Article

Effect of the application of Levasa (sugar cane must) on the production and quality of *Agave Tequilana* Weber

Jesús Manuel Arreola Tostado[1]
Víctor Manuel Montoya Jasso[2]
Jesús Manuel Arreola Nava[1]
Ximena Castillo Valdez[2]
Edgar Adrián Olivares Arreola[3]
Aurelio Báez Pérez[4§]

[1]Private agricultural consultant. Apaseo el grande no. 114, colony Guanajuato, Celaya, Guanajuato. CP. 38010. [2]*Campus* Montecillo-Postgraduate College. Mexico-Texcoco Highway km 36.5, Montecillo, Texcoco, State of Mexico, Mexico. CP. 56230. [3]Master's student at the National Technological Institute of Mexico. [4]Bajío Experimental Field-INIFAP. Highway Celaya-San Miguel de Allende km 6.5, Celaya, Guanajuato. CP. 38110.

[§]Corresponding author: baez.aurelio@inifap.gob.mx.

Abstract

The use of organic fertilizers in agricultural production is gaining importance today, given the need to improve soil fertility and make rational use of chemical fertilizers. The sugar cane must be a by-product generated from the industrial fermentation of the molasses obtained from the sugar cane (Levasa), to obtain and produce yeasts for baking. An experiment was established to evaluate the effect of Levasa application on the growth, production and quality of *Agave tequilana* Weber. Greater amount of Levaza can better development of the crop and increase production and quality of agave. Three increasing doses were evaluated: 5, 10 and 15 m^3 ha^{-1} and two controls: one without application of fertilizers and the other as the farmer does. The trial was evaluated using a randomized block design with four replications. An analysis of the main components was made. The experiment was established in April 2018, in a 6-year-old agave plantation, one year prior to harvest. Performance components, N, P, K content and Brix degrees were evaluated. The Levasa application promoted the development and nutrition of the *Agave tequilana* Weber crop. The best results were obtained with the application of 10 and 15 m^3 ha^{-1}, which was reflected in greater length of the leaf (129 cm), width (11.8 cm) and thickness (1.7 cm) of the same, diameter of cone (49 cm), plant height (191 cm), cone length (53 cm) and therefore higher yield of jima (253 t ha^{-1}) and percentage of degrees Brix (30), which implied a greater quantity of tequila with better quality. At the main components level, the most important variables were: jima yield, aerial dry weight, leaf thickness, cone diameter, plant height and cone length.

Keywords: *Agave tequilana* Weber., biofertilizer, organic agricultural production.

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Introduction

Tequila production in Mexico has become very important in recent decades. Of the 104 million liters that were produced in 1994 (Villa-Flores, 2009), currently more than 270 million liters are produced annually (Comité Nacional del Sistema Producto Agave Tequilana, 2018). Consumption has increased significantly, both in Mexico and abroad, which has resulted in a high demand for the raw material for its production, which is the *Agave tequilana* Weber Var. Azul.

Currently, in the Tequila Designation of Origin Zone, in municipalities of the states of Jalisco, Guanajuato, Michoacán, Nayarit and Tamaulipas, there is a cultivated area of more than 60 000 ha, with more than 120 million agave plants and it is sought new areas for its cultivation, which must meet favorable characteristics for the development of the plant for the production of good quality tequila for the industry (Consejo Regulador del Tequila, 2019).

According to figures estimated by the National Committee of the Agave Tequilana Product System, AC (2018), 271 million liters of tequila are produced in Mexico annually, so 80 million cones are required, of which 50 are distributed million for the production of tequila, 12 million for inulin and agave syrup and it is estimated that 12 million are lost due to accidents (fires, pests, floods and diseases).

Agave adapts to semi-arid and sub-humid regions, with most of the year having sunny days, and it shows little tolerance to low temperatures, especially at night (Ruiz-Corral, 2007). It is preferably used in loam-clay or loam-sandy textured soils in areas with a high degree of slope. For the selection of areas to produce agave, the following main variables are examined: night temperature, probability of frost, altitude, soil slope and annual precipitation.

For the adequate production of the *Agave tequilana* Weber Var. Azul, proper nutrition of the crop is necessary, for which fertilization plays a very important role. Although this species adapts to grow in thin, not very fertile soils, its production is enhanced when optimal nutritional conditions are provided. The use of organic fertilizers, in addition to containing essential nutrients for crop growth, provides elements to improve soil fertility and increase organic soil reserves.

Among the great variety of organic fertilizers that are available in the market, the sugar cane must, which is obtained as a by-product of the industrial process in the production of yeasts for baking, has shown good results in the production of various crops; however, they are not reported; there is only information at the level of sugar cane residues (Chandra *et al*., 2008). The objective of the present study was to evaluate the effect of increasing doses of sugar cane must on the development, yield and quality of *Agave tequilana* Weber Var. Azul.

Materials and methods

The study was carried out in the municipality of Ciudad Manuel Doblado, Guanajuato, on the 'El Guayabo' ranch, in the community of Santa Rita (Figure 1). It is located at coordinates 20º 43 '49" north latitude and 101º 57 '12" west longitude, at an altitude of 1 725 m. The annual average temperature is 20.5 ºC, with a maximum temperature of 38.5 and a minimum of 2.6 ºC. The average pluvial precipitation is 787 mm (Figure 3). The type of climate is semi-warm (A) C (wo) (w) to (e) g with annual temperature between 18 and 22 ºC with warm summer, the warmest of the subhumid with rainfall in summer, with minimal winter precipitation (<5%); extreme, that is, the difference between the coldest and the hottest month is between 7 and 14 ºC and the march of the same is Ganges type (García, 1987).

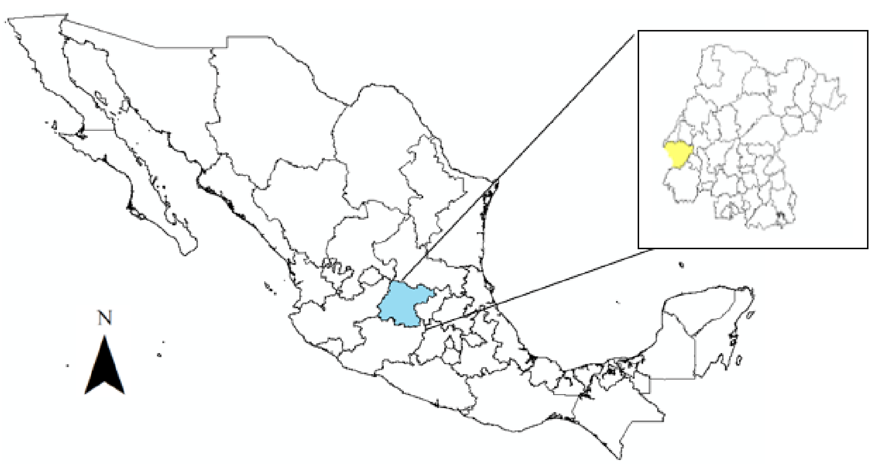

Figure 1. Geographical location of the municipality of Ciudad Manuel Doblado, Guanajuato, Mexico.

Description of the sugar cane must

Delevated sugar cane must (Levasa) (Jaramillo, 2019), is a fertilizer of organic origin, obtained as a by-product of the industrial fermentation of molasses, obtained from sugar cane, during the process of preparation of yeasts for alcohol production and baking. The process of obtaining this by-product, from sugar cane, is similar to that of vinasse (Lorenzo-Acosta *et al*., 2014). Sugar cane is a species commonly used for the production of yeast (*Saccharomyces cerevisiae*) (Suárez-Machin, 2016).

After the fermentation process, yeast is obtained, which is a living organism and, on the other hand, a residual organic material or unleavened must, which is the raw material for the manufacture of this organic fertilizer. Because a lot of water is used during the production process, the by-product is liquid and could be disposed of as waste water, so it could also be considered as a biosolid. Yeast production includes various processes, such as the preparation of molasses, fermentation, separation of yeast and drying. In various stages of the process and also for cleaning purposes, chemicals such as sulfuric acid, phosphoric acid, mono ammonium phosphate, ammonium hydroxide, caustic soda, sodium hypochlorite and salts are used.

Liquid residues with a high concentration of contaminating load are generated in the yeast separation process and in the vacuum rotary filter. The wastewater is treated and acids are removed by biochemical methods and aerobic and anaerobic processes (Jaramillo, 2019). In the end, liquid residues are obtained with little or no contaminant load. The liquid can also undergo a dehydration process and obtain a solid presentation. The basic composition of the sugar cane must is mainly made up of organic matter, nitrogen, phosphorus, potassium, calcium and magnesium (Table 1).

Table 1. Must composition of the sugar cane must based on its dry weight.

Element	Value	Units
pH (25 °C)	6.66	
Density	1.22	g ml^{-1}
Humidity	40	%
Dry material	60	%
Total nitrogen (N)	1.03	%
Potassium (K_2O)	6.92	%
Phosphorus (P_2O_5)	0.65	%
Calcium (Ca)	1.02	%
Magnesium (Mg)	0.784	%
Organic material	34.05	%
Dry material	48.1	%
Ashes	19.5	%

Soil edaphic characteristics

The physical and chemical characteristics of the soil where the test was established are presented respectively in Tables 2. The texture, based on the percentage of sand, silt and clay, was loamy-clay. The apparent density varied between 1.07 and 1.1, which indicated that there are no compaction problems. The usable humidity, based on the field capacity (55 and 57%) and the permanent wilting point (29%), was 27%. The saturation point is high, 75% on average. This indicates that the soil has a high moisture retention capacity, which is favorable for crops.

At the chemical characteristics level, the soil is moderately alkaline and the content of organic matter was low; however, the content of inorganic N ($N-NO_3 + N-H_4$) and extractable Olsen P are high, due to the fact that the crop would have been fertilized in the previous six years or due to residual content of these fertilizations prior to soil sampling. The K content is also high; however, this element is abundant in many soils in Mexico.

The Ca and Mg contents are extremely high; however, these elements are not harmful to agave cultivation, even if they are in excess. Due to the physiological and anatomical adaptations of this species, plants can proliferate in areas with little precipitation and soils with low fertility or salinity problems, as well as being highly tolerable to other elements considered as divalent metals (Cen *et al*., 2015). The Na content was low, which is a desirable condition for crops, because the excess of this element is harmful to crops. At the micronutrient level, Fe and Mn were found in high concentration, but Zn was not, as its content is deficient. Finally, Cu was found in a medium concentration.

Table 2. Physical-chemical characteristics of the soil.

Physical characteristics											
Sand	Silt	Clay	DA	CC	PMP	HA	Saturation				
	(%)		(g cm^{-3})			(%)					
24.5	41	34.5	1.09	56	29	27	75				
Chemical characteristics											
				Ammonium acetate 1 N pH 7.0				DTPA 0.005 M pH 7.3			
pH	MO (%)	NI	PE	K	Ca	Mg	Na	Fe	Zn	Mg	Cu
		($mg\ kg^{-1}$)									
7.64	1.46	66.6	41.3	3.4	4299	944.5	26	23.4	0.66	23.4	1.05

CC= field capacity; DA= bulk density; HA= usable humidity; MO= organic matter; NI= inorganic nitrogen ($N\text{-}NO_3$+$N\text{-}NH_4$); PE= Olsen extractable phosphorus; PMP= permanent wilting point.

Experiment description

Five treatments were evaluated: (1) control without application of fertilizers, (2) control with application of 300-160-700 kg ha^{-1} of N-P_2O_5-K_2O, (3) application of 5 m^3 ha^{-1} of Levasa, (4) application of 10 m^3 ha^{-1} of Levasa and (5) application of 15 m^3 ha^{-1} of Levasa. The treatments were established in beds with three rows of plants (9 m wide) by 72 m long; that is, about 648 m^2 of surface per repetition or block. The distance between plants was 1 m. The basic experimental unit included three rows or rows of plants and 12 m long (36 m^2), there were 36 plants per experimental unit. The four central plants of the central row (12 m^2), which corresponded to the sampling unit, were considered as a useful plot. The total experimental area was 2 592 m^2.

Statistical analysis

The experimental design was in complete random blocks with four repetitions, each block corresponding to one repetition. A principal component analysis was also performed. The data was analyzed using the Statistical Analysis Software (SAS) program. Possible significant statistical differences between treatments were detected by analysis of variance. The variables with statistical significance underwent a Tukey mean comparison test ($p< 0.05$), using the statistical package SAS 9.0 (SAS, 2002), as well as the principal component analysis.

Levasa application

The test was carried out under storm conditions. The application of Levaza in the field in three fractions, with intervals of one month: (1) during the rainy season, on July 30, 2018, 25% of the total was supplied; (2) on August 30, 50% of the total; and (3) October 1st, the remainder. The corresponding Levasa doses were applied manually in each agave plant. A 30 cm deep cavity was made, trying to cover 40 cm in length at the periphery of each agave plant, at a distance of 40 cm from them. Subsequently, the corresponding amount of the product was deposited with a jar in each treatment and the cavity was covered with soil. The application of the chemical fertilizer in the control treatment was done in the same way

Parameter evaluation

The evaluation period ranged from July 21, 2018 to April 5, 2019. The following parameters were evaluated:

Climatic. Data records of maximum, minimum temperatures and precipitation from the automated station El Vallado, located in Ciudad Manuel Doblado, near the study area, were considered. This station is part of the Guanajuato network of climatic stations (FGP, 2020).

Agronomic. Plant population, height, leaf length, maximum extended leaf diameter, leaf thickness, aboveground biomass, root biomass, cone diameter and length, and jima yield were evaluated.

Nutrition. In samples collected during this last parameter, the total N content was also evaluated using the Kjeldahl method, described by Jakson (1976), the total P content, with ammonium molybdate and titration, and total K by atomic absorption, after wet digestion (Jakson, 1976). Finally, the content of degrees Brix was evaluated, according to the method of Miller (1956).

Results and discussion

Rainfall temperatures and precipitation

The maximum and minimum temperatures and precipitation, which prevailed at the study site throughout the evaluation, from April 2018 to April 2019, are presented in Figure 2. The extreme minimum temperatures occurred in mid-December 2018, reached near -5 °C. On the other hand, extreme maximum temperatures occurred between the end of May and the beginning of June 2018, reaching up to 36.5 °C in the shade. The total rainfall volume during the study period was 586.6 mm. These were mostly concentrated in spring-summer 2018, while until April 2019 they barely added 4 mm.

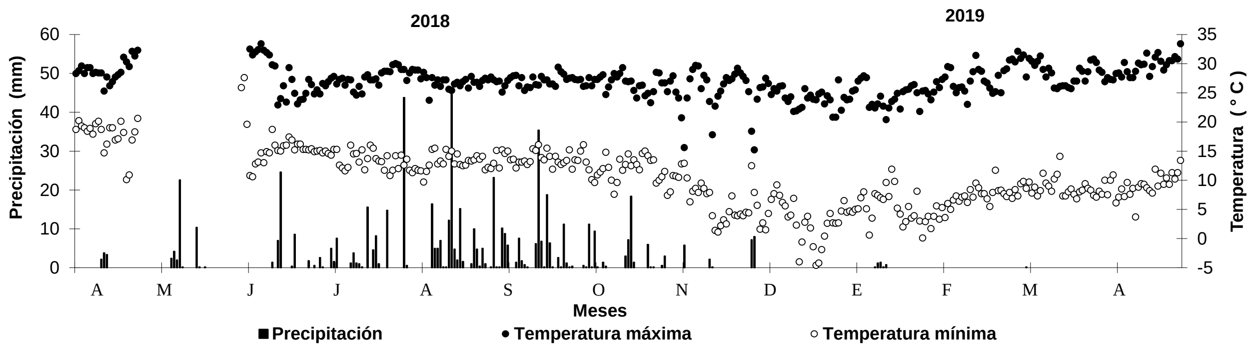

Figure 2. Maximum and minimum temperatures and daily precipitation from April 2018 to April 2019. Ciudad Manuel Doblado, Guanajuato.

At the level of average temperatures and monthly precipitation, it was observed that May 2018 was the hottest month, during the period of this study, with an average monthly temperature of 31.4 °C (Figure 3). In contrast, the coldest month was December 2018, at 13.6 °C. On the other hand, the rainiest month corresponded to August 2018, where 170.4 mm of precipitation fell; that is, 29% of the total.

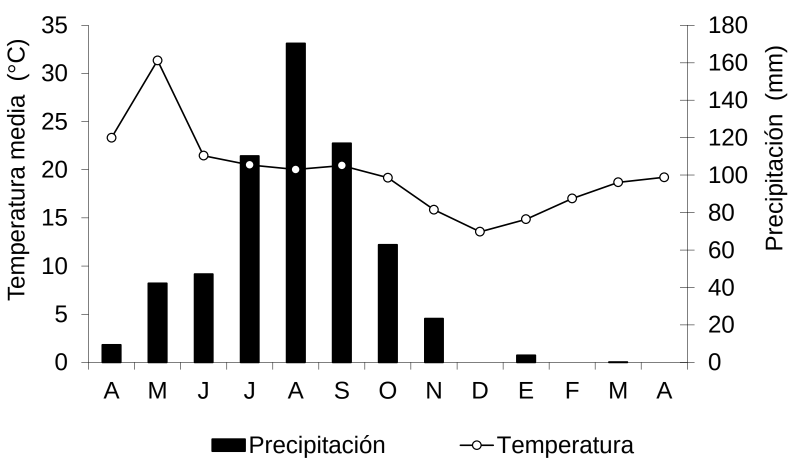

Figure 3. Ombrothermic diagram from April 2018 to April 2019. Cd. Manuel Doblado, Guanajuato.

The extreme temperature conditions and the distribution of the rains, which prevailed during the study period, are typical of the Bajío. The best temperature conditions for the development of the plant are 15 to 25 °C during the day and 10 to 15 °C at night. Extreme temperatures of -3 °C and greater than 35 °C negatively affect the development of the plant. Temperatures of -6 °C can be very detrimental to the development of young plants, they can even succumb to adult plants between 5 and 6 years old. According to Ruiz-Corral *et al*. (2002) the optimal and marginal thermal conditions for photosynthesis in the *Agave tequilana* Weber crop in the state of Jalisco, it increases with cool daytime average temperatures (22-25 °C) and nighttime temperatures (14-16 °C), but they decrease with warm average temperatures during the day (> 28 °C) and at night (> 20 °C). According to this information, the thermal conditions at the monthly average temperature level of the warmest month (August) were above the optimal level.

Agronomic parameters

The plant population fluctuated between 3 220 and 3 333 plants ha^{-1} (Table 3). In the reproductive phenological stage of the crop, the plants had an average height that varied between 125.6 and 141.6 cm. The lowest average was obtained in the control treatment without application of fertilizers (1), where 117.6 cm was recorded in the first evaluation and 125.6 cm in the last evaluation; that is, a growth rate of 0.8 cm per month (Figure 4). With the application of 10 and 15 m^3 ha^{-1} of sugar cane yeast must in treatments 4 and 5, the highest plant height and a growth rate of 2.8 and 3.2 cm month^{-1}, respectively, were obtained.

Table 3. Results of evaluation parameters of *Agave tequilana* Weber, Azul variety.

Treat	Num. plants	Height plant	Leng. leaf	Width leaf	Thickness leaf	Num. leaves	Leng. cone	Diameter cone	Dry weight aerial	Dry weight root	Weight jima
		(cm)							(t ha^{-1})		
1	3320 a*	125.6 b	102.2 b	10.7 a	1.3 b	36.3 a	29.1 b	26.9 b	184.1 a	24.4 a	123.8 c
2	3320 a	133.2b a	110.9 ba	10.8 a	1.6 a	48.5 a	47.4 a	44.4 a	323.9 a	29.6 a	217.8 ab
3	3320 a	136.8b a	110.6 ba	11.3 a	1.6 a	48.3 a	48.8 a	44.1 a	346.6 a	31.4 a	214.6 b
4	3333 a	141.6 a	127 a	11.7 a	1.7 a	51.5 a	52.4 a	48.7 a	436.9 a	31.3 a	234.4 ab
5	3333 a	141.6 a	129.2 a	11.8 a	1.7 a	48.5 a	52.8 a	49.2 a	443.7 a	35.3 a	252.8 a
DMS	32.09	13.45	20.55	1.31	0.22	22.86	8.61	9.43	269.35	23.66	37.6
VE (%)	0.43	4.39	7.86	5.17	6.26	21.76	8.29	9.81	34.44	34.52	7.99

DMS= minimum significant difference; VE= experimental variation; *= equal letters are statistically similar (p< 0.05).

The plant height of the *Agave tequilana* Weber Azul variety, with designation of origin, according to reported results Zúñiga-Estrada *et al*. (2018), can vary between 130 and 160 cm in height, who obtained larger plants with fertigation production systems. This behavior, in the evaluated treatments, was observed in all agronomic parameters. The lowest leaf length averages were obtained in the control treatment without fertilizer application (1), where 92.1 cm was recorded at the start of the study and 102.2 cm in the last stage; that is, a growth rate of 1.18 cm per month. The treatments corresponding to the control with chemical fertilizer (2) and the increasing doses of the sugar cane yeast must (treatments 3 to 5) were similar to each other (p< 0.05). However, with the application of 10 and 15 m^3 ha^{-1} of this product, in treatments 4 and 5, it was where the greatest leaf length was obtained, with 127 and 129.2 cm, respectively, and a growth rate of 4.3 and 4.62 cm per month.

According to Saldaña-Robles *et al*. (2012) the leaf length of the *Agave tequilana*, in the reproductive stage (7 to 8 years old) can reach more than 1.1 m. At the leaf thickness level, the treatments corresponding to the control, with chemical fertilizer (2) and the increasing doses of the sugar cane must (treatments 3 to 5) were similar to each other (p< 0.05). However, with the application of 10 and 15 m^3 ha^{-1} of this product, in treatments 4 and 5, it was where the greatest thickness of the leaf was obtained, with 1.7 cm and a growth rate of 0.06 and 0.07 cm per month. It was observed that as the dose of sugar cane must increase, the growth rate in the thickness of the leaves of the agaves evaluated increased (R^2= 0.97). According to Saldaña-Robles *et al*. (2012) the leaf thickness of the *Agave tequilana*, in the reproductive stage can vary between 2 and 4 cm.

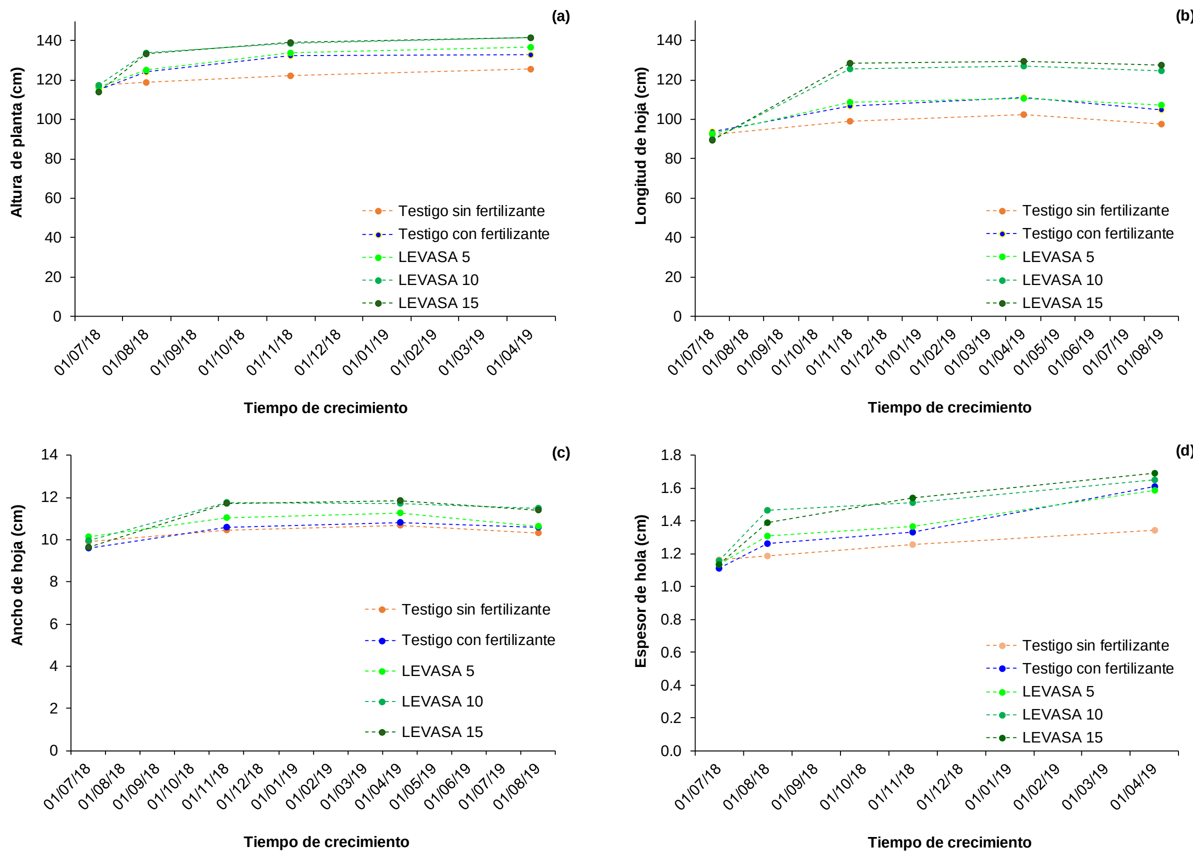

Figure 4. Crop development in evaluation period. (a) plant height; (b) leaf length; (c) leaf width; and (d) leaf thickness.

The agronomic values obtained in the different parameters that were evaluated in this study, according to Saldaña-Robles (2012), are adequate to implement mechanized harvesting. The dimensions and weights determined in the agave plants, as well as each one of its elements present a certain variability that is due to the factors of development of each plant and its interaction with the edaphic and climatic conditions; however, characteristic for a 7 to 8 year old agave plantation.

The production of jima, the most relevant parameter, showed significant statistical differences ($p<$ 0.05) due to the effect of the treatments. The treatment corresponding to the chemical control and the treatments with increasing doses of the sugar cane yeast must were statistically similar ($p<$ 0.05). However, with the application of 15 m^3 ha^{-1} of sugar cane must, a yield of 192.3 t ha^{-1} was achieved, which was 20% more than the yield obtained by the chemical control (1) (154.4 t ha^{-1}) and 59% higher than the control without fertilizer application (79.3 t ha^{-1}).

According to Zúñiga-Estrada *et al*. (2018) for the period 2006-2015, in the state of Jalisco, the average production of agave was 100.1 t ha^{-1}, the results obtained show that the nutritional contribution and the fractionation of the applications made with the yeast must from sugar cane exceed, in almost 100%, the average yields with the application of Levasa in doses of 15 m^3 ha^{-1}.

N, P and K content

The nitrogen content N, P and foliar K showed significant differences ($p< 0.05$) due to the effect of the treatments (Table 4). The lowest value of N was obtained in the treatment where there was no application of fertilizer (1). In this treatment, a content of 60.6 ppm of this element and 100 ppm at the end of the study was estimated at the beginning of the study, with an accumulation rate of 4.56 ppm per month, in the study evaluation period.

Table 4. Content of N, P, K and ºBrix in study of *Agave tequilana* Weber, Azul variety.

Treatment	N	P	K	ºBrix
		(%)		
1	99.9 b*	0.14 b	0.65 c	27.3 b
2	212.3 a	0.25 a	1.59 ba	28.2 a
3	201.5 a	0.23 a	1.27 ba	27.4 a
4	222.4 a	0.25 a	1.51 b	29.2 a
5	209.5 a	0.27 a	1.89 a	30.2 a
DMS	56.63	0.75	0.57	2.81
VE (%)	13.12	14.61	17.95	4.39

DMS= minimum significant difference; VE= experimental variation; *= equal letters are statistically similar ($p< 0.05$).

The treatments corresponding to the control with chemical fertilizer (2) and the increasing doses of sugar cane must (treatments 3, 4 and 5) were statistically similar to each other ($p< 0.05$). However, with the application of 10 and 15 m^3 ha^{-1} of this product (4 and 5) it was where the highest numerical value was observed in the content of N in leaves, with 170.3 and 157.6 ppm, respectively, and an accumulation rate of 19.8 and 18.32 ppm of N per month. According to the nutritional sufficiency ranges established by Uvalle-Bueno and Velez-Gutiérrez (1987), the content of N in leaves in *Agave tequilana* Weber Var. Azul can vary in a range of 62.5 ppm, which is a poor level, to 500 ppm, which is an excessive level.

Finally, it was observed that as the dose of sugar cane must increase, the content of leaf N also increased (R^2= 0.38). This value implies an r= 0.62; that is, the degree of association of both variables was 62%, with an adjustment to a logarithmic model. The so abrupt variations that are observed in the different evaluations are due, on the one hand, to the nitrogen applications that were carried out, by means of the evaluated fertilizers and, on the other hand, to the availability that was in the soil solution after the start of the rainy season. When there is moisture in the soil, there is more metabolic activity in the plant, than when it is dry season (Nobel and Valenzuela, 1987; Nobel *et al*., 1988). The behavior in the foliar P content was similar to that explained in the N content.

According to Uvalle-Bueno and Velez-Gutiérrez (1987) the content of P in leaves in *Agave tequilana* A. Weber Var. Azul fluctuates in a range of 0.08 ppm, which is a poor level, to 0.6 ppm, which is an excessive level. Based on this range, it was observed that during the first evaluation (07-21-2018), the content of this element in the leaves varied between 0.12 and 0.14

ppm; that is, deficient for the second evaluation (08-22-2018) and at the end of the study the ranges were between 0.14 and 0.27 ppm; that is, from low to sufficient. The foliar potassium (K) content also showed significant statistical differences ($p < 0.05$) due to the effect of the treatments.

According to Uvalle-Bueno and Velez-Gutiérrez (1987), the foliar K content in *Agave tequilana* ranges from a range of 0.75 ppm, which is a poor level, to 6 ppm, which is an excessive level. Based on the above, during the first evaluation the content of this element fluctuated between 0.65 and 0.73 ppm, it is deficient; however, at the end of the study the values fluctuated between 0.65 and 1.87 ppm, that is, from poor to moderately low.

According to Zuñiga-Estrada (2013) the accumulation of N, P and K absorbed by the plant accumulates mostly in the leaves. He estimated that at the end of the crop cycle, the dry matter corresponding to these stores 65.9, 82.4 and 71.9%, respectively.

Brix degrees

This parameter showed significant statistical differences ($p < 0.05$) due to the effect of the treatments. The lowest averages were obtained in the control without the application of fertilizer (T1) and in the treatment with the application of 5 m^3 ha^{-1} of sugar cane must, with 27.3 and 27.4% of total sugars reduced, respectively (Figure 27). The values that were in the treatments with 10 and 15 m^3 ha^{-1} of the product (T4 and T5) were slightly higher with respect to the other treatments.

According to Latsague *et al*., (2014), the sugar content increases when fertilization is higher, mainly due to the effect of potassium disposal. Based on the above and considering that the content of this element in sugar cane must is 6.92%, the higher production of sugars was closely related to the increasing doses in the application of this product ($R^2 = 0.815$).

Similarly, the length of the leaves was favorable ($R^2 = 0.942$) for the increase in sugars due to the age of the plant and the management of pruning, which caused the movement of water, nutrients, sugars and carbohydrates towards the cone, causing increases in its content. The above agrees with results reported by Escamilla-Treviño (2012); Zúñiga-Estrada *et al*. (2018).

Principal component analysis

The analysis of yield of jima, of the five treatments, at the level of main components, is presented in Table 5. It was observed that the main component one explained 86.66% of all the variance of the experiment, while the main component two explained 8.9 % of the remaining variance, that is, this analysis explains 95.56% of the total variation of the experiment, due to all the variables evaluated. In the first main component, the most important original variables were: jima yield, aerial dry weight, leaf thickness, cone diameter, plant height and cone length. In the second main component, the most important variables were population, reduced total sugars, leaf nitrogen, and number of leaves. The importance of each main component is reflected in the characteristic value of each one of them

Table 5. Characteristic vectors and variance explained by the first two main components in the study of *Agave tequilana*.

Variables	Characteristic vectors	
	CP1	CP2
Health	0.211545	0.536823
Plant height	0.270935	0.070858
Leaf length	0.256032	0.32402
Leaf width	0.24143	0.331228
Leaf thickness	0.272087	-0.154829
Number of leaf	0.254053	-0.300625
Foliar nitrogen	0.251372	-0.298774
Foliar phosphorus	0.26526	-0.210221
Foliar potassium	0.25892	-0.104421
Cone length	0.270005	-0.18945
Cone diameter	0.271788	-0.171011
Aerial dry weight	0.273871	0.010465
Root dry weight	0.262288	0.005944
Yield	0.275654	-0.067312
Brix	0.228652	0.404447
Characteristic value	12.9995	11.6647
Variance (%)	86.66	8.9

Figure 5 shows the dispersion of treatments based on the most important variables. It was observed that the treatments with the highest application dose of sugar cane must (10 and 15 m^3 ha^{-1}) were those that had the highest yield of jima, aerial dry weight, leaf thickness, cone diameter, plant height and cone length. The absolute control, without fertilizer application, was always the one with the lowest values in all the parameters evaluated. The control treatment, with the application of chemical fertilizer, and the treated with the application of 5 m^3 ha^{-1} of sugar cane must, represent a group that, although they have an average production of jima, have a lower content of degrees Brix with respect to treatments 5 and 6.

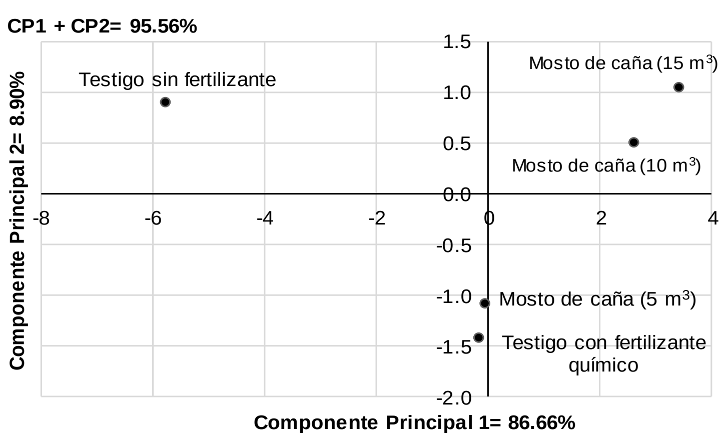

Figure 5. Principal component analysis, dispersion of treatments.

In the abscissa axis (CP1) it was observed that the treatment that gave rise to the highest yield was the application of the highest dose of sugar cane must, which presented the highest values in all the parameters evaluated. Regarding the ordinate axis, it was observed that the lowest parameters were obtained in the absolute control, without the application of fertilizers.

Conclusions

The application of sugar cane must promote the development, production and organic nutrition of the *Agave tequilana* A. Weber Var. Azul. The best results were obtained with the application of 10 and 15 m^3 ha^{-1}, which was reflected at the level of development of the crop in plant height, length, width and thickness of leaves, in terms of yield in a greater length and diameter cone and jima production and higher sugar content. Likewise, the organic nutrition in the plants of *Agave tequilana* A. Weber Var. Azul, with the application of 15 m^3 ha^{-1} of Levasa allowed to have an assimilation of phosphorus and potassium, 10 and 5% higher than the chemical and absolute fertilization controls, respectively.

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