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Fertilization and pruning on agronomic performance of *Hibiscus sabdariffa* L. plants cultivation

Adubação e poda no desempenho agronômico no cultivo de *Hibiscus sabdariffa* L.

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Hibiscus sabdariffa L. is a widely cultivated and economically valuable species within the diverse *Hibiscus* genus, holds significant potential as an unconventional food plant for sustainable family farming. Therefore, the objective of this study was to evaluate the effects of fertilization and pruning on the growth and agronomic performance of commercial branches of *H. sabdariffa* L. The field experiment was conducted using four fertilization treatments (control, chemical, organic, and mixed) and two pruning managements (with and without pruning). Growth evaluations included plant height, stem diameter, leaf width, number of commercial branches, total fresh weight, fresh weight of commercial branches, and total dry weight. Plant height, stem diameter, and leaf width showed linear growth, and plants treated with chemical and mixed fertilization exhibited a higher number of commercial branches, greater fresh weight of commercial branches, total fresh weight, and leaf dry weight. Chemical and mixed fertilization treatments resulted in better performance in growth parameters (plant height, stem diameter, leaf width, and number of commercial branches) of *H. sabdariffa* L., and when combined with pruning, promoted greater production of commercial branches.
Keywords: branch yield, roselle, unconventional food plants.

Hibiscus sabdariffa L. é uma espécie amplamente cultivada e economicamente valiosa dentro do diverso gênero *Hibiscus*, possui significativo potencial como planta alimentícia não convencional para a agricultura familiar sustentável. Portanto, o objetivo deste estudo foi avaliar os efeitos da fertilização e da poda no crescimento e no desempenho agronômico de ramos comerciais de *H. sabdariffa* L. O experimento de campo foi conduzido utilizando quatro tipos de adubação (controle, adubação química, orgânica e mista) e dois manejos de poda (com e sem). As avaliações de crescimento consideraram a altura e o diâmetro da planta, a largura das folhas, o número de ramos comerciais, o peso fresco total, o peso fresco dos ramos comerciais e o peso seco total. A altura da planta, o diâmetro do caule e a largura das folhas apresentaram crescimento linear, e as plantas tratadas com adubação química e mista apresentaram maior número de ramos comerciais, maior peso fresco dos ramos comerciais, maior peso fresco total e maior peso seco foliar. Os tratamentos com adubação química e mista resultaram em melhor desempenho nos parâmetros de crescimento (altura da planta, diâmetro do caule, largura das folhas e número de ramos comerciais) de *H. sabdariffa* L. e, quando associados à prática de poda, favoreceram a produção de ramos comerciais.
Palavras-chave: produção de ramos, vinagreira, plantas alimentícias não convencionais.

1. INTRODUCTION

The genus *Hibiscus*, part of the botanical family Malvaceae, comprises over 300 species with diverse applications, including ornamental, culinary, and medicinal uses. Among these, *Hibiscus sabdariffa* L. - commonly known as roselle or red sorrel - is the most widely utilized species for food and traditional medicine, largely due to its richness in bioactive compounds [1]. Cultivated extensively in tropical regions worldwide, roselle holds significant economic value as a food crop and serves ornamental purposes [2].

Throughout human evolution, the need to differentiate between edible and toxic plants led to the classification and naming of plant species, ensuring safer use and the transmission of knowledge across generations [3]. In this context, unconventional food plants (UFPs) have gained attention for their nutritional and functional value. These species, often cultivated by family farmers, are generally rustic and require minimal inputs [4]. In Brazil, however, UFPs remain underexplored by science and society, resulting in restricted regional consumption and limited acceptance in broader markets [5].

Among these UFPs, *H. sabdariffa* L. stands out for its productive potential in family farming, especially in the state of Maranhão, Brazil. Its adaptability and low input requirements make it a promising alternative for the adoption of accessible and sustainable agricultural technologies tailored to local farming conditions [6].

Nevertheless, family farmers in Brazil often face barriers such as limited access to technical assistance and information, which are crucial for improving and qualifying agricultural production through public policy programs [7]. For optimal plant development, adequate nutrient availability is essential. However, many soils lack sufficient mineral content, making fertilizer application a fundamental practice in crop management. Proper fertilization enables nutrient uptake and supports plant growth. In addition to fertilization, pruning is another key agronomic practice that influences plant physiology by reshaping plant architecture, improving the balance between vegetative and reproductive structures [8, 9].

Thus, the objective of the present work was to evaluate growth and agronomic performance of Hibiscus sabdariffa L. under different types of fertilizer and pruning.

2. MATERIALS AND METHODS

The experiment was carried out under field conditions at the School Farm of the Maranhão State University, in São Luís, MA, Brazil (2º30'S, 44º18'W, altitude of 24 m) from April to August 2019. The predominant climate of the region is Aw, equatorial hot humid, according to the Köppen classification, with two well-defined seasons: a rainy season from January to July and a dry season with a marked water deficit from July to December [10]. Rainfall depths vary from 1700 mm to 2300 mm and is concentrated (80%) between January and May. Climatic conditions during the experimental period are shown in the Figure 1.

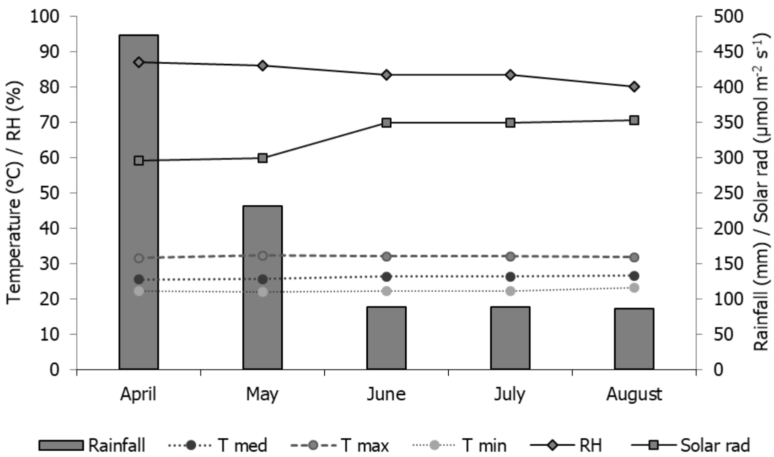

Figure 1. Maximum temperature (T max), average temperature (T ave), minimum temperature (T min), relative humidity (RH), rainfall, and solar radiation (Solar rad) during experimental period (April – august/2019).

The analysis of the 0-20 cm soil layer before roselle planting presented the following characteristics: pH $CaCl_2$ = 4.8; organic matter = 17 g dm^{-3}; P = 10 mg dm^{-3}; K += 0.8 mmolc dm^{-3}; Ca = 12 mmolc dm^{-3}; Mg = 3 mmolc dm^{-3}; H + Al3+= 18 mmolc dm^{-3}; sum of bases = 15.8 mmolc dm^{-3}; cation exchange capacity = 33.8 mmolc dm^{-3}; base saturation = 47%; coarse sand = 240 g kg^{-1}; fine sand = 610 g kg^{-1}; silt = 7 g kg^{-1}; 80 g kg^{-1}, and silt to clay ratio = 0.88.

The organic fertilizer (poultry litter) had the following characteristics: N = 23.3 g kg^{-1}; P = 15.3 g kg^{-1}; K = 22.4 g kg^{-1}; Ca = 32.6 g kg^{-1}; Mg = 7.4 g kg^{-1}; S = 4.6 g kg^{-1}; Na = 3.6 g kg^{-1}; Cu = 470 mg kg^{-1}; Fe = 928 mg kg^{-1}; Zn = 279 mg kg^{-1}; Mn = 419 mg kg^{-1}; B = 44 mg kg^{-1}.

A randomized block experimental design with three replications was used, in a 4 × 2 factorial arrangement consisted of four fertilizers: control (without fertilizer), chemical, organic (poultry litter), and mixed (chemical + poultry litter) and two pruning managements (with and without). The fertilizers were applied to the planting furrows using 1,200 kg ha^{-1} of the 04-30-16 formulation (N-P_2O_5-K_2O) for the chemical fertilizer, 1.5 liters of poultry litter per hole for the organic fertilizer, and 1.5 liters of poultry litter and 175 kg ha^{-1} of the N-P-K formulation at 15 days before the transplanting of the seedlings for the mixed fertilizer. The experiment consisted of 24 experimental plots of 5 plants, with spacing of 1.20 m between plants and 1.00 m between rows; the 3 central plants of each plot were used for evaluation. The seedlings were planted at 45 days after germination and the growth pruning was carried out manually at 40 days after planting (DAP).

The growth parameters evaluated were plant height, stem diameter, and leaf width. The agronomic parameters evaluated were number of commercial branches (NCB), fresh mass of commercial branches (FMCB; kg ha^{-1}), total fresh mass (TFM; kg ha^{-1}), and leaf dry mass (LDM; kg ha^{-1}).

Plant height was evaluated by measuring the plants with a tape ruler (cm) from the stem base to the apex. The stem diameter was measured with a digital caliper at 5 centimeters above the ground, and the leaf width was measured with a tape ruler.

The shoot of the plant was cut at ground level and weighed on a 0.01 g-precision scale at 125 days after planting to obtain the fresh mass (g). The primary and secondary branches of the harvested plants of each treatment were cut at 30 cm from the shoot apex; this is considered by growers as the length of commercial branches when they are composed of at least 10 fully expanded leaves. The number of commercial branches were quantified in absolute numbers that met the parameters adopted by the growers. These branches were weighed in a 0.01 g-precision scale to obtain the fresh weight (g) and then taken to a forced air circulation oven at 70±5°C until constant weight to obtain the total dry weight.

Data on the effect of treatments on plant height, stem diameter, and leaf width parameters were submitted to analysis of variance (ANOVA) in a split-plot design, with interaction between treatments and assessment times (50, 65, 80, 95, 110, and 125 days after planting). The remaining data were analysed by one-way ANOVA. Data normality was assessed by the Shapiro-Wilk test and means were compared using Tukey’s test at 5% significance. The ExpDes.pt statistical package [11] of the program R version 4.4.1 [12] was used for the statistical analyses.

3. RESULTS AND DISCUSSION

According to Da-Costa-Rocha et al. (2014) [13], roselle plants adapt better to environments with monthly rainfall between 130 and 250 mm. Monthly rainfall depths were high in the first two months, with 473 and 230 mm, respectively, and an average of 85 mm from june to august. Therefore, the rainfall during the experimental period was within the requirements for the crop, except for april (Figure 1).

The plant height showed interaction between factors ($p < 0.05$) and was affected by the fertilizer used at 95, 110, and 125 days after planting. In all treatments, the greatest plant height was observed at 125 DAP, and no significant differences were found among treatments up to 80 DAP ($p > 0.05$). Pruning management, regardless of fertilization, resulted in the tallest plants at 125 DAP, whereas the lowest plant heights were recorded in treatments without pruning (Table 1). According to Castro and Devide (2019) [1], the vegetative growth of the plants was considered vigorous, and in the pruned treatments, plants exceeded 100 cm in height before 100 DAP.

These results are similar to those found by Sousa et al. (2010) [14], who evaluated *H. sabdariffa* plants and found that plants subjected to chemical fertilizer presented higher mean plant heights than those treated with organic fertilizer.

Table 1. Growth variables evaluated in roselle plants subjected to different fertilization treatments and pruning.

DAP(1)	Height (cm)							
	Control		Mineral		Organic		Mixed	
	pruning	without pruning	pruning	without pruning	pruning	without pruning	pruning	without pruning
50	$24.5^{\pm0.7\ F}$	$22.9^{\pm1.7\ E}$	$26.9^{\pm1.1\ F}$	$26.1^{\pm0.7\ E}$	$28.3^{\pm0.7\ F}$	$24.9^{\pm0.9\ E}$	$26.3^{\pm0.7\ F}$	$27.6^{\pm0.3\ E}$
65	$55.3^{\pm3.7\ E}$	$52.8^{\pm3.8\ D}$	$58.8^{\pm3.4\ E}$	$63.0^{\pm4.2\ D}$	$59.4^{\pm2.7\ E}$	$56.7^{\pm1.7\ D}$	$62.8^{\pm4.1\ E}$	$64.5^{\pm0.6\ D}$
80	$88.6^{\pm1.6\ D}$	$85.1^{\pm3.7\ C}$	$89.1^{\pm2.8\ D}$	$99.7^{\pm2.6\ C}$	$92.5^{\pm2.3\ D}$	$86.4^{\pm1.8\ C}$	$99.4^{\pm3.7\ D}$	$97.9^{\pm1.9\ C}$
95	$101.7^{\pm2.4\ Cab}$	$84.9^{\pm4.5\ Cb}$	$102.4^{\pm1.0\ Cab}$	$99.1^{\pm4.3\ Cab}$	$105.4^{\pm4.2\ Cab}$	$85.4^{\pm4.8\ Cb}$	$112.2^{\pm1.9\ Ca}$	$95.9^{\pm1.3\ Cab}$
110	$129.4^{\pm2.6\ Bab}$	$108.1^{\pm5.2\ Bc}$	$129.0^{\pm0.5\ Babc}$	$127.1^{\pm4.2\ Babc}$	$131.9^{\pm5.7\ Bab}$	$112.2^{\pm5.6\ Bbc}$	$136.8^{\pm4.9\ Ba}$	$120.2^{\pm1.4\ Babc}$
125	$168.7^{\pm1.6\ Aa}$	$141.6^{\pm4.5\ Abc}$	$171.7^{\pm2.9\ Aa}$	$155.1^{\pm6.3\ Aab}$	$169.2^{\pm9.4\ Aa}$	$127.4^{\pm10\ Ac}$	$169.6^{\pm6.7\ Aa}$	$154.4^{\pm6.3\ Aab}$
DAP	Stem diamenter (cm)							
	Control		Mineral		Organic		Mixed	
	pruning	without pruning	pruning	without pruning	pruning	without pruning	pruning	without pruning
50	$0.32^{\pm0.0\ E}$	$0.30^{\pm0.0\ C}$	$0.39^{\pm0.0\ D}$	$0.34^{\pm0.0\ E}$	$0.39^{\pm0.0\ D}$	$0.39^{\pm0.0\ D}$	$0.40^{\pm0.0\ E}$	$0.42^{\pm0.0\ E}$
65	$0.86^{\pm0.0\ Db}$	$0.86^{\pm0.0\ Bb}$	$1.32^{\pm0.1\ Cab}$	$1.39^{\pm0.1\ Da}$	$1.11^{\pm0.1\ Cab}$	$1.03^{\pm0.1\ Cab}$	$1.41^{\pm0.0\ Da}$	$1.31^{\pm0.1\ Dab}$
80	$1.27^{\pm0.1\ BCc}$	$1.32^{\pm0.0\ Abc}$	$1.86^{\pm0.1\ Ba}$	$1.94^{\pm0.1\ Ca}$	$1.72^{\pm0.0\ Babc}$	$1.51^{\pm0.0\ Babc}$	$1.93^{\pm0.0\ Ca}$	$1.79^{\pm0.2\ Cab}$
95	$1.42^{\pm0.1\ Cb}$	$1.41^{\pm0.0\ Ab}$	$2.10^{\pm0.1\ Ba}$	$2.17^{\pm0.1\ BCa}$	$1.72^{\pm0.2\ Bab}$	$1.68^{\pm0.0\ ABab}$	$2.17^{\pm0.1\ BCa}$	$2.16^{\pm0.1\ Ba}$
110	$1.71^{\pm0.2\ ABc}$	$1.54^{\pm0.0\ Ac}$	$2.51^{\pm0.1\ Aa}$	$2.37^{\pm0.1\ ABab}$	$1.92^{\pm0.1\ Bbc}$	$1.79^{\pm0.1\ ABc}$	$2.43^{\pm0.0\ ABa}$	$2.39^{\pm0.1\ ABab}$
125	$1.79^{\pm0.2\ Ab}$	$1.63^{\pm0.1\ Ab}$	$2.64^{\pm0.0\ Aa}$	$2.49^{\pm0.2\ Aa}$	$2.37^{\pm0.1\ Aa}$	$1.87^{\pm0.1\ Ab}$	$2.68^{\pm0.1\ Aa}$	$2.50^{\pm0.1\ Aa}$
DAP	Leaf width (cm)							
	Control		Mineral		Organic		Mixed	
	pruning	without pruning	pruning	without pruning	pruning	without pruning	pruning	without pruning
50	$7.33^{\pm0.4\ Cab}$	$5.96^{\pm0.2\ Cb}$	$9.31^{\pm0.6\ Da}$	$9.87^{\pm0.9\ Da}$	$8.56^{\pm0.3\ Ba}$	$8.26^{\pm0.3\ Bab}$	$8.61^{\pm0.7\ Ca}$	$8.91^{\pm0.9\ Da}$
65	$9.33^{\pm0.4\ Cab}$	$7.96^{\pm0.2\ Cb}$	$11.31^{\pm0.6\ CDa}$	$11.87^{\pm0.9\ CDa}$	$10.56^{\pm0.3\ Ba}$	$10.26^{\pm0.3\ Bab}$	$10.61^{\pm0.7\ BCa}$	$10.91^{\pm0.9\ CDa}$
80	$11.43^{\pm0.3\ B}$	$12.63^{\pm0.9\ B}$	$13.00^{\pm0.0\ BC}$	$12.67^{\pm0.3\ BC}$	$13.22^{\pm0.2\ A}$	$13.52^{\pm0.3\ A}$	$12.63^{\pm0.9\ AB}$	$12.33^{\pm0.3\ BC}$
95	$13.28^{\pm0.7\ AB}$	$14.01^{\pm0.2\ AB}$	$14.02^{\pm0.2\ AB}$	$14.60^{\pm0.3\ AB}$	$13.84^{\pm0.3\ A}$	$14.71^{\pm0.3\ A}$	$13.51^{\pm0.4\ A}$	$13.83^{\pm0.1\ AB}$
110	$13.93^{\pm0.7\ A}$	$14.66^{\pm0.0\ AB}$	$14.63^{\pm0.1\ AB}$	$15.27^{\pm0.4\ A}$	$14.31^{\pm0.4\ A}$	$15.23^{\pm0.3\ A}$	$13.99^{\pm0.3\ A}$	$15.04^{\pm0.5\ A}$
125	$14.73^{\pm0.9\ A}$	$15.00^{\pm0.0\ A}$	$15.07^{\pm0.1\ A}$	$15.06^{\pm0.3\ A}$	$14.76^{\pm0.5\ A}$	$15.50^{\pm0.4\ A}$	$14.33^{\pm0.4\ A}$	$15.83^{\pm0.3\ A}$

Means followed by the same uppercase letter in the column do not differ by Tukey's test ($p < 0.05$) across evaluation days; means followed by the same lowercase letter in the row do not differ by Tukey's test ($p < 0.05$). Superscript values represent ± standard error of the mean.

(1) DAP, days after planting.

The stem diameter was affected by the treatments throughout the experimental period. Treatments with mixed and chemical fertilizers showed greater mean plant diameter, but they did not differ from each other from 65 DAP. Stem diameter is an important parameter; plants with larger basal diameter are less prone to lodging and breakage, facilitating the harvest.

Plants under treatments with fertilizer showed greater leaf widths than those of the control up to 65 DAP. According to Queiroga et al. (2003) [15], variation in leaf shape is a characteristic of the species and is connected to growth conditions; they found that the leaf growth in width at 80 DAP tended to stabilize, not differing significantly from the control.

The variables number of commercial branches (NCB), fresh mass of commercial branches (FMCB), total fresh mass (TFM), and leaf dry mass (LDM) did not show interaction between the factors, so their simple effects were analyzed. The use of chemical and mixed fertilizers resulted in a greater number of commercial branches, higher than the control treatment (p=0.002) (Table 2). No statistically significant difference was found between the treatments with pruning for commercial branch production.

Table 2. Number of commercial branches (NCB), fresh mass of commercial branches (FMCB), total fresh mass (TFM), and leaf dry mass (LDM) of Hibiscus sabdariffa L. plants subjected to different pruning and fertilizer managements.

Treatments	NCB	FWCB (kg ha^{-1})	TFW (kg ha^{-1})	LDW (kg ha^{-1})
Control	42.26 c	1,042 b	2,153 b	313 b
Chemical	87.57 a	2,118 a	4,931 a	1,042 a
Organic	58.65 bc	1,528 ab	3,229 b	521 b
Mixed	70.97 ab	2,014 a	5,174 a	903 a
With pruning	62.78 ^{ns}	1,771 ^{ns}	4,549 a	868 a
Without pruning	66.94 ^{ns}	1,563 ^{ns}	3,194 b	521 b
CV (%)	23.1	22.19	21.21	30.4

Means followed by the same letter in the columns do not differ from each other by the Tukey's test at 5% probability; ns: not significant by the F test.

The fresh mass of commercial branches of plants treated with fertilizers was statistically different ($p < 0.001$) from the control treatment (Table 2).

Regarding the effect of fertilizers on total fresh mass (TFM), the chemical and mixed fertilizers resulted in biomasses about 5,000 kg ha^{-1}, which were similar to each other, and higher than the means found in the other treatments (Table 2). The treatments with pruning stood out with the highest means ($p < 0.001$), differing from the treatment with no pruning in total fresh mass and leaf dry mass.

The leaf dry weight (LDW) was different between treatments; the treatments with chemical and mixed fertilizers ($p < 0.001$) presented means superior to the control of 233 and 189%, respectively. In addition, plants under treatments with pruning showed higher leaf dry mass, different from those that were not pruned (Table 2).

This may be explained by the increase in soil fertility due to mineral fertilizer application, which promoted a rapid plant nutrition and, therefore, greater development of aerial biomass [16]. The use of mineral fertilizers to complement organic fertilizer applications improves the use of nutrients by plants through the synchronism of release throughout the plant cycle [17].

These higher weights may be explained by the greater availability of nutrients, such as nitrogen [18]. According to Bovi et al. (2002) [19], an adequate application of nitrogen to growing plants improves leaf N levels and, consequently, their growth. Similar results were found by Egharevba and Law-Ogbomo (2007) [20], who evaluated the effect of nitrogen sources on growth and yield of roselle in a tropical forest region and found no significant difference in number of leaves as a function of the fertilizer type; although plants treated with NPK presented better performance than control plants.

The greater development of primary and secondary branches observed in the pruning treatments is likely associated with increased photosynthetic activity [21] and higher levels of growth hormones such as cytokinins, whose concentration tends to rise when apical meristem dominance is reduced [22, 23]. This effect results from the disruption of apical dominance caused by pruning, which lowers auxin concentrations in axillary buds and consequently stimulates lateral branch sprouting. Auxins normally promote cell elongation but inhibit the growth of lateral buds [22, 24]. Thus, when the apical bud is removed, axillary buds overcome dormancy and develop into lateral branches. Similar results were reported by Castro and Devide (2019) [1], who observed greater biomass accumulation and growth after pruning, even in roselle plants of smaller size.

Mendonça et al. (2024) [25], when evaluating organic and mineral fertilization on the growth and nutrition of roselle, found that the application of poultry litter significantly increased biomass accumulation and the number of commercial branches, particularly at doses between 1.5 and 2.0 L plant^{-1}. Furthermore, poultry litter enhanced the efficiency of mineral fertilization, with the combination of 1.0 L plant^{-1} plus 66.3% of the recommended NPK dose showing the best performance in crop management.

Furthermore, Aguilar-Luna et al. (2023) [26] concluded that variety, environmental growing conditions, and planting density are key factors influencing the agronomic performance and physicochemical characteristics of roselle. In this context, many studies on fertilizers have shown that high-fertility soils, either with organic or mineral fertilizer, result in greater dry weight accumulations [27]; therefore, well-fertilized soils and pruning management stimulate plants aerial biomass growth, resulting in higher leaf dry mass.

4. CONCLUSION

The use of chemical fertilizer, alone or combined with organic fertilizer, results in plants of *Hibiscus sabdariffa* L. with better performances regarding growth parameters and, combined with the use of pruning, favors greater the production of commercial branches.

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