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Soil conditioner efficacy on Lajas Valley sweet corn production[1]

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ABSTRACT

Improved soil-water relations through supplemental irrigation or the application of a soil conditioner can increase crop yield in semiarid regions. Barbary-Plante (BP) is a soil conditioner consisting of a sodium acrylamide-acrilate copolymer with macro- and micronutrients and other components that improve nutrient availability, water retention, and aggregate stability in the soil. The efficacy of BP as a soil conditioner was tested on sweet corn (*Zea mays* L. cv. Sure Sweet) yield in the semiarid southwestern region of Puerto Rico (Lajas Valley). The soil at the experimental site is classified as Fraternidad clay (fine, smectitic, isohyperthermic Typic Haplusterts). The treatments consisted of three rates of BP (0, 50, and 100 kg/ha, without hydration) and three irrigation levels (corresponding to evapotranspiration replenishment of 0, 50, and 100%). Irrigation treatments were scheduled by using the Pan A evaporation method. Barbary-Plante was incorporated into the soil and supplemented with inorganic fertilizer to attain final rates of 150-50-150 kg/ha (N-P_2O_5-K_2O). Sweet corn was planted on 20 February 2001 at a density of 64,000 plants per hectare. Drip irrigation treatments significantly affected marketable sweet corn yields. Marketable corn yield and cob number were unaffected by BP addition. Applications of 50 kg BP/ha under rainfed conditions produced the highest sweet corn emergence, although this effect was not significantly different from that in the untreated plots. Generally, BP effect on seed corn emergence was inconsistent.

Key words: sweet corn, yield, LAI, soil conditioner, Vertisols

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RESUMEN

Eficiencia de un acondicionador de suelo en la producción de maíz dulce en el Valle de Lajas

El rendimiento de los cultivos en regiones semiáridas puede aumentarse mejorando el contenido hídrico en el suelo o el uso de acondicionadores de suelo. Barbary-Plante (BP) es un acondicionador comercial de suelo que consiste de un polímero de acrilamida de sodio que contiene macro- y micronutrimentos, entre otros componentes. El fabricante alega que este producto mejora la disponibilidad de nutrimentos, retensión de agua y la estabilidad de agregados en el suelo. La eficacia de BP como acondicionador de suelo se probó en maíz dulce (*Zea mays* L. cv. Sure Sweet) en la región semiárida del suroeste de Puerto Rico (Valle de Lajas). El suelo en el predio experimental pertenece a la serie Fraternidad (fino, esmectítico, isohipertérmico Typic Haplusterts). La serie Fraternidad es un Vertisol, orden de suelo más predominante en el Valle de Lajas. El maíz dulce se sembró el 20 de febrero de 2001 a una densidad de 64,000 plantas por hectárea. Los tratamientos probados fueron 0, 50 y 100 kg/ha de BP sin hidratar y riego por goteo a razón de 0, 50 y 100% de reposición de evapotranspiración. Los tratamientos de riego por goteo se programaron utilizando el método del tanque de evaporación. Una vez hidratado, según la recomendación del fabricante, el BP se incorporó al suelo al momento de la siembra. Los tratamientos de BP se suplementaron con fertilizantes inorgánicos hasta alcanzar un nivel de 150-50-150 kg/ha de N-P_2O_5-K_2O. Los niveles de riego afectaron el rendimiento de mazorcas comerciales. En cambio, las aplicaciones de BP no afectaron el rendimiento de mazorcas comerciales. Aplicaciones de 50 kg/ha de BP produjeron la mayor germinación, aunque no significativamente mayor que en las parcelas no tratadas. En términos generales el efecto de BP en la germinación del maíz dulce fue inconsistente.

Palabras clave: maíz dulce, rendimiento, IAF, acondicionador de suelo, Vertisols

INTRODUCTION

Some physical characteristics of Vertisols affect their management (Bonnet and Sulsona, 1950). Vertisols are soils in which 2:1 clays predominate, resulting in soil with a high water retention, low hydraulic conductivity and thus difficult to manage. Vertisols are classified as fertile soils with a cation exchange capacity (EC) greater than 20-cmol/ kg. In Puerto Rico Vertisols predominate in the Lajas Valley. Crop management in this type of soil greatly depends on soil moisture content. Tillage becomes extremely difficult when the soil is too dry or too wet; therefore, soil moisture should be adequate to facilitate tillage (Lugo-López, 1995).

Historical rainfall recorded within the Lajas Valley varies from 760 to 880 mm/yr, with a dry season occurring predominantly from January to March and June, and a wet season from August to November (Graves, 1991). Agronomic management practices that increase water supply to crops or improve soil water availability are indispensable to optimize crop yields in the Lajas Valley. The use of commercial soil conditioners may increase soil-available water, thus reducing risk for crop production. In the 1950s, the synthetic soil conditioners Krilium, Aerotil, and Goodrite were tested in Puerto Rico (Lugo-López et al., 1957a). The soil conditioners tested did not affect tomato (*Lycopersicon esculentum*), white bean (*Phaseolus vulgaris*), or sweet potato (*Ipomoea batatas*) response in a Santa Isabel clay soil (Typic Haplusterts) located in the Lajas Valley. In a Lares clay soil (Aquic Paleudults), all crops tested [sweet potato, cotton (*Gossypium hirsutum*), and corn] showed a small response to the synthetic organic product addition (Lugo-López et al., 1957b).

The soil conditioner Barbary-Plante® (BP) is manufactured by the French company Barbary-Plante International and distributed in Puerto Rico by AgroEco Solutions[4]. The compound is a sodium acrylamide-acrilate copolymer containing macro- and micronutrients, fungicide and root growth promoter (Table 1). The manufacturer states that nutrient availability, water retention, and aggregate stability are improved with application of BP to the soil. The manufacturer indicates that this product holds 500 times its weight in water, and when mixed with soil it will slowly release water and nutrients if plant roots penetrate the product particles. Another claimed advantage of the product is that nutrients and water remain in the particle if not absorbed by roots, increasing water holding capacity and reducing potential leaching.

Barbary-Plante has been evaluated in several areas with good results. It was tested in Hyderabad, India, in corn and sunflower (Rao, 1997). They tested three BP rates (0, 50, and 100 kg/ha) and three irrigation sub-treatments (normal, 50, and 75%) based on soil moisture depletion indicated by tensiometers. Normal irrigation was considered at 50% of soil moisture depletion. In the study BP did not affect seed emergence, plant height, cob width, test weight, or number of cobs per plant. On the other hand, BP had a significant effect on cob weight, cob length, and grain yield. An application of 50 kg/ha produced higher yields than no BP. This product has been tested in China, Egypt, and the Dominican Republic and may be useful to improve physical and chemical properties of heavy clay soils like Vertisols.

The objectives of this research were to investigate the efficacy of the BP on sweet corn production in a Vertisol, at varying soil moisture lev-

[4]Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

TABLE 1. *Barbary-Plante composition reported by manufacturer.*

Component	
Macronutrients	%
$N\text{-}P_2O_5\text{-}K_2O$	18-18-18
Micronutrients	mg/kg
B	200
Cu	60
Fe	480
Zn	160
Mn	600
Mo	60
Fungicides	%
Hymexazol	20
Potassium Hydroxide	45
Growth Regulators	
Alfa naftilacetamide	0.018
Alfa naftalenacetic acid	0.002
Thio-urea	0.098

els obtained through supplemental drip irrigation in the semiarid southwestern region of Puerto Rico.

MATERIALS AND METHODS

The research was conducted at the Lajas Agricultural Experiment Substation of the University of Puerto Rico (18°02'N and 67°04'W). Fraternidad clay (fine, smectitic, isohyperthermic Typic Haplusterts) is the soil at the experimental site (Beinroth et al., 2003). Rainfall recorded in the Lajas Valley varies from 760 to 880 mm per year and is limited and not well distributed. The total rainfall registered at Lajas during the trial was 30, 94, and 364 mm for March, April and May 2001, respectively. The average monthly temperature was 24.6, 24.2 and 26.4° C and pan evaporation was 72, 87 and 97 mm for the same months, respectively.

The soil was plowed and disked twice. Sweet corn (cv. Sure Sweet) was planted by hand on 20 February 2001 and thinned to a density of 64,000 plants per hectare in four 4.54-m rows. The experiment consisted of three irrigation treatments in whole plots arranged in a randomized complete block design with four replications and split plots of BP or fertilizers treatments.

The drip irrigation system in the main plot consisted of 5.08-cm polyethylene sub-mains and drip laterals with drippers spaced 20 cm apart. The irrigation treatments consisted of 50% and 100% of evapotranspiration replenishment (ET) scheduled by using the Pan A evaporation methods and a rainfed treatment included as a check. To estimate ET using the Pan A evaporation methods a Pan Coefficient (Kp) and Crop Coefficient (Kc) are needed. Kp values used were 0.59, 0.62, and 0.69 for March, April, May, respectively (Goyal, 1989). The Kc values used were 0.60, 0.99, and 0.73 for the growing period corresponding to 0 to 30, 31 to 60, and 60 to 91 days after planting (Hotchmuth et al., 1999). These Kc values are estimates for a sweet corn plant that reaches maturity at 90 days after planting. Irrigation treatments were applied twice a week. To aid seedling establishment three uniform irrigations at 100% ET were applied to the whole experiment approximately a week after planting. Daily cumulative ET and rainfall from the previous irrigation was used to calculate the irrigation amount to be applied to each treatment. The time of water application to treatments was based on flow rate (obtained from irrigation line specifications) and system pressure. The subplots were treated with conventional fertilizer 150-50-150 kg/ha ($N-P_2O_5-K_2O$) and two rates of the BP (50 and 100 kg/ha of the material without hydration). The manufacturer recommends hydration of BP in a 1:9 (BP: water) ratio. Hydrated BP was applied and incorporated by hand in the row at seeding time. The two soil conditioner treatments were supplemented with inorganic fertilizer to attain final rates of 150-50-150 kg/ha. Forty percent of conventional fertilizer was applied at planting (Quiles-Belén et al., 1988). The remaining 60% was applied 45 days after planting (10 April 2001). Urea, triple superphosphate, and potassium chloride were the nutrient sources applied.

Insects were controlled with methomyl, *Bacillus thruringiensis* var. *Bizawar*, a commercial mixture of pyrethrin & rotenone, and diazinon. Mechanical and hand weeding were performed as needed.

Variables measured were total seed emergence, total yield (TY), marketable yield (MY), marketable cob number (MN), Leaf Area Index (LAI), and dry matter (DM). Yield was determined by using the two middle rows of the subplot. A cob was considered non-marketable when thin, small, and undeveloped at harvest. Leaf area and dry matter accumulation were measured on one plant per subplot selected at random on 15 March, 2 April, 20 April, and 10 May (harvest). Corn plant samples were separated into leaves and stalk. Leaf area was measured by using a leaf area meter (LI-3100). Plant samples were oven-dried at 60° C for 48 hours for dry matter determination.

Volumetric soil moisture content was measured at two-day intervals with a TRIME (MESA Systems Co., Medfield, MA) using the Time Domain Reflectometry (TDR) technique (Dasberg and Dalton, 1985).

One TDR access tube was installed per subplot and readings were measured at 20-cm depth. Probe plates were oriented toward corn roots within rows. The corn was harvested at R3 stage (10 May 2001), approximately 20 days after silking (80 days after planting). The data were analyzed with ANOVA and LSD for means separation (SAS Institute, 2002).

RESULTS AND DISCUSSION

No significant interaction was detected between irrigation and BP rates for total yields, marketable yield, and cob number (Table 2). Drip irrigation treatments significantly affected marketable yield. Marketable cob number per hectare varied from 43,256 to 55,108 (Table 2). The application of an irrigation replenishment of 50% ET produced the highest marketable yield (12,236 kg/ha) even though it was not significantly different from yield obtained with the 100% replenishment. The rainfed treatment produced the lower marketable yield (8,696 kg/ha) even though it was not significantly different from that with 100% ET. Barbary-Plante rates and conventional fertilizer did not affect the yield variables studied (Table 2).

The yield observed from non-irrigated plants (rainfed) was acceptable for a region with a low rainfall pattern. Sweet corn yield was higher than yields reported by several authors. Mangual-Crespo (1977) reported 16,729 and 26,834 marketable cobs per hectare for two sweet corn cultivars grown on an Oxisol at Isabela utilizing a density of 37,000 plants per hectare and a fertilizer application of 227-227-181 kg/ha (N-P_2O_5-K_2O). The hybrid Hawaii 68 planted at a density of 53,333 plants per hectare produced a marketable yield of 11,974 kg/ha (74,780 cobs per hectare) in a fertilizer study conducted on a Fraternidad clay in Lajas (Muñiz, 1979). Sure Sweet was tested in an irrigation study at Juana Díaz in which the mean marketable yield and marketable cob number was 5,134 kg/ha and 23,826 cobs per hectare, respectively (González-Fuentes et al., 1988). In our study, yields expressed by Sure Sweet were higher than yields reported from other areas or seasons in which sweet corn production is traditionally promoted. Our results indicate that sweet corn production in the Lajas Valley is feasible.

Leaf Area Index (LAI) and dry matter (DM) accumulation data were analyzed by date of sampling (Table 2). A significant interaction was detected between irrigation and BP in the second sampling, 2 April 2001 (43 days after planting) for DM. On this sampling date, less DM accumulated when adding BP under 100% ET. In contrast, slightly more DM accumulated when adding BP under rainfed and 50% ET. This negative effect of BP under full irrigation was an unexpected re-

TABLE 2. *Probability of the F value on the analysis of variance of yield, dry matter production (DM) and Leaf Area Index (LAI) of sweet corn (cv. Sure Sweet) as a response to irrigation levels (rainfed, 50, and 100% ET[1]) and Barbary-Plante rates (0, 50, and 100 kg/ha, without hydration) at Lajas, Puerto Rico.*

					15 March		2 April		20 April		10 May	
Treatments	TY[2] kg/ha	MY kg/ha	MN No./ha	SE plants/m	DM g/plant	LAI	DM g/plant	LAI	DM g/plant	LAI	DM g/plant	LAI
Irrigation *(I)* % ET												
rainfed	12,770	8,696	43,256	5.50	13.71	0.16	21.16	1.32	50.33	1.92	129.33	2.45
50	14,880	12,236	55,108	4.33	14.45	0.20	19.16	1.15	56.00	2.06	161.66	2.48
100	12,773	10,231	47,108	4.58	13.59	0.19	26.33	1.31	45.00	1.77	165.50	2.55
Sign. F[3]	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
LSD[4]	—	2,223	—	—	—	—	—	—	—	—	21.46	—
Barbary-Plante *(BP)* kg/ha												
0	13,106	10,170	47,014	4.66	13.67	0.17	22.16	1.44	48.83	1.86	158.66	2.39
50	13,377	10,555	49,003	5.08	14.23	0.20	23.41	1.18	56.50	2.13	154.83	2.68
100	13,939	10,436	49,355	4.66	13.85	0.19	21.08	1.16	46.00	1.76	143.00	2.42
Sign. F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I*BP Sign. F	NS	NS	NS	*	NS	NS	*	NS	NS	NS	NS	NS

[1]ET = evapotranspiration replenishment.
[2]TY = Total yield, MY= marketable yield, MN = marketable cob number, SE = seed emergence.
[3]Sign. F = significance of the F test, where NS = not significant, * = significant.
[4]LSD = Fishers protected least significant difference ($\alpha = 0.05$).

sult. A similar, but non significant, trend was observed on the March 15 and May 10 sampling dates. Addition of BP was expected to possibly increase DM under rainfed conditions; however, this effect was usually weak or non significant. Overall, we observed little or no effect of BP on DM and LAI. Table 3 presents details on individual means interaction.

Irrigation significantly affected total DM production at harvest (10 May 2001). No treatment achieved a LAI close to 3.0 (Table 2), which is the reported threshold value to achieve acceptable yields for field corn. A significant interaction was found between BP and irrigation treatments for seed emergence (Table 2). The highest seed emergence, eight plants per meter, was observed in rainfed conditions applying BP at 50 kg/ha. This result partially agrees with the manufacturer's statement that BP promotes germination under limited rainfall conditions. In general, the effect of BP on seed emergence depending on irrigation levels was inconsistent.

Figure 1 shows water added (rainfall and drip irrigation) to sweet corn scheduled by utilizing the Pan A evaporation method. Rainfall registered for March, April, and May 2001 was 20.57, 92.71, and 364 mm, respectively. No irrigation was applied in May because of the high rainfall event registered on 6 May, and harvest was performed on 10 May.

TABLE 3. *Interaction between irrigation levels (rainfed, 50, and 100% ET[1]) and Barbary-Plante rates (0, 50, 100 kg/ha, without hydration) on dry matter accumulation (g/plant) and seed emergence (plants/m) of sweet corn (cv. Sure Sweet) at Lajas, Puerto Rico.*

	Irrigation Level		
Barbary-Plante Rate	rainfed	50%	100%
	Dry matter accumulation on 2 April 2001 (43 dap[2])		
0	17.50	11.50	37.50
50	24.75	24.50	21.50
100	21.25	21.50	20.50
LSD[3]= 16.18			
	Seed emergence		
0	4.00	5.25	4.75
50	8.00	4.75	2.50
100	4.50	3.00	6.50
LSD[3] = 4.39			

[1]ET = evapotranspiration replenishment.

[2]dap = days after planting.

[3]LSD = Fishers protected least significant difference ($\alpha = 0.05$) for comparing any two treatment means.

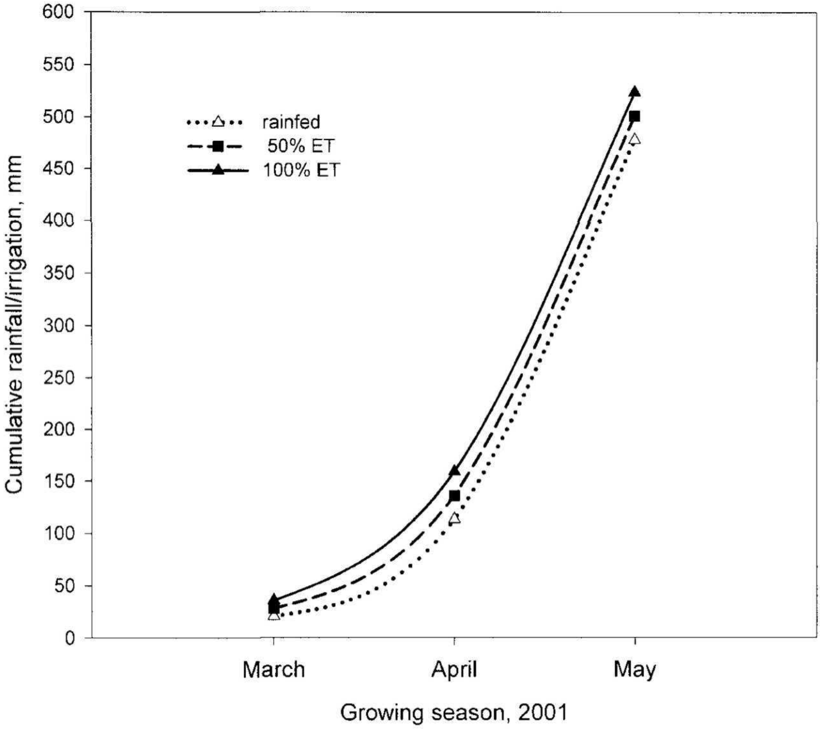

FIGURE 1. Cumulative rainfall and irrigation applied by irrigation treatment (rainfed, 50%, and 100% evapotranspiration replenishment, ET) scheduled by using the Pan A evaporation method in sweet corn (cv. Sure Sweet) at Lajas, Puerto Rico.

Neither irrigation treatments nor BP affected (statistical analysis not shown) volumetric soil water content (θ). Figure 2 shows trends of θ for each of the BP rates and irrigation treatments. The water content tended to be higher than 60% close to harvest (80 days after planting). A high variability was associated with θ means (coefficient of variation = 56.6). A trial conducted on the same soil by Harmsen et al. (2001) using the same instrument showed similar θ values, which were interpreted as too high for the soil. Even though a θ = 60% could be possible on Vertisols, especially under extremely wet conditions, we concluded that the instrument showed some inconsistency in data acquisition. Despite the possibility of the inconsistency in θ data, BP applications did not increase the water holding capacity of the soil.

The results of the experiment show that BP application did not affect yield or plant growth under Lajas Valley conditions. This result

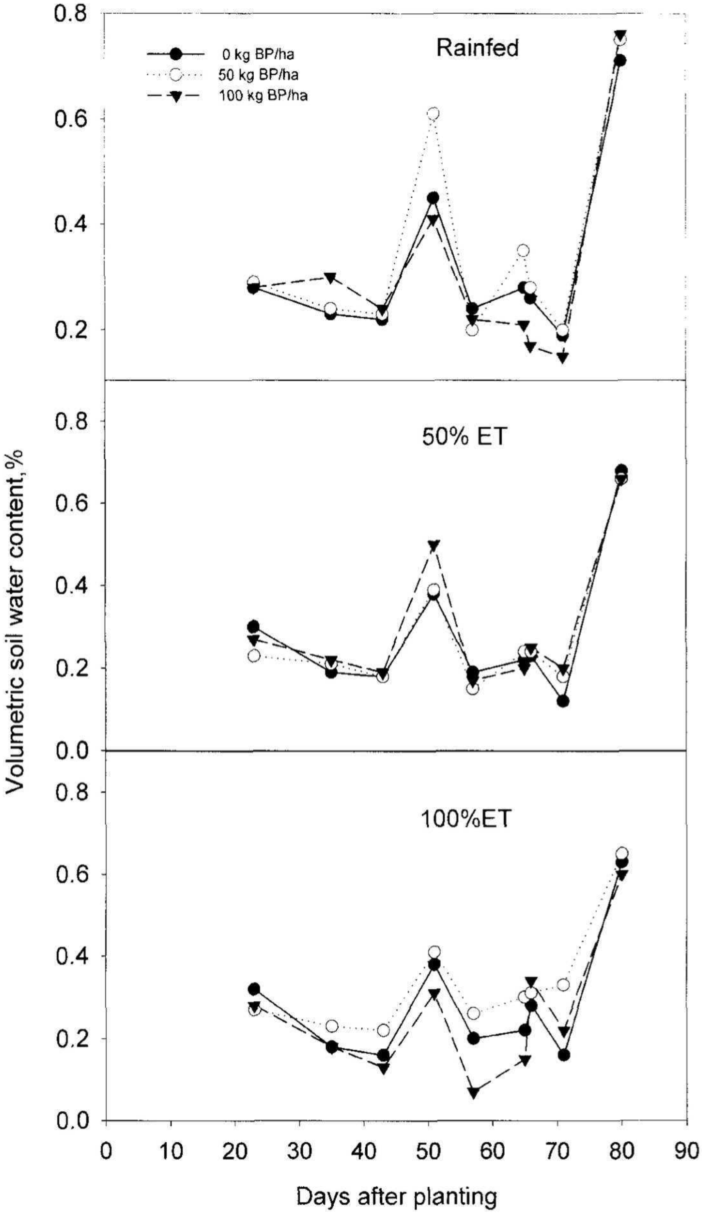

FIGURE 2. Volumetric soil water content measured using TDR technique as affected by three irrigation levels (rainfed, 50%, and 100% ET) and three rates of a soil conditioner (0, 50, and 100 kg/ha Barbary-Plante, BP) in sweet corn (cv. Sure Sweet) at Lajas, Puerto Rico.

coincides with results obtained by Lugo-López et al. (1957a) in the same soils, with three crops (tomato, white bean, and sweet potato) that showed no response to soil conditioners. The application of 100 kg BP/ha did not increase θ in Fraternidad clay. The apparent advantage of high water retention given by BP that may reduce irrigation requirements on dry land conditions was not observed in this experiment, especially in March and April. Probably, drip irrigation overcomes the lack of adequate rainfall and the BP ability to hold water becomes less important because of the high water retention of Vertisols. Note that sweet corn is harvested when the kernel is in the linear growing phase of dry matter accumulation. In contrast, field corn is harvested when dry matter accumulation has stopped. The ability of BP to provide nutrients and micronutrients may be beneficial when the kernel is in the linear growth phase. This finding may be the explanation for the positive response demonstrated in field corn under different soil conditions, locations, and crop managements reported in the literature. This lack of response may be explained by several reasons: The short growing period of sweet corn might not be enough for the product to manifest its advantages. Second, most of the soils of the Lajas Valley are fertile and have a high aggregate stability. Finally, there was a high rainfall registered close to harvest.

Most of the farming presently done in the Lajas Valley is under drip irrigation systems. Under those conditions, the use of soil conditioners, such as BP, may not be as effective. It may not be cost efficient to replace high tech drip irrigation systems and plastic mulch by a soil conditioner which could jeopardize crop production. This is more critical in vegetable production in which the farmer incurs high costs to harvest acceptable yields in a zone with a small and erratic rainfall distribution. The BP may have potential for golf courses and landscaping at shopping centers or hotels. Landscape and turf areas are high value and long-term crops in which BP may be suitable as a soil conditioner. Another potential use is in sandy soils with a lower water holding capacity than Vertisols. Under those conditions BP may increase water retention, thus resulting in less need for irrigation.

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