Morphological Development of Agave Under Different Planting Layouts

Walleska P. Medeiros de Oliveira[1]*, Emily dos Santos Cunha[1], Marcos de Souza Rodrigues[1], Danilo Jefferson Romero[1], Matheus Martins Teixeira Cota[2]

[1]SENAI CIMATEC, Agroindustry; [2]SENAI CIMATEC, Environmental Area, Salvador, Bahia, Brasil

Agave is a perennial xerophytic plant with CAM metabolism, adapted to arid and semiarid regions. This species represents a promising option for the utilization of Brazil's northeastern semiarid, a region scarcely explored for cultivation due to adverse edaphoclimatic conditions. Despite the widespread ornamental use of agaves and succulents, little is known about seedling production characteristics, especially regarding nutrition in the early months of establishment. Therefore, this study aimed to plant Agave seedlings from suckers and bulbils. The field experiment was conducted in Conceição do Coité - BA, in a 255 m² experimental area arranged in a randomized block design (9 × 4), using *Agave sisalana* seedlings from suckers and bulbils, as well as hybrid 11648 seedlings from bulbils measuring 30 cm in length. Results showed that proper management, including fertilization and irrigation, is essential for Agave development. Bulbils demonstrated greater vigor and morphological performance, with a possible growth peak observed at 270 days after planting.

Keywords: Bulbils. Suckers. *Agave sisalana*.

Sisal (*Agave sisalana*) is a perennial xerophytic plant with CAM metabolism, adapted to arid and semi-arid regions, cultivated primarily for fiber extraction from its leaves. Its growth is slow, with the first harvest for decortication typically occurring three years after planting. These characteristics make sisal a promising option for the Brazilian northeastern semiarid, a region underutilized for cultivation due to adverse edaphoclimatic conditions such as high temperatures and low rainfall [4].

Although agaves and succulents are widely used in landscaping, little is known about their seedling production characteristics, particularly regarding nutritional aspects during early growth.

Despite limited exploration, fertilization with mineral nutrients has shown excellent results and should be encouraged for application to other species, whether grown in confined or open environments [5].

The objective of this work was to evaluate the morphological development of Agave as a function of different management strategies, including fertilization and irrigation, as well as the type of propagule used, aiming to identify the most efficient combinations for vegetative growth over six months of evaluation.

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Address for correspondence: Walleska P. Medeiros de Oliveira. Rua Praia de Pajussara - Vilas do Atlântico, Lauro de Freitas - BA, 42708-902, Lauro de Freitas, Bahia, Brazil. Zipcode: 41650-010. E-mail: walleska.oliveira@fieb.org.br.

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Materials and Methods

The experiment was conducted at CIMATEC Sertão, located in Conceição do Coité - BA, using *Agave sisalana* seedlings from suckers and bulbils measuring 30 cm in length (Figure 1).

Figure 1. Experimental crop located at the CIMATEC Sertão unit, in the municipality of Conceição do Coité, Bahia.

A 255 m² area (17 × 15 m), fallow for about three years after grass cultivation, was used. Prior to the experiment, the area was mowed mechanically, plowed once, and harrowed once. The blocks and plots were then marked, with four blocks spaced 3.0 m apart.

Soil pH correction and fertilization were performed based on prior soil analysis pH (Potential of hydrogen in the soil) 5.3; OM (Organic matter) 1.25%; P (Phosphorus) 24 mg/dm³; K (Potassium) 69 mg/dm³; Ca (Calcium) 1.7 cmol/dm³; Mg (Magnesium) 0.8 cmol/dm³.

The conventional planting system included treatments (Table 1) with and without irrigation, arranged in a randomized block design with ten treatments and four replications.

At the end of the experiment, the morphological characteristics height (cm), diameter (mm), number of leaves, and leaf length and width. Measurements were taken at 180, 210, 270, and 360 days after planting.

The results obtained were subjected to analysis of variance (ANOVA), and the means were compared using the F-test at a 5% significance level. Statistical analyses were performed using Statistica® v.10.0 software.

Table 1. Description of the treatments (TRAT), including Number of rows (Nº R), Spacing (S), Propagule type (PT), and Irrigation (IRR).

TRAT	Nº R	S	PT	IRR
T0	2	3x1x1	SUC	No
T1	2	3x1x1	SUC	No
T2	2	3x1x1	BB	No
T3	1	3x1	SUC	No
T4	1	3x1	BB	No
T5	1	3x1	SUC	Yes
T6	1	3x1	BB	Yes
T7	2	3x1x1	SUC	Yes
T8	2	3x1x1	BB	Yes
T9	2	3x1x1	BB	Yes

*BB: Bulbils; SUC: Suckers. T0 to T8: Seedlings of *Agave sisalana*; T9: Agave Hybrid 11648.

Results and Discussion

Height

Statistically significant differences were observed in Agave plant height between treatments over time. At 180 and 210 days after planting, treatments T1, T2, T4, T5, T6, T8, and T9 differed significantly from the control (T0). At 270 days, the differences were maintained in treatments T2, T4, T6, T8, and T9, all composed of bulbils, regardless of the layout type or irrigation use, reinforcing the role of propagule type on height growth. At 360 days, treatments T1, T2, T4, T6, and T8 outperformed T0, indicating that the positive influence of bulbils persists over time and that propagule type has a greater effect on plant growth than irrigation.

The improved height results observed in treatments using bulbils can be attributed to the superior morphophysiological characteristics of these propagules.

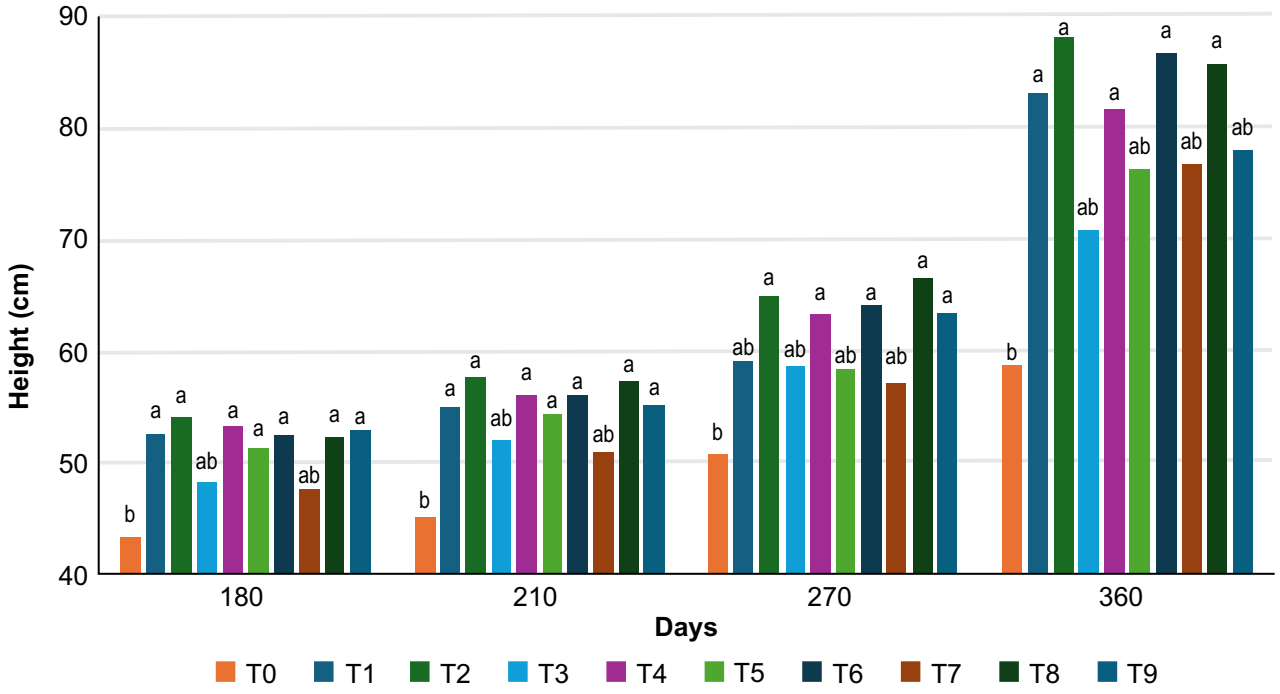
According to a study with *Agave angustifolia*, bulbils showed greater uniformity in size compared to suckers, in addition to developing roots more quickly than shoots from rhizomes. These factors may explain the greater vigor and, consequently, the better development of plants grown from bulbils [2]. Figure 2 demonstrates a gradual increase in height over time in all treatments evaluated. After 270 days, more pronounced growth is observed in most treatments, indicating a possible peak in vegetative development during this period.

Diameter

For T9, composed of propagation by bulblets of hybrid 11648 and with irrigation, showed a statistically significant difference in relation to the control (T0) at 180, 270 and 360 days after planting for the diameter variable (Figure 3).

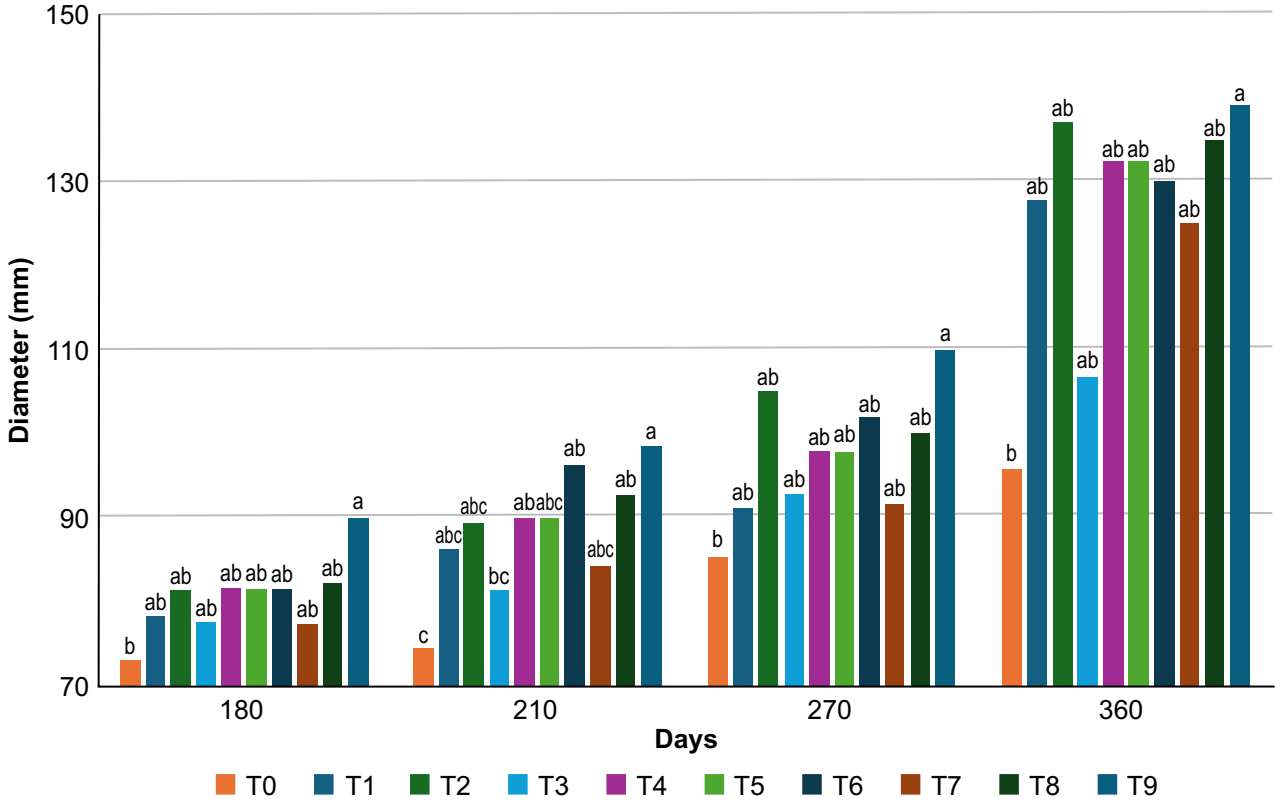
Over 210 days, in addition to the difference between T9 and T0, a statistical difference was

Figure 2. Average height (cm) of *A. sisalana* plants among treatments.



*Means followed by the same letter in the column do not differ statistically from each other, according to the F test at 5% probability.

Figure 3. Averages for the diameter (mm) of *A. sisalana* plants, among treatments.



* Means followed by the same letter in the column do not differ statistically from each other, according to the F test at 5% probability.

also observed between T9 and T3. T9 had higher averages, while T3, consisting of suckers and without irrigation, did not differ statistically from T0, both with the lowest averages observed.

Leaf Number (Unit)

As shown in Figure 4, T9 showed a statistically significant difference at all evaluation times, highlighting the positive effect of the interaction between the use of improved genetic material, irrigation, and adequate nutrition. At 270 days after planting, in addition to the statistical difference between T9 and the other treatments, T2 and T8 performed better than T3. The main distinction between these treatments lies in the type of propagule and water management: T2 and T8 used bulbils with or without irrigation, while T3 was managed with suckers and without irrigation.

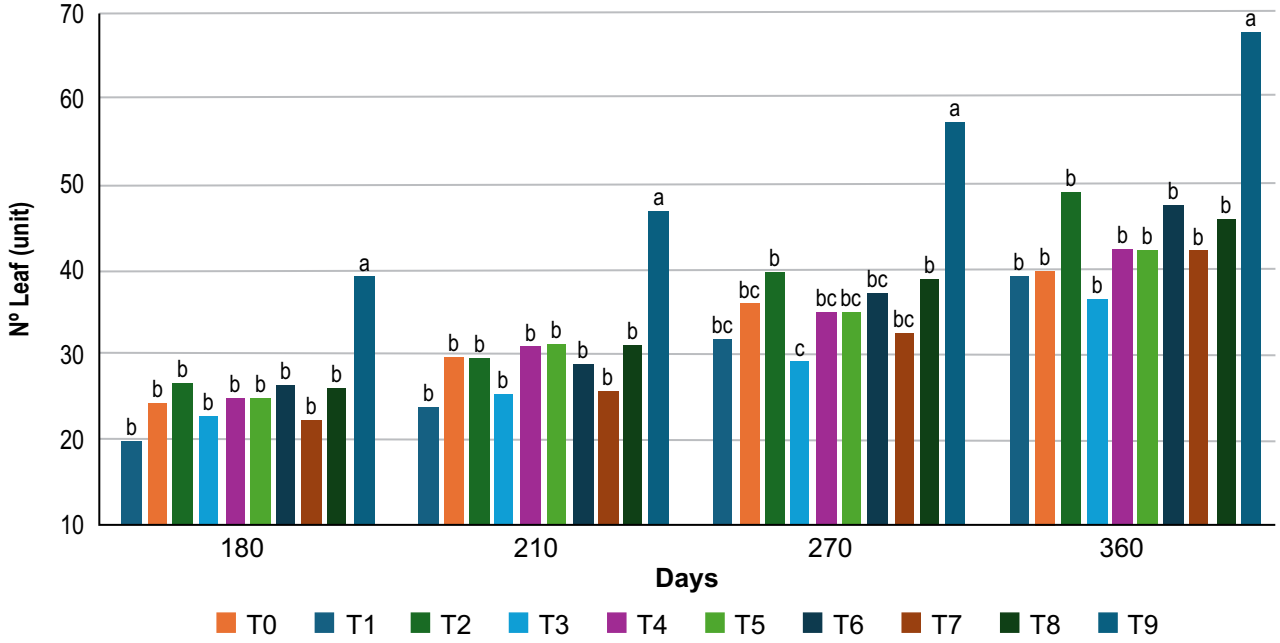
The double-row arrangement proved to be the most efficient strategy for increasing leaf number in Agave cultivation. The results also indicated that bulbils outperformed suckers, regardless of irrigation. This behavior can be explained by Agave's high water resilience, typical of plants with CAM metabolism, whose efficient water conservation physiology allows cultivation even under conditions of low water availability [1].

The data indicate that T9 presented the highest number of leaves in all evaluated periods, standing out from the others. At 270 days after the start of the experiment, Treatments 2 and 8 also stood out among the conventional treatments, demonstrating significantly superior performance. In contrast, T0 (control) maintained the lowest values throughout the period (Figure 3).

Leaf Width

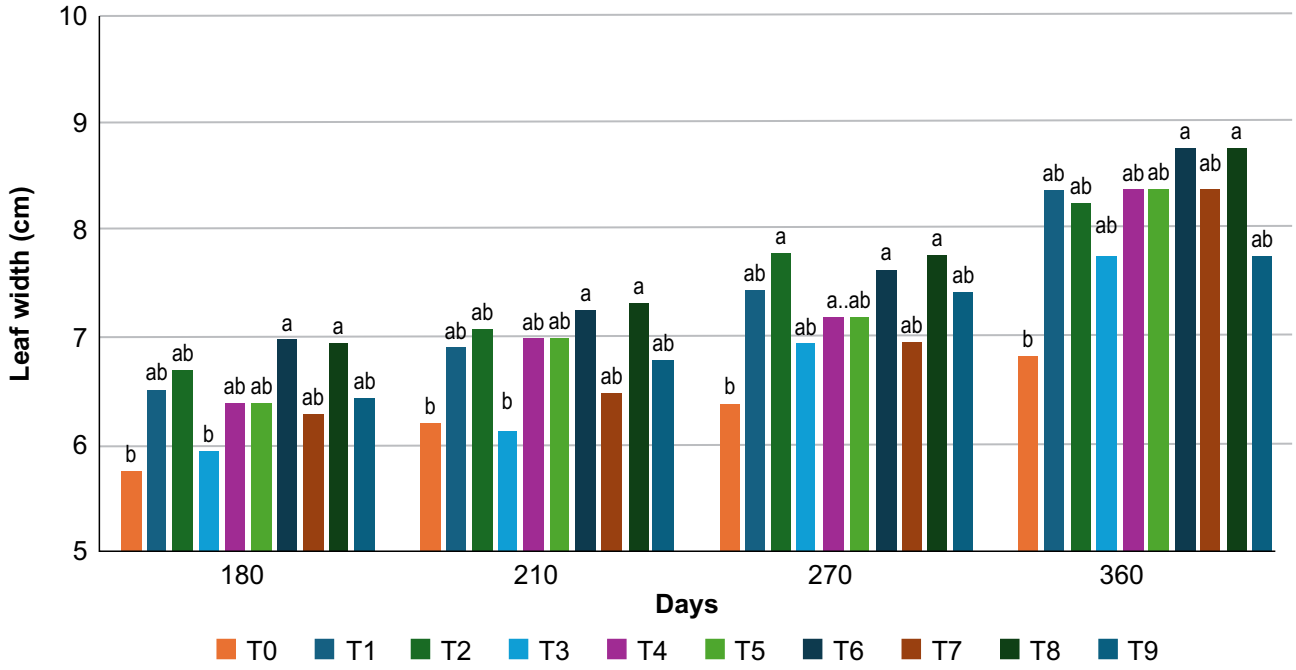
Statistically significant differences between treatments were observed throughout the evaluated periods for the variable leaf width. At 180 and 210 days, treatments T6 and T8, both consisting of bulbils under irrigation, presented higher averages compared to the control (T0) and T3, it is using suckers and grown without irrigation. At 270 days, treatments T2, T6, and T8 differed statistically from T0, all consisting of bulbils, regardless of planting arrangement and irrigation use (Figure 5).

Figure 4. Average leaf number (unit) of *A. sisalana* plants, among treatments.



* Means followed by the same letter in the column do not differ statistically from each other, according to the F test at 5% probability.

Figure 5. Average leaf width (cm) of *A. sisalana* plants, between treatments.



* Means followed by the same letter in the column do not differ statistically from each other, according to the F test at 5% probability.

Over 360 days, treatments T6 and T8 maintained the highest mean values and showed statistically significant differences compared to T0. These results indicate that the main factor responsible for the observed differences in leaf width was the type of propagule used, with bulbils performing better than suckers, regardless of irrigation and row arrangement.

In a study evaluating the production potential of *A. sisalana* under three irrigation conditions in Pakistan, they found that the treatment subjected to higher irrigation was the least efficient, resulting in lower plant height, fewer leaves, and smaller leaf area, suggesting possible negative effects of excess water, such as soil saturation and physiological stress [3]. The control treatment without irrigation, however, showed satisfactory results, especially regarding leaf diameter, demonstrating the species' high drought resistance, a hallmark of plants with Crassulacean acid metabolism (CAM).

Leaf length

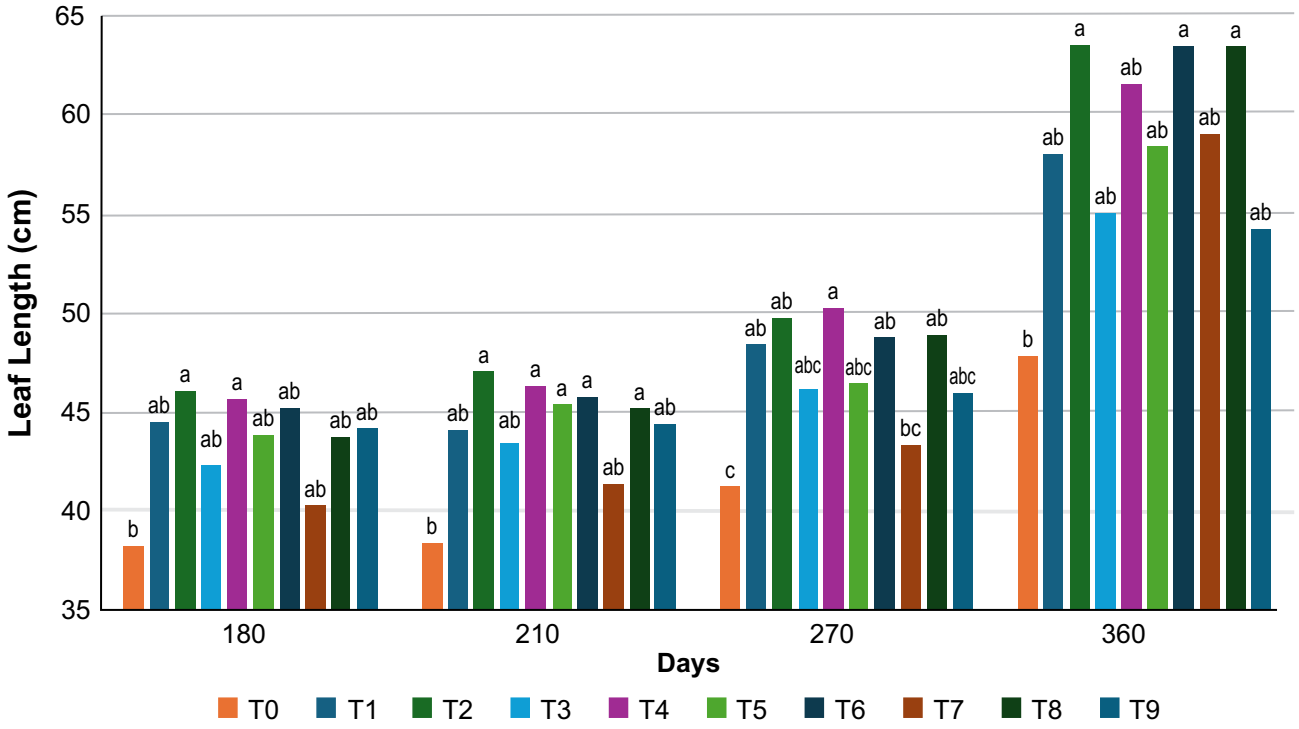
As shown in Figure 6, at 180 days, treatments T2, consisting of bulbils and grown without irrigation, showed a higher mean than the control T0, suggesting better performance of this type of propagule, regardless of planting arrangement. At 210 days, treatments T2, T4, T5, T6, and T8 differed significantly from T0. Of these, only T5 used suckers, reinforcing the superiority of bulbils, even under different water conditions.

At 270 days, T4 (bulbils without irrigation) had the highest average, statistically different from T0 and T7, the latter irrigated and composed of suckers, reinforcing the influence of propagule type on plant performance. Finally, at 360 days, treatments T2, T6, and T8, all using bulbils, had the highest average values, with significant differences compared to T0, demonstrating that bulbils provided better development regardless of irrigation.

Conclusions

The control (T0), without fertilization and irrigation, presented the lowest values in all morphological variables evaluated compared to the other treatments, demonstrating that the lack

Figure 6. Average leaf length (cm) of *A. sisalana* plants across treatments.



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of management significantly limits the vegetative development of Agave. This reaffirms that the adoption of good management practices such as fertilization and soil amendment, used in the other treatments, plays a fundamental role in the vegetative development of the crop. Another point observed was that plants from bulbils showed greater development and vigor regardless of arrangement and irrigation, indicating a promising alternative for promoting greater productivity. Furthermore, 270 days after planting, more significant growth was observed in most variables and treatments, indicating the possibility of a peak in vegetative growth at this stage of Agave development, indicating a strategic time for intensified management.

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