Organic Fertilization for Production of Young Tender Pads of *Opuntia* spp in Nuevo Leon, Mexico

Rigoberto E. Vazquez A.
Researcher Professor
Facultad de Agronomía de la Universidad Autónoma de Nuevo León
Apartado Postal 358, San Nicolás de los Garza, N. L.
Telefax 91 (824) 80101

Clemente Gallegos V.
Student from the Doctoral Program in Agricultural Science
Facultad de Agronomía de la Universidad Autónoma de Nuevo León
Apartado Postal 358, San Nicolás de los Garza, N. L.
Telefax 91 (824) 80101.

SUMMARY

Mexico is the main nopalito and prickly pear producer in the world with an approximate area of 49,000 ha in plantations, 10,000 ha of which are specialized. (Flores and Gallegos, 1993). An additional 3,000,000 ha of wild nopal has been reported, which are exploited by rustic methods for different purposes (fruit, vegetable, and forage).

Based on the importance of the vegetable nopalito, the following objectives were established: evaluate the adaptability and productivity of two genotypes of vegetable nopalito (*Opuntia ficus-indica* L.) in the municipality of Marín, Nuevo Leon, and determine the best interaction of three cow-manure levels with the genotypes.

The variables evaluated were: total observed buds (TOB), harvested nopalitos (HN), mean fresh weight per nopalito (FWN), and, based on five commercial-size nopalitos, nopalito length (NL) and width (NW). The yield per hectare (Y) and the cumulative yield (CY) were estimated from HN and FWN for each harvest date.

According to the hypothesis of this work, these conclusions were reached:

- Based on the climatic conditions of Marin, N.L., it is possible to establish commercial plantings of vegetable nopalito with high possibility of success.
- Field observations of the genotypes reveal great variation in the susceptibility to high temperatures, especially the Villanueva genotype, but information related to the origin and causes of variation is lacking.
- Experimental data shows that the Jalpa genotype has better production possibilities during the warmer periods.
- The tested manure levels of 400 t/ha produced a significant increase in young tender pads or nopalitos.

INTRODUCTION

Mexico is the main nopalito and prickly pear producer in the world with an approximate area of 49,000 ha of plantations and another 10,000 ha of specialized plantations (Flores and Gallegos, 1993). An additional 3,000,000 ha of wild nopal has been reported which are exploited under rustic methods for different purposes (fruit, vegetable, and forage).

Historically, prickly pear has been grown in Mexico under three different production systems that are still being used. The systems are: wild prickly pear, prickly pear in backyards of rural homes, and prickly pear in commercial plantations. According to Flores and Olvera (1994), the primary cultivated area for vegetable nopalito production is in Distrito Federal (7500 ha), Morelos State (450 ha), Puebla (400 ha), Michoacan (318 ha), Guanajuato (280 ha), Baja California (150 ha, Jalisco (120 ha), and Oaxaca (100 ha). Besides the Mexico State, Queretaro, San Luis Potosi, Durango, Tlaxcala, and Zacatecas, each harvest from 50 to 100 ha.

Due to the climatic conditions in the main production areas, high and low production periods occur. These differences in production affect prices in the market. Higher consumption of the product has been observed mainly in the central part of the country; however, during recent years, consumption of nopalitos has increased in the northern part of Mexico (Flores y Gallegos, 1994). An alternative to meet market demand is producing nopalitos during the winter using the tunnel system or producing in areas not subject to cold damage that have enough water for irrigation. The vegetable nopalito can be used as an alternative in the Nuevo Leon state mainly in those areas where crops have problems with low yields due to the low and decreasing fertility of the soil or in areas with restricted irrigation. Another important consideration is the presence of the Monterrey city market because it is the second highest consumption center of Mexico where the main suppliers are Milpa Alta, D.F.; the Cañon de Juchipila; Zacatecas; and San Luis Potosi. All these considerations appear more important because, in Nuevo Leon, there has not been important commercial exploitation of vegetable nopalito.

Manure is easy to obtain in the Nuevo Leon state from large and small farms that accumulate this product. The cost of manure is lower than any chemical fertilizer and the benefits of manure are superior due to the residual effects in the long term of maintaining and improving the soil fertility for several cycles of a crop. On the other hand, continuous and intense exploitation of the cultivated soils of the north part of the country have produced premature nutrient deficiencies. The regular use of cow manure as a cultural practice for farm production can help alleviate the lack of fertility of the soils. Manure allows recuperation and stabilization of the natural fertility of the soil, a situation that is reflected by the quality and quantity of the agricultural products.

Based on the preceding ideas, the following were established:

Objectives:

1. To evaluate the adaptability and productivity of two genotypes of vegetable nopalito (*Opuntia ficus-indica* L.) in the municipality of Marín, N.L.
2. To determine the best interaction of three cow manure levels with the genotypes.

Hypothesis:

1. The prickly pear cactus have a wide adaptive characteristics under unfavorable conditions.
2. The organic matter as an indirect food for the plants may increase the number of buds on the cladodes and, consequently, produce a better yield of cactus leaves.

LITERATURE REVIEW

Climatic Requirements for Vegetable Cactus Leaves

Climate plays a important role in agriculture production; extreme or adverse conditions are important restrictions for plant development. In the case of young tender pads, the critical exogenous factors are temperature and water (Aquino, 1987). According to Muñoz (1992), the temperature, instead of water, is directly responsible for bud production. Muñoz found an increase in bud production with high temperatures, but bud production decreased with low temperatures. Maximum precipitation was not related to bud production. Muñoz (1992) mentioned that the optimum temperature range for the prickly pear fluctuated between 16°C and 28°C, tolerating maximum temperatures of 35°C during rebuding. Muñoz (1992), also reported that temperatures of 40°C can produce a decrease in bud development and 6°C causes some burns in the young buds.

These environmental requirements are influenced by latitude and altitude. There are reports that the vegetable prickly pear can be cultivated from 800m to 1800 m above sea level and can grow outside of this altitude range.

Organic Matter Generalities

The use of organic matter in cultivated soils, began with ancient agriculture. Even in periods of maximum production of chemical fertilizers, worldwide consumption of nitrogen and phosphorous from organic fertilizers exceeds that of chemical fertilizers. Organic manure has several advantages over chemical products. Some advantages are increased residual effects, higher water-holding capacity of the soils, reduced surface runoff and erosion, and other characteristics (Garcia 1994). One of the more important factors in using organic matter is the available nitrogen supply to the plants. The precise chemical composition of the solid and liquid fraction of manure is too difficult to determine because several variables and factors can change rapidly. For example, the present quantity and proportion of nitrogen, phosphoric acid, and potassium. The quality of manure has been determined by the animal species, age, food, bed type, and handling of the materials (Gresshoff, P.M. 1990). The composition of the cow manure is shown in Table 1 according to the works of Adams et. al., (1954) and Buckman and Brady (1966).

Table 1. Composition of fresh cow manure

Composition of cow manure	Percentage			
	H_2O	N	P_2O_5	K_2O
Solid 70%	85	0.40	0.20	0.10
Urine 30%	92	1.00	traces	1.35
Total 100%	86	0.60	0.15	0.45

Prickly Pear Fertilization

There is general acceptance among farmers and researchers that even the prickly pear rusticity, this plant, can give a favorable response when organic or chemical manure is applied. (Pimienta, 1990; Mondragón and Pimienta, 1990). Several scientific papers certify the influence on buds (nopalitos) and forage production of manure and chemical fertilizers.

Felker (1991) mentioned that researchers from USDA have found that fertilization with N and P_2O_5 increases forage production up to 500% and increases the protein level from 5% to 10%.

The area cultivated in the Milpa Alta region, which is the main vegetable nopalito zone in Mexico, has grown rapidly since 1950 by using empirical technology. Organic manure is the main investment farmers in this region make after the initial planting, using up to 800 t/ha of cow manure (Fernandez et al., 1990).

Based on the concepts of Fernandez et al. (1990) research was developed with these objectives:

- Determine the doses of chemical and organic fertilization that will produce the greatest cost reduction
- Determine the effect of these doses on nopalito production related to the time of the year.

The results from this investigation showed that during spring and summer the best dose was 300 tons of cow manure, 120 kg of N and 100 kg of P. The dose that was second best was 330 tons of cow manure, 120 kg of N, and 50 kg of P. During fall and winter there were no significant differences detected among treatments. It is too difficult to modify the yield with fertilization products alone because the lack of rainfall and unfavorable temperatures limit the expression of the potential productivity of this specie.

MATERIALS AND METHODS

Some plant characteristics were quantified in order to evaluate adaptability and productivity of two vegetable nopalito genotypes to determine the best interaction with three cow-manure levels. For the purpose of this work, nopalitos are the tender prickly pear stems (also called cactus leaves).

Experimental Site Location

The present experiment was carried out during the winter of 1994, at the experimental station of the UANL agronomy faculty. The experimental station is located in Marin, Nuevo Leon, at an altitude of 375 m above sea level, between the coordinates 25° 53' N latitude and 100° 03' W longitude. The predominant climatology conditions during the experiment are shown in Table 2. Higher temperatures were observed in April and May; the minimum occurred during December and January. The largest precipitation was in May when the plantation was six months old.

Table 2. Climatic conditions during development of the crop

Month	Maximum Temperature (°C)	Minimum Temperature (°C)	Mean Temperature (°C)	Precipitation (mm)	Days of Precipitation
Dec 1994	21.6	11.7	16.6	23.3	8
Jan 1995	21.0	9.60	15.3	12.40	3
Feb 1995	27.0	11.0	19.0	18.3	5
Mar 1995	27.0	13.0	20.0	22.9	5
Apr 1995	34.0	16.4	25.0	3.0	2
May 1995	35.0	22.0	29.0	80.0	4

Manure Used

Cow manure was obtained from the UANL agronomy faculty dairy farm in Marin, N.L. The levels used were 200, 400, and 600 t/ha, which were the same amounts used regularly in Milpa Alta, D.F. The manure was six months old and was collected at the same time to be used in the experiment. The amounts used were determined relative to the experimental results obtained in Milpa Alta (Fernández et al., 1990). The three manure levels were corrected for their moisture content and uniformly incorporated in each plot using a hoe.

Genetic Material

The Villanueva and Jalpa genotypes of nopalito (*Opuntia ficus-indica* L.) were collected in Juchipila Canyon, Zacatecas. The mother cladodes were one year old and were selected from commercial plantations according to their size and vigor. The cladodes were treated with copper sulfate solution to avoid future contamination, mainly from disease produced by bacteria and fungus.

Experimental Design

A randomized complete block was used, with a split-plot treatment array. Manure levels were assigned at random to the whole plots within each block, (D1=200, D2=400, and D3=600 t/ha, respectively) and the genotypes were assigned randomly to the subplots within each whole plot (C1=Villanueva and C2=Jalpa). The manure levels and the genotypes give six treatments (T1=D1C1, T2=D1C2, T3=D2C1, T4=D2C2, T5=D3C1, and T6=D3C2) distributed in four blocks.

Plantation System

Each plot of 2 m^2 had 32 cladodes planted, distributed in 4 rows with 8 cladodes per row. Individual rows were 25 cm wide and 2 m long, leaving 1 m between plots, and 2 m spacing between blocks. The two middle rows (12 cladodes) were used as the sampling area, eliminating the two border rows and the extreme cladodes.

The data obtained from the field work were analyzed under the following statistical hypothesis:

Ho T1=T2=T3=T4=T5=T6
vs.
Ha At least one treatment is different from the others.

The following model was used:

$$y_{ijkl} = \mu + ###_i + A_j + G_k + A_j G_k + C_l + A_j C_l + G_k C_l + A_j G_k C_l + E_{iikl}$$

Where:

y_{ijkl} = observation of treatment y in block j.
μ = true effect of the general mean.
$###_i$ = effect of block i.
A_j = effect of manure j.
G_k = effect of genotype k.
$A_j G_k$ = effect of the interaction between the jth manure and the kth genotype.
C_l = effect of harvest l.
$A_j C_l$ = effect of the interaction between the jth manure and the lth harvest.
$G_k C_l$ = effect of the interaction between the kth genotype and the lth harvest.
$A_j G_k C_l$ = effect of the interaction between the jth manure, the kth genotype and the lth harvest.
E_{iikl} = experimental error.

Field Work

Planting of both genotypes was done manually November 11, 1994, using 50% of the manure dose. The other 50% of the dose was applied the following month in order to protect the cladodes from low temperatures. The first irrigation was the day after planting and subsequent irrigations were done when the crop showed some water deficiency or after each harvest. The harvesting was scheduled each 15 days; however, the real time of harvest was when nopalitos reached commercial size.

During the experimental cycle, several cultural practices were followed, including weed and insect control. In May several damaged cladodes of the Villanueva genotype were replanted because of a bacterial problem.

Plant Observations

The evaluated variables were: total observed buds (TOB), harvested nopalitos (HN), mean fresh weight per nopalito (FWN), and, from five commercial-size nopalitos, nopalito length (NL) and width (NW) were evaluated. The yield per hectare (Y) and the cumulative yield (CY) were estimated from the HN and FWN at each harvest date.

RESULTS AND DISCUSSION

Effect of Manure Levels on the Genotypes

To evaluate the behavior of the genotypes studied, different analyses of variance were carried out from the following variables: TOB, NL, NW, HN, FWN, CY. Table 3 shows the mean square error (MSE) according to the respective sources of variation. The manure doses showed high significant differences only for the total number of buds; other variables did not show any significant differences.

Table 3. Analysis of variance for total observed buds, length and width of nopalito, number and weight of harvested nopalito and fresh cumulative yield of two genotypes of *Opuntia ficus-indica* L. at three levels of cow manure. Marín, N. L. 1995

Source of Var.	TOB M.S.E.		NL M.S.E.		NW M.S.E.		HN M.S.E.		FWN M.S.E.		CY M.S.E.	
BLOCK	61.5	NS	30.8	*	6.2	**	4.4	NS	632.1	*	0.046	NS
M	153.4	**	17.6	NS	1.3	NS	18.3	NS	42.9	NS	0.014	NS
G	1694.4	**	1236.5	**	497.3	**	432.8	**	26639.0	**	3.632	**
M*G	1.5	NS	6.9	NS	0.8	NS	1.4	NS	197.3	NS	0.019	NS
C	7908.7	**	1422.5	**	367.1	**	1222.7	**	33790.1	**	9.263	**
M*C	13.0	NS	11.8	NS	1.0	NS	12.5	NS	495.9	**	0.066	NS
G*C	1793.6	**	322.4	**	61.4	**	188.9	**	5021.1	**	1.535	**
M*G*C	18.6	NS	3.9	NS	0.9	NS	18.0	*	179.6	NS	0.121	NS
R2	0.94		0.92		0.90		0.87		0.89		0.87	
cv	20.4		24.7		21.3		50.4		30.4		52.61	

M = Manure doses ** Significant at α=0.01
G = Genotypes * Significant at α=0.05
C = Harvest number NS = No significance

Depending on the genotype (G), high significant differences were detected for all the studied variables. The interaction of manure doses with genotypes (M*G) did not show significant differences in any case. Harvest number (C) showed significant differences at α=0.01 and it can be interpreted that at least one harvest is different across all the variables. A different situation existed with the interaction between manure doses and harvest number (M*C), in which case the total harvested fresh weight of nopalito (FWN) showed a high significant difference.

Concerning the interaction between genotypes and harvest number (G*C), high significant differences were found in all the analyzed variables; however, only the harvested nopalito

(HN) was significantly different for the triple interaction (M*G*C) between doses, genotypes, and harvest number (α=0.05).

Tukey's procedure was used to compare the mean differences between doses and genotypes, results of which are in Tables 4 and 5, respectively. From these tables it can be concluded that doses of 400 and 600 t/ha produced the larger number of buds, and these doses were significantly different from the 200 t/ha doses.

Table 4. Effect of manure doses on total observed buds, number of harvested nopalitos, length and width of nopalito, fresh weight per nopalito, and cumulative yield of two cv. of *Opuntia ficus-indica* L. at Marín, N. L., 1995

Doses (t/ha)	TOB (number)	HN (number)	NL (cm)	NW (cm)	FWN (g)	CY (t/ha/day)
400	28.67 a	7.083 a	11.82 a	5.69 a	52.68 a	0.5680 a
600	28.45 a	6.639 a	12.05 a	5.90 a	52.72 a	0.5510 a
200	26.50 b	6.259 a	11.26 a	5.88 a	53.68 a	0.5458 a

Means followed by a different letter are significantly different with α=0.05.

Table 5 shows statistics of the genotypes according to the variables TOB and HN. In this table, Jalpa is superior to the Villanueva genotype in 15% and 30%, respectively. In the case of NL and NW, the Villanueva genotype was superior in both cases, in 29% and 36%, respectively. The Villanueva genotype had 18.15 g greater average weight than the Jalpa genotype. Finally, the converted sample of fresh weight in kg/ha/day (CY) of the Jalpa genotype was greater and with statistically significant differences than the Villanueva genotype at 212 kg/ha. These facts can be explained by the larger amount of total buds and harvested nopalitos in the Jalpa genotype; nevertheless, the size and the weight of the nopalitos were larger in the Villanueva genotype, explaining the results.

Table 5. Mean values of total observed buds, number of harvested nopalitos, length and width of nopalito, fresh weight per nopalito, and cumulative yield of two cv. of *Opuntia ficus-indica* L. at Marín, N. L., 1995

Genotype	TOB (number)	HN (number)	NL (cm)	NW (cm)	FWN (g)	CY (t/ha/day)
Jalpa	30.0 a	7.7 a	9.8 b	4.67 b	44.33 b	0.657 a
Villanueva	25.5 b	5.4 a	13.7 a	7.26 a	62.48 a	0.445 b

Means followed by a different letter are significantly different with α=0.05.

Performance of the Genotypes

Immediately after planting, different behavior between the two genotypes was observed. Villanueva genotype was much better during winter than the Jalpa genotype, showing first, initial bud formation and total amount of buds (TOB). Villanueva genotype started to show bud formation 10 days after planting; however, the Jalpa genotype did not show any bud until 36 days later when the temperatures were warmer (Figure 1). That particular behavior was observed until harvest number six (64 days). After this harvest, the Jalpa genotype had a better performance in bud production. These statistics indicate that Villanueva genotype can grow much better at sites with relative fresh temperatures; however, Jalpa had better performance at warmer temperatures. These observed behaviors, do agree with the thermic-origin characteristics of the two genotypes.

Figure 2 shows a similar behavior of the production of nopalito (fresh weight t/ha) per harvest. However, even though the Villanueva genotype yield was higher for the first six harvests, these values were not as significant as they were for the Jalpa genotype after the seventh harvest. The results suggest that, for the type of climatic condition of the region during the the experiment, the Jalpa genotype had a better yield potential.

It is important to emphasize that the Villanueva genotype was affected by severe rot produced by bacteria (Bacterium aeroide)*. The problem was more severe during the warmer period. After observation number 14, the harvest was suspended for this genotype and all damaged plants were replanted.

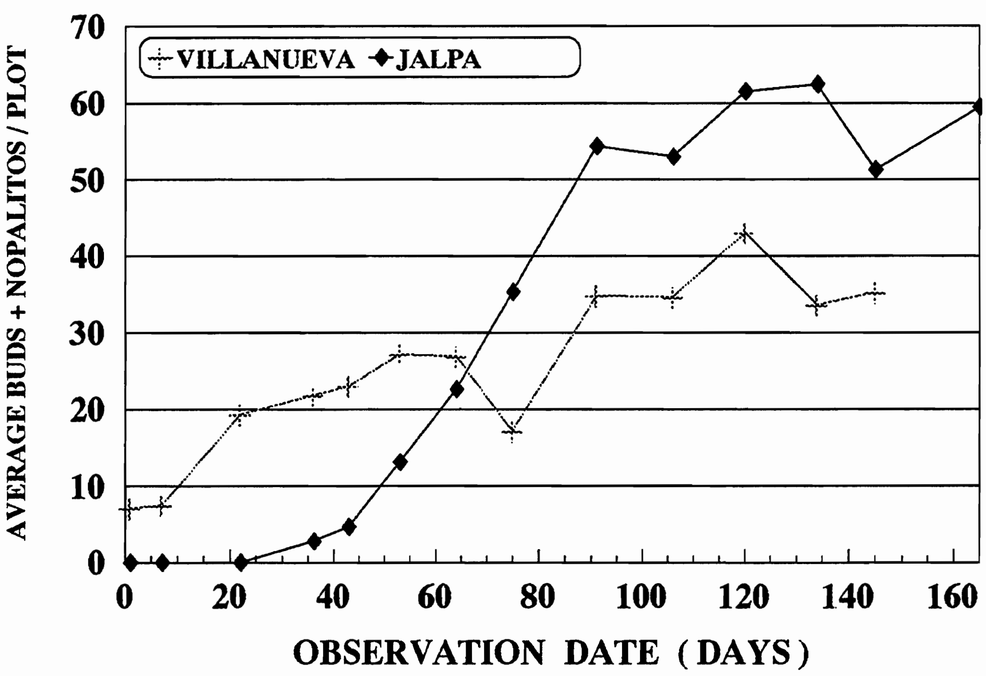

Figure 1. Average number of buds and nopalitos per plot of two genotypes of *Opuntia ficus-indica* L. under three manure levels. Marín, N. L., 1995.

* Identified with the collaboration of Ph. D. José Luis de la Garza

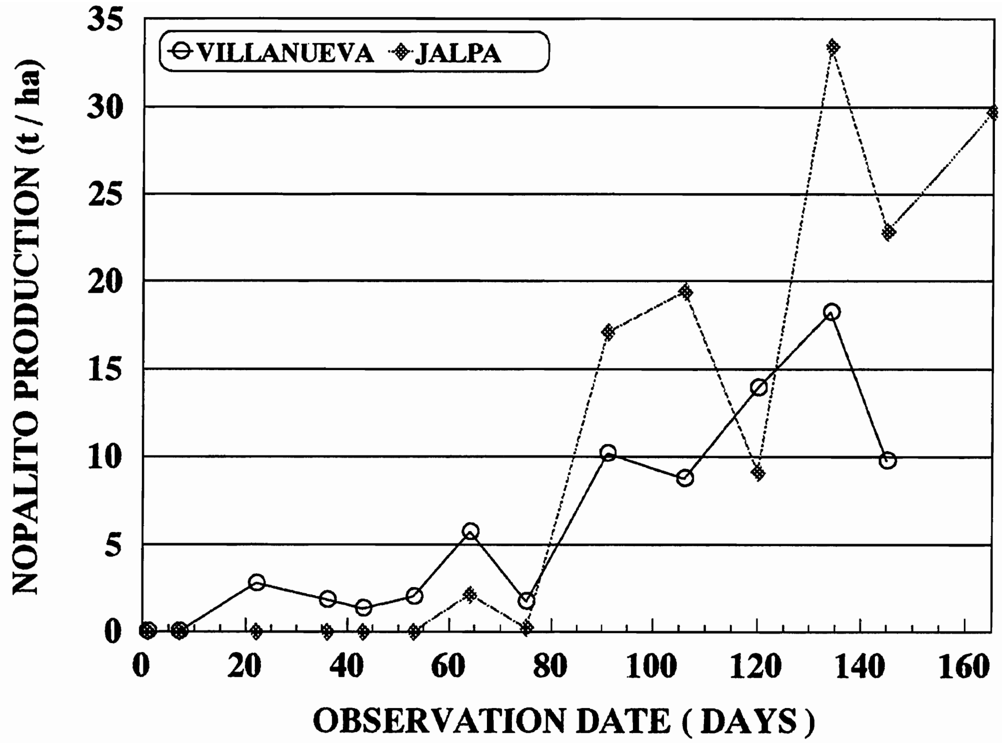

Figure 2. Yield of nopalito per harvest date of two genotypes of *Opuntia ficus-indica* L. under three manure levels. Marín, N. L., 1995

CONCLUSIONS AND RECOMMENDATIONS

Based on the hypothesis of this work, these conclusions can be drawn:

- In the climatic conditions of Marin, N.L., it is possible to establish commercial plantings of vegetable nopalito with high possibility of success.

- Field observations of the genotypes reveal great variation in the susceptibility to high temperatures. The Villanueva genotype, particularly, has this problem. At this point information related to the origin and causes of variation is lacking.

- Experimental data indicates that the Jalpa genotype has better production possibilities during warmer periods and deserves pilot-scale evaluation for this area.

- The tested manure level of 400 t/ha, produced a significant increase in young tender pads or nopalitos.

Based on the conclusions above, some suggestions for future research are:

- Analyze residual effects of manure and the interactions with nitrogen fertilization. In this case, competition for nitrogen between soil bacterial mineralization and prickly pear plants can be avoided by using nitrogen fertilization.

- The present research is incomplete; only preliminary results were presented. New genotypes need to be incorporated and a larger number of observations made.

- The tunnel system was not used in winter but this possibility should be considered for future evaluations.

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