C.; Salazar, S.; Fortis, H. M. (Eds.). Gómez Palacio, Dgo., México: FAZ-UJED, SMCS. 152-172 pp.

Hassan, A. M. E. 2011. Effect of different nitrogen sources on growth, yield and quality of fodder maize (*Zea mays* L.). J. Saudi Soc. Agric. Sci. 10(1):17-23.

Jurado, G. P.; Lara, M. C. R. y Saucedo, T. R. A. 2014. Paquete tecnológico para la producción de maíz forrajero en Chihuahua. INIFAP. Centro de Investigación Regional Norte Centro, Sitio Experimental La Campana, Aldama, Chihuahua.

Khorasani, S. K.; Mostafavi, K. and Heidarian, A. R. 2012. Response of maize (*Zea mays* L.) hybrids and inbred lines to salinity stress under field condition. Tech J. Engin. App. Sci. 2(2):28-34.

Lauer, J. G.; Coors, J. G. and Flannery, P. J. 2001. Forage yield and quality of corn cultivars developed in different eras. Crop Sci. 41(5):1449-1455.

Little, Thomas M. y Hills, F. Jackson. 1989. Métodos estadísticos para la investigación en la agricultura: transformaciones. 2a (Ed.). México. Trillas 1989. ISBN 978968-243629-1. 4 p.

Magri, A. and Teira-Esmatges, M. R. 2015. Assessment of a composting process for the treatment of beef cattle manure. J. Environ. Sci. Health B. 50(6):430-438.

Núñez, G. 2006. Maíz forrajero de alto rendimiento y calidad nutricional. México. ISBN 970-43-0092-1 Ed. INIFAP. Torreón, Coah., México. Libro científico núm. 3. 255 p.

Núñez, G.; Payán, J. A.; Pena, A.; González, F.; Ruiz, O. y Arzola, C. 2010. Caracterización agronómica y nutricional del forraje de variedades de especies anuales en la región norte de México. Rev. Mex. de Cienc. Pec. 1(2):85-98.

Ramírez, J. A.; Figueroa, U.; Núñez, G.; Reta, D. G. and García, J. L. 2016. Evaluation of tillage methods and manure incorporation into corn silage production. Rev. Chapingo Ser. Zonas Áridas. 15(2):67-76.

Saha, U.; Sonon, L.; Hancock, D.; Hill, N.; Stewart, L.; Heusner, G. and Kissel, D. E. 2017. Common terms used in animal feeding and nutrition. UGA Extension. Bulletin 1376. Published by the University of Georgia in cooperation with Fort Valley State University, the U.S. Department of Agriculture, and counties of the state. Georgia, USA. 1-20 pp.

Salazar, E.; Trejo, H. I.; Vázquez, C. y López, J. D. 2007. Producción de maíz bajo riego por cintilla, con aplicación de estiércol bovino. Rev. Int. Bot. Exp. 76(1):169-185.

Sánchez, M. A.; Aguilar, C. U.; Valenzuela, N.; Joaquín, B. M.; Sánchez, C.; Jiménez, M. C. y Villanueva, C. 2013. Rendimiento en forraje de maíces del trópico húmedo de México en respuesta a densidades de siembra. Rev. Mex. Cienc. Pec. 4(3):271-288.

Sánchez, M. A.; Aguilar, C. U.; Valenzuela, N.; Sánchez, C.; Jiménez, M. C. y Villanueva, C. 2011. Densidad de siembra y crecimiento de maíces forrajeros. Agron. Mesoam. 22(2):281-295.

SAS Institute Inc. 2010. SAS/STAT 9.22. User´s Guide. Cary, NC. USA.

SIAP. 2012. Sistema de Información Agropecuaria y Pesquera. Cierre de la producción agrícola por cultivo. http://www.siap.gob.mx/cierre-de-la-produccion-agricola-por-estado/.

SIAP. 2014. Sistema de Información Agropecuaria y Pesquera. Cierre de la producción agrícola por cultivo. http://www.siap.gob.mx/cierre-de-la-produccion-agricola-por-cultivo/.

Silva, P. R. F.; Strieder, M. L.; Coser, R. P. S.; Rambo, L.; Sangoi, L.; Argenta, G.; Forsthofer, E. L. and Silva, A. 2005. Grain yield and kernel crude protein content increases of maize hybrids with late nitrogen side-dressing. Scientia Agric. 62(5):487-492.

Tadeo-Robledo, M.; Espinosa-Calderón, A.; Zaragoza-Esparza, J.; Turrent-Fernández, A.; Sierra-Macías, M. y Gómez-Montiel, N. 2012. Forraje y grano de híbridos de maíz amarillo para Valles Altos de México. Agron. Mesoam. 23(2):281-288.

Tariq, M.; Ayub, M.; Elahi, M.; Ahmad, A. H.; Chaudhary, M. N. and Nadeem, M. A. 2011. Forage yield and some quality attributes of millet (*Pennisetum americannum* L.) hybrid under various regimes of nitrogen fertilization and harvesting dates. Afr. J. Agric. Res. 6(16):3883-3890.

Trejo, H. I.; Salazar, E.; López, J. D. y Vázquez, C. 2013. Impacto del estiércol bovino en el suelo y producción de forraje de maíz. Rev. Mex. Cienc. Agríc. 4(5):727-738.

Wong-Romero, R.; Gutiérrez-del Río, E.; Rodríguez-Herrera, S. A.; Palomo-Gil, A.; Córdova-Orellana, H. y Espinoza-Banda, A. 2006. Aptitud combinatoria y parámetros genéticos de maíz para forraje en la Comarca Lagunera, México. Ecos. Rec. Agrop. 22(2):141-151.

Zhao, Z. P.; Yan, S.; Liu, F.; Ji, P. H.; Wang, X. Y. and Tong, Y. A. 2014. Effects of chemical fertilizer combined with organic manure on Fuji apple quality, yield and soil fertility in apple orchard on the Loess Plateau of China. Int. J. Agric. Biol. Eng. 7(2):45-55.