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DESEMPENHO AGRONÔMICO DE CULTIVARES DE LÚPULOS EM CLIMA TROPICAL NA NOVA ALTA PAULISTA

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RESUMO: Esta pesquisa visou avaliar o desenvolvimento agronômico inicial de cultivares de lúpulo na região da Nova Alta Paulista em função a aplicação de fertilizante após o plantio. O delineamento experimental inteiramente casualizado foi realizado com seis repetições em esquema fatorial 2 x 3, correspondente a dois cultivares de lúpulo (Hallertau e Cascade) e a três dosagens do formulado 20-05-20 (300, 600 e 900 kg ha^{-1}), aplicadas 60 dias após o plantio das mudas. O período de desenvolvimento vegetal ocorreu entre novembro de 2018 e a colheita, que ocorreu durante o mês de junho de 2019, sendo avaliado: altura das plantas; teor foliar de N, P e K; biomassa seca da parte aérea; e peso de cones por planta. Após 8 meses de cultivo, ambas as variedades de lúpulo mostraram desempenho similar. Doses acima de 300 kg ha^{-1} do fertilizante resultaram em menor desenvolvimento, especialmente na variedade Cascade. Os cultivares lúpulos cultivados em clima tropical priorizaram a absorção de nitrogênio, seguido de potássio e fósforo. Embora a produtividade tenha sido modesta no primeiro ano, evidencia-se o potencial agronômico e econômico do lúpulo no Brasil, abrindo caminho para sua exploração em regiões como a Nova Alta Paulista.

Palavras-chaves: cascade, fertilizante, hallertau, *Humulus lupulus*.

AGRONOMIC PERFORMANCE OF HOP CULTIVARS IN TROPICAL CLIMATE IN NOVA ALTA PAULISTA

ABSTRACT: This research aimed to evaluate the initial agronomic development of hop cultivars in the Nova Alta Paulista region on the basis of fertilizer application after planting. The completely randomized experimental design was performed with six replications in a 2 × 3 factorial scheme, corresponding to two hop cultivars (Hallertau and Cascade) and three doses of 20-05--20 fertilizer (300, 600, and 900 kg ha^{-1}) applied 60 days after transplanting. The vegetative development period occurred between November 2018 and June 2019, with evaluations of plant height; leaf nitrogen, phosphorus, and potassium contents; aboveground biomass; and cone weight per plant. After 8 months of cultivation, both hop varieties presented similar performance. Fertilizer doses above 300 kg ha^{-1} resulted in reduced development, especially in the Cascade cultivar. N absorption is prioritized in hops cultivated in tropical climates, followed by potassium and phosphorus absorption. Despite the modest yield in the first year, the agronomic and economic potential of hops in Brazil is evident, paving the way for their exploration in regions such as Nova Alta Paulista.

Keywords: cascade, fertilizer, hallertau, *Humulus lupulus*.

1 INTRODUCTION

Humulus lupulus L. is a plant species native to Europe, Western Asia and North America and has a root system composed of a rhizome, which is used for planting (Eyck, 2015). Its commercial cultivation is usually tutored on ropes, and it can reach heights of 6 m with roots up to 5 m deep. Thus, hops produce flowers (also called cones) used in beer production for their bacteriostatic potential and

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stability in drinks, in addition to providing bitterness and aromas.

In commercial hop production, only unfertilized (seedless) female cones are desired, as they produce the highest yield of lupulin. Male plants are used only when new varieties are to be developed (Dodds, 2017). In this sense, several varieties of this plant have been developed worldwide, and their yields are influenced by genetic, environmental and management conditions (Lafontaine *et al.*, 2018).

With respect to cultivation, this species prefers deep, well-drained soils with periodic fertilizer applications. Darby (2013) recommended incorporating nitrogen into the soil at doses between 85 and 230 kg ha $^{-1}$, depending on the year and the level of organic matter. Gingrich, Hart and Christensen (2000) reported that seasonal potassium absorption in hops is approximately 90–170 kg ha $^{-1}$, with a quarter of this amount stored in the plant cones. Therefore, annual potassium fertilization can vary from 120 to 240 kg ha $^{-1}$ of K_2O. P is an element that is not highly desirable to hops, representing approximately 0.5% of their weight. Thus, phosphate fertilizer should be included according to soil availability (Dodds, 2017).

The experiment was conducted in the field in the experimental area of the Faculty of Agricultural and Technological Sciences of Unesp - Dracena Campus (21° 27' 22.5" S and 51° 33' 23" W) in the agricultural years 2018 and 2019.

A randomized experimental design with a 2 × 3 factorial scheme and six replications was used. The first factor corresponds to the Hallertau and Cascade hop cultivars, and the second factor corresponds to the doses of the formulated fertilizer 20-05--20 (300, 600 and 900 kg ha^{-1}) applied 60 days after the seedlings were planted.

The area was prepared by subsoiling and harrowing to depths of 0.4 m and 0.2 m, respectively. Agricultural limestone with a PRNT of 70% was then applied in an amount equivalent to 530 kg ha $^{-1}$ to increase the base saturation to 60%.

With respect to agronomic cultivars, traditional American cultivars tend to have high yields, vigorous growth and a high adaptive capacity to various soil types. European cultivars, on the other hand, are relatively small plants with low yields and relatively low adaptive capacity to different growing conditions. Therefore, hop production is concentrated in temperate and humid climates, with a large part of world production occurring in the Northern Hemisphere (Kemmer, 2013).

In this context, Brazil imports approximately four thousand tons per year, totaling a cost of 200 million reais (Araújo, 2016). Therefore, the production of national hops has emerged as a great business opportunity, also considering the growing craft beer market in the country (Lopes; Morales; Montagnolli, 2017).

Given this promising scenario and great agronomic potential for the implementation of a new crop in Brazil, the objective of this work was to evaluate the initial agronomic performance of hop cultivars in a tropical climate combined with different levels of fertilization.

2 MATERIALS AND METHODS

The plots consisted of one plant with a spacing of two meters between plants and four meters between rows. Thus, two 20-meter-long and 3.5-meter-high vines were planted, spaced 4 meters apart. Their ends were composed of treated eucalyptus posts, while the middle of the vine used demolition wood every 5 m. To guide the plants, a galvanized steel wire was used for each pillar 3.5 m above the ground, and nylon ropes were used to connect the wires.

The seedlings were purchased from a nursery in Rio Grande do Sul and were planted by opening planting beds to a depth of 0.15 m in November 2018. Pest control was achieved during the initial development phase by applying the insecticide fipronil to control leaf-cutting ants and caterpillars. Weed control was carried out by weeding whenever necessary. Finally, there was an irrigation system consisting of one drip nozzle per self-compensating plant at a flow rate of 10 L h $^{-1}$.

The fertilizer was applied around each hop seedling within a radius of 0.3 m. After this step, vigorous irrigation was carried out with approximately 30 L of water per seedling.

The evaluation of plant development in the two hop varieties under different fertilizer conditions was carried out after 8 months of cultivation (July 2019) on the basis of the following analyses: (1) plant height; (2) cone weight per plant, when approximately 20% dry matter was reached (Eyck, 2015); (3) leaf content of N, P and K from 10 leaves of each portion of the plant, i.e., basal, median and apex; and (4) dry biomass of the aerial part.

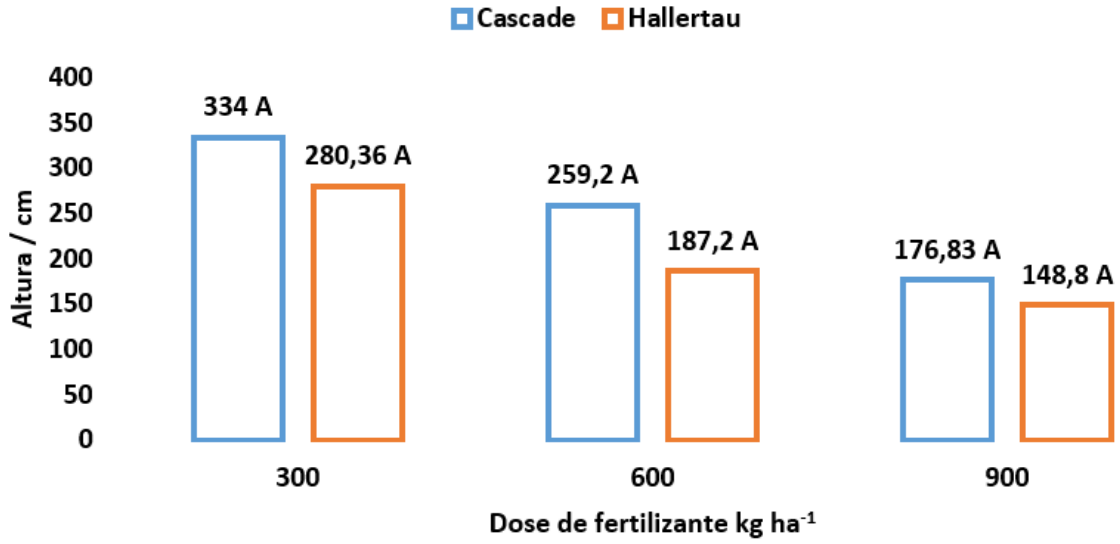
All the data were subjected to analysis of variance (ANOVA), and regression analysis was subsequently performed for the doses, and Tukey's test was used for the cultivars; a significance level of 5% was adopted via Sisvar software.

3 RESULTS AND DISCUSSION

Eight months after planting, no significant difference in plant height was detected between the Cascade and Hallertau varieties grown in a tropical climate in Nova Alta Paulista (Figure 1). However, increasing the fertilizer dose promoted a significant linear decrease in this parameter for the Cascade variety, since the plants were 3.35 m tall with an application of 300 kg ha^{-1} and only 1.5 m tall with the highest dose applied (Figure 2). Similarly, this result was found for the Hallertau variety, although it was not statistically significant.

Similarly, the vegetative development of the aerial parts of the plants did not differ between the cultivated varieties since the dry biomass values were between 47.63 and 115.77 g per plant (Figure 3). This result, which was not statistically significant, was also observed when the fertilizer doses were compared. However, it is worth highlighting the reduction in the dry biomass of the aerial parts of the plants in relation to the increase in the dose applied as a top dressing (Figure 4).

Figure 1. Height of hop plants as a function of dose of the formulated fertilizer from 20--05--20 8 months after planting in Dracena-SP (means with equal letters do not differ according to Tukey's test ($p<0.05$) between cultivars).



On the basis of this behavior, care is recommended when high doses of fertilizer are applied for the cultivation of this species. Dagostim (2019) reported a significant reduction in plant development due to excess nitrogen (160 kg ha^{-1}), which promoted the stagnation of vegetative growth. Therefore, fertilizer formulation is very important for

obtaining better results, since Oliveira (2016) obtained maximum phosphorus absorption by plants with the application of up to 300 kg ha $^{-1}$ P_2O_5.

Figure 2. Height of hop plants as a function of the dose of the formulated fertilizer from 20--05--20 8 months after planting in Dracena-SP (*significant at 5% probability).

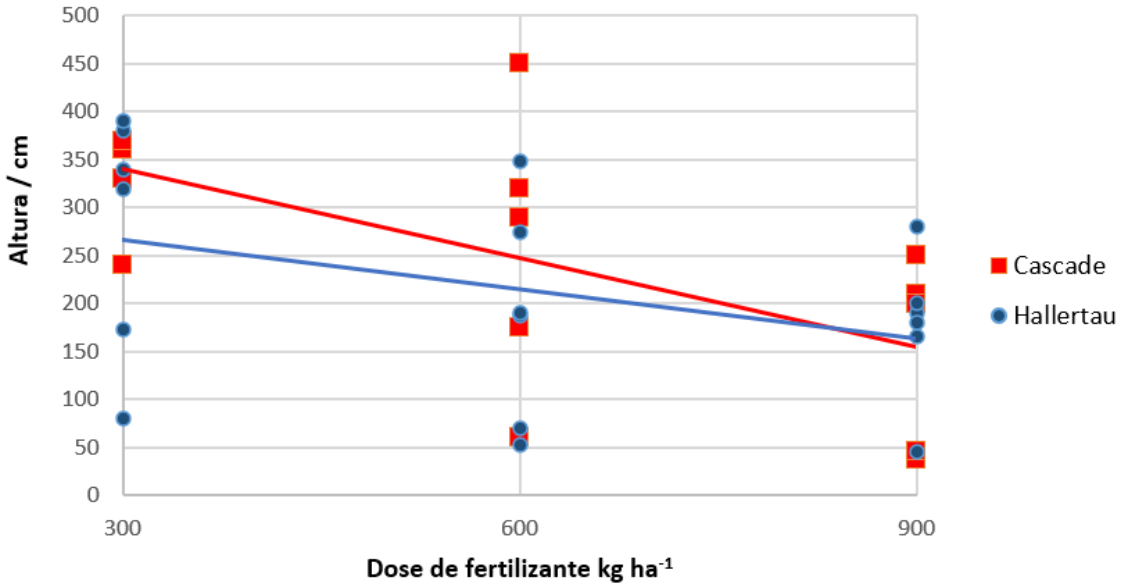


Figure 3. Dry biomass of hop plants as a function of dose of the formulated fertilizer from 20--05--20 8 months after planting in Dracena-SP (means with equal letters do not differ according to Tukey's test ($p<0.05$) between cultivars).

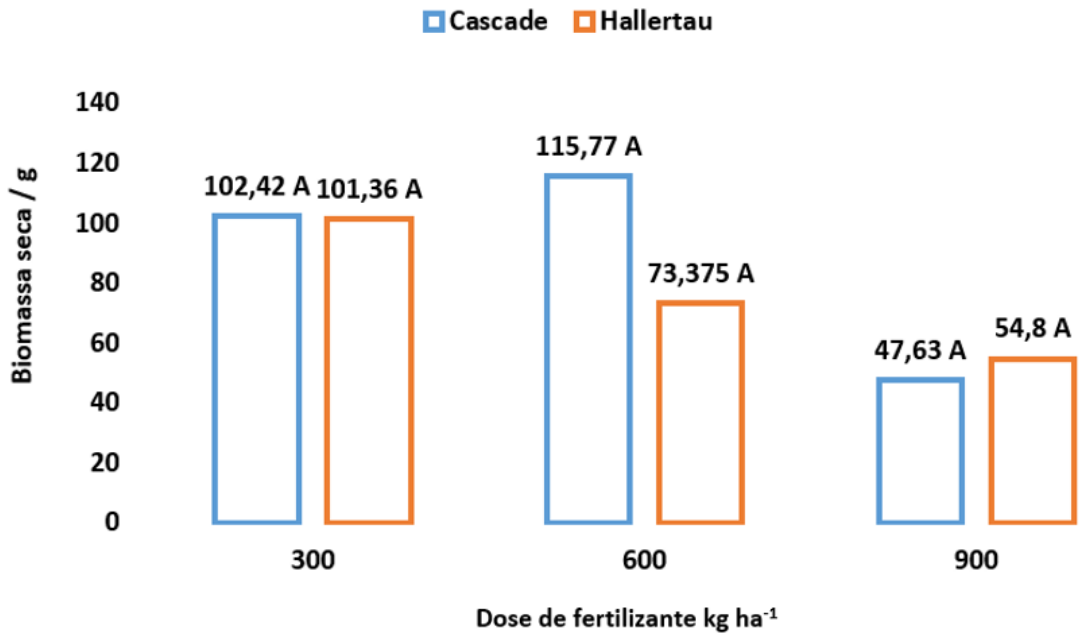
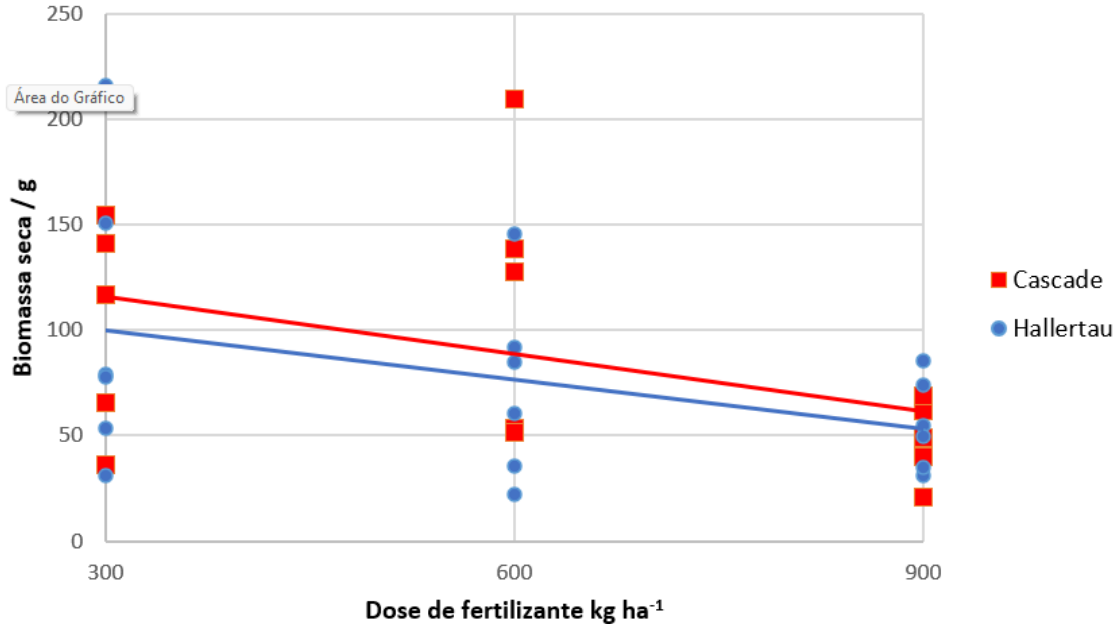


Figure 4. Dry biomass of hop plants as a function of the dose of the formulated fertilizer from 20--05--20 8 months after planting in Dracena-SP.



In terms of productivity, there was little flowering of the plants, with 36% of them reaching this stage. This fact did not allow a broader statistical approach to be carried out, and the results of cone biomass per plant are presented as the values found in all the treatments and repetitions (Table 1). Low hop production in the first year of cultivation is expected, with the absence of cones even being reported during this period. It is expected to reach 50% and more than 60% of the plant's productive potential in the second and third years, respectively. Thus, the peak of crop production is observed after the fourth year of cultivation (MAPA, 2022).

Table 1. Biomass of cones produced, in grams, according to cultivar and dose of formulated fertilizer from 20--05--20 8 months after planting in Dracena-SP.

	R1	R2	R3	R4	R5	R6
T1		56.17	18.3			
T2			23.5		62.35	
T3		25.1		20.1		
T4	18.4					14.5
T5	17	67.3			21.1	
T6	18		55.25			

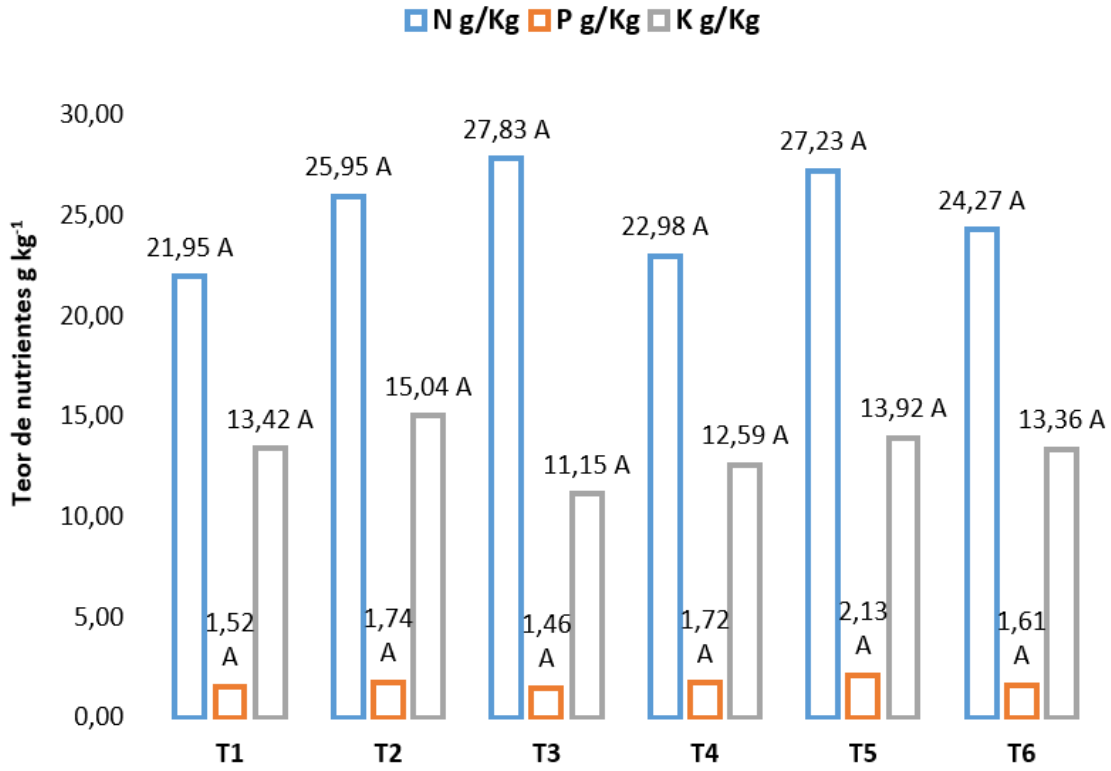
***Legend:** Composition of treatments (variety and dose): C – Cascade; H – Hallertau. T1-C300, T2-C600, T3-C900, T4-H300, T5-H600, T6-H900.

When the foliar contents of N, P and K were evaluated, the Cascade and Hallertau cultivars presented similar absorption of these nutrients (Figure 5). The same was demonstrated according to the fertilizer dose, which implies that the increased availability of these elements in the soil was not reflected in greater accumulation by the plants (Table 2).

However, the analysis of the percentage of each nutrient in hop leaves according to the cultivar and dose of the formulated fertilizer from 20--05--20 demonstrated that nitrogen is

the element that is most highly absorbed by the plants, followed by potassium and phosphorus (Table 3).

Figure 5. Leaf nitrogen, phosphorus and potassium contents according to cultivar and dose of formulated fertilizer from 20--05--20 8 months after planting in Dracena-SP (means with the same letters do not differ according to Tukey's test ($p<0.05$) between cultivars).



**Legend: Composition of treatments (variety and dose): C – Cascade; H – Hallertau. T1-C300, T2-C600, T3-C900, T4-H300, T5-H600, T6-H900.*

Table 2. Leaf nitrogen, phosphorus and potassium contents according to cultivar and dose of formulated fertilizer (20–05–20) 8 months after planting in Dracena-SP (significant difference according to regression analysis between fertilizer doses if $p<0.05$).

Nutrient g kg $^{-1}$	T1	T2	T3	P value
N	21.95	25.95	27.83	0.105
P	1.52	1.74	1.46	0.761
K	13.42	15.04	11.15	0.140
Nutrient g kg $^{-1}$	**T4**	**T5**	**T6**	**P value**
N	22.98	27.23	24.27	0.613
P	1.72	2.13	1.61	0.735
K	12.59	13.92	13.36	0.661

***Legend:** Composition of treatments (variety and dose): C – Cascade; H – Hallertau. T1-C300, T2-C600, T3-C900, T4-H300, T5-H600, T6-H900.

Table 3. Percentages of nitrogen, phosphorus and potassium accumulated in hop leaves according to cultivar and dose of formulated fertilizer from 20--05--20 8 months after planting in Dracena-SP.

Nutrient g kg $^{-1}$	T1	T2	T3	T4	T5	T6
N	2.19%	2.60%	2.78%	2.30%	2.72%	2.43%
P	0.15%	0.17%	0.15%	0.17%	0.21%	0.16%
K	1.34%	1.50%	1.12%	1.26%	1.39%	1.34%

***Legend:** Composition of treatments (variety and dose): C – Cascade; H – Hallertau. T1-C300, T2-C600, T3-C900, T4-H300, T5-H600, T6-H900.

The results of NPK levels in plants from this innovative hop crop in a tropical climate in Nova Alta Paulista are consistent with the studies by Gingrich, Hart and Christensen (2000) and Dagostim (2019). This author reported a nitrogen percentage between 1.40% and 2.46%, observing that fertilizer doses above 160 kg ha $^{-1}$ for this nutrient are not fully utilized by the plants. The same behavior was observed in the present study, since there were no significant differences in the foliar nitrogen content at the highest doses of the formulated fertilizer.

In terms of phosphorus, the results of Dagostim (2019) are greater than the results obtained in this study. However, Oliveira (2016) reported levels of this element between 0.08% and 0.14% with the application of up to 350 kg ha^{-1} phosphorus as fertilizer.

Finally, Dagostim (2019) and Oliveira (2016) reported greater and lesser amounts of potassium, respectively, in hop leaves than in the present work, even without fertilization.

4 CONCLUSIONS

The two hop varieties used did not differ in terms of agronomic performance after 8 months of cultivation. However, doses higher than 300 kg ha $^{-1}$ of the formulated fertilizer 20--05--20 resulted in lower development, highlighting the reduction in plant height for the Cascade variety.

Although no differences were found between cultivars and fertilizer doses, hops grown in tropical climates absorbed nitrogen primarily, followed by potassium and phosphorus.

In terms of productivity, some plants of both varieties reached the flowering point. Although the percentage found is low, this positive result for the first year of cultivation highlights the agronomic and economic potential of hops in Brazil, enabling the exploration of yet another important crop in Nova Alta Paulista and other tropical regions of the country.

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