

## RESEARCH ARTICLE

# Agronomic performance of hops cultivars in the northern region of Rio Grande do Sul, Brazil

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**ABSTRACT**

Hops (*Humulus lupulus* L.) is a plant native to Europe and northern Asia, belonging to the Rosales order and the Cannabaceae family. Hops are used in the production of beer, which contributes to the bitterness and aroma of different types. In view of this, the objective was to evaluate the adaptation and productivity of two hop cultivars, under soil and climate conditions in the north of the state of Rio Grande do Sul. The experiment was implemented at the university CESURG Sarandi - RS, the cultivars evaluated were Cascade and Chinook. The experimental design used was randomized blocks, consisting of two cultivars, in four blocks, 7 replications (plants). Initial development was evaluated during the crop cycle. In the phenology at the stage of maturation, the following were measured: plant height and green mass, green and dry mass of cones, number of cones, width and length of the cone, number of bracts. The data were submitted to analysis of variance. Tukey's means were compared ( $p>0.05$ ). In addition, a descriptive analysis was performed. Analyzes were performed using the R program and Microsoft Office Excel was used to make graphs. There was an adaptation and productivity of the hop cultivars chosen, in edaphoclimatic conditions of the region. In addition, this project will make it possible for producers in the region to get to know the culture, and for it to be seen as a source of income, demonstrating aspects of the cultivar and how to start implementation. In view of this, the best cultivar was Chinook, demonstrating better productivity and production. The 2021/2022 crop season was a year of habituation and knowledge of cultural practices, from the second hop crop onwards, there will be an increase in production, as the rhizomes acquire more nutritional reserves.

**Highlighted Conclusions**

1. Cascade and Chinook cultivars showed similar cone productivity, showing growth and development in the North Region of Rio Grande do Sul in the first year of cultivation.
2. The Chinook cultivar showed great potential due to the larger size and fresh mass of 10 pine cones.

**INTRODUCTION**

Hops (*Humulus Lupulus* L.) is a plant native to Europe and Northern Asia, belonging to the Rosales order and the Cannabaceae family (Heale 1989). Hops are used in the production of the beer, in which they contribute to the bitterness and aroma of different types of beers (Marceddu et al. 2020).

Hop production stands out mainly in temperate countries. World production of hops reached 125.9 thousand tons in an area of 62.7 thousand ha in 2021. Of this total, the United States is responsible for 40%, followed by Germany (36%), Czech Republic (6%), China (5%), England (1%), other European countries represent 7%, and the rest of the world is responsible for the production of 4% (USAHOPS 2022). In Brazil, the planted area is approximately 60 ha distributed in the states of Rio Grande do Sul, Santa Catarina, Paraná, São Paulo, Rio de Janeiro and Minas Gerais (Ezequiel 2022). So far, Brazil produces a small amount, so a large part of the hops needed for brewing is imported (Fagherazzi 2017).

Hops can be grown in well-drained or sandy clay soils. For the culture, pH correction is recommended in the range of 6.2 to 6.8. The ideal temperature for crop development is 19.5 °C. The crop has great water demand, especially in the sprouting period, which occurs between June and August. In relation to fertilization, hops is a plant that is demanding in magnesium, calcium, potassium, phosphorus and nitrogen (Sasso 2021).

Lupulin is found in the female hop plant, called cone, which is used in the manufacture of resins that are not found in other species (Spósito et al. 2019), which are present in alpha and beta-acids, responsible for bitterness, and essential oils for the aroma of beer (Muller 2021). The percentage of acids is related to the period in which the cones are boiled in the must, the simple fact of adding hops in different stages of boiling, fermentation or maturation is enough to change the final result. The varieties of hops are divided into 3 categories: bitterness, aroma and double fitness (Nascimento et al. 2020).

Through sensory and qualitative analyses associated with the climatic conditions of the place of cultivation, the type of soil and agricultural practices that establish unique and unique characteristics of taste and aroma. Due to these genotypes, the choice of cultivars should be evaluated in each microclimate, with better adaptability and phenotypic balance, emphasizing the selection of new flavors and aromas, resulting in a beer with regional identity and with greater added value (Santos 2022).

Recently, the area of cultivation of this crop has grown satisfactorily and expanded in the country. To serve the different edaphoclimatic regions of Brazil, there are 50 cultivars registered with the Ministry of Agriculture, Livestock and Supply (2022). Among the most planted cultivars are Cascade, Centennial, Fuggle, Magnum, Hallertau, Northern Brewer and Nugget that have greater expressiveness. The development of culture in the South region, and especially in the North of Rio Grande do Sul, can collaborate with regional development, and bring another culture to the diversification of rural property.

In view of the above, it becomes increasingly important to know the agronomic performance of each cultivar according to the edaphoclimatic factors of the region. Thus, the present work aimed to evaluate the adaptation and productivity of hop cultivars in the northern region of the state of Rio Grande do Sul.

## MATERIAL AND METHODS

The experiment was implemented at the Centro de Ensino Superior Riograndense-CESURG, with the help of professors and interns. The area is located in the municipality of Sarandi in the state of Rio Grande do Sul, 27°99'47" S, 52°89'69" W. The soil in the region is classified as a typical dystrophic Hapludox (Santos et al. 2018). According to the Koppen climate classification, it is humid subtropical - Cfa, with an average annual temperature of 19.1°C and an average annual rainfall of 2,100 mm (Alvares et al. 2013).

The support structure was composed of wooden sticks (eucalyptus) with a height of 6 meters, spaced 4 meters apart, and at the top it has a T-shaped structure for conducting the crop. The structure follows the direction of implantation North-South. The anchoring method was carried out on the edges using a master platform, ratchet and anchor rod (dead). The support and binding of the hops was done by wires attached to wooden sticks, and with a sisal cord from the base of the soil to the top, spaced 1 meter apart. The area has a drip irrigation system.

Before the planting of the crop, the area was prepared, in which soil analysis, correction, fertilization and installation of the necessary structure for the cultivation of hops were carried out. A soil sample was collected from 0-20 cm, and from the chemical analysis carried out pH correction to 6.5 with magnesian limestone. In addition, subsoiling was carried out at a depth of 60 cm. For base fertilization, 20 t ha<sup>-1</sup> of organic fertilizer (poultry litter) was used. As cover and green manure, pearl millet (*Pennisetum glaucum*) was used in the summer period, broadcast sown at a density of 25 kg ha<sup>-1</sup>. During the winter, coverage with black oats (*Avena strigosa*) was used, sown in May with a density of 100 kg ha<sup>-1</sup>.

The cultivars used for evaluation were Cascade and Chinook. The seedlings used came from Americas' Beverage Company - AmBev/ Lages, SC. The cultivar seedlings, recommended by AmBev itself, were transplanted in December 2021. Each cultivar will have 80 seedlings, subdivided into two rows with 40 seedlings, spaced 1 m between plants and 4 m between rows. The experiment has a total area of 640 m<sup>2</sup>, totaling 160 seedlings. The experimental design used was randomized blocks, with four blocks (rows) and 7 plants per block for each cultivar. Therefore, 28 plants per cultivar were evaluated.

The formation fertilization, carried out in the first harvest, had three applications of 50 g of NPK (10-10-10) per plant. The first application was carried out at the beginning of sprouting, the second in leaf development and the third in the elongation phase of the main branch. For the second and third year, three applications of 150g of NPK (10-10-10) per plant were made in the same systematics as in the first year. Needing to complement with nitrogen fertilization (ammonium sulfate) in November/December. In December, the use of nitrogen is interrupted and fertilizers based on potassium (K), calcium (Ca) and boron (B) are started by foliar application to stimulate better flowering quality. Preventive management will be carried out to control pests and diseases. Among the insects observed and controlled, there are the leaf-cutting ant (*Atta sexdens*, *Atta laevigata* and *Acromyrmex* spp.) and the cowbird (*Diabrotica speciosa*) (Testa 2022).

The collected data were examined by analysis of variance, after meeting the assumptions. For the initial growth analysis, quantitative effect, selection analysis for regression fitting. And for the other qualitative variables, in case of a significant effect, comparison of means is performed by Tukey ( $p>0.05$ ). In addition, a descriptive analysis of the data obtained was carried out. The analyzes were performed using the R program (R Core Team 2019), and Microsoft Office Excel was used to make graphs.

## RESULTS AND DISCUSSION

Analysis of variance (ANOVA) revealed effects experienced for the variables fresh mass of 10 cones (FM 10), dry mass of 10 cones (DM 10), cone length (CL) and cone width (CW) (Table two). For the other variables, insertion height of the first cone (IHF), total plant height (TPH), plant green mass (PGM), cone mass (CMASS), fresh cone yield (FC) and number of bracts (NB) there was no significant difference for the treatment factor (Table 1 and 2).

**Table 1. Summary of the Analysis of Variance for insertion height of the first cone (IHF), total plant height (TPH), plant green mass (PGM), cone number (CN), cone mass (Cmass).**

Factor of Variation	Degrees of Freedom	Mean Square				
		IHF	TPH	PMG	CN	Cmass
BLOCK	3	537.58 <sup>ns</sup>	444.79 <sup>ns</sup>	1,463.81 <sup>ns</sup>	957.11 <sup>ns</sup>	568.92 <sup>ns</sup>
TREATMENT	1	1,512.5 <sup>ns</sup>	4,387.03 <sup>ns</sup>	2,134.33 <sup>ns</sup>	355.64 <sup>ns</sup>	725.23 <sup>ns</sup>
RESIDUE	3	701.82	3,157.97	6,222.51	1,627.75	508.56
TOTAL	7					
AVERAGE		116.25	398.21	231.79	89.96	52.44
CV(%)		22.79	14.11	34.03	44.85	43.01

\*Significant to the F test at 5% probability of error. ns Not significant.

**Table 2. Summary of the Analysis of Variance for the fresh mass of 10 cones (FM 10), dry mass of 10 cones (DM 10), cone length (CL), cone width (CW), number of bracts (NB) and fresh cone yield (FC).**

Factor of Variation	Degrees of Freedom	Mean Square					
		FM 10	DM 10	CL	CW	NB	FC
BLOCK	3	0.77 <sup>ns</sup>	0.012 <sup>ns</sup>	4.33 <sup>ns</sup>	0.80 <sup>*</sup>	16.64 <sup>ns</sup>	4,460.77 <sup>ns</sup>
TREATMENT	1	31.72 <sup>*</sup>	1.93 <sup>*</sup>	189.05 <sup>*</sup>	38.41 <sup>*</sup>	59.24 <sup>ns</sup>	5,685.33 <sup>ns</sup>
RESIDUE	3	0.61	0.015	13.017	2.49	25.00	3,987.10
TOTAL	7						
AVERAGE		7.07	1.67	31.59	19.11	45.11	
CV(%)		10.99	7.33	11.49	12.41	11.08	43.01

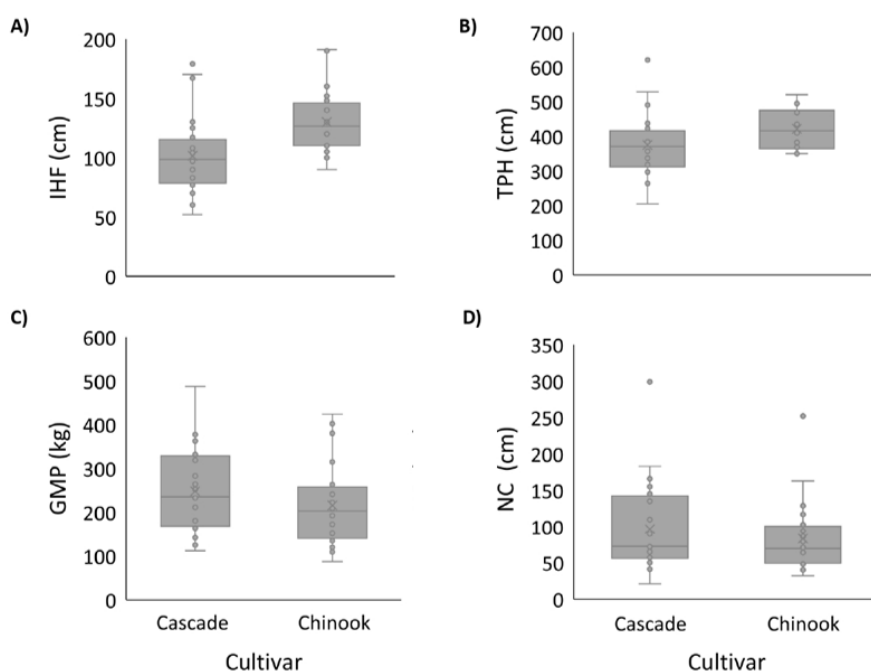
\*Significant to the F test at 5% probability of error. ns Not significant.

For the IPA (Height of insertion of the first cone) an average of 116.3 cm and coefficient of variation (CV) of 22.79% was observed. The cultivar Chinook presented the maximum height being 191 cm, and the cultivar Cascade in about 179 cm (Figure 1 - A). The insertion height of the first cone is a demonstration of how much the plant can produce, assisting in the management of the crop. This feature is linked to the development, architecture of the plant and the production of cones, the sooner the plant begins its process of developing lateral branches, it will present more cones, these originate from the main stem, and may have two to four cones per node.

In Brazil, the duration of daylight reaches less than 14 h in the regions of higher latitude (Gonsaga 2021). Jastrombek (2022) points out that hop plants grown under this day length condition tend to flower prematurely and therefore have limited branch growth and cone yields. Comparing the three hop growing sites, the length of day throughout the year differs between them. For example, in higher latitude regions, such as Lages (28° S), day length in winter (June-August) is shorter, but in mid to late summer (December-March), day length is shorter. Larger than Palotina and Ribeirão Preto. This climatic condition was, in fact, one of the main causes of failure in the cultivation of hops in the country in all previous attempts, when there were no techniques for manipulating hop flowering through supplementary lighting (Bizotto 2019).

In the APT (Total Plant Height) the plants presented an average of 398.2 cm, and CV 14.11%, indicating that both can reach on average the same height at the end of development, i.e., at the cone maturation stage. The cultivar Cascade showed a plant height variation from 205 cm to 620 cm, with an average of 374.8 cm. For the

cultivar Chinook, a variation from 350 cm to 520 cm was observed, with an average of 421.6 cm (Figure 1 - B). According to research carried out by Gonsaga (2021), among the evaluated cultivars, the cultivar that stood out was Mantiqueira in relation to the others, reaching the top of the trellis with 6 meters. Fagherazzi (2020) pointed out in his work that all cultivars reached the maximum point of proposed height of the conduction system in the experimental fields, with a height of 5 m. In addition, during the two years of evaluation, Fagherazzi (2020) observed that the Cascade and Chinook cultivars stood out in relation to the others (Columbus and Yakima Gold), and had an average height of 5.13 and 5.18 m.



**Figure 1. Results for A) insertion height of the first cone (IHF), B) total plant height (TPH), C) green plant mass (GPM), and D) number of cones per plant (NC) for the cultivars Cascade and Chinook in the season of 2021/22. Sarandi, RS, 2022.**

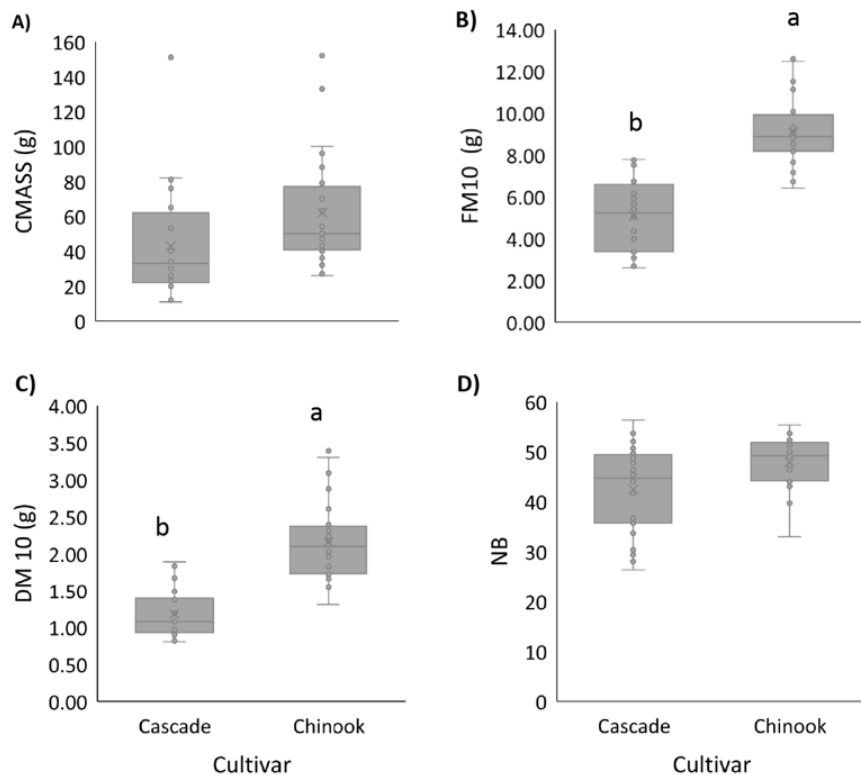
The harvesting of hop plants begins when the cones reach maturity, that is, when they have characteristic aroma and color. Chinook presented an amplitude of 87 g to 424g at the MVP (green mass of the plant) weighing, closing an average of 215.5 g (Figure 1 - C). The cultivar Cascade ranged from 112g to 487g, totaling an average of 248.1 g. This indicates that both after harvest, have indicated a good adaptability and the analysis of this characteristic considers adequate both cultivars to production. Totalling an average 231.79 g and a CV(%) 34.03.

Female hop plants have powerful ability to produce inflorescence and cones (FAGHERAZZI, 2020). The final number of cones depends on the number of terminal buds being transformed into flower buds. The NC (Number of cones) in the first harvest was on average 89.96, and a CV of 44.85% (Table 1). A high amplitude was observed for NC, with a minimum value of 21 and a maximum of 299 cones for Cascade. Chinook presented an advantage to Cascade with a maximum of (252) and a minimum of 32 (Figure 1-D).

Hop quality is primarily measured by the alpha acid content of the strobili, which also determines the value and price of the crop. The alpha acid content has been decreasing in some growing areas, for example in the Czech Republic, due to changes in climatic conditions and high concentration of non-air CO<sup>2</sup> which may compensate for some negative effects (KORPELAINEN, 2021).

In Brazil, identification and quantification of receipts has been differentiating the characteristics of the most planted cultivars. In the Cascade variety, a high concentration of myrcene, caryophyllene and humulene components was observed, and in the Hallertau Mittelfruh variety, the presence of high levels of alpha and beta selinene and farnesene was observed. The presence of these components adds to the herbaceous aromas of Hallertau Mittelfruh produced in Curitiba, with woody, sweet and citrus notes (FAGHERAZZI, 2017).

Santos (2022) states that the great edaphoclimatic influence, dry weather and low rainfall in harvest time, can lead to the accumulation of terpenoids in relation to other cultivation sites. Cascade and Chinook cultivars did not differ for CM (Cone mass). There is an average of the cone mass of 52.44 grams and the CV (%) 43.01 (Figure 2– A). The Cascade cultivar obtained a minimum of 11 g and a maximum of 151 g and an average of 42.9 g, unlike Chinook which ended with 26g to 152g and an average of 62 g (STANIUS, 2022).



**Figure 2. Results for A) cone mass (CMASS), B) fresh mass of 10 cones (FM 10), C) dry mass of 10 cones (DM 10), and D) number of bracts (NB) for Cascade cultivars and Chinook in the 2021/22 season. Sarandi, RS, 2022. \*Averages followed by a different letter show differences for the Tukey test ( $p < 0.05$ ).**

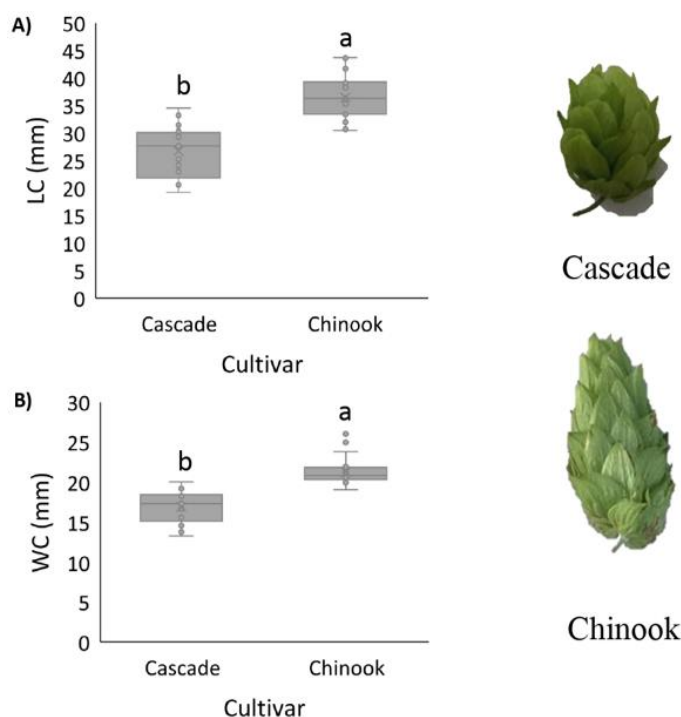
For a fresh mass of 10 cones (MF 10), an average of 7.074g was observed. In addition, there was a difference between Cascade and Chinook, demonstrating that the Chinook variety has a greater fresh mass (12.6 g) compared to Cascade (7.8 g). These results are due to meteorological conditions and mainly because it is the first growing season (Figure 2 – B). Fagherazzi (2020) reports that the Chinook, Columbus and Cascade cultivars did not differ in the first year in the experiment in Lages for a fresh mass of 10 cones. Meanwhile, in the second year of the study, the Chinook and Yakima Gold cultivars obtained heavier cones. In the experiment located in São Joaquim, the same author reports an average fresh mass of 8.77 g, and there was no significant difference between the evaluations of cultivars. Still in the same work, Fagherazzi (2020) evaluates different cultivars in the municipality of Palmeira, and highlights the cultivar Columbus, which differed from the other cultivars and weighed 2.51 grams more than Cascade for the variable fresh mass of 10 cones.

The dry mass of 10 cones (DM 10) showed significance between cultivars, indicating that Chinook had a maximum of 3.4 g and Cascade 1.9 g, considering that Chinook was highlighted in the observation in relation to the final weight (Figure 2 - C). With a CV of 7.33% and an average of 2.2 g compared to Cascade, which concluded with an average of 1.2 g.

For the number of bracts per cone (NB) there was no significant difference. A maximum value of 55.3 and a minimum of 26.3 was observed, and an average of 42.4 bracts per cone. According to Fagherazzi (2020), in a controlled experiment in Lages - SC, the number of bracts was higher for Columbus and Cascade, with means of 73.14 and 69.55 respectively. However, the author points out that in the other municipalities (São Joaquim - SC and Palmeiras - SC), there was no statistical difference between cultivars in terms of the number of bracts per count. The Chinook, Columbus and Cascade cultivars did not differ in the first year in the experiment in Lages for fresh mass of 10 pine cones. Already in the second year of study, the Chinook and Yakima Gold cultivars obtained heavier cones. In the experiment located in São Joaquim, the same author reports an average fresh mass of 8.77 g, with no significant difference between the evaluations of the cultivars. Still in the same work, Fagherazzi (2020) evaluates different cultivars in the municipality of Palmeira, and highlights the Columbus cultivar, which differed from the other cultivars and weighed 2.51 grams more than Cascade for the variable fresh mass of 10 pine cones.

Figure 3 shows the characteristic length cone (LC) and width cone (WC). Note the difference between cultivar assessments for cone size. The Chinook cultivar had an average of 36.4 cm for LC and 21.3 cm for WC. While the cultivar Cascade showed an average value of 26.7 cm for CL and 16.9 cm for WC. It should also be noted that the

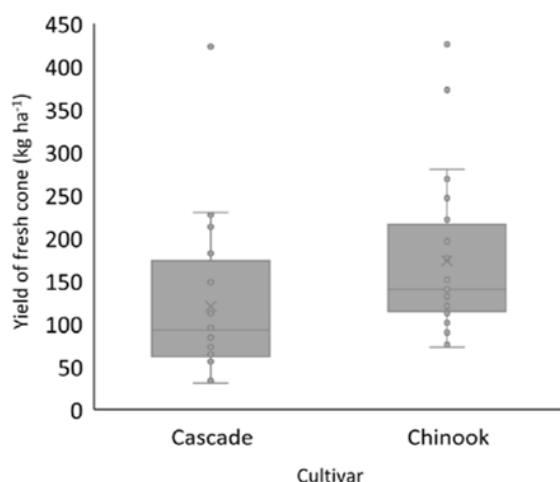
Chinook cultivar has the potential to increase the cone size in the next harvests, due to the observed maximum values of 43.7 cm in length and 26 cm in width (Bolton 2019).



**Figure 3. Results for A) length cone (LC), B) width cone (WC), for Cascade and Chinook cultivars in the 2021/22 season. Sarandi, RS, 2022. \*Averages with different letters within each graph differ by Tukey's test ( $p < 0.05$ ).**

Knowing that the production of lupulin is evaluated in hop cones, the best formation of these, makes a good production, in view of this, Chinook becomes the cultivar that obtained the most point positives. Fagherazzi (2020) reports that in the first year of cultivation, Chinook has the longest cone length, fitting as a medium cone.

In figure 4, an evaluation of the yield of fresh hop cones (FC) determines that the Chinook cultivar obtained a better yield with an average of 173.48 kg/ha, higher than Cascade with an average of 120.17 kg/ha. Fagherazzi (2020), in a controlled experiment in the municipality of Lages in the 2018/2019 harvest, highlights Columbus as the cultivar that produced the most, totaling 2,400 kg/ha, higher than Yakima Gold. Fagherazzi (2020) reports the difference for the following year (2019 - second year of cultivation), where the harvest makes Columbus the best cultivar for both years, with a difference of 3,189 kg/ha. Among the other municipalities, the cultivar Columbus continues to stand out in terms of yield, both in São Joaquim and in Palmeiras.



**Figure 4. Results for A) Yield of fresh cone (FC) for Cascade and Chinook cultivars in the 2021/22 season. Sarandi, RS, 2022. \*Averages followed by a different letter show differences for the Tukey test ( $p < 0.05$ ).**



In this first harvest, which took place in 2021/2022, the reduced fresh cone productivity may be linked to the plant cycle, and the reduced period from sprouting to maturity, due to the transplantation taking place in December. The estimated production per plant in the first year is always lower, and there is a tendency to increase in the second and third years, as the rhizomes acquire more nutritional reserves (JASTROMBEK, 2022).

In conclusion, Cascade and Chinook cultivars showed similar cone productivity, showing growth and development in the North Region of Rio Grande do Sul in the first year of cultivation. The Chinook cultivar showed great potential due to the larger size and fresh mass of 10 pine cones. It underscores the importance of yield evaluations in the next harvests, as well as the analysis of chemical compounds in the pine cones. In this way, the results obtained are of great value for the scientific community, as well as for producers in the North of Rio Grande do Sul.

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