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Forage maize nutritional quality according to organic and inorganic fertilization

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Abstract
The research was conducted on a commercial land plot from the ejido Granada, municipality of Matamoros, Coahuila, situated inside the Comarca Lagunera, from April to August 2015, in order to establish the effect of two fertilization sources – organic and inorganic, upon the nutritional quality of forage maize during the spring-summer cycle with a randomized block experimental design. T_1= Acadian soil +Acadian foliage (marine algae extracts) and T_2= Regional control, with 16 replications. The evaluated variables were the nutritional quality of forage maize and the milk production (L•t^{-1} dry matter and L•ha^{-1}). Due to the effect of the evaluated treatments, statistical differences were registered, both for, nutritional values of forage maize, such as: neutral and acid detergent fiber, non-fiber carbohydrates, total digestible nutrients, total net energy for lactation and for milk production, in favor of organic fertilization. Therefore, it can be concluded that fertilizers of marine origin applied to forage maize increased both nutritional quality of forage maize and milk yield per ton of dry matter and per hectare of this forage.

Keywords: Crude protein; forage; milk yield; organic fertilizers.

1. Introduction
The Comarca Lagunera region has been considered through the time as one of the most important dairy basins from Mexico (Pedroza-Sandoval *et al.*, 2014), this production is mainly based upon the intensive growth of high quality forage as alfalfa (*Medicago sativa* L.), maize (*Zea mays* L.) and forage sorghum (*Sorghum* spp.), during spring and summer, and oats (*Avena* spp.), wheat (*Triticum aestivum* L.) and triticale (*Triticosecale* spp.) during winter (Zamora-Villa *et al.*, 2016) from which the raw materials used to elaborate the cattle´s feed are obtained. In order to satisfy the growing demand of forage and being able to feed the dairy cattle of this region, it has been necessary to establish large acreages for these forages, especially for maize and sorghum. In this matter, statistics indicate that approximately 27,486 ha of forage maize were sown in the Comarca Lagunera, from which 12,923 ha corresponded to the Laguna from Coahuila and 14,563 ha to the Laguna of Durango (SIAP-SAGARPA, 2014).
The farming of maize for forage production constitutes a fast way of obtaining high dry matter production rates and an ideal quality for cattle feeding when it is administered either as fresh forage or as silage (Boschini and Amador, 2001; Iqbal *et al.*, 2015). Furthermore, this forage, while fresh, has a 7.2 to 8.5% of

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protein, from 32.5 to 33.5% of crude fiber, from 1 to 2.5% of fat, besides containing high quantities of carbohydrates, it has the potential of providing an energy rich material for cattle feeding and of being used at all levels of production without damages derived from oxalic acid or hydrocyanic acid (prussic), as is the case with sorghum (Dahmardeh, 2011).

Plant nutrition is one of the fundamental factors affecting crop production and it plays an essential role in guaranteeing the right performance of forages. In fact, plant nutrition management is one of the main strategies for increasing crop yield and forage maize is not the exception. In the nutrition process, nitrogen and phosphorus have great relevance because they are the nutritious elements with the highest transcendence in yield as well as in the quality attributes of green forage (Iqbal *et al*., 2015).

On the nutritional aspect, Fortis-Hernández *et al*. (2009) highlighted that high quality forage production, without the use of synthetic fertilizers, is a necessity in regions where there is a marked limitation of natural resources. Also, it is highly recognized that, because of the increment of anthropogenic activities, all ecosystems have been impacted by the release of polluting agents such as heavy metals, pathogens, pesticides and synthetic fertilizers, modification of natural conditions, situation that gets reflected upon human health (García-Gutiérrez and Rodríguez-Meza, 2012). Due to these constraints, together with the constant increment of inorganic fertilizer prices, on the last few years, rethinking the situation and the search for alternatives to diminish the use of synthesis soluble fertilizers has been motivated (Contreras *et al*., 2014).

A recent alternative to the use of synthetic fertilizers has been the application of diverse organic fertilizers that contain a part of N in organic forms, more or less stable, which gets mineralized on a gradual way and become available for the growing plant, for which reason, synthetic fertilizers could be replaced by these materials (Ramos-Agüero and Terry-Alfonso, 2014). One of the alternatives that has the interest of both researchers and agronomic producers is the extract from sea algae, being one of the reasons that these grow fast, produce a great biomass volume and are a source of many substances with biologic activity (Bettiol, 2006) and in this way, Zermeño-González *et al*. (2015) highlighted that the use of sea algae extracts as biofertilizers to the soil and foliage increases the performance and quality of different crops, this is related to the photosynthesis rate of the plants. Also, it has been put into view that these extracts contains nutritious macro and micro elements, organic compounds such as auxin and gibberellins that favor plant growth besides increasing crop yield and plant vigour against adverse environmental effects (Arun *et al*., 2014; Aymen *et al*., 2014), for these reasons, these biofertilizers, applied to the soil or foliage, could be used with the purpose of replacing, totally or partially, conventional fertilizers (Hernández-Herrera *et al*., 2014). Because of the above mentioned, the effect of liquid organic sea originated fertilizers, Acadian Soil and Acadian Foliage (Stimplex®), upon nutritional value of forage maize during spring-summer 2015 cycle was evaluated.

2. Materials and methods

The experimental place, with an extension of 22 ha, known as the “Tablas de Solima”, is located inside de Comarca Lagunera (101° 41' and 104° 61' W, and 24° 59' and 26° 53' N, with 1100 m average altitude, its climate is dry, desert-like, the annual mean precipitation is 258 mm, and annual mean temperature is 21 °C (García, 1973), at approximately 5 km from the “La Partida-Granada” road, municipality of Matamoros, Coahuila.

The research was carried out in April – August 2015 period. The surface, whose previous crop, in summer, was maize, was plowed and tracked as is traditionally done. Sowing of yellow hybrid 2A120 corn seeds (Dow® AgroSciences of México, S.A de C.V.) with 99% purity, was done dry planting on April 20, 2015, placing from six to seven seeds per lineal meter, in order to achieve a population density *ca.* 60,000 plants•ha^{-1}. The first irrigation took place four days afterwards, in total, four auxiliary irrigations were applied, distributed with an interval of 28 to 30 days with a total irrigation lamina of 80 cm, for which a system with an alfalfa valve was used (Delgado-Ramírez *et al*., 2013).

The fertilizing treatments were:

T1: Acadian soil [seed inoculation (200 mL•20 kg^{-1} seed) and applied to soil on the 2º and 3º auxiliary irrigation (0.5 L•ha^{-1}•irrigation^{-1})] + Acadian foliage (Stimplex) [two applications on foliage of 0.5 L•ha^{-1}, using an Hagie 10STS sprinkler system Hagie ® Inc. USA, when the plants presented four to six true leaves]

T2: Regional control. At sowing, the dose 50-80-00 was applied using $(NH_4)_2SO_4$ and mono-ammonium phosphate (MAP) with a dose of 140-00-00 (N-P-K) at first auxiliary irrigation using urea fertilizer. The Acadian Soil and Acadian Foliage products (Stimplex) were obtained from the Acadian Sea plants Mexicana, S.A. de C.V. Inc®.

Acadian Soil is a formulation specially designed to be applied to the soil (pH of 7.8-8.2 with an OMRI and BSC certification) and the Acadian Foliage (Stimplex) is a formulation specially designed to be applied to the foliage (pH of 3.6-4.2 with an OMRI and BSC certification). Its chemical composition includes: 0.34, 6.84, 14.16, 3.95, 0.168, 0.23% of N, K, MO, S, Ca, Mg, as well as 64.5, 40.2, 3.6 and 7.5 ppm de B, Fe, Mn and Zn, respectively. Meanwhile, Stimplex composition contains: 0.3, 1.0, 4.0, 8.0, 0.5, 0.05, 15.0, 5.0% of N, P, K, MO, S, Mg, Bo and Zn, respectively, as well as 280 ppm of Ca (Terralia, 2016).

The programed cutting date, 90 days after sowing (das), was delayed to 112 das because an extraordinary rainfall. At the harvest green samples were obtained from each treatment and repetition, these were laid in paper bags, properly labeled, for their transfer to the laboratory AGLOLAB of México and, after registering their weight, they were laid on a forced air oven at 72 ºC for a period of 24 h. On dry foliage, in addition to determining the quality of dry matter (DM), using the technique of near infrared spectroscopy (NIRS), the following variables were evaluated: crude protein (CP) content, acid detergent fiber (ADF) content, neutral detergent fiber (NDF) content, non-fibrous carbohydrates (NFC), total digestible nutrients (TDN) and net energy for lactation (NEL), in mega calories per kilogram of dry matter. Finally, the potential milk productions per ton of dry matter and per hectare were determined using the Milk 2006® software (Shaver *et al*., 2006).

For the experiment, a completely randomized block design with two treatments and 16 replications was used. The statistical analyzes for the studied variables were done using an analysis of variance and the mean separation by the least significant difference test ($LSD_{0.05}$) (Olivares-Sáenz, 1993).

3. Results and discussion

The analysis of variance applied registered significant differences ($p \leq 0.05$) for the CP, ADF, NDF, NFC, TDN and NEL variables (Table 1). As can be seen on that table, the application of organic fertilizers favored increments in four of the six quality variables from the research: CP, ADF, NDF and TDN. In accordance with Schwab *et al*. (2003) concentrations of CP, NDF and NFC and digestibility of these components impact the energetic value of forages.

Crude protein content

In regard to CP, forage maize treated with organic fertilizers surpassed forage maize treated with inorganic fertilizers in 10.41%. Values obtained for CP (Table 1) were slightly higher at the mean interval, from 7.9 to 9.1%, than the CP reported for different forage maize hybrids – intermediate and precocious - evaluated in the Comarca Lagunera (INIFAP, 2006). On the other hand, values obtained both with organic and inorganic fertilization at 112 das in the present study surpassed CP values, 7.8, 7.4 and 6.5% reported by Amodu *et al*. (2014) for two varieties of forage maize in three different harvest dates, at 91, 105 and 119 das, respectively. Nonetheless, results obtained differ from that established by Hassan-Amin (2010) who when evaluation organic and inorganic fertilization upon growth, quality and yield of forage maize from Giza – 2 and Mugtama - 45 cultivars during two consecutive productive cycles in Sudan determined that there were no significant differences registered both for cultivars and fertilization –organic *vs* inorganic- effects in both production cycles registering CP values that oscillated between 6.3 and 6.7%. On the present research, organic fertilization applied to 2A120 hybrid maize significantly surpassed inorganic fertilization with CP values of 10.41%.

Moreover, CP contents found in the present research were contrary to those established by Faisal *et al*. (2013) who determined that inorganic fertilization significantly surpassed organic fertilization in accordance to those characteristics. Crude protein fluctuated between values of 10.74 and 10.80% *vs* 9.86 and 10.05%, for inorganic and organic fertilization, respectively. Similarly, Fortis- Hernández *et al*. (2009) determined that PC with inorganic fertilization (12.68%) surpassed registered values for the application of bio compost (10.41%) and vermicompost (10.23%). The highest PC, 9.6%, registered in forage maize plants, as a result of applying organic fertilizers, could have been due in great part to these materials, besides being a source of nutrients of slow release to soil (Mulet-del-Pozo *et al*., 2008; Domínguez *et al*., 2010), which become available for plants as they need them (Domínguez *et al*., 2010) and also have high contents of N mineral for plant species (Ramos-Agüero and Terry-Alfonso, 2014), element that is an essential content of amino acids, basic units of proteins (Rasheed *et al*., (2004). Furthermore, it can be highlighted that a food or a diet has to have a 7% of CP content to guaranty an enough supply of nitrogen for an effective ruminal microbial fermentation (Oramas-Wenholz and Vivas-Quila, 2007), value that was easily covered as a result of applying organic fertilization.

Acid detergent fiber

The ADF is used to estimate energetic value of maize silage (INIFAP, 2006) and, because it is constituted from cellulose, lignin and proteins, it is the component that is most related to forage digestibility (Castillo-Jiménez *et al*., 2009) the more content of this fiber, the less digestibility of the materials (INIFAP, 2006). For fodder crops to be considered of quality, it is necessary that they have ADF values lower than 28% (Gallegos-Ponce *et al*., 2012), value that was surpassed by 7.5% of ADF content of forage maize treated with organic fertilization (Table 1).

Table 1

Mean values and statistical significance of dry matter quality values of forage maize developped with different sources of fertilization, organic and inorganic, in the Comarca Lagunera

Treatment	CP	ADF	NDF	NFC	TDN	NEL
	(%)					(Mcal•kg^{-1})
T1	9.6 a	35.9 a	53.5 a	21.2 b	47.0 a	0.98 b
T2	8.6 b	27.2 b	42.6 b	31.4 a	46.0 b	1.05 a

CP = crude protein, ADF = acid detergent fiber NDF = neutral detergent fiber, NFC = non fibrous carbohydrates, TDN = total digestive nutrients; NEL = net energy for lactation. Means with different letters in columns statistically differ ($LSD_{0.05}$).

The present research showed that organic fertilization favored ADF content which surpassed 24.33% to that found in plants treated with inorganic fertilization. The interval of values obtained with the experiment (Table 1) was similar to the range reported by the INIFAP (2006) for this kind of fiber in forage maize – intermediate and precocious on the Comarca Lagunera, whose values oscillated between 27.3 and 34.7%. While, in accordance to FDA values reported by Amodu *et al*. (2014) in two maize varieties, applying synthetic fertilizers with 24.7 and 30.8%, resulted slightly higher.

On the other hand, the use of organic fertilizers Vermicompost and Biocompost to the yellow maize hybrid HT90-19HR occasioned that ADF content reached values that oscillated between 26.5 and 28.7%, while Salazar-Sosa *et al*. (2007), applied 40 Mg•ha^{-1} of bovine manure to the Saint Lorenzo maize variety and reported values of 28%. These values were surpassed in at least 20.05% of FDA content to those values found on the present research, which were of 35.9%, when organic fertilization was applied. Content that could reduce dry matter intake of the forage maize evaluated because of the higher content of cell wall components (Castillo-Jiménez *et al*., 2009).

Neutral detergent fiber

The content of NDF in forages is negatively correlated with intake and digestibility (Oramas-Wenholz and Vivas-Quila, 2007) so, to obtain forages with high energetic value it is necessary to use maize hybrids that contain less than 50.0% of this type of fiber (INFAP, 2006; Gallegos-Ponce *et al*., 2012). The NDF content registered with organic fertilization (Table 1) surpassed by 7% to the reference value.

The FDN values of forage maize from the present experiment (Table 1) resulted inferior that the mean interval of 33.7 and 59.8% of NDF values reported for 11 hybrids of temperate origin and seven or tropical origin (Núñez-Hernández *et al*., 2004) and likewise resulted inferior to the mean interval of 48.3 and 59.3% reported for this type of fiber found in forage maize – intermediate and precocious – all of them developed with inorganic fertilization in the Comarca Lagunera region (INIFAP, 2006). Also, they were surpassed by mean NDF contents of 66.31% reported for five maize genotypes developed under limited irrigation and treated with inorganic fertilization also from the Comarca Lagunera region (Gallegos-Ponce *et al*., 2012).

The 53.5% content of NDF, obtained in forage maize treated with organic fertilization, was surpassed in at least 8% by the mean NDF value, 58.25%, reported by Amodu *et al*. (2014) for forage maize treated with inorganic fertilization.

The use of Vermicompost and Biocompost in forage maize favored the NDF content whose values ranged between 49.5 and 51.7% (Fortis-Hernández *et al*., 2009), which were slightly different to the NDF value obtained with organic fertilization applied to hybrid forage maize from the present experiment (Table 1). On the same sense, the administration of 0 to 160 Mg•ha^{-1} of bovine manure to Saint Lorenzo forage maize, by these authors, gave as a result a mean value of 47.88%, value that also resulted inferior to the 53.5% NDF value obtained in the present study.

Non fibrous carbohydrates

Carbohydrates are diverse (free sugars, fructans, hemicellulose, cellulose, and so on) and can be classified in fibrous (structural) and non-fibrous fractions (non-structural or for reserve). The ratio as well as the digestibility of fiber affects forage energy (INIFAP, 2006; Martínez-Marín, 2008).

Contrary to the behavior observed for CP, for ADF and NDF, NFC was significantly favored by inorganic fertilization in comparison to organic fertilization (table 1). Contrary to that stablished by Urrutia-Morales *et al*. (2014), who reported that the highest contents of NDF and NFC reduce digestibility of materials, on this research the reduction of digestibility of forage maize could be due only to the NDF content and not the NFC content that was registered on plants treated with organic fertilizers.

The NFC content registered on this experimental study with organic fertilization was 32.5% lower than the value obtained with inorganic fertilization. Similarly, it resulted 35% lower than the mean values for NFC reported by Reta-Sánchez *et al*. (2010) for developed maize on the spring and summer cycles on the Comarca Lagunera region and those reported by Corral-Luna *et al*. (2013) for five maize hybrids developed on the central region of the Chihuahua state in Mexico, it was also slightly inferior to the 21.7 and 23.8% NFD values reported by Reta-Sánchez *et al*. (2013) for four leguminous species also from the Comarca Lagunera, during the 2005 and 2006 productive cycles, respectively.

Total digestible nutrients

The TDN, as an expression unit of the energy content of feed, constitutes and approximate measure unit of the digestibility of these (Posada *et al*., 2012). Again, for this variable in forage maize, organic fertilization significantly surpassed inorganic fertilization (Table 1). Nonetheless, taking into account what Olague-Ramírez *et al*. (2006) stated in respect to this characteristic which is that high quality forage should have values equal or higher that 65% of TDN, the obtained values both for organic and inorganic fertilization, 47.0 and 46.0% respectively, allows us to signal that yellow 2A120 hybrid maize evaluated on the present research can be considered as of lower forage quality.

Meanwhile, Kim *et al*. (2001), when evaluating five maize hybrids in five different harvest dates, determined that the mean value at 111 das, which is similar to the harvest dates of this research, was an optimum TDN value of 64.6%, which surpassed in 27.2% the value obtained with organic fertilization

Net energy for lactation

The energetic requirements for maintenance and milk production are expressed as net energy for lactation (NEL). As with NFC content, in respect to NEL, inorganic fertilization was significantly surpassed by the organic fertilization (table 1). Values of 0.98 and 1.05 Mcal•kg^{-1} of DM, were surpassed in at least 30% of NEL by the mean value reported by Núñez-Hernández *et al*. (2010), who studied 21 forage maize varieties in the Comarca Lagunera, they determined a mean value of 1.52 Mcal•kg^{-1} of DM with inorganic fertilization.

The low values of NEL registered in both treatments could be due in a great part, as stated by Peña-Ramos *et al*. (2002), Núñez-Hernández *et al*. (2004) and de la Cruz-Lázaro *et al*. (2007), to the fact that selection programs used to develop forage hybrids give a higher relevance to forage yield per surface unit than nutritional value of the materials. Besides, the same authors signal that maize silage presents NEL values that oscillate between 1.3 and 1.5 Mcal•kg^{-1} of DM, which also highly surpassed NEL values determined on the present research (Table 1).

Forage quality

Finally, organic fertilization of yellow hybrid 2A120 maize generated an average quality forage because values registered on the research were slightly inferior or similar to values reported by Olague-Ramírez *et al*. (2006) and Zamora-Villa *et al*. (2016), the first authors established that maize with a high forage quality should have values of 10, 28.56, 54.41 and 59.71% for CP, ADF, NDF and TDN, respectively, as well as 1.22 Mcal•kg^{-1} of DM. Meanwhile, the second authors determined that forages of low quality have values higher than 35 and 60% of ADF and NDF, respectively with a NEL lower than 1.4 Mcal•kg^{-1} of DM.

Milk production in liters

The use of the Milk 2006 software from the Wisconsin University, which was fed with the data from the evaluated variables, allowed us to predict quantities equivalent to liters of milk per ton of dry matter and per hectare. According to kilograms of milk per ton of dry matter, the obtained values for organic and inorganic fertilization were 764 and 765 kg•t^{-1} of DM, respectively and they were slightly superior to the mean value of 751 kg•t^{-1} of DM, reported by Peña-Ramos *et al*. (2006) who evaluated two precocious maize hybrids using different sowing dates, N doses and population density. Results of this research surpassed in at least 31% the mean value of 583 kg•t^{-1} of DM, determined by González-Castañeda *et al*. (2006) for two maize hybrids – one precocious (Halcón by Asgrow®) and another of intermediate cycle (3028W by Pionner®) – applying inorganic fertilizers.

Meanwhile, milk production in tons per hectare, which is of higher interest for producers because it allows us to define if we want to harvest liters of water or liters of milk, a decision that has as support the selection of the hybrid that is being considered for sowing and the harvest date. As a result of applying organic or inorganic fertilization, a production of 15.4 and 13.7 t•ha^{-1}, respectively was estimated. Milk production with organic fertilization surpassed by 6.5% the mean value of 14.4 t •ha^{-1}, reported by Peña-Ramos *et al*. (2006), who used inorganic sources of fertilization. Also, it surpassed in 30% the mean value of 10.71 t •ha^{-1}, determined by González-Castañeda *et al*. (2006) in two maize hybrids with the management described on the previous paragraph. In addition, it resulted to be similar to the maximum value of milk production determined by Peña-Ramos *et al*. (2002) who reported values that oscillated between 6.7 and 15.5 t •ha^{-1}, while evaluating 19 populations and six commercial hybrids in two locations - Pabellón in Aguascalientes and Torreón in Coahuila – applying inorganic fertilization.

4. Conclusions

We conclude that it is feasible to obtain a higher nutritional value of spring forage maize with the administration of Acadian soil and Stimplex, because there was a favorable effect in relation to the response to these organic fertilizers. Forage harvested in general was considered about the average quality although results obtained showed inferior values to those used as reference in forage material. The afore mentioned could be due to the maturity state of the crop since harvest was delayed for 22 days by rain.

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