Opuntia Forage (Opuntia Ficus-Indica L), Response to Solarized Cattle Manure Amendments in Four Plant Densities

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Abstract— **Three doses of solarized manure (20, 40, 60 t ha-1) and a control (zero application) and an additional chemical treatment (100-100-00 of Nitrogen (N) Phosphorus (P) and Potassium (K)) at four densities of opuntia plantation (4435, 8871, 8887 and 13 323 plants ha-1) were evaluated. The experiment was established in the Agricultural Experimental field of the Juarez University of Durango State in 2008, 2009 and 2010, with the main objective to determine the best dose of solarized manure and opuntia density plantation in a clay arid soil. The results show higher production in the treatment of 60 t ha-1 of solarized manure with 29, 66.3 and 43 t ha-1 for 2008, 2009 and 2010, respectively; the density of 13 323 plants ha-1 is the most productive with 35.6, 77.6 and 57.9 t ha-1 for each year of study, changes in forage production were affected by climate condition (frost and hail) mainly in the third year. In regards to the thickness and length of cladodes, 60 t ha-1 manure doses and 13 323 plant density ha-1 showed the highest values. The organic matter in the soil at the end of the experiment increased in respect to the beginning values from 2 to 2.29% in 40 to 60 t ha-1 manure treatments, being 2.29% the highest. The electrical conductivity remain in the start values of 1.5 and 1.7 dSm-1 in manure treatments, witnesses decreased in to 1.3 dSm-1. The highest content of nitrates by the end of the experiment was 7.1 mg kg-1 in the treatment of 60 t ha-1 of solarized manure so, solarized manure is a good alternative for nutrient crop production and to save the use of chemical fertilizer by farmers.**

Index Terms— **opuntia forage, solarized manure, production.**

I. Introduction

Agricultural production systems currently practiced destroy vegetation and accelerate desertification, representing a serious risk to the native plants and wild life in the North of Mexico. Therefore, it is very important to implement feasible strategies to alleviate desertification involving native species, such as Opuntia, Agave, Acacia, Mimosa, among others (López et al., 2003). Previous studies in semi-arid areas of Mexico showed that the administration of nutritional supplements as forage enables the system optimization, increasing the primary productivity of forage production areas and the productivity of livestock. However, the low economical level of the local producers make commercial supplementation non viable, thus it is necessary to explore the local natural resources as an alternative for forage supplementation with nutritional characteristics for the live stock, accessible for the farmer (Baraza et al., 2008).

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In arid and semi-arid areas, forages used by goats and sheep are characterized by large seasonal changes in production, annual fluctuations and seasonal variations in forage quality (Azocar, 2003). Opuntia ficus–indica is among cacti, the one with the largest agronomic importance, both for its tasty fruit and stems which serve as forage or can be eaten as a vegetable (Kiesling, 1995; Moßhammer, 2005). Its use increased in the early 17th century with the introduction of livestock to semi-arid areas and the subsequent declination of grasslands. The situation scares forage availability farmers to use the Opuntia cladodes to feed their livestock after burning the spines, especially during droughts (Anaya, 2003). The productive and reproductive performance of cattle, sheep and goats are higher when producers supplement the diet with Cactus during the dry season (Flores, 1997). As a native plant of México Opuntia can be used for forage production in the Comarca Lagunera region located between two states Coahuila and Durango, Mexico (Moßhammer, 2005). In semi-arid regions Opuntia species are considered a good and economic alternative for feeding goats, sheep and cattle when forage availability is low or there is no rainfall (Cordeiro y Gonzaga, 2003; Felker, 2003). Solarized manure can be used for fertilization purposes: to reduce farmer's efforts to resolve soil fertility problems, to improve water retention capacity, which helps to stimulate plants development to achieve a greater production capacity, among other benefits. The costly chemical fertilization stimulates the use of cattle manure by farmers not only to improve physical and chemical soil characteristics but also to increase forage production (Salazar et al., 2010 b). The objective of this trial was to determine the effects of four solarized cattle manure levels and density of plantation, for plantation densities in Opuntia forage productions.

II. Materials and Methods

Region features

The Comarca Lagunera region is located in the central part of the northern portion of the Mexican territory. It is located in the parallel 24 ° 22' and 26 ° 23' North and meridians 102 °

22' and 104 ° 47' west. The average above sea level height is 1,139 m. has a mountainous area and a flat surface where the agricultural areas are located, as well as 4,788,750 ha urban areas. According to the Koeppen classification, modified by Garcia (1981), the climate is dry desert or steppe warm with rain in the summer and winters. The average annual temperature in the Comarca Lagunera is 21 ° C, with an annual average evaporation of about 2,396 mm. The annual rainfall is 258 mm.

The experiment was conducted at an agricultural experimental field at a facility of the Universidad Juarez del Estado de Durango which is located at km 28 Gómez Palacio-Tlahualilo road, in the vicinity of Ejido Venecia, municipality of Gómez Palacio, Dgo. The native soils are alluvial, type aridosol. The type of soil in which the experiment was conducted is clay type according to Matus and Maire (2000), this interferes with the mineralization of nitrogen. Manure used characteristics: pH of 7.6, electrical conductivity (EC) 0. 63 dS m-1, organic matter (OM) of 5.47%, total N of 1.12%, ammonium (NH4) of 0.1135%, 0.3535 P %, calcium (Ca) of 3.38%, magnesium (Mg) of 0.71%K of 3.27%, sodium (Na) of 0.97 ppm, molybdenum (Mo) of 560 ppm, iron (Fe) of 12300 ppm, 198 ppm zinc (Zn), copper (Cu) of 45 ppm, and boron (Bo) of 410 ppm, manure had 8% humidity at the time of application.

III. Experiment Establishment

The study was carried out for three years (2008-2010); variety used is Lisa forage. The factors in study were three doses of solarized manure (20, 40, 60 t ha-1), a zero witness and a chemical treatment (100-100-00 of N, P, K respectively) in orther to compare it with solarized manure; in four planting densities 4,435, 13,323 ,871 and 8,887 plants ha-1, with different topological arrangements (Figure1).

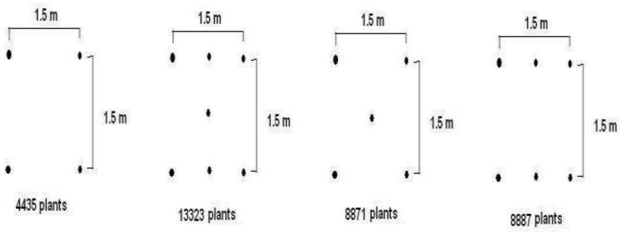

Figure1

The evaluated parameters were: pH (in extract) with potentiometer, EC in extract with conductivity meter procedure, OM with the Walkley and Black method (Page et al, 1982), nitrate (NO3)-Colorimetric (Page et al., 1982). The variables measured in the plants, allowed to determine which one of the treatments is best, these parameters were: performance of forage and vegetative development, cladode width/length and thickness.

The distribution of treatments in field was carried out under a random block design with three replicates (Martínez, 1996). The data was analyzed using SAS statistics program (SAS Institute, 1996) with a statistic probability of 0.05. Analysis of variance and mean separation average of the honest significant difference (DMS) separation test was used for the statistical analysis of the experiment.

IV. RESULTS AND DISCUSSION

Opuntia forage production

Interaction solarized manure X planting density was significant (P<0.01) m, 2008 and 2010 buy no in 2009. Production values of opuntia forage were different between manure treatment and planting densities (Table 1), the higher production rates were observed in the 60 t ha-1 solarized manure treatment with a value of 90.2% compared to the control treatment in 2008, 48.9% in 2009 and 59.6% in 2010, respectively, it also produced more forage than the other treatments of solarized manure. Only in 2009 was similar to the chemical treatment (Figure 2). The control (0 t ha-1) showed the lowest production. The planting density of 13,324 plants ha-1 showed the highest results with 249.7% in 2008, 107.5% in 2009 and 150.3% in 2010 in comparison to the density with the lowest production results, 4,435 in 2008 and 8,871 plants ha-1 for 2009 and 2010 (Figure 1).

The Opuntia forage production in 2009 and 2010 are higher than those reported by Salazar et al. (2010), whom obtained 35.6 t ha-1, for the treatment of 60 t ha-1 of manure, but less than that reported by Martinez et al., (2009) whom indicated that 100 t ha-1 in bovine manure as fertilizer produced 74.3 t ha-1 of green forage. Zúñiga et al., (2009) concluded that the improved performance of opuntia variety "Jalpa" was obtained in the treatment of 100 t ha-1 applied manure. Gutierrez et al., (2007) reported that with good management of cultivation the smooth opuntia forage can produce 200 to 400 t ha-1 of fresh forage. These results are corroborated by Reveles et al., (2010) concluding that forage Cactus reply favorably to the applications of fertilizer and high densities of population, Murillo-Amador et al., (2005) indicate that the opuntia responds well to the application of nitrogen; However López et al., (2008) reported that in Coahuila opuntia production varies from 5 to 15 t ha-1.

Table 1.

Variation Source	DF	Years (Pr > F)		
		2008	2009	2010
		- -		
R (Repetition)	2	0.7818	0.8337	0.0128*
FA (manure treatments)	4	0.0132*	0.0433*	0.0140*
FB (Densities)	3	<00001**	0.0224*	0.0186*
FA X FB	19	<.0001	0.4855	0.200
DMS $_{solarized}$ manure		8.3636	16.785	9.0136
DMS $_{densities}$		4.3898	22.96	20.088

* different ** highly different

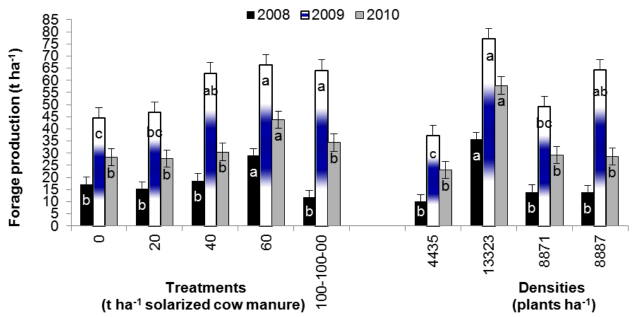

Figure 2

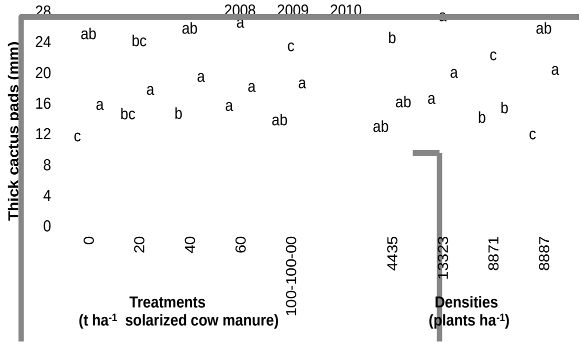

Figure 3

Cladode thickness

Interaction solarized manure x planting density was not different (P = 0.16). The cladode bulk exhibited significant difference for both solarized manure treatment and the densities of planting, with averages shown in Figure 3. Solarized manure treatment that showed the thickest cladodes was 60 t ha-1; with values of 40.3%, 6.6% and 16.5% higher than those in the control in the years 2008, 2009 and 2010, respectively. Density of 13,323 plants ha-1 was higher with 32.9, 25.0 and 34.1% over the density that presents thinner cladodes which were the 4,435 ha-1 in 2008 and 8871 plants ha-1 in 2009 and 2010, respectively. Reyes et al., (2005) showed that Opuntia ficus indica presents minimum thickness of 10 mm and maximum of 30 mm cladode-1 in his experiment and the thickness varies depending on the species. Experiments carried out by Martinez et al., (2001) reported thicknesses of cladodes variety Copena T5 of maximum 28 mm cladode-1 and minimum 20 mm cladode-1; in our experiment we found a maximum thicknesses of 24.7 mm cladode-1 and minimum of 21.16 mm cladode-1 with the Lisa variety.

Cladode width

Interaction solarized manure X planting density was not different (P = 0.26). Regarding the cladode width there is no significant difference for any of the two factors studied in all the years; the observed denote production for treatment of 6.3 to 6.5 in 2008, 13.8 to 14.8 in 2009 and 14.4 to 14.7 in 2010 cm cladode-1. The thickness correspond to the treatment of solarized manure of 40 t ha-1 in 2008, 60 t ha-1 in 2009 and 40 to 60 t ha-1 in 2010, correspondingly. Reyes et al., (2005) reported that Opuntia ficus-indica develops better width than other genders obtaining a minimum of 14 cm cladode-1 and a maximum of 31 cm cladode-1 depending on the agronomic variety used; This experiment yielded a maximum width of 14.82 cm cladode-1 in the treatment of 60 t ha-1 of solarized manure, being in the range of the specie. Santos et al., (2010) reported that with 100 t ha-1 for manure they obtained results of 13.1 cm wide cladode-1, using the forage smooth variety.

Cladode Length

Interaction solarized manure + planting density was different (P< 0.01). Opuntia cladode forage length shows a significant difference for the treatment of solarized manure every year; regardless to the densities of planting only in 2009, it found no significant difference with averages shown in Figure 4. Manure treatment with longer cladodes was 60 t ha-1, values of 31.4, 14.5, and 7.8% over width for the years of 2008, 2009 and 2010, respectively. The density of longer cladodes was 13,323 plants ha-1 with 95.5, 9.8 and 7.8% for the years 2008, 2009 and 2010, the shorter cladodes density was observed at 4,435 plants ha-1 (Figure 4); which is opposite to that reported by Ruiz-Espinoza et al., (2008) for varieties of prickly pear cactus whose length decreases as the density increases. This experiment was able to obtain a maximum length of 27.7 cm cladode-1 in 2009, in the treatment of 60 t ha-1 for solarized; with only 2 irrigation periods per year, which is in the range that reported Reyes et al., (2005) and obtained minimum 27 cm and maximum of 63 cm cladode-1 in the genotype Opuntia ficus indica. Ramírez et al., (2007) reported that the genotype Opuntia ficus managed a maximum length of 41 cm cladode-1 at its fourth stage using hydroponic methods and providing nutritional solutions every third day.

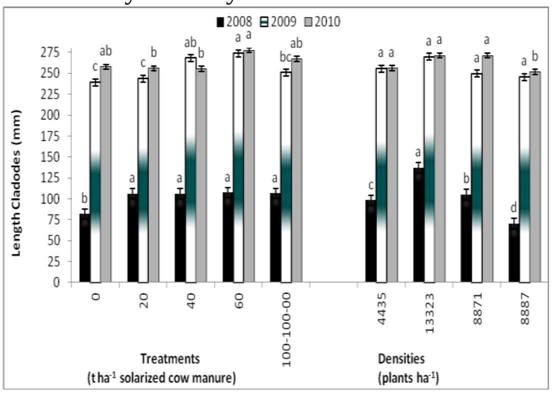

Figure 4

Soil Variables

PH of the soil

Soil pH observed, showed a statistically significant difference for solarized manure treatment and densities of planting, with averages of 7.3 to 8.1 (Table 2). The highest values correspond to the treatment control in 2008, and chemical treatment in 2009 and 2010 being statistically superior to the solarized manure treatments ranging from 7.5 to 7.9, values that are optimal for Cactus species, Flores y Reveles (2010). De Kock (2003) mentioned that opuntia tolerates relatively high values of pH to support up to a pH of 8.5. The density showing the highest values of pH per year were 13,323 plants ha-1 and by the end of the year 2008 is when the highest values are observed.

Table 2.

Solarized cow manure	**pH per year**			
	2008 *	**2008 ****	**2009**	**2010**
0 t ha^{-1} (control)	7.9 a	8.1 c	7.3 b	7.3 b
20 t ha^{-1}	7.6 c	7.6 a	7.5 a	7.6 a
40 t ha^{-1}	7.9 a	7.5 b	7.5 a	7.8 a
60 t ha^{-1}	7.9 a	7.4 c	7.7 a	7.7 a
100-100-0	7.8 a	7.4 c	7.6 a	7.7 a
DMS	0.0553	0.0258	0.3111	0.3082
Density (plants ha^{-1})				
4435	7.8 c	8.12 b	7.95 a	7.37 b
13323	8.0 a	8.11 b	7.97 a	7.81 a
8871	7.9 b	8.08 b	7.58 b	7.69 ab
8887	7.99 a	8.20 a	7.63 b	7.80 a
DMS	0.0325	0.0553	0.2313	0.3364

*initial sampling **end of the year sampling ++same letter indicates similar values

Electrical conductivity

Soil electric conductivity showed a statistically important difference for the treatment of manure, with an average of less than 3.3 dS m-1, being the treatment of 60 t ha-1 for manure (introduced the maximum value). By the end of the year 2008 the higher values for treatments and densities were found, except in the 4435 plants which was the highest value at the beginning of 2008 with 3.73 dS m-1 (Table 3), however the values are within the optimal range, that De Kock (2003) mentioned for a better development of the Cactus plant maximum soil electrical conductivity must not exceed 5-6 DSm-1. In 2010 the values decreased over the previous year, contrary to what Castellanos mentioned et al., (2000) who claimed that the application of manure electrical conductivity tends to increase. These results indicated that soluble ions probably moved deeper in the soil sampling depth or were uptaken by plants.

Table 3.

Solarized cattle manure	Electrical conductivity (dS m^{-1}) per year			
	2008 *	2008 **	2009	2010
	- -			
0 t ha^{-1}(control)	0.896 c	2.52 d	1.15 d	1.3 b
20 t ha^{-1}	0.886 d	2.68 c	2.74 a	1.5 ab
40 t ha^{-1}	1.135 b	3.13 b	2.31 b	1.7 a
60 t ha^{-1}	1.554 a	3.29 a	2.41 b	1.7 a
100-100-00	0.765 e	2.42 e	1.55 c	1.5 ab
DMS	0.0065	0.0276	0.2443	0.381
Density (plants ha^{-1})				
4435	3.73 a	3.20 b	1.69 c	1.57 a
13323	2.61 b	3.17 c	2.44 a	1.70 a
8871	1.55 c	3.32 a	2.17 ab	1.43 a
8887	1.21 d	1.94 d	1.83 bc	1.37 a
DMS	0.0304	0.0282	0.4408	0.3935

*initial sampling **end of the year sampling ++same letter indicates similar values

Organic matter

For soil organic matter there is statistically noteworthy difference for the treatment of solarized manure with highest averages for 40 to 60 t ha-1 manure treatment. Chemical fertilizer (100-100-00 N, P, K respectively) showed the lowest amount of organic matter, similar to the control treatment in 2009 and 2010 (Table 4). Organic matter increased since the beginning of the investigation until 2010 due to biodegradation of manure that contains more than 5% of OM. The application of organic fertilizers in agricultural soils increases as a mean of disposal, recycling of nutrients and water conservation (López et al., 2001). The decomposition of OM depend on microorganisms present and it is a general concept of a complete sequence of very detailed processes, in which organisms use organic compounds as a source of food (Cabrera et al., 2005; Lamm and Schlegel, 2000). This coincides with Zúñiga et al., (2009) who concluded that manure applications in the cultivation of nopal increase the mineral content of organic matter in the soil at the end of the experiment. Salazar et al., (2010) reported a higher percentage of organic matter in soil and Salazar et al., (2009) concluded that with application of 60 t ha-1, the addition of bovine manure increases the content of organic matter on the ground, which coincides with Castellanos et al., (2000).

Table 4.

Solarized cow manure	Organic matter (%) per year			
	2008 *	2008 **	2009	2010
0 t ha^{-1}(control)	1.45 b	1.24 c	1.74 b	1.87 c
20 t ha^{-1}	1.44 b	1.34 b	2.72 a	2.03 b
40 t ha^{-1}	1.54 a	1.41 a	2.68 a	2.29 a
60 t ha^{-1}	1.54 a	1.40 a	2.55 a	2.29 a
100-100-00	1.51 a	1.11 d	1.54 b	1.84 c
DMS	0.0618	0.0257	0.2808	0.1698
Density (plants ha^{-1})				
4435	1.59 b	1.39 a	2.79 a	1.94 a
13323	1.65 a	1.23 c	2.34 b	2.09 a
8871	1.43 d	1.32 b	1.96 c	2.04 a
8887	1.47 c	1.25 c	1.89 c	2.19 a
DMS	0.0129	0.0288	0.3056	0.3011

*initial sampling **end of the year sampling ++same letter indicates similar values

Soil Nitrates

Soil NO3 concentration was different due to solarized manure application, with 60 t ha-1 which present the highest values, more than double with respect to the control, except in 2010 which is only 13% higher (Table 5). The density of 4435 plants ha-1 showed the highest values of nitrate, except in late 2008 when the density of 8871 plants ha-1 showed higher content of nitrates. Cusick et al., (2006) revealed that applications of manure with uniform characteristics have different impacts on production and nitrogen absorption; because of that mineralization is affected by various factors such as moisture, temperature, aeration, type and amount of fertilizer applied, type of soil, climate, mineralogy of clays, soil nutrient status, activity of soil biota (Trinidad, 2007; Flores et al., 2007; Eghball et al., 2002), and the diversity of microorganisms in soil (Tate, 1995). The shadow of the plants can affect the moisture of soil and thereby mineralization (Flores-Márgez et al., 2009)

Table 5.

Solarized cattle manure	**Nitrates (mg kg^{-1}) per year**			
	2008*	2008 **	2009	2010
	- -			
0 t ha^{-1}(control)	5.33 e	3.618 d	6.3 c	6.1 a
20 t ha^{-1}	6.22 d	3.943 c	6.5 c	6.4 a
40 t ha^{-1}	7.78 b	4.427 b	12.8 b	7.1 a
60 t ha^{-1}	11.36 a	7.415 a	30.1 a	6.9 a
Chemical fertilizer	7.00 c	2.783 e	13.7 b	5.4 a
DMS	0.0285	0.0743	3.16	2.06
Density (plants ha^{-1})				
4435	**13.56 a**	4.24 b	**19.86 a**	**7.9 a**
13323	7.43 b	2.65 d	14.97 a	4.74 c
8871	4.87 c	**7.51 a**	10.18 a	6.41 b
8887	4.30 d	3.35 c	10.51 a	6.53 b
DMS	0.0129	0.077	12.416	1.3644

*initial sampling **end of the year sampling ++same letter indicates similar values

V.Conclusions

The results shows that the best dose of solarized manure for the production of Cactus Lisa forage variety is 60 t ha-1 and the ideal density is 13323 plants ha-1. The ground organic matter levels were increased in the third year of study, being 40 to 60 t ha-1 for solarized manure treatment the most benefited. The pH of the soil is optimal, this is pointed out by some authors for the production of forage opuntia and electrical conductivity remained at low levels (less than 2 dS m-1), therefore solarized manure is an excellent option to avoid chemical fertilizer application reducing cost in crop production for farmers for opuntia forage production and soil quality in this region.

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