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Effect of population density on growth and yield of aloe (*Aloe barbadensis* M.)

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Abstract

The objective of this study was to measure the effect on aloe (*Aloe barbadensis* M.) yield, of 16 different rows plantation, which were increased in constant intervals of 0.08 m from 0.40m to 1.60m. The distance for all plants were of 0.40m for all treatments. The field work was carried out at San Juan de Lagunillas Experimental Station, state of Mérida, Venezuela, on a Typical Cambortid sandy-clay-loam Soil, using a wagon wheel design with four replications. The number of leaves per plant, leaf dimensions (long, broad and thickness) and the leaf production of raw gel and acíbar (resinous latex-aloina-) were not influenced by the treatments. The number of suckers per plant was higher with greater row spacing, whereas gel and resinous latex yields were significantly higher with the least row spacing used.
Key words: *Aloe barbadensis*, row spacings, vegetative growth, production, yield.

Introduction

The vegetal specie known in Spanish as zábila, zabira, zabida, pita-zábila, in Portuguese as aloes, erva, babosa, azebre vegetal, in French as aloes, and in Italian, English and German as aloe, is a perennial plant native from the south of Africa, and nowadays sow in several tropical and sub-tropical countries. According to the Botanical taxonomy, aloe is considered inside the spermatophyte division, Lliidae type, Liliales order, Aloeaceae family, Aloe genus, Aloe Vera specie (L.) Burm.f. or *Aloe barbadensis Miller* (4, 5).

Aloe, monocotyledon plant, which name is an attribute to a deformation of the Arabian term çabila that means thorny plan, is cultivated by the thick and beefy leaves from which is obtained a gelatinous substance (gel), which has positive effect on different types of illnesses of skin, stomach, and a resinous latex (acíbar), that leaves exudates when are cut, and have an oily liquid (aloina) used as laxative. The

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specie has been used by humans from ancient times as 6.000 years b.c, being the Chinese the first using it. Alejandro "Magno" (356-323, b.c) conquered the Socotora island, in the south of Arabia, because in this island was a huge quantity of aloe, employed to treat wounds and illnesses of soldiers. On the antique Egypt the use was very common, Cleopatra VII (69-30, b.c), used aloe as an essential ingredient in her daily beauty treatments. In the first century of the Christian age, Dioscorides described aloe in his Greek herbalist, and highlighted the medicinal and cosmetics importance of the plant. Spanish, who knew the curatives properties brought aloe to the American Continent (5, 6).

Traditionally, aloe has been sowed in relatively big quantities in El Cabo (South Africa) and in some Caribbean islands (Barbados, Puerto Rico, Cuba, Dominican Republic-Haiti, Netherlands islands- Aruba, Bonaire, Curazao). Since 1930 the medical and cosmetic industry of the United States and Europe were interested in this plant, which stimulated the establishment of plantations in Mexico, Texas, Dominican Republic, Haiti and Namibia. In Aruba, is exploited from the beginnings of XIX century, and around 1920 had more than 6.000 hectares and produced more than 50% of the commercialized aloina in the world. In Venezuela, the commercial exploitation began in 1934, on the Peninsula and coasted region on Falcon state (5, 6, 10).

The genus name aloe, seems to come from the Arabian term alloeh or from Hebrew hallal; both terms mean shiny and bitter substance. There are around 200 species of the Aloe genus, but only 12 have acíbar, which active ingredient is aloina. Three of them are commercially important: *Aloe ferox, Aloe perryi* and *Aloe barbadensis*.

Aloe feroz (Aloe from Cabo) with 4.5 to 9.0 of aloina, Aloe peri (sucotrino Aloe, Socotora Aloe) with 5.5 to 10.0 of aloina, and barbadensis (Aloe Vera, Curazao Aloe) with an aloina content from 20 to 24%, is the most common in Venezuela.

Authors will try to do a trustable description of *Aloe barbadensis* by the importance in Venezuela of this plant. This is a monocotyledon specie, of a preferable asexual reproduction (multiplication), it can measure from 0.5 to 0.6 m height with a canopy of even 1.0 m, depending on the conditions where it grows (Contreras, 1990). It is an acaulous or almost acaulous plant with a small and thick stem (maximum of 10 cm), from where emerges a basal rosette of 13 to 25 simple, triangle, juicy, thick, wide-lanceolated with mucronated edges from 30 to 60 cm long, with a wide on the inferior part of 5 to 8 cm, and from 0,8 to 3.0 thick, which depends on humidity conditions. Leaves margins have triangle, sharp and spinulose teeth with an average of 2mm and of 8 to 10mm of separation between each. The color of the leave varies from dull greenish-yellow, green, to brown, and when are young have colourless marks of approximately 4 mm of diameter. The radical system, consist on a main root that varies from 5 to 10 cm long, and from 4 to 5 cm diameter. The main root has from 5 to 15 secondary roots of 5 to 7mm thick with almost 80 cm long and from these originate third roots with a longitude of almost 5cm. Normally, most part of the radical system is on the first 15 cm of the soil profile.

Flowers have a longitude from 2.5 to 3.0 cm, are yellow and are gathered on simple and compound bunches on a stand peduncle of approximately 1.0m height. Flowers are homogamous (hermaphrodite-allogamous); the floral verticil are tetramerous, the calyx as the corolla have three coloured pieces. The gynoecium is formed by three carpel with a superior ovary of three lobules. There are six stamens with long filaments that begin form the bottom of the flower, under the pistil. The fruit is dry, capsular, and extended of dehiscent walls, it means, the fruit pyrene opens and allows to take away a variety of very small hybrids (5, 6, 11).

If the weather and soil characteristics of Venezuela are considered, is noticed that aloe can be successfully sow in several ecologic areas of the country, specially in those with limits of Tropical Dry Forest and of the Very Dry Tropical Forest, which cover more than 40% of the national territory (around 370.000 Km^2 surface), from the sea level to 1.000 msnm, with annual means precipitations from 500 to 1.800 mm and average temperatures from 22 to 29ºC.

Aloe adapts pretty good to arid and semi-arid conditions, and this crop has grown and has become popular on the national and international merchandise due to the cosmetic properties of the gel or pulp of the leaves, and the latex of these, with pharmacologist purpose. This specie, with African origin, appears as an attractive option for the rural area of regions, with the already mentioned edaphoclimatic conditions, by the wide ranging, easy dissemination and handling functions.

In San Juan de Lagunillas and nearby parishes (Mérida state), exist areas with very convenient characteristics for the commercial exploitation of aloe. This, among an inexistent investigation of this crop, motivated the authors to make some research in order to obtain information about this specie.

Is here where the study of plant's population is almost imperative, by the influence that this plants have on growing, production and biological proficiency of crops; and specially, by the incidence on the economical proficiency (commercial product) with quality attributes, to which are satisfied the buyers necessities (3).

There are lots of factors that influence the crop's production. Therefore, when is going to decide the sow's distance to be employed, must be considered the radical space, and the forage size, also considering the variety, the productive potential by plant and the weather and soil conditions of the place of exploitation. However, in this matter, the emphasis will be on the intraspecific competence. This is the process where two or more plants that grow together, fight part of an unavailable environmental factor in enough quantities to adequately supply the necessities of the involved plants (2).

The plantation distances used by the aloe producers, reported on the literature, are very variable: 0.50 m, 0.65 m, 0.70, 0.80 m until 1.0 between rows, and 0.31 m, 0.35 m, 0.40 m, 0.50 m, 0.55 m, 0.8 m and 1.0 between plants (5, 6, 8).

Contreras (4) said that the most used plantation's density in Venezuela is the one of 10.000 plants.ha^{-1} (1.0 m between rows x 1.0 m between plants) because a higher density seems to affect the general growth of plants, and difficult the collection of fleshy leaves. Enough reason to avoid recommendations that surpass 20.000 plantas.ha^{-1}.

Henderson *et al.*, (7) indicated that for the adequate handling of any crop, from which does not exist much information, a total look and precision of the optimum space between rows, and the plant's response to the crop densities are essential to obtain maximum proficiencies. Optimum distances between rows for a maximum production of aloe, are not very known in this region, or at least do not appeared on ended research. In this situation, it is desirable to use tools as "consecutive distances", which allows to prove on a small plot, a high number of distance between rows, without too much effort and without validity detriment of the obtained results.

The design allows to increase distances constantly and consecutively, from a "minimum" limit until a "maximum" limit previously fixed, trying that those limits be always lower and higher, respectively, than those that were expected of the expression of the morphological characteristics and the ontogeny of the specie to be tested. If this works, it would then be logic to suppose that on the minimum and maximum extremes must be the optimum distance for the maximum proficiency of the tested crop, under the weather and soil conditions of the place where takes place the research (1).

The scarce information about aloe makes it necessary the execution of an integral research program of the crop, which is initiated on this research, which objective was to determine distances of commercial plantation of aloe in San Juan de Lagunillas, estado Mérida.

Materials and method

The field labour were made for almost two years, on the experimental station of I.I.A.P., in San Juan de Lagunillas, Mérida state, Venezuela (08º31' N, 71º21' W), altitude of 1110 msnm, average annual precipitation of 500 mm, annual mean temperature 22ºC. located on an area described as Bswh weather; way of life; Sub-tropical Premontano Dry Forest; horticulture vegetation on irrigation; soil Cambortid typic type, fine loamy, isothermal (9).

To a compound sample of soil (0.0-0.20 m depth) was done a routine analysis on the soil and agriculture chemical laboratory of IIAP-ULA (table 1).

For the essay was used the design known by English people as "Systematic fan design", and by Americans as "Wagon wheel", which was adapted for the operational conditions by Añez (1983-1985), who named it as “Consecutive distances”. A complete circle was used; in a way that every square represented a replication and distances between rows were formed by concentric circumferences lanes (figure 1) with the following characteristics:

Range of the highest circumference (R)= 8.00m

Range of the lowest circumference (r)= 2.00m

Sowed space (R-r) = 6.00m

Highest distance between rows (L) = 1.60m

Lowest distance between rows (l) = 0.40 m

Distance between plants (d) = 0.40m

Distance variation between rows every 0.40m (re) = 0.08m

Treatments and plantation distances between rows in number 16, increased 0.08m every 0.40m, from a lower distance of 0.40m until a higher distance of 1.60m (figure 1(b), table 2).

Number of plants per row on each square = 31.416/4 = 7.854.

Total number of plants to establish the essay, including the internal and external borders was of 504.

The soil preparation was done with a tractor, ploughing the land, and was conditioned with a hoe. The plantation was done on 20-05-99, with asexual seed (sons) of aloe, of approximately 20 cm long, obtained in nearby towns of San Juan de Lagunillas, from plantations without any type of technical assistance.

On 30-11-99 desuckering were cut, and on 01-12-99 the fertilization with 40 $Kg.ha^{-1}$ of the 15-15-15 formula was done. For this purpose, around each plant was supplied the fertilizer quantity in proportion of the area they occupied, according to the design of the essay. The manuring operation served to earth up all the plantation.

During the essay’s development, every time that was considered necessary a weeds’ control with a hoe was done, an irrigation by gravity was used to accomplishes the rainy contribution, and supply the hydric requirements of aloe.

The information of the evaluated variables were taken from the three central plants of each treatment. On 30-05-2000 were registered: leaf dimension in cm (total longitude, wide and thickness), leaf Nº 3 was measured, counted from the newest visible leaf. Wide and thickness were determined with vernier in 10 cm of the leaf insertion on the pot; total number of leaves by plant, this information was counted every month from 30-05-2000 to 06-09-2000, and allowed to precise the emission estimate of leaves on this time.

On 21-11-2000, was written the number of sons by plant; fresh weight in g of the gel or parenchyma of the leaf,

Table 1. Soil analysis of the place under research

Type of Texture	PH 1:2	C.O. %	N. Total %	P.Olsen (ppm)	K.Aprov. meq.100g	Mg.Aprov. meq.100g	Ca. Aprov. meq.100g
FAa	7,5	1,35	0,17	4	0,39	1,7	12,10

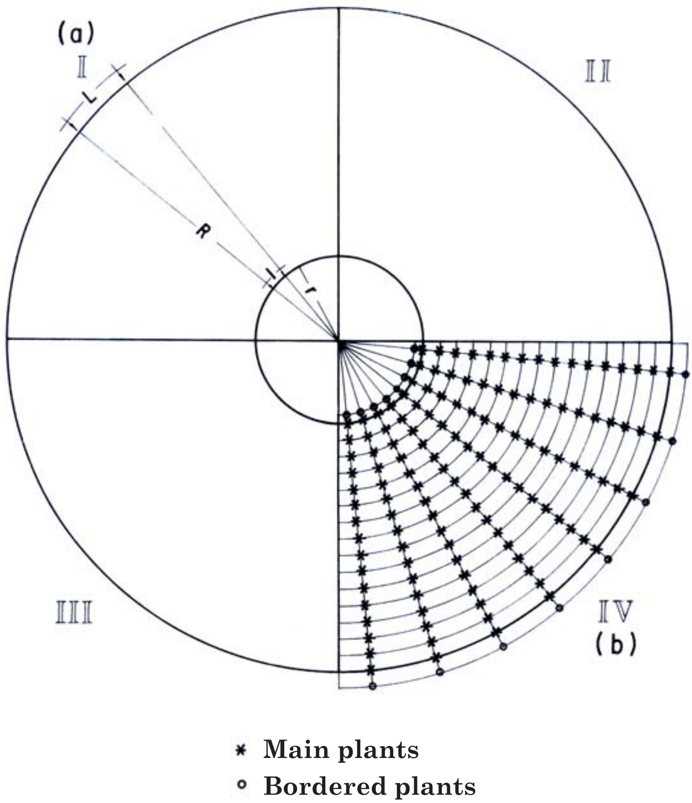

Figure 1. Design characteristics of consecutives distances. (a) Radius relation and higher-lower distances; R/r=L/l (b) Division in fan-shaped with the plantation distances between rows I, II, III, IV. (replications)

an average of 9 by treatment (3ª, 4ª, and 5ª youngest leaves by plant). In order to obtain this, the chlorenchyma parenchyma tissue of the leaf was eliminated with a knife, and weight in g of the fresh acíbar, for this, the latex coming from the overflow of the harvested leaves was taken on a glass container, using a funnel (treatment 9), this operation took around 30 minutes.

On 22-01-2000, the average weight of a completed plant was registered; from the superior part and from the radical system.

Leaf dimension in cm, production in g by plant of gel and fresh acíbar, and proficiency in $t.ha^{-1}$ of gel and fresh acíbar, were statistically analyzed in their original values; in a way that the leaves number and sons by plant were transformed in $X^{1/2}$ values, to avoid that means and variances tend to be the same and would follow the Poisson distribution (12). Merry Christmas

Table 2. Plantation distances between rows, and area by plant of each treatment, of the aloe sow in San Juan de Lagunillas, Mérida state.

Position	Distance	Area
1	0.40 m	0.160 m^2
2	0.48 m	0.192 m^2
3	0.56 m	0.224 m^2
4	0.64 m	0.256 m^2
5	0.72 m	0.288 m^2
6	0.80 m	0.320 m^2
7	0.88 m	0.352 m^2
8	0.96 m	0.384 m^2
9	1.04 m	0.416 m^2
10	1.12 m	0.448 m^2
11	1.20 m	0.480 m^2
12	1.28 m	0.512 m^2
13	1.36 m	0.544 m^2
14	1.44 m	0.576 m^2
15	1.52 m	0.608 m^2
16	1.60 m	0.640 m^2

Every replication was sowed with 112 plants; seven by every distance between rows and by replication, measured of the following way:
P = 2pR (perimeter of the highest circumference).
L = 1.60 m (highest distance between rows)
N = Plants number of range circumference higher –8.0m
N = P/L = 2pR/L = 2 x 3.1416 x 8/1.60 = 50.2656/1.60 = 31.416 plantas

Results and discussion

Vegetative characteristics

The leaves number by plant, leaf dimensions (length, wide and thickness), which average values were: 19.29; 22.53cm; 3.27cm and 1.26cm; respectively, did not showed significant differences between treatments.

The foliar emission, measured from 375 days after the plantation, by a period of 99 days, was of 1.7 leaves by each 30 days.

The sons' number by plant, registered 18 months after the plantation and few less of 12 months after the first desuckering, was significantly affected by distances between employed rows (table 3).

As was expected, there was an almost perfect link between the climatic requirements of aloe and the predominant ecological conditions in San Juan de Lagunillas.

The vegetative growth mostly expressed by the leaves number by plant, and by leaves dimensions (length, wide and thickness) was not influenced by the plantation distances between rows. Meanwhile, the sons number by plant, was significantly affected by the used distances. In general terms, the sons' number by plant increased with the distance increments between rows, circumstance that could need additional manpower for desuckering.

Production and yield by leaf, gel and fresh acíbar (humid base), with averages of 252.28g and 23.08g respectively, were not significantly influenced by treatments.

Yields in $t.ha^{-1}$ of gel and raw acíbar (humid base), revealed significant differences between the tested treatments. Regression allowed to determine the provoked variation in yields by every change unit occurred on the plantation distances between rows (figures 2 and 3).

Since production by gel leaf and raw acíbar, did not show significant differences between the employed plantation distances, yields were directly affected by the increment of plants population by surface unit, which in this case, means the distance reduction of plantation between rows.

On the botanic aspect, the specie did not have growth or production restrictions with lower plantation distances used on this research, o.40 m between rows x 0.40 m between plants (62.500 $plants.ha^{-1}$), contradicting Contreras (1990) who said that the optimum density could be of 18.182 $plants.ha^{-1}$ (1.00 m x 0.55 m) and that a higher density seems to affect the general growth of plants, and difficult the collection labours of fleshy leaves, enough reason for not recommending more than 20.000 $plants.ha^{-1}$.

Table 3. Mean values of the number of sons by aloe plant on different plantation distances between rows.

Distance	16	11	12	10	14	15	8	9	13	6	3	7	5	4	2	1
m	1,60	1,20	1,28	1,12	1,44	1,52	0,96	1,04	1,36	0,80	0,56	0,88	0,72	0,64	0,48	0,40
Means	26,75	21,09	21,04	20,41	20,29	20,09	19,38	19,36	18,81	18,66	16,56	15,78	15,09	14,61	14,01	11,70
Identification	a	ab	ab	abc	abc	abc	bc	Bc	bc	bc	bcd	bcd	bcd	cd	cd	d

Means identified with the same letter are not significantly different to the 5% level, according to the new multiple range test of Duncan (12).

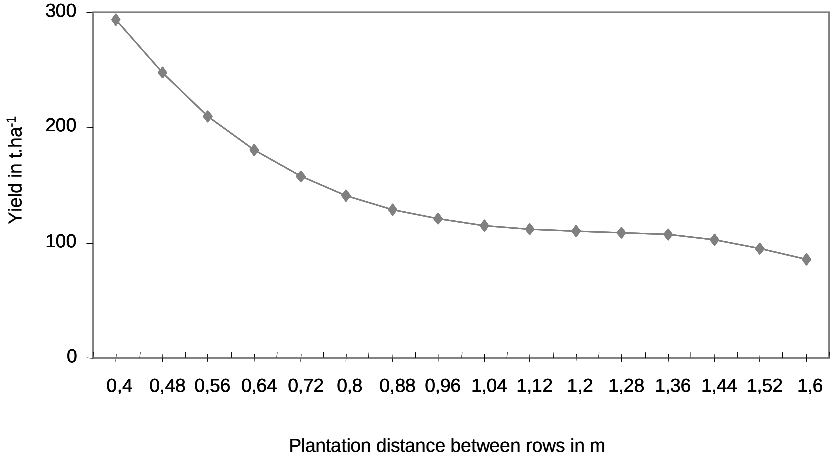

Figure 2. Relation between gel's yield (humid base) of the total of leaves, and plantation distances between rows of aloe plants in San Juan de Lagunillas (Mérida, Venezuela). The fix curve. $Y= 691.48 - 1399X + 1137.5X^2 - 312.5X^3$, $R^2 = 0.9021$

The few available information about aloe among to the high obtained yields on a healthy population (without pest or illnesses problems), motivated the authors to continue investigating about sowing in general, but specially, about which must be the optimum plantation density to obtain a maximum yield, without obstacles for the sow and harvest labour.

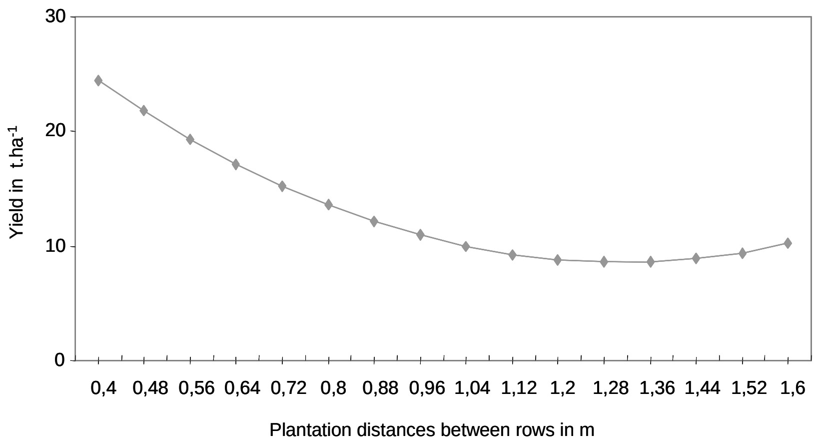

Figure 3. Relation between fresh acíbar yield (humid base) of the total of leaves, and plantation distances between rows of aloe plants in San Juan de Lagunillas (Mérida, Venezuela). The fix curve. $Y= 41.56 - 50.40X + 19.25X^2$, $R^2=0.9878$

Conclusions

From the obtained results on the conditions and limitations of the research, can be concluded:

The leaves' number by plant and leaves' dimension (length, wide and thickness) did not correspond to the plantation distances between rows.

Sons' number by plant increased with the distance increment between employed rows.

The production by gel or acíbar leaf was not affected by distances between rows.

In general terms, gel and acíbar yield increased when reduced plantation distances between rows.

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