Soil Amendment With Organic Products Increases the Production of Prickly Pear Cactus as a Green Vegetable (Nopalitos)♦

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ABSTRACT

In this work, the effect of organic fertilization in the production of young cladodes (nopalitos) (cladode sprouts) in prickly pear was studied. The treatments of organic fertilizers used were: T1 = 75% soil + 23% compost + 2% red crab flour; T2 = 75% soil + 23% compost + 2% fish flour; T3 = 75% soil + 25% compost; T4 = 75% soil + 25% cow manure; and T5 = soil only (control), which were arranged in a complete randomized block design with five replications. The data were analyzed using univariate and multivariate analysis of variance and multiple comparison means (Tukey *p*=0.05) when the variables showed significant statistical differences among treatments. The results indicate that all variables showed significant differences among treatments, including the multivariate analysis. All variables showed the highest values in treatment T2 and this treatment was the better combination of organic matter and animal source (terrestrial and marine), i.e., compost + fish flour. In general, the treatments with organic fertilization increased the production of nopalitos in comparison with the control treatment.

Keywords: cow manure, compost, red crab flour, fish flour, multivariate analysis of variance, prickly-pear cactus, nopalitos

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INTRODUCTION

In Mexico, 53% of the national surface is arid and semiarid zones, characterized by deficiency in water availability, which constitutes a factor that limits the majority of farming production (CONAZA, 1992). Under these conditions, the prickly pear (*Opuntia* spp.) arises as one of the resources with greater potential for efficient use by human populations of the arid zones and represents an alternative like a natural resource with an economic value (Flores, 1994). In the areas of Mexico where the prickly pear is cultivated, in most cases the use of chemical fertilizer is implemented within the culture practices, except for certain regions like Milpa Alta, D.F. (Fierro, 1997); Ojocaliente, Zacatecas (Méndez, 1990); and San Nicolas de Los Garza, N.L. (Vázquez and Gallegos, 1997), where some farmers use a continuous chemical fertilization and sometimes with organic fertilizers, such as cow manure (Méndez, 1990). The present study is focused toward productivity by using organic matter as a fertilization source through application of materials of animal origin, such as cow manure, compost, and fish and red crab flour. There are no other related studies on this subject in prickly pear, this being the first study where fish and red crab flours are used.

MATERIAL AND METHODS

Study site, plant material, and experimental design

The experiment was done in the Centro de Investigaciones Biológicas del Noroeste, 17 km northwest of La Paz, Baja California Sur, Mexico (24°08´N. 110°24´W), at sea level, with a dry-warm climate (type BW (h') hw (e)). One-year-old uniform and healthy rooted cladodes of the cultivar Copena V-1 were dehydrated for 15 days under shade and then planted directly in the ground for rooting, where they remained for 30 days. Once cladodes took root, uniform and healthy cladodes were selected and planted in plastic pots (30 cm x 40 cm) that were filled with the respective substrate of the corresponding treatment.

The materials used were soil, compost, cow manure, red crab flour, and fish flour, which were analyzed previously and the content of N, P, K, and organic matter (Table 1) was obtained. The materials were mixed uniformly in different proportions to obtain the following treatments: T1 = 75% soil + 23% compost + 2% red crab flour; T2 = 75% soil + 23% compost + 2% fish flour; T3 = 75% soil + 25% compost; T4 = 75% soil + 25% cow manure; and T5 = soil only (control). The experiment had a completely random block design with five replications containing three rooted cladodes per replication for each treatment for a total of 75 rooted cladodes in the experiment.

Variables measured in young harvested cladodes (nopalitos)

Well-developed nopalitos were sampled each week from 4 April 1998 to 17 November 1998. The following variables were measured: the number of nopalitos (NC), fresh weight (FW, in g), dry weight (DW, in g). FW and DW were determined using an electronic balance (Portable OAHUS Advanced model No. CT600-S). Dry weight was determined after oven-drying (BLUE M UL 543H, Blue Island Illinois, USA) to constant weight at 80°C. Pad thickness (PT, in cm) of the cladodes was measured using a digital caliper (GENERAL No. 143, General Tools Manufacturing Co., Inc. New York, USA); width of cladodes (WC, in cm); length of cladodes (LC, in cm); stem area of harvested nopalitos (SA, in cm^2) was measured using a portable leaf-area meter Li-Cor Model Li-3000A (Li-Cor Lincoln, Nebraska, U.S.A.); total biomass (TB, in g) that represents the sum of the dry weight of harvested cladodes, dry weight of rooted cladodes, and dry weight of roots; and average weight (CAW, in g) of harvested nopalitos, which was calculated using the equation:

5CAW = total fresh weight of harvested nopalitos divided by the number of harvested nopalitos.

Variables measured in rooted cladodes

At the end of the experiment, each rooted cladode was harvested and washed with tap water and distilled water. The following variables were measured: fresh weight (FWRC, in g); dry weight (DWRC, in g); length (LRC, in cm); width (WRC, in cm); pad thickness (PTR, in cm); stem area (SARC, in cm^2); length of roots (LRR, in cm), number of roots (NR); fresh weight (FWR, in g) and dry weight of roots (DWR, in g).

Data analysis

All statistical analyses were done with univariate and multivariate analysis of variance [ANOVA and MANOVA procedures in SAS (SAS Institute, 1988)]. $P \leq 0.05$ was used to define statistical significance. When significant effects of treatments were found in all variables, mean separations were done using Tukey at p=0.05.

Table 1. Content of N, P, K, and organic matter of the organic fertilizers used as primary materials

Organic fertilizers	Organic matter (%)	N (%)	P (%)	K (%)
Compost	11.7	0.65	0.3	0. 5
Fish flour	86.50	10.25	2.22	1.17
Cow manure	73.77	2.95	1.32	1.27
Red crab flour	70.52	6.27	1.25	1.10
Soil	0.4	0.04	0.8	7.72

RESULTS AND DISCUSSION

The results of the univariate analyses for the variables measured in harvested nopalitos showed that treatments of different organic fertilizers were statistically different from the response variables: NC (p=0.0025), LC (p=0.0003), WC (p=0.02), SA (p=0.0002), FW (p=0.0001), DW (p=0.0026), and PT (p=0.001). These variables showed higher values in treatments T2 and T1, medium values in treatments T4 and T3, and the lower values in treatment T5 (Table 2). The variables CAW (p=0.691) and TB (p=0.092) did not show significant differences between treatments.

Table 2. Number, length, width, stem area, fresh weight, dry weight, and pad thickness of harvested nopalitos under five organic fertilization treatments

Treatments	**NC**	**LC**	**WC**	**SA**	**FW**	**DW**	**PT**
(T1) 75% soil + 23% compost + 2% red crab flour	13.80a	13.16a	6.16ab	84.88a	53.43ab	2.51a	0.43a
(T2) 75% soil + 23% compost + 2% fish flour	15.80a	13.98a	6.36a	92.14a	60.55a	2.97a	0.45a
(T3) 75% soil + 25% compost	11.20ab	10.48a	5.04ab	65.63a	41.90b	2.12ab	0.36a
(T4) 75% soil + 25% cow manure	11.80ab	11.04a	5.18ab	70.20a	42.99ab	2.28ab	0.35a
(T5) Soil from the experimental field of CIBNOR (control)	6.80b	6.18b	3.86b	37.28b	22.13c	1.36b	0.19b

Means in the same column followed by the same letter indicates no significant differences between treatments (Tukey *p*=0.05). NC=number of cladodes, LC=length of cladodes, WC=width of cladodes, SA=stem area of cladodes, FW=fresh weight of cladodes, DW=dry weight of cladodes, PT=pad thickness of cladodes.

The multivariate analysis showed that the relation of possibilities of Wilks' Lambda was significant at a level of p=0.001, indicating that differences between the treatments in the variables mentioned in the univariate analysis actually exist (Johnson, 1998). On the other hand, the statistical test of the relation of possibilities showed that the two first canonical variables were statistically significant with p=0.0015 and p=0.03 for CAN1 and CAN2, respectively, suggesting that the dimensionality of the alternative space is two. Also, the results showed that these two first canonical variables explain 85.90% of the variability between the averages of the variables evaluated under the treatments of organic fertilizers (Table 3).

Table 3. Proportion of the variance explained by means of canonical variables in the production of harvested nopalitos using five organic fertilization treatments

Canonical variable	Eigenvalue	Difference	Proportion	Cumulative
1	9.9000	5.8717	0.6083	0.6083
2	4.1183	2.2534	0.2508	0.8590
3	1.8649	1.4143	0.1136	0.9726
4	0.4506		0.0274	1.0000

The canonical coefficients without standardizing (Table 4) were used to create the values of each experimental unit in the space of the two canonical variables and to calculate the averages of the groups of treatments in their canonical space, as well as the graphic representation of the averages in this space. Figure 1 shows that the treatments T1 and T2 are equal. In the same way, treatments T3 and T4 are equal, whereas treatment T5 is different from the rest of treatments.

Table 4. Raw canonical coefficients showing the proportion of participation by each of the determining variables of production of harvested nopalitos in each of the canonical variables

Variable	CAN1	CAN2	CAN3	CAN4
NC	1.2780	0.6562	0.7357	0.7513
LC	0.6593	-0.3614	-0.0744	1.4147
WC	-0.6038	-0.8426	-1.2602	0.1284
SA	-0.1019	-0.5129	-0.0869	-0.4088
FW	0.1232	0.3053	-0.4400	0.4115
DW	-4.8972	12.7649	2.2311	-3.1994
PT	-3.4688	-20.9102	49.3986	-22.7772
CAW	0.3229	0.1515	0.2888	0.1876
TB	-0.0137	-0.1626	-0.0814	0.1460

NC=number of cladodes, LC=length of cladodes, WC=width of cladodes, SA=stem area of cladodes, FW=fresh weight of cladodes, DW=dry weight of cladodes, PT=pad thickness of cladodes, CAW=cladodes average weight, TB=total biomass.

To quantify statistically these valuations, regions of confidence around the averages of the treatments were constructed in the canonical space. Both canonical variables (CAN1 and CAN2) showed significant differences between treatments (CAN1: F=39.96, p=0.0001, CAN2: F=16.47, p=0.0001) whose maximum values represent the "*F*" that can be reached when considering linear combinations of the nine measured response variables in the prickly pear plants. Also, the quadratic errors of both canonical variables showed values of 1 (0.9999), verifying that both vectors that define both canonical variables were selected appropriately. Thus, the multiple comparison of averages in the canonical variables showed that T2 (75% soil + 23% compost + 2% fish flour) was the best treatment for the first canonical variable (CAN1), which represents the most excellent mixture for the variables directly related to the production of nopalitos.

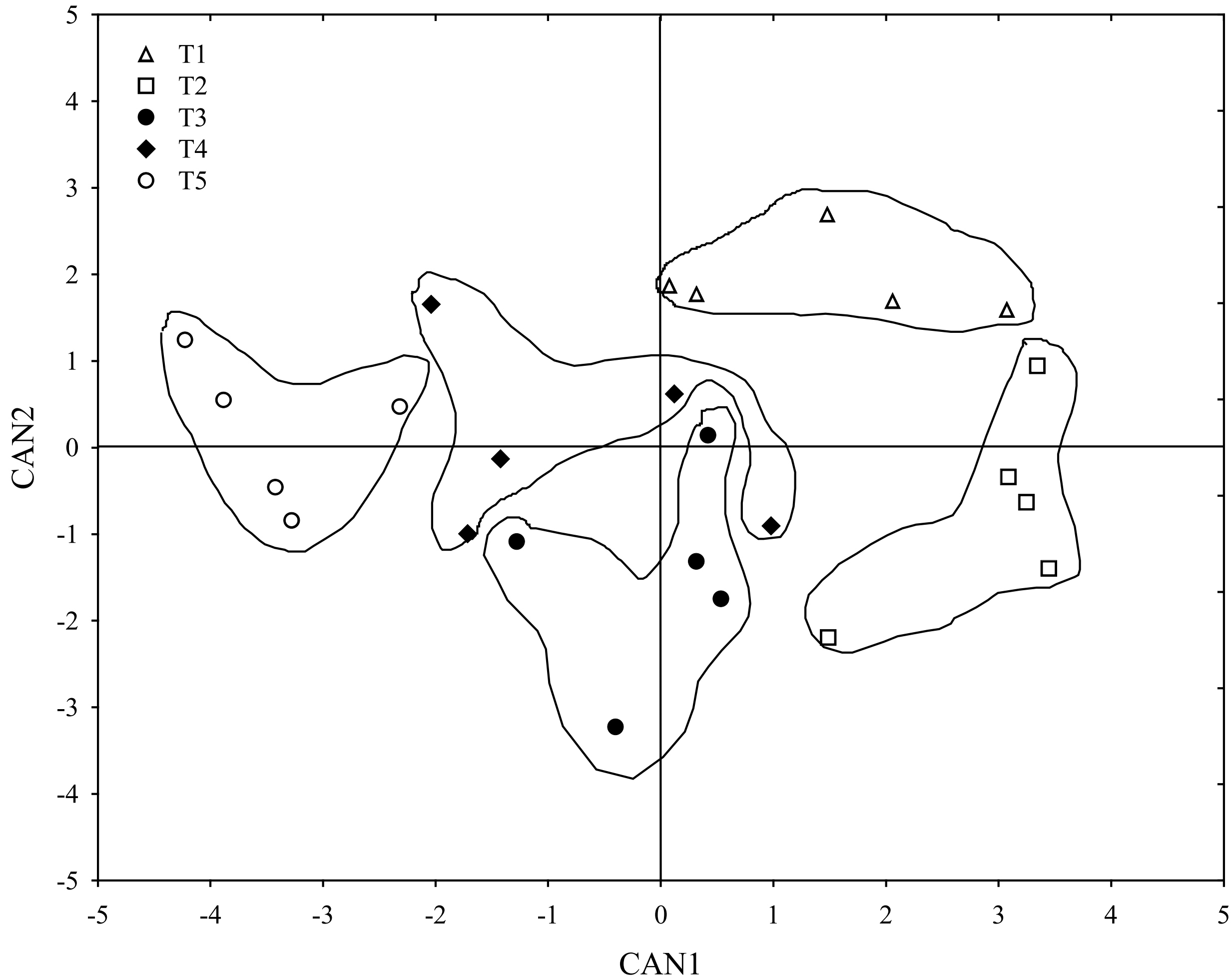

Figure 1. Graphic representation of the means of treatments of organic fertilization in its canonical bi-dimensional space. T1= 75% soil + 23% compost + 2% red crab flour; T2= 75% soil + 23% compost + 2% fish flour; T3= 75% soil + 25% compost; T4= 75% soil + 25% cow manure; and T5= soil (control).

Also, treatment T1 (75% soil + 23% compost + 2% red crab flour) was equal statistically to treatment T2, demonstrating that the origin by-product combination of terrestrial animal (compost) and marine animal (fish flour and red crab flour) had a better effect on production of nopalitos and on the other variables related to production.

On the other hand, treatment T3 (75% soil + 25% compost) and treatment T4 (75% cow manure + 25% soil) were equal statistically to each other and treatment T5 (soil, control) was different from the other treatments and showed the lower values in the response variables. The previous analysis allowed corroborating the averages of treatments in the bi-dimensional canonical space shown in the graphic representation (Figure 1). Because treatments T2 and T1 are located at the right side of the graph, treatments T3 and T4 are located at the middle of the graphs, whereas treatment T5 is located to the left end of the graph. Considering the standardized canonical coefficients (Table 5), it is possible to affirm that variables NC, LC, FW, and CAW are related positively to CAN1, while the other variables (WC, SA, DW, PT, and TB) are related negatively. Therefore, it is deduced for these response variables that the means values will be based on the treatments, where the higher values of the means will be at T2 and T1, the intermediate values of the means will be at treatments T4 and T3, and the lower values of the means will be at treatment T5.

Table 5. Standardized canonical coefficients that show the relation with the determining variables of production of harvested nopalitos with each canonical variable

Variable	CAN1	CAN2	CAN3	CAN4
NC	5.5993	2.8753	3.2233	3.2916
LC	2.5240	-1.3836	-0.2850	5.4159
WC	-0.9771	1.3635	-2.0393	0.2078
SA	-2.6372	-13.2754	-2.2511	-10.5802
FW	2.1053	5.2154	-7.5151	7.0290
DW	-3.9730	10.3558	1.8100	-2.5956
PT	-0.4498	-2.7116	6.4059	-2.9537
CAW	2.2538	1.0542	2.0098	1.3059
TB	-0.1000	-1.1850	-0.5936	1.0642

NC=number of cladodes, LC=length of cladodes, WC=width of cladodes, SA=stem area of cladodes, FW=fresh weight of cladodes, DW=dry weight of cladodes, PT=pad thickness of cladodes, CAW=cladodes average weight, TB=total biomass.

According to the relationship of the response variables with CAN1, it is possible to determine that production and yield of harvested nopalitos require a greater number of cladodes (NC); the cladodes should be long (LC), with high fresh weight (FW), and high cladode average weight (CAW). On the other hand, response variables that were related negatively with CAN1, indicate that cladodes should not to be wide (WC), should show minor stem area (SA), and should not show high pad thickness (PT), but they have to show greater water content to obtain a smaller dry weight (DW) and its energy must to be used more toward the aerial part (nopalitos production) that to the rooted cladode (TB).

The results of correlations between the means of treatments of the original variables (response variables) and the first canonical variable (CAN1), showed that all variables (except CAW) are correlated significantly with CAN1, with absolute correlations from r=0.94 to r=0.99, where TB showed a negative correlation (r=-0.90) (Table 6). However, in the univariate analysis, TB did not show significant differences between treatments. In this sense, a linear tendency between the significant variables with the first canonical variable (CAN1) was shown, being a strong relationship with those original response variables with means significantly different (NC, LC, WC, SA, FW, DW, and PT) than those that were not different (CAW and TB). In addition, treatments T1 and T2, and T3 and T4, are located very close to each other in the response variables (NC, LC, WC, SA, FW, DW, and PT), whereas treatment T5 falls at the extreme left in all graphs (Figure 2).

Considering the second canonical variable (CAN2), the differences between treatments were not as evident as they were with CAN1, showing that the greater values were in treatment T2 (75% soil + 23% compost + 2% fish flour), followed by treatments T4, T3, T5, and T1. When the standardized canonical coefficients (Table 4) were considered and, based on them, variables NC, FW, DW, and CAW are related positively to CAN2 (Table 4), whereas variables LC, WC, SA, PT, and TB, are related negatively. In the same way and based on the standardized canonical coefficients, the means of the variables related positively with CAN2 will be functions of the treatments, where the higher values of the means of these response variables will be at treatment T2, the intermediate values will be at treatments T4, T3, and T5, and the lower values of the means at treatment T1.

Table 6. Correlation analysis between the determining original response variables of the production of harvested nopalitos and the two main canonical variables

	NC	LC	WC	SA	FW	DW	PT	CAW	TB	CAN1	CAN2
NC	1.00	0.69*	0.61*	0.69*	0.65*	0.72*	0.74*	-0.65 *	0.33 NS	0.96*	0.12 NS
LC		1.00	0.71*	0.97*	0.92*	0.95*	0.89*	0.003 NS	0.22 NS	0.97*	0.01NS
WC			1.00	0.70*	0.74*	0.74*	0.82*	0.006 NS	0.17 NS	0.96*	-0.02NS
SA				1.00	0.96*	0.97*	0.90*	0.03 NS	0.28 NS	0.96*	0.03 NS
FW					1.00	0.94*	0.94*	0.08 NS	0.26 NS	0.97*	0.08 NS
DW						1.00	0.92*	-0.01NS	0.41 NS	0.94*	0.19 NS
PT							1.00	-0.06 NS	0.33 NS	0.99*	0.007 NS
CAW								1.00	-0.11 NS	0.85NS	-0.11 NS
TB									1.00	-0.90*	-0.22 NS

*=Significant differences (p<0.05), and NS=No significant differences (p>0.05). NC=number of cladodes, LC=length of cladodes, WC=width of cladodes, SA=stem area of cladodes, FW=fresh weight of cladodes, DW=dry weight of cladodes, PT=pad thickness of cladodes, CAW=cladodes average weight, TB=total biomass.

According to the relationship of these variables with CAN2, results are similar to those obtained in CAN1, except that CAN2 was not related positively with LC but is related positively with DW. Therefore, it is possible to determine that production and yield of harvested nopalitos require a greater number of cladodes (NC), with high fresh weight (FW), high dry weight (DW), and high cladode average weight (CAW). On the other hand, response variables that were related negatively with CAN2, indicate that cladodes should not be wide (WC), should not be long (LC), should show minor stem area (SA), should not to show high pad thickness (PT), but they have to use its energy toward the aerial part (nopalitos production) that to the rooted cladode (TB).

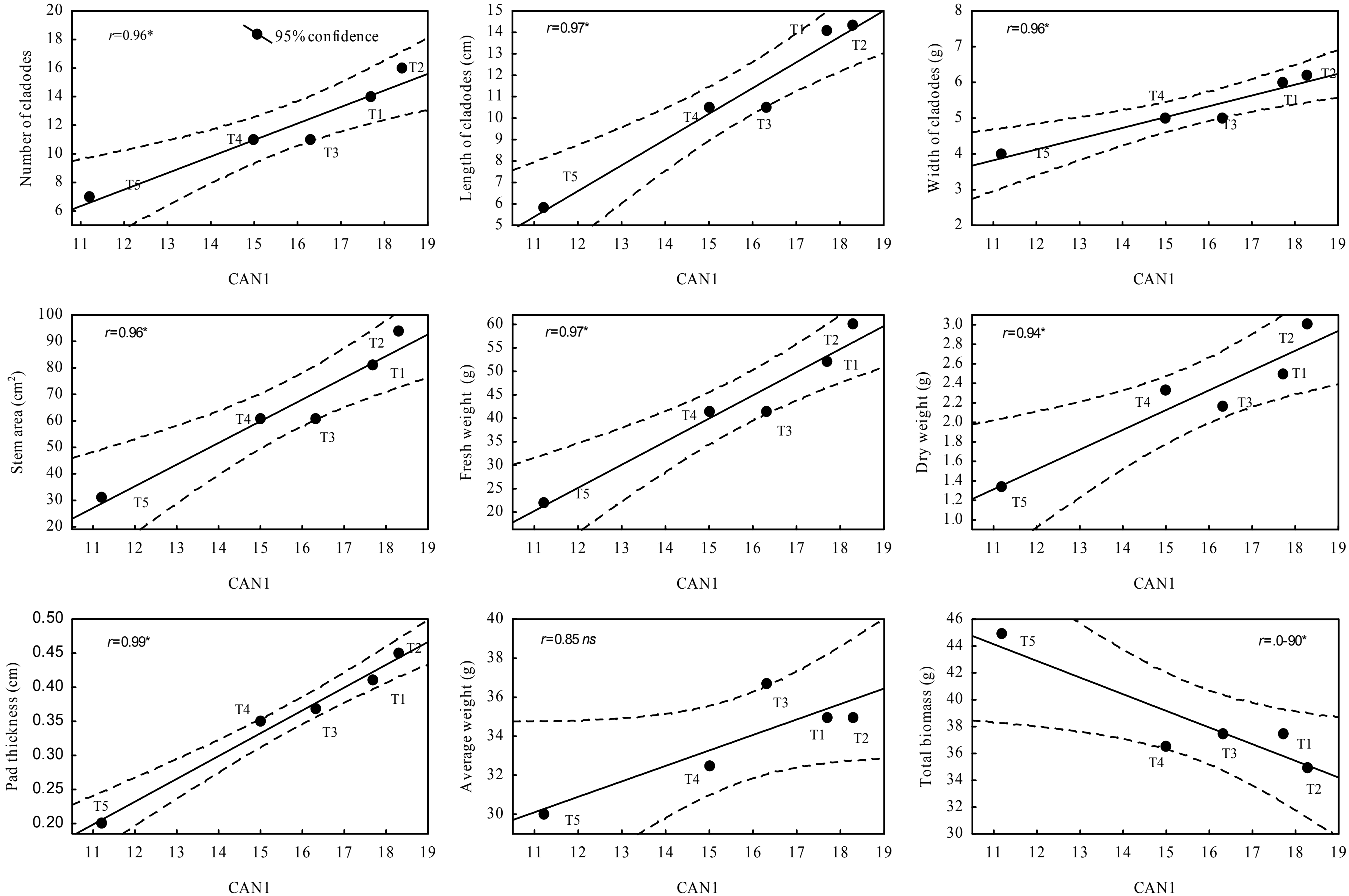

Figure 2. Graphic representation of the means of treatments in each response variable and its relationship with canonical variable CAN1

Following with the interpretation of CAN2, treatment T1 at CAN2 contributes to the variables FW and DW, treatments T4 and T5 showed tendencies to contribute to the same variables, whereas treatments T2 and T3 contribute to variable SA. On the other hand, the results of the correlations between the means of treatments of the response variables with CAN2 showed that none of the response variables are correlated significantly with CAN2 (Table 5).

Results of the univariate analysis (ANOVA) of the variables measured in rooted cladodes showed that the treatments of different organic fertilizers were statistically different with respect to three variables: LRC (p=0.05), NR (p=0.0005), and LRR (p=0.001). The multivariate analysis (MANOVA) showed that the relation of possibilities of Wilks' Lambda did not show a level of acceptable significance (p>0.05), indicating that differences between the treatments in these variables (LRC, NR, and LRR) in the univariate analysis do not exist, then, multivariate analysis was not performed for these variables.
Similar studies regarding the use of fish and red crab flour for production of nopalitos in prickly pear are not available. Consequently, the data of the present study covers an aspect with scientific relevance related to the combination of fish and red crab flour with those based on cow manure and compost. In the same way, it is important to considerer that the use of cow manure is not recommended for organic agriculture. Consequently, the use of composts and some manures, such as fish and red crab flour, are being used more frequently (Ruiz, 1996).

Measured variables have shown superior values in treatments with products of marine origin (fish and red crab flour) because these represent a source of nutritious elements for the plants. Manure and compost act mainly on the physical-structural conditions of the soil, such as humidity, apparent and real density, and structure of the soil (Ruiz, 1996). The organic materials contain numerous nutritious elements but, like manures, their content is determined by nitrogen, phosphorus, and potassium. Most of these materials, whose origin is the vegetal or animal-matter vegetal, contain in different proportions other elements, such as magnesium, sodium, sulfur, and micronutrients. These materials play a more useful role, providing to the plants an essential complement of nutritious elements because organic fertilizers lack these types of elements, sometimes because the raw materials are different or the manufacturing methods have changed (Ruiz, 1996).

Results of the present study agree with those of Vázquez-Alvarado and Gallegos-Vázquez (1995). Vázquez-Alvarado and Gallegos-Vázquez (1997*a*) studied different doses of cow manure (200, 400, and 600 t ha^{-1}) and found that the number of harvested nopalitos increased at 400 and 600 t ha^{-1}. In a second evaluation (Vázquez-Alvarado and Gallegos-Vázquez, 1997*b*) found that the length and the weight of harvested nopalitos were greater with the dose of 600 t ha^{-1}. On the other hand, Fierro-Alvarez (1997) mentions that in the region of Milpa Alta, D.F., the farmers applied volumes of organic fertilizer (cow manure) that ranged from 250 to 500 t ha^{-1} and shows (Fierro *et al*., 1999) that different doses of cow manure (100, 200, 400, and 600 t ha^{-1}) do not influence the number of buds. However, the number of harvested nopalitos increased at doses of 400 and 600 t ha^{-1}. The length, width, and yield of young harvested cladodes increased as cow-manure doses increased.

Murillo-Amador *et al*. (2000), using doses of cow manure (0, 400, and 800 t ha^{-1}), emphasizes that the number, fresh and dry weight, length and width, stem area, and average weight of harvested nopalitos showed significant differences among doses, and all variables increased as levels of doses increased. On the other hand, Rodriguez *et al.* (2001), using doses of cow manure (0, 400, and 600 t ha^{-1}), found annual production of 10.86, 20.57, and 18.05 kg m^2, respectively, with 400 t ha^{-1} being the best treatment. Also, Lopez *et al.* (1999), using three doses of cow manure (0, 690, and 940 t ha^{-1}), found that as doses increased, the nutrients concentration increased. Application of organic fertilizers mixed with chemical fertilizers is recommended by CONAZA (1992) because growth, yield, and quality of the fruits increase.

For other species of plants, Castellanos and Muñoz (1987) evaluated the effect of different doses (0, 30, 60, 120, and 240 t ha^{-1}) as well as the depth of cow manure incorporation into the soil on several physical and chemical characteristics of the soil and on the yield of alfalfa. They found that yield increased 24%, 40%, and 60% for doses of 30, 60, and 120 t ha^{-1}, respectively, relative to the control, whose effects were attributed to the improvement of the physical properties of the soil. The speed of water infiltration significantly reduced as doses increased from 120 to 240 t ha^{-1}, while the differences between yield and the speed of water infiltration with the depth of incorporation of cow manure were not significant statistically. Also, Velasco (1998) evaluated the effect of chemical elements (T1=65.2 to 130-4-00, T2=130.4 to 65-2-00 of N, P, and K, respectively) and organic fertilization (T3=28 t ha^{-1} of cow manure) in *Vicia purpuria* and *Avena sativa* and did not find significant differences between the doses or chemical fertilizations. However, yield increased in both species with the treatment of cow manure. Alvarez *et al*., (1996) found that the cow manure increases the activity of nitrogenase in *Vicia purpuria*, improving as well the production of fresh and dry matter. Also, Vázquez *et al*. (1996) evaluated three treatments [T1=soil without fertilization, T2=soil with chicken manure (1 g of total nitrogen by kg of dry soil), and T3=soil with chicken manure (2 g of total nitrogen by kg of dry soil)] in some legume and gramineous species and found that organic fertilization increased yields of all species. Other studies (Lynch and Bragg, 1985; Fortun and Fortun, 1989) indicated that the organic matter influences porousness, structure, retention of humidity, capacity of cationic and anionic interchange, regulation of pH of the soils, and development of roots of plants.

CONCLUSIONS

We conclude that organic fertilizer, using products of animal and vegetable origin (both marine and terrestrial), has a positive effect on production and other variables related to yield of the harvested nopalitos. Higher values for these variables were in the treatments based on the combination of marine and terrestrial products with compost: T2 (75% soil + 23% compost + 2% fish flour) and T1 (75% soil + 23% compost + 2% red crab flour). The variables showed medium values in the treatments based on terrestrial animal products: T3 (75% soil + 25% compost) and T4 (75% cow manure + 25 of soil), whereas low values were associated with the control treatment, T5 (soil). Also, we conclude that the multivariate analysis allowed us to summarize the information of all data collected in the present study.

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REFERENCES

Álvarez S.J.D., Ferrera-Cerrato R. Santizo R.J.A., Zebrowski C. 1996. Establecimiento y actividad de *Rhizobium* y de *Azospirillum* introducidos en tepetate durante el primer año de roturación. Agrociencia, 30(2):177-184.

Castellanos R.J.Z., Muñoz V.J.A. 1987. Efecto del estiércol de bovino sobre las características de un suelo arcilloso y el rendimiento de alfalfa. INIFAP. La Laguna. Torreón, Coahuila. Núm. 68. 40 p.

CONAZA. 1992. Nopal cultivo alternativo para las zonas áridas y semiáridas de México. Edit. Comisión Nacional de las Zonas Áridas, Instituto Nacional de Ecología, Secretaría de la Reforma Agraria. Saltillo, Coahuila, México.

Fierro-Álvarez, A. 1997. Producción de nopal verdura (*Opuntia ficus-indica*) utilizando altos volúmenes de fertilizante orgánico (estiércol de bovino) en Milpa Alta. Memorias del VII Congreso Nacional y V Congreso Internacional sobre conocimiento y aprovechamiento del nopal. Vázquez-Alvarado, R., Gallegos-Vázquez, C., Treviño-Hernández, N., Días-Torres, Y. (compiladores). Universidad Autónoma de Nuevo León. Monterrey, México. pp. 133-134.

Fierro-Álvarez, A., Gonzáles-López, M.M., Rodríguez-Abundis, F. 1999. Producción de nopalito (*Opuntia ficus-indica*) con cuatro dosis de estiércol fresco en la región de Tulyehualco, D.F. En: Aguirre-Rivera, J.A. y Reyes-Agüero, J.A. (Editores). Memorias del VIII Congreso Nacional y VI Internacional sobre el conocimiento y aprovechamiento del nopal. Universidad Autónoma de San Luis Potosí, México. pp. 77-78.

Fortun C., Fortun A. 1989. Diversos aspectos sobre el papel de la materia orgánica humificada en la formación y estabilización de los agregados del suelo. Anales de Edafología y Agro biología. 48:185-204.

López P., J.; D. Montiel S.; P. Zavaleta B.; J. Olivares O. 1999. Registro de micorrizas en nopal (*Opuntia ficus-indica*) en Milpa Alta con tres dosis de fertilización orgánica. En: Aguirre-Rivera, J.A. y Reyes-Agüero, J.A. (Editores). Memorias del VIII Congreso Nacional y VI Internacional sobre el conocimiento y aprovechamiento del nopal. Universidad Autónoma de San Luis Potosí, México. pp. 83-84.

Lynch J.M., Bragg E. 1985. Microorganism and soil aggregates stability. In: Advances in Soil Science. Sewart, B.A. (Ed.) Vol. 2. Springer-Verlag, N.Y. USA. Pp.133-170.

Méndez, G.S., Martinez, H. J. 1988. Efecto de la fertilización química y orgánica sobre el rendimiento de tres variedades de nopal *(Opuntia spp)* en una plantación comercial. En: López, G. J. J. y Ayala, O. M. J. (Editores). Programas y resúmenes. 3a. Reunión Nacional y 1a. Reunión Internacional Sobre el conocimiento y aprovechamiento del nopal. Universidad Autónoma Agraria Antonio Narro. Saltillo, Coahuila, México. pp. 207-241.

Méndez, G. 1990. Efecto de la fertilización química y orgánica en tres formas de nopal (*Opuntia spp*.), sobre el rendimiento, en una plantación comercial de Ojocaliente, Zacatecas. Memorias, 1a. Reunión internacional sobre el nopal su conocimiento y aprovechamiento. Edit. Universidad. Autónoma Agraria "Antonio Narro". Buenavista, Saltillo, Coahuila, México. pp. 207-213

Murillo-Amador, B., Troyo-Diéguez, E., Villaseñor-Beltrán, A. 2000. Efectos del estiércol de bovino en cultivares de nopal verdulero (*Opuntia spp*.) introducidos a Baja California Sur, México. En: Aguirre-Rivera, J.A. y Reyes-Agüero, J.A. (Editores). Memorias del VIII Congreso Nacional y VI Internacional sobre el conocimiento y aprovechamiento del nopal. Universidad Autónoma de San Luis Potosí, México. pp. 87-88.

Rodriguez A., A.; M. Fierro Á.; M. González L.; Á. Soberanes S. 2001. Cultivo sostenible de nopal verdura (*Opuntia ficus-indica*) variedad Milpa Alta, en camellones, como una alternativa de agricultura urbana para áreas pequeñas y marginales. I Congreso Nacional y VI Simposio Internacional Sobre, Agricultura Sostenible. Colegio de Posgraduados, Campus Veracruz. 25-28 Nov. 2001.

Ruiz F.J.F. 1996. Los fertilizantes y la fertilización orgánica bajo la óptica de un sistema de producción orgánico. En: Zapata. A.R.J. y Calderón, A.R. (Eds.). Memorias del Primer Foro Nacional sobre Agricultura Orgánica. pp. 23-47.

SAS Institute (1988). SAS/STAT user's guide. Ver.6.12 SAS, Institute, Cary, N.C.

Vázquez-Alvarado, R. Gallegos-Vázquez, C. 1995. Organic fertilization for production of young tender pads of *Opuntia* spp in Nuevo Leon, Mexico. First Annual Conference on Professional Association for Cactus Development. pp 49-60. San Antonio Texas. Texas A. & M. University Extension Service. Sep 14-17. 1995.

Vázquez-Alvarado R., Gallegos-Vázquez C. 1997*a*. Efecto de altos niveles de estiércol en la producción de dos variedades de nopal verdura. En: Vázquez-Alvarado R., Gallegos-Vázquez N., Treviño-Hernández N., Díaz-Torres Y. (compiladores). Conocimiento y aprovechamiento del nopal. Memorias del 7º congreso nacional y 5º internacional. Facultad de Agronomía. Universidad Autónoma de Nuevo León, Monterrey, N.L. México.

Vásquez-Alvarado, R., Gallegos-Vázquez, C. 1997*b*. Efecto del estiércol vacuno en el segundo año de producción de nopal verdura. Memorias del VII Congreso Nacional y V Congreso Internacional sobre conocimiento y aprovechamiento del nopal. Vázquez-Alvarado, R., C. Gallegos-Vázquez, N. Treviño-Hernández, Y. Días-Torres (compiladores). Universidad Autónoma de Nuevo León. Monterrey, México. pp. 148-149.

Velasco T.J.A. 1998. Efecto de la fertilización química y orgánica en la producción de avena forrajera con veza. Colegio de Postgraduados, Campus Puebla.

Vázquez, F.J., V. Petrikova, M.C. Villar y T. Carballa. 1996. Use of poultry manure and plant cultivation for the reclamation of burnt soils. Biol. Fertil Soils, 22:265-271.