International Journal of New Technology and Research (IJNTR)
ISSN:2454-4116, Volume-4, Issue-1, January 2018 Pages 36-41

Corn Forage Yield with Bovine Manure Solarized and Mycorrhiza

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***Abstract*— Increase in dairy bovine cattle in Mexico central region, has raise maize forage production demand, however there are not any varieties or hybrids that accomplish both quantity and quality of this feed and also there is no tendency to organic agriculture system. The objective of this research is to generate an organic maize forage production technology. In 2012 four solarized bovine manure (SBM) treatments were evaluated. Factor A was mycorrhiza, with (MA) and (WMA), without application and factor B was SBM with 0, 20, 40, 60 and 80 Me-gagrams (Mg), respectively. A chemical fertilizer control (CFC) 200-150-00 Nitrogen (N) Phosphorus (P) and potassium (K) Mg ha-1 were also used. The experimental design in each crop cycle was a complete randomized block with split block arrangement and four replica-tions with a density of 133, 340 plants ha-1 (p ha-1). Forage yields (FY) were evaluated for total green mater (TGM) and total dry matter (TDM) in Megagrams por hectare (Mg ha-1). The variables studied in the soil samples were: electric conductivity (EC), hydrogen potential (pH), organic matter (OM), and nitrates (NO3). Production results showed the highest FY in the 80 Mg ha-1 of SBM with mycorrhiza application. There were no statistical significant differences between factor A levels for TGM and TDM forage yields.**

***Index Terms*— manure, solarization and mycorrhiza.**

I. Introduction

In the northern part of central Mexico, the main milk basin is located in the region known as Laguna region, which includes parts of the states of Coahuila and Durango. Maize is one of the most important crops and occupying most of the arable land in irrigated and temporary areas. The corn and sorghum produced in the Laguna region as a source of forage, play an important role, since between 22 and 26 thousand hectares per year are planted in the spring-summer cycles. Corn is a grass native from the American continent, of great importance for human and animal consumption. This crop is characterized by a high adaptability to climatic conditions, a relatively short phenological cycle and esquilmantes properties, whence it has been used as a model in various investigations and as successor cultivation in crop rotation systems. (Verissimo, 2003). Cattle manure has been long used as a source of organic matter (OM) and important nutrients. Among the nutrients it provides is nitrogen, which is a scarce nourishment in arid areas, as it is the Laguna Region. In this regard, it is considered that the OM is an important indicator of soil quality and agriculture susteinability. On the contrary, it is considered that conventional intensive agriculture affects the content of soil organic matter, soil fertility and crop production. (Han et al., 2006). The use of this type of resources such as organic fertilizers has the potential to reduce production costs and pollution levels in soils (Medrano, 2002).

The use of organic fertilizers is a fundamental management practice in the rehabilitation of the productive capacity of degraded soils. Organic fertilizers can prevent, control and influence the severity of soil-borne pathogens; also they serve as fertilizers and soil improvers (FAO, 1991). 900, 000 tons of cattle manure are produced annually in the region (Figueroa et al., 2010). Which allows to raise a possibility of their use in agriculture, because of that the importance of using this waste of the milk industry in forage maize production by reducing the use of chemicals, production costs and pollution levels. Unfortunately, though in limited cases, direct manure applied without treatment has been indicated as a transmitter of pathogens in fresh vegetables (Wells and Butterfield, 1997), so it is recommended to treat before its use on crops.

The two most important types of manure are composting and solarization (Ruiz et al., 2007), this way pathogens presented in manure and soil can be eliminated and soil because with this method it is possible to obtain innocuous products or substrates, that can be used safely in food production. A method that has been used with success in the agricultural soils for the disinfection, is heating through plastic covers that have capacity to capture solar radiation and to increase temperature considerably, this method is known worldwide as solarization (Katan, 1980; Katan, 1996). In addition to the usage of manure solarized arbuscular mycorrhizal fungi (AMF) play an important role in agricultural activities as these fungi have a wide range of cultivars species with which they form a mutualistic symbiosis between these, so we can consider the HMA as a key part to sustainability of ecosystems. The benefits provided by HMA crops make them competitive with fertilized in inorganic form (Diaz et al., 2005), in this sense, the main objective of the research is to generate an organic technology to forage maize production for Laguna region.

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II. MATERIALS AND METHODS

Study area. The experiment was conducted in the spring-summer cycle of 2012, in the Mexican region known as the Laguna Region; this region is located in the central part of northern México. The study site was the Experimental Agricultural Field of the Faculty of Agriculture and Zootecnia of the Juárez University of Durango State (CAE- FAZ-UJED). This site is located at Km. 28 of the Gomez Palacio-Tlahualílo road, near the ejido Venecia, Municipality. Gomez Palacio, Durango. Mexico. The region is located between parallels 24° 22' 12" and 26° 47' 24" north latitude and 102° 15' 36" and 104° 45' 36" west longitude of Greenwich to an altitude of 1,120 meters above sea level (García, 1981).

Characteristics of bovine manure solarized. The manure used presented the following characteristics: 7.6 pH, 0.63 dS m-1 EC, 5.47% OM, 1.12% total N, 0.1135% ammonium (NH4), 0.3535% P, 3.38% calcium (Ca), 0.71% magnesium (Mg), 3.27% K, 0.97 ppm sodium (Na), 560 ppm molybdenum (Mo), 12 300 ppm iron (Fe), 198 ppm Zinc (Zn), 45 ppm copper (Cu), and 410 ppm boron (Bo); the manure contained 8% moisture when applied.

The treatments were determinates considering to explore most of the used doses within the region, from cero up to 160 Mg ha^{-1} cow manure applied by the producers, the small doses applied by small stables, and higher doses used by larger stables, with herds of over 1 000 cow for productión. Experimental plots of 3 m, wide by 4 m, long established; establishing 48 experimental units to evaluate the following treatments: Factor A (mycorrhizae), A1= without mycorrhizae and A2= with mycorrhizae. Factor B (levels of bovine manure solarized), B1 = 0 t/ha, B2 = 20 Mg ha^{-1}, B3 = 40 Mg ha^{-1}, B4 = 60 Mg ha^{-1} y B5= 80 Mg ha^{-1} and B6= Chemical fertilizer with recommended this region by the National Institute of Forestry Research, Agriculture and Livestock doses (INIFAP), of 200-150-00 kg ha^{-1} of N, P and K respectively. An experimental design of randomized block arrangement in stripes and four replications was used. Variance analysis and MSD mean separation test were used for the statistical analysis of the experiment., a statistical probability of 0.05., with (SAS Institute, 1996) statistics software.

Site preparation and application of manure: Before planting the following tasks were carried out in the field: fallow at a depth of 30 cm, a crawl before application of solarized manure and then to the manure incorporation, according to the dose distribution indicated by the dosses, and proceeded to the installation of drip irrigation system. Interest in subsurface drip irrigation (G-SUB) has increased over the past two decades as consequence of the pressure to conserve water sources (Rivera et al., 2004).

Seed Inoculation. Inoculation was performed manually with Glomus intraradices (strain INIFAP), Inoculation was performed manually with Glomus intraradices (strain INIFAP), placing the shade the amount of seed required for the experiment in a plastic container with a ratio of 1 kg. Mycorrhizal per hectare as directed by INIFAP, the contents of the envelope with the bonding that comes with mycorrhiza was placed in a container, 250-300 ml was added water and finally stirred until evenly mixed. Subsequently the adhesive was mixed with the seed, the amount of mycorrhiza indicated for each crop and mix again ensuring that the seeds are covered with Biofertilizer, and finally the inoculated seed is planted in the way it normally is added.

Sowing. - Planting took place on April 4 manually in dry soil. A distance between rows of 50 cm, between rows and 15 cm, between plants was used, considering the distance between rows as narrow grooves in the region since the normal distance for this crop is between 70 and 75 cm. The harvest took place at 105 days after the date of planting, harvesting 1 m^2 per experimental unit to determine the yield of green and dry matter.

Variables evaluated. The variables measured in culture were green matter (GM), dry matter (DM), expressed in Mg ha^{-1} and the effect of arbuscular mycorrhizal inoculation in the seed. Soil variables at the beginning and end of the experiment were evaluated at two depths (0-20 and 20-40 cm), to determine the electrical conductivity (dS m^{-1}), hydrogen potential (pH), both extract saturation, organic matter (%) by the method of Black and Walkey and nitrates (NO_3^-) with colorimeter, Kjeldahl (Page et al., 1982) method. To measure the effect of mycorrhizal inoculation seed in each plot were randomly 2 floors in physiological maturity, which were completely extracted to measure root biomass; cutting the roots to the stem base, soil residues are removed by washing and finally dried before weighing. It became clear the promoter impact inoculation HMA G. intraradices in root biomass, however treatments reported no significant values with mycorrhiza and without it.

III. RESULTS AND DISCISSIONS

Initial soil characteristics. - Before establishing the experiment, soil samples were collected at depths of 0-30 cm, to determine the initial conditions of soil analyzes were performed in the laboratory (FAZ-UJED), finding the following physicochemical characteristics: pH 7.9, an electrical conductivity 2.4 dS m^{-1}, a percentage of organic matter 1.2 % a percentage of 17.9 mg calcium l % and 5.8 mg^{-l} of Magnesium and nitrate content of 6 parts per million (ppm).

The potential hydrogen (pH)

Table 1 shows the results of physical and chemical analysis of soil before experiment was established. Variance analysis (Table 1), statistical difference was found only in the first depth with a (Pr > F of 0.0237), in figure 1 we can see the values for the pH after harvest at two depths, where values ranged between 7.6 and 7.9 for the first depth (0-20 cm) and values from 7.4 to 7.7 for the second depth (20-40 cm). Lopez et al., (2001) mentions that the application of organic fertilizers, like bovine, caprine and composting mainly raise the content of nitrogen (N), phosphorus (P) and calcium (Ca), but no significant changes in pH, EC, Mg, Na and K.

Table 1.- Analysis of variance the chemical characteristics of the soil at two depths (0-20 and 20-40 cm) at Pv > F 0.05. CAE-FAZ-UJED-DICAF, 2012.

Analysis of variance	GL	pH		CE (dS m^{-1})		MO (%)		NO_3^- (Mg kg^{-1})	
		0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
R (Repetitión)	3	0.77	0.75	0.10	0.06	0.90	0.63	0.38	0.655
FA *(WMA-MA)	1	0.34	0.38	0.24	0.98	0.06	0.08	0.87	0.81
FA*R	3	0.12	0.71	0.08	0.23	0.72	0.42	0.02	0.02
FB (Manure)	5	**0.02***	0.06	**0.004***	0.31	**0.003***	0.23	**0.04***	**0.035***
FA*FB	5	0.10	0.07	0.002	0.06	0.12	0.22	0.37	0.488
FB*R	15	0.19	0.85	0.44	0.17	0.151	0.52	0.865	0.870
Error	15	0.03	0.18	0.26	0.56	0.122	0.06	149.7	139.5
Total	47	3.01	6.55	30.3	44.30	13.15	0.63	8043	8066
R^2		0.8	0.55	0.86	0.80	0.85	0.08	0.72	0.74
C.V.		2.5	5.58	14.06	23.74	17.34	0.42	51.88	45.5

*WMA= without arbuscular mycorrhizal fungi, MA= with arbuscular mycorrhizal fungi

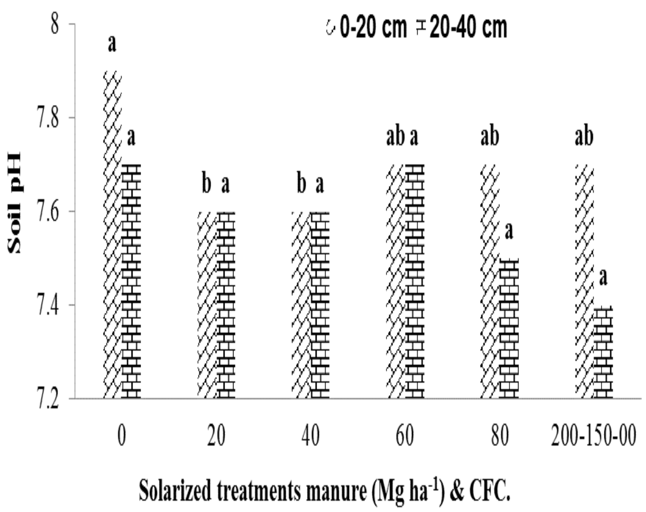


Figure 1.- Soil pH at two depths between manure treatments. CAE-FAZ-UJED-DICAF, 2012.

Electrical Conductivity

Clay soils that are irrigated by pressurized systems, do not allow the possibility of washing salts, whereby in the first depths is the highest content of these is found, the electrical conductivity showed difference in the first depth with a Pr> F 0.043 (table 1) in figure 2 the electrical conductivity shows the highest values in treatments solarized manure, showing chemical fertilization the lowest value with a value of 3.1 dS m^{-1}, the first depth, however for the second depth all treatments is statistically the same but with values lower than the first depth and greater than the initial analysis 2.4 dS m^{-1}. Quiroga et al., (2011) conducted a study in pots where he concludes that increasing the dose of manure also increases the salt content in the soil and this affects dry matter yields. Soria *et al.*, (2001) mentioned in their research with pig liquid excrete under an anaerobic digestion process that bacteria in a FAO 95 type bio-digester, microorganisms consume mineral salts dissolved in water and sustrate and reported as results that by measuring the initial EC had a value of 5.8 dS m^{-1} and decreased by 29.65% to end the process with 4.08 dS m^{-1}.

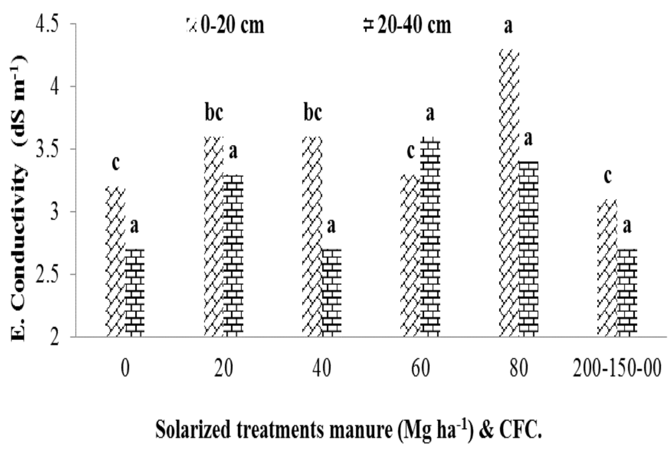


Figure 2.- Electrical conductivity of the soil at two depths between manure treatments. CAE-FAZ-UJED-DICAF,

2012.

IV. Organic Matter

The arable layer of soils in the region oscillates between 25 and 35 cm, in this stratum of soil is the highest content of organic matter, ANOVA (Table 1) shows the difference in depth with Pr> F of 0.0035. Figure 3, shows that in the first depth the dose of 80 Mg ha^{-1} solarized manure presents the highest values of organic matter 2.5% and the dose of 60 Mg ha^{-1} solarized manure with 2.3% for the second depth highest values were obtained in the dose of 40 Mg ha^{-1} of manure solarized with 2.5% and other treatments and even the witness had higher values to chemical fertilization showed a value of 2.2%. Fitzpatrick (1996) points out that most soils contain 1.6% of OM, or less but in very dry soils; the low percentage less than one, but in soils where manure has been applied consecutively in doses of more than 100 Mg ha-1 concentration can reach 5% or more (Salazar et al., 1998).

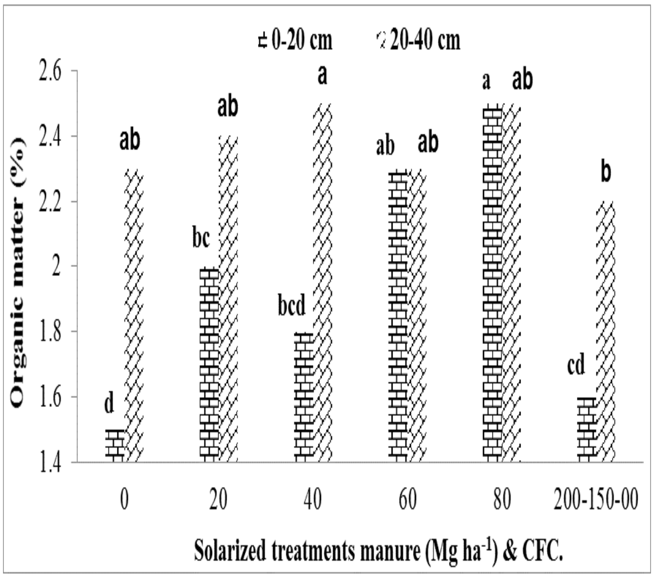


Figure 3.- Organic matter of the soil at two depths between manure treatments. CAE-FAZ-UJED-DICAF, 2012.

Nitrates

The amount of nitrates in the soil depend on the amount of manure applied, to the soil due to its high solubility allows these to be easily leachable this explains why both depths there is presence of nitrates (Table 1), with a Pr> F of 0.0419 for the first depth and Pr> F of 0.0357 for the second depth for this reason, figure 4 shows the nitrate content in the soil where the highest values are manifested in the highest dose of solarized manure at both depths with values of 32.8 and 37.9 mg kg^{-1} for the first and second depth respectively, which coincides with (Vazquez-Vazquez *et al.*, 2011), who conclude that treatment of 80 mg ha^{-1} solarized manure significantly increased the OM values and nitrate content regarding treatments of least amount of manure and chemical fertilizer (witness). The layer of 20-40 cm soil sample shows greater values than the first depth, which is explained by the high ion leaching, in both depths lower values are presented in zero witness application and chemical fertilizer.

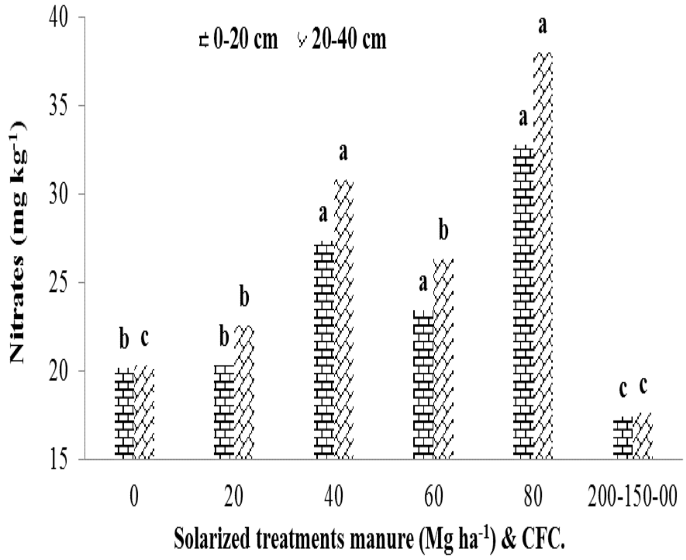


Figure 4. Nitrates soil at two depths between manure treatments. CAE-FAZ-UJED-DICAF, 2012.

Yield Corn

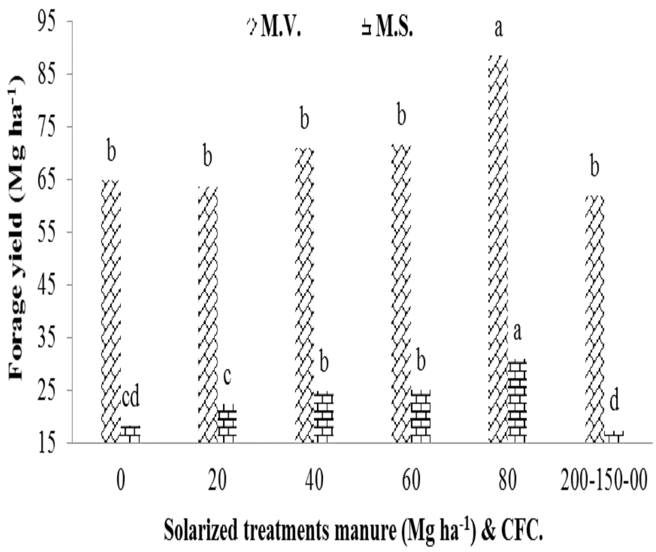
In the yield variable both green and dry matter (Table 2), anova presented values with a Pr> F 0.0050 for G.M. and 0.0001 for D.M. thus shown in Figure 5, the highest yield of G.M. was found in the dose of 80 Mg ha^{-1} of manure solarized with 88.5 Mg ha^{-1} G.M. the rest of the treatments with the witness were statistically equal with values from 62 to 71.75 Mg ha^{-1}, however these treatments outweigh reported by (Reta et al., 2004), where the regional average og green forage production is mentioned to be 45-60 Mg ha^{-1} of green fodder. Meanwhile (Salazar et al., 2009) found higher yields 100 Mg ha^{-1} of green forage with manure applications at high doses (120 and 160 Mg ha^{-1}) of fresh forage. Ramirez-Seanez (2012), mentioned in a reasearch with cotton that as the distance between rows is reduced and the population density increases, unit yields and the amount of biomass produced per area increases.

The yield D.M. (Figure 5) showed differences in all treatments being the dose of 80 Mg ha^{-1} of solarized manure which obtained the highest yield with 30.99 Mg ha^{-1} D.M., followed by doses of 60 and 40 Mg ha^{-1} of solarized manure these being statistically equal with values of 25.1 and 24.8 Mg ha^{-1} D.M., the dose of 20 Mg ha-1 of manure reached a yield of 22.3 Mg ha^{-1} DM, chemical fertilization and the witness reported 17.36 and 18.17 Mg ha^{-1} respectively. Meanwhile (Montemayor et al., 2012) obtained increments of F.Y. in corn in two irrigation systems with increases of 41% in drip irrigation system and 33% with central pivot compared to gravity irrigation.

Table 2. Analysis of variance for performance of green matter and dry in forage corn.FAZ-UJED-DICAF, 2012.

Analysis of variance	**GL**	**Green weight**		**Dry weight**	
		Sum Squares	**Pr > F 0.05**	**Sum Squares**	**Pr > F 0.05**
R (Repetitión)	3	662.5766	0.1794	71.889068	0.2023
FA * (WMA-MA)	1	38.8800	0.5754	7.332033	0.4772
FA*R	3	640.5633	0.1904	71.842420	0.2025
FB (Manure)	5	3812.5391	**0.0050***	1018.3830	**<0.0001***
FA*FB	5	1056.5125	0.1772	117.813048	0.1934
FB*R	15	2127.9808	0.3666	255.805623	0.3432
Error	15	1779.0741	118.60494	206.9006	206.900683
Total	47	10118.1266	10118.126	1749.965	1749.965
R^2		0.8241		0.8817	
C.V.		15.48		16.05	

*WMA= without arbuscular mycorrhizal fungi, MA= With arbuscular mycorrhizal fungi



V. Conclusions

No statistical difference between bands with and without mycorrhizae was found, but statistical differences between treatments manure is shown, the witness and chemical fertilization.

Doses of 80 Mg ha^{-1} manure applied produce the highest yield of green and dry matter.

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