



Performance and variability for agronomic characteristics and brewing interest of hop genotypes in the Planalto Catarinense

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ABSTRACT: Studies on the improvement of hops (*Humulus lupulus*) in Brazil are recent and seek to establish self-sufficiency in production. Knowledge of the variability of genotypes available in the country is of fundamental importance for the development of a hop improvement program. The objective of the research was to characterize and identify hop parents with agronomic and brewing potential for the Planalto Catarinense region, Brazil. The randomized block design arranged in a 3x4 factorial scheme was used with 12 treatments: (Factor 1: three years of cultivation (2019, 2020 and 2021) and combined with factor: four genotypes (Cascade, Chinook, Columbus and Hallertau). The characters evaluated were fresh mass of plants (MFP, g), green mass of cones (MTV, g), dry mass of cones (MSC, g), alpha-acid content (ALFA, %) and production (PROD, g per plant). The Hallertauer genotype showed better performance and differentiated behavior for the characters of fresh mass of plants, dry mass of cones and production, when compared to the others. Thus, from these results it was observed that there is variation available for the genetic improvement of hops for these characters, a factor that will allow obtaining productive gains in the development of new cultivars, based on this promising genotype.

Key words: *Humulus lupulus* L., plant genetic improvement, genetics, cultivars.

Desempenho e variabilidade para caracteres de interesse agrônomo e cervejeiro de genótipos de lúpulo no Planalto Catarinense

RESUMO: Os estudos visando o melhoramento de lúpulo (*Humulus lupulus*) no Brasil são recentes e buscam estabelecer a autossuficiência da produção. O conhecimento da variabilidade dos genótipos disponíveis no país é de fundamental importância para o desenvolvimento de um programa de melhoramento de lúpulo. O objetivo do trabalho foi identificar genitores de lúpulo com potencial agrônomo e cervejeiro para o Planalto Catarinense, Brasil. Foi utilizado o delineamento em blocos casualizados em esquema fatorial 3x4 com 12 tratamentos: Fator 1: três anos de cultivo (2019, 2020 e 2021) e combinado com o fator 2: quatro genótipos (Cascade, Chinook, Columbus e Hallertau). Os caracteres avaliados foram a massa fresca de plantas (MFP, g), massa verde de cones (MTV, g), a massa seca de cones (MSC, g), os teores de alfa-ácidos (ALFA, %) e a produção (PROD, g por planta). O genótipo Hallertauer demonstrou melhor desempenho e comportamento diferenciado para os caracteres de massa fresca de plantas, massa seca de cones e produção, quando comparado aos demais. Assim, a partir destes resultados observou-se que, existe variação disponível ao melhoramento genético do lúpulo para esses caracteres, fator que permitirá obter ganhos produtivos no desenvolvimento de novas cultivares, a partir deste genótipo promissor.

Palavras-chave: *Humulus lupulus* L., melhoramento genético vegetal, genética, cultivares.

INTRODUCTION

Hops (*Humulus lupulus* L.) are a perennial climbing herb, belonging to the Rosales order and the Cannabaceae family, dioecious, of possible Asian origin and adapted to temperate climates. The species is cultivated on a large scale for the manufacture of beer due to the crystalline resin (lupulin) produced by its female inflorescences or also commercially called cones. Lupulin is composed of alphas, beta-acids and essential oils. Its functions are to impart aroma, flavor and microbiological stability to the drink (ALMAGUE, 2014; HIERONYMUS, 2012).

Brazil is the third largest producer and consumer of beer in the world, the country produced

15.3 million liters of beer in 2023 and has around 1800 commercial establishments of the product (CERVBRASIL, 2024). Craft beers are a niche market in Brazil that has been expanding rapidly in the last 5 years (35% per year). The state of Santa Catarina has national beers that are internationally awarded due to their best quality. Beers are made up of four elements: water, malt, yeast, and hops. The main difficulty encountered in the sector is the lack of hops on the market or their high cost. The country imports practically all the hops consumed, mainly from the United States, Germany, and the Czech Republic. In 2022, around 4 thousand tons of hops were imported, generating an amount of 298 million reais per year (JASTROMBEK et al., 2022; COMEXSTAT/MDIC, 2023; APROLÚPULO, 2024).

Hop planting occurs predominantly in latitudes between 35° to 55° North and South (HIERONYMUS, 2012) due, initially, to the belief that it would not be possible to produce hops on a commercial scale in low latitude countries. Historically in Brazil, the species has been cultivated on a small scale (SILVA, 1868). Recently, the planting of the species has spread in initial phases across 11 Brazilian States, Santa Catarina is the state with the largest cultivation area with approximately 8.5 hectares and around 50 producers (BRASIL, 2022). Hop cultivation in the region will make it possible to meet local demand, offering better quality fresh hops.

However, sustainable and economically viable hop production requires the development of new cultivars. Through plant genetic improvement, it is possible to develop hybrid or transgressive genotypes that can result in obtaining more productive cultivars with improved characteristics for flavor and; therefore, with greater added value (SANTOS et al., 2022). The success of genetic improvement depends on the availability of a collection of germplasm with a frequency of genes with high potential (effective variability). Its commercial production only started to be important in 2016 when several cultivars were imported and registered by commercial nurseries with authorization and registered with MAPA (Ministério da Agricultura, Pecuária e Abastecimento) and are available for commercialization with around 50 hop genotypes from the United States and Germany (BRASIL, 2022).

The most used and commercialized genotypes in the public domain are: Columbus, Chinook, Cascade and Hallertauer. The genotypes were selected for bitterness, dual purpose and aroma characteristics, that is, in relation to their function in beer production (HIERONYMUS, 2012). Information on individual performance, genetic structure of genotypes and their phenotypic variations are directly linked to cultivar recommendations and their use in genetic improvement programs for the South region (ALLARD, 1999; ORTON, 2019).

The objective of the research was to characterize and identify hop parents with agronomic and brewing potential for the Planalto Catarinense region, Brazil.

MATERIALS AND METHODS

The trial was conducted in the experimental garden located in the area of the Universidade Estadual de Santa Catarina at the Center for Agroveterinary Sciences (CAV), in Lages-SC (27°47'S, 50°18'W and

916 m altitude) Planalto Catarinense region, Southern Brazil in three consecutive years (2019 to 2021). The soil at the study site is classified as Cambisol Húmico Alumínio Léptico (EMBRAPA, 2004), with a moderate A horizon, clayey texture and wavy relief, and has the following properties: 34% clay, pH: 5.93, P: 10.06 mg dm³; K: 80 mg dm³, MO: 2.61%, Ca: 5.42 cmol dm³ and Mg: 2.10 cmolc dm³. The climate according to Koeppen's classification is Cfb-Temperate mesothermal, humid with mild summers. The climate is temperate subtropical, with an average temperature of 14.3 °C. Absolute maximum temperature: 36 °C. Absolute minimum temperature: -7 °C. Relative air humidity annual average of 79.3%. The length of the day in Lages varies throughout the year. The shortest day is June 20, with 10 hours and 23 minutes of sunlight. The longest day is December 21st, with 13 hours and 55 minutes of sunlight.

Four hop genotypes were evaluated (Cascade, Chinook, Columbus and Hallertauer), originating from local rural production. The young plants were propagated asexually (rhizomes) and planting was carried out in October. The trial was conducted on a trellis system and the spacing used was 3 m between rows and 1 m between plants, without the use of artificial lighting. For productivity, a water depth of 5 L per plant was used daily from flowering to cone maturation. Cultural treatments followed technical recommendations for culture (DODDS, 2019). The experimental design used in blocks complete, with two repetitions in a 3 x 4 factorial scheme, with 12 treatments: (Factor 1: three years of cultivation (2019, 2020 and 2021) and combined with factor 2: four genotypes (Cascade, Chinook, Columbus and Hallertau). The data for experimental units were collected from two experimental plots within each block and for the observational units, two central plants (clones) were measured per plot, with each plot consisting of 5 plants, totaling 10 plants per treatment.

The response variables evaluated were plant fresh mass (MFP, g), dry weight of cones (MSC, g), alpha-acid content (ALFA, %) and production (PROD, g per plant). Productivity (kg ha⁻¹) was obtained from the production of cones (g per plant) and estimated per hectare, with a planting density of 3,200 plants. To determine the harvest point, the methodology according to DODDS (2019) was used, which consists of: 1) Analysis of the texture of the cone (texture that resembles slightly rough and dry) and; 2) Amount of lupulin (very present, with golden color and intense aroma of lupulin). To quantify the levels/content of alpha acids, conductometric titration (HOPS 6.B – Conductometric Titration) and HPLC

(High performance liquid chromatography) were used and the values were converted into percentages according to the official analysis of the American Society of Brewing Chemists (1976):

$$\text{Alpha-acids \% (m/m)} = \frac{358x\left(\frac{100}{10}\right) \text{End.p} \times C}{379,4 * W}$$

Where:

m/m: mass ratio of alpha-acids to the mass of lead acetate; End. p: volume of the titration end point of the lead acetate solution used, in m L⁻¹; 358: average molecular mass of α -acids; C: concentration of lead acetate solution, in % (g per 100 m L⁻¹); 379,4: molecular mass of the reagent lead (II) acetate trihydrate; W = initial weight of the sample (g).

The homogeneity of variance was assessed by Levene's test and data normality by Shapiro Wilk (STEEL & TORRIE, 1980). The global analysis of variance with unbalanced data for the evaluated traits of the genotypes was performed using general linear models (GLM procedure) in F at 5% probability. The mathematical model used was:

$$Y_{ijkl} = \mu + B_{lk} + Gen_j + Year_k + Gen * Year_{jk} + B_{lk} * Gen * Year_{ijk} + \varepsilon_{ijkl}$$

Where: Y_{ijkl} represents the observed value of the Gen_j response variable in Year k in Blk_l evaluated in each experimental unit; μ is the overall test average; Blk_l is the effect of the l-th block level; Gen_j is the j-th level of the genotype factor; $Year_k$ represents the k-th level of the environment factor; $Gen * Year_{jk}$ is the effect of the genotype*year interaction; $Blk * Gen * Year_{ijk}$ is the effect of the error within each plot and; ε_{ijkl} is the effect of the experimental error associated with the observation units.

The relationship between errors between and within was carried out to evaluate the accuracy of the assessments. The orthogonal univariate contrasts of interest were established according to the following scheme: C1: Hallertauer vs Cascade, Chinook and Columbus; C2: Cascade vs Chinook and Columbus; C3: Chinook vs Columbus. The phenotypic correlations between all characters were estimated using Pearson's correlation coefficients at 5% probability and the direct and indirect effects were broken down using path analysis. The analyzes were processed with SAS computational assistance (SAS Ondmands for academics).

RESULTS

According to the analysis of variance for the genotype factor, significant differences were observed for the plant fresh mass (MFP) and production (PROD) traits ($P < 0.05$). However, the

variables dry mass of cones (MSC), alpha-acids (ALFA) did not show significance between the genotypes evaluated (Table 1).

The relationship between the error between and within was not significant, therefore, indicating that the effects between plants within the same sampling unit are purely random. Genetic variance values were high. The results of the F test showed that there were no interactions between genotype and year for the evaluated characters. However, if in the analysis of variance only one of the comparisons involves few differences and the others do not, an average F test may fail, requiring a thorough analysis of the data (MELO et al., 2018). Thus, orthogonal univariate contrasts were performed when comparing means to evaluate the behavior of the genotypes, making it possible to determine the presence of phenotypic variability between previously established genotypes or groups of genotypes. According to the contrast results, only contrast C1 showed significant differences at 5% probability (Table 2).

For the contrast values (estimated averages) the fresh mass character of plants, it was observed that the Hallertauer genotype was superior to the others with 493 g per plant and an estimated productivity of 1575g ha⁻¹ (data not shown), in relation to the media of Cascade, Chinook and Columbus genotypes. These values are expressed as 128g per plant (34% higher), when compared to the average of the Cascade, Chinook and Columbus genotypes. Meanwhile, our Columbus and Chinook genotypes inspired average values of 312g per plant, respectively. The lowest average fresh mass values were distributed at 256g per plant (Cascade), that is, 49% lower than the Hallertauer genotype.

The Hallertauer genotype also produced better average values for the dry mass of cones (50% higher or average of 85g per plant) when compared to the other genotypes (Data not shown). The average values obtained for the dry mass of cones were: Chinook (51g per plant); Colombo (48g per plant); and the lowest results with Cascade (26g per plant). For the alpha-acid concentration (ALFA) character values, there were no significant differences between the genotypes and their concentration values were low (less than 7%) for all genotypes evaluated.

The character with the greatest power to discriminate between genotypes was production (Table 2, mean square: 825.699). Production between plants within genotype ranged from 30g to 1,500g per plant and between genotypes from 200 to 650g per plant (Data not shown). The genotype that demonstrated the highest productivity was Hallertauer with an average of 604kg ha⁻¹ (Table 3). The other genotypes do not correspond to the differences (Table 3). The Columbus

Table 1 - Summary of the analysis of variance (Mean squares) with the partition of errors between and within the sampling units for the variables plant fresh mass (MFP), dry mass of cones (MSC), alpha-acids (ALFA) and the production (PROD) for hop genotypes (Gen). Average of three consecutive cultivation years (2018/2019, 2019/2020, 2020/2021). Lages - SC, 2021.

Sources of variation	DF	MFP (g)	MSC (g)	ALFA (%)	PROD (g per plant)
Blk	1	5.270	2.901	0.554	121.579
Gen	3	121.753*	2.672	3.194	255.414*
Year	2	52.612	1.616	1.974	2.832
Gen * Year (e)	6	34.619	750	6.106	50.479
Error within (d)	10	29.083	2.023	2.431	52.043
e/d Ratio	6	35403.360	1791.040	4.705	50658.578
Total	19/17	216.138	1.270	0.046	31.480
CV (%)		32	60	10	48
Genetic variation ($\hat{\sigma}_g^2$)		14.52	320	0.48	34.15
Overall average		341	59	2	367

DF: degrees of freedom; e/d Ratio: Ratio of the error between and within; CV: coefficient of variation; Blk: Block; ns: not significant; *: significant at 5% probability using the F test.

genotype was the one that changed the most from Hallertauer, showing production 42% lower, with an average of 347kg ha⁻¹ and the lowest value was distributed to Cascade with an average value of 234 kg ha⁻¹ or 61% lower than best genotype (Table 3). In the present research increment values (13% or 47kg ha⁻¹) were also collected for the average production when the genotypes reached maturity in the third year compared to the first year of cultivation (Table 3).

The process of examining variation, evaluating phenotypic correlations and their consequences in direct and indirect effects are fundamental for the selection of promising traits to be used in breeding programs (VELHO et al., 2017). According to CARVALHO et al. (2004), indirect selection can be used to improve traits that are difficult to measure and that suffer high environmental influence. The results in table 4 show that productivity was positively correlated at 0.77 and with a high direct effect of 0.46 for plant fresh mass (MFP). For cone dry mass (MSC) a correlation value of 0.85 was observed, with a direct effect of 0.54 demonstrating high values. Conversely no positive and significant direct or indirect effect correlations were found between alpha-acids and vegetative or productive traits.

DISCUSSION

According to the results of contrast C1: Hallertauer vs Cascade; Chinook; Columbus (Table 2), Hallertauer was superior to the other

genotypes. Therefore, despite the low performance, there is variation between genotypes. The use of strategies in breeding programs, in relation to the selection and development of cultivars, enabled exploration in regions previously considered marginal or unsuitable for hops (BRITS, 2008). The first stage in the development of new plant cultivars is the introduction of varieties (recommended cultivars and/or hybrids) from other breeding programs in similar climatic conditions to which hops are intended to be introduced. The evaluation of the productive potential and the initial screening of the cultivars present in the country are extremely important, aiming to select superior genotypes or those with characteristics to be used in crossing blocks aimed at improving the crop in the Planalto Catarinense Highlands environment.

The values were higher than the studies with hops carried out in Brazil, in which MACHADO et al. (2018) obtained 200g per plant. The different results between the authors and the low values found are due to the cultivation environment, management practices, age of the plants and the origin of the matrices from which seedlings were obtained. For alpha-acids, an extremely important character for defining the bitterness of beers, the values were low when compared to those described for elite hop genotypes (with values of 12-15% alpha-acids). The genotypes may have been initially selected for aroma, thus genetically presenting low values of alpha-acids (values below 7% according to international standards) regardless of the year of cultivation.

Table 2 - Summary of univariate contrasts (Mean Squares) for the variables: plant fresh mass (MFP), cone dry mass (MSC), alpha-acids (ALFA), production (PROD) for hop genotypes grown in three years (2018/2019, 2019/2020, 2020/2021). Lages-SC, 2021.

EFFECT	MFP (g)	MSC (g)	ALFA (%)	PROD (g per plant)
C1: Hall vs Cas Chi e Col	376.717*	11.208*	0.147	825.699*
C2: Cas vs Chi e Col	5.965	2.261	2.214	75.121
C3: Chi vs Col	8.669	61	2.479	19.671

*Significant at 5% error probability by the F; *: significant at 5% probability; hall; Hallertauer; Cas: Cascade; Chi: Chinook and Col: Columbus.

Similar results were presented by SANTOS et al. (2022), did not obtain values below 5% of alpha-acids for most of the genotypes evaluated. Conversely, the authors observed three genotypes with values of 8%, 9% and 15% as they were genetically superior for the character (SANTOS et al., 2022).

For resource production, values were similar to other low latitude regions of the United States, Europe and South Africa for photoperiod-sensitive cultivars (maximum 500 g per plant). The results demonstrated that under climatic conditions such as those of the Santa Catarina Plateau, there is a reduction in the productive index for the evaluated genotypes. At physiological maturity (around 3 to 5 years) 2000 g per plant of dry cones is expected, a condition sought in the regions of Hallertauer -USA and Corvalis-ALE. According to DODDS (2019), there is low vegetative development of the evaluated cultivars (sensitive to photoperiod) in low latitudes or those that limit high production. The results corroborated the tests by PEARSON et al. (2018) 350 g per plant in Florida-USA and are higher than that carried out in the state of Paraná-BR with an average of 60 g per plant. The results are also similar to the average of genotypes cultivated in South Africa with

values of 500 to 1000 g per plant of green cones (BRITS, 2008).

The differences between the cone production values obtained refer to the response of the genotypes to the cultivation environment. The adaptation problems of the genotypes evaluated in the conditions of the Santa Catarina Plateau occurred, since they were not selected and developed for low latitude regions, thus, they did not express their full productive potential due to the adaptation of the specific type. BRITS (2008), highlighted those American and German cultivars planted mainly in South Africa also showed lower productivity performance of 40 to 60% and in alpha-acids in the same proportions as their potential. The lack of adaptation or low performance occurs because hop genotypes are generally grown in Brazil, or develop better, when provided with at least 15 hours of light daily. On the Santa Catarina plateau, the maximum length of the day is around 14 hours and 30 minutes. Plants of genotypes grown under this day length condition tend to flower prematurely and, therefore, limit cone yields (DODDS, 2019). Thus, the genotypes that are sensitive to the photoperiod evaluated demonstrated low productive potential in the production system used, and a system with

Table 3 - Absolute mean values and comparison between the means for the production variables (PROD, g per plant) on the upper diagonal and lower diagonal for plant fresh matter (MFP, g per plant) for hop genotypes cultivated in three years (2018/2019, 2019/2020, 2020/2021). Lages-SC, 2021.

Variable: PROD (kg per plant)					
i/j		1 = 604	2 = 195	3 = 283	4 = 346
Variable: MFP	1=493	1	409*	321	246
	2=257	*236	1	-88	-151
	3=270	223	13	1	-63
	4=312	181	-55	-42	1

1 = Hallertauer; 2 = Cascade; 3 = Chinook; 4 = Columbus. *Significant at 5% probability of error using the Tukey-Kramer test.

Table 4 - Direct and indirect phenotypic effect of the explanatory independent variables: fresh mass (MFP), cone dry mass (MSC) and alpha-acids (ALFA), on the main dependent variable production (PROD). Lages-SC, 2019 to 2021.

Variables	Effects	Path coefficient
MFP	Direct effect on PROD	0.46
	Indirect effect via MSC	0.35
	Indirect effect via ALFA	-0.05
	Total	0.77**
MSC	Direct effect on PROD	0.54
	Indirect effect via MFP	0.3
	Indirect effect via ALFA	0.01
	Total	0.85**
ALFA	Direct effect on PROD	0.23
	Indirect effect via MFP	-0.10
	Indirect effect via MSC	0.02
	Total	0.15 ^{ns}
DETERMINATION COEFFICIENT		0.84
EFFECT OF THE RESIDUAL VARIABLE		0.46

** $P \leq 0.01$; ^{ns}: not significant by Pearson test.

artificial lighting can be used to make up for the lack of hours of light and obtain high production. Despite the low production found in the present work, it appears to be economically viable and would be sufficient to supply small breweries, since high quantities are not necessary to produce craft beers, in which 1 gram of hops is enough to develop 10 liters of beer.

Furthermore, part of the phenotypic variation is genetic (Table 1), and breeders can use it as raw material to apply selective processes that result in significant genetic gains to reduce the need for hours of light. The morphological analyzes were sufficient to discriminate the evaluated genotypes, making it possible to identify contrasting genotypes. The presence of variability can be explained by the geographic distribution of the species and by different selection pressures (natural and artificial) to which each genotype was naturally subjected, inducing changes in gene frequencies. Hops are likely of Asian origin and in the process of evolution one group was dispersed or taken to Europe and another to North America, these being the three gene pools or centers of diversity of the species (PATZAK, 2018; SKOMRA, 2013).

Hallertauer is a hop genotype with a long history of development that has been improved through an ongoing process of mutation and selection. Research conducted by PATZAK & HENYCHOVÁ (2018) highlighted those plants of this genotype demonstrated remarkable robustness

and high vigor, indicating high adaptability to environmental conditions. The greater adaptability can be attributed, in part, to the lower sensitivity of the European genotype to photoperiod compared to other varieties originating in the United States. As a result, Hallertauer was able to develop a greater number of productive lateral branches and complete its growth cycle successfully in the Planalto Catarinense region environment (data not shown). These observations provide solid evidence that the Hallertauer has a high-quality genetic base.

The distinction between hop genotypes occurred mainly due to their different genetic origins. As noted by BASSIL et al. (2008), hops have their origins in distinct gene pools, with European and American origins, which results in genetics variations of great interest for breeding programs. The advantage of using these constitutions currently used may have originated from seeds and, over time, went through an acclimatization and empirical selection process conducted by Brazilian farmers, demonstrating superior performance to non-adapted exotic material (Unpublished data). During this process, superior genetic constitutions were identified and cultivated.

The modern propagation of hops is carried out through clones of synthetic hybrids, which involve a combination of backcrossing followed by targeted crossings. This breeding method is effective in breaking down genetic blocks and releasing the variation available in the segregating population.

When two genotypes are crossed, this can directly result in a segregating population with a high frequency of favorable genes, facilitating the selection of genotypes that exhibit superior characteristics relative to their parents.

According to CARVALHO et al. (2004), productivity has been increased through the selection of related traits. Thus, the results demonstrated that vigorous plants present high productions, due to the presence of high correlation and its breakdown by trail analysis with direct and significant values ($P \leq 0.01$) between green matter of plants and fresh mass of cones, dry mass of cones and production (Table 3). Results of the efficiency of indirect selection in hops were demonstrated by Mafakheri et al. (2020), who obtained positive phenotypic correlations between vegetative traits, cone size and yield. The lack of significant correlation between alpha-acid characters indicates the need to evaluate more characters. According to HIERONYMUS (2012), the character that shows the greatest correlation with alpha-acids is the size of the cones. These results are extremely important for genetic improvement, since by selecting genotypes with larger cones and high vigor, it will be possible to develop more productive cultivars, without losses in alpha-acid levels.

However, hop cultivation does not initially depend solely on high production, as the plant is responsible for numerous functions in beer production. At the beginning of the process, it is responsible for bitterness and microbiological stability (boiling the must or wirpool), in the final stage it gives flavor and aroma to the drink (cooling or dry hopping). According to recent studies, the climate, soil, relief and management practices associated with the genetic constitution of the cultivar used can express unique and exclusive characteristics of hop flavor and aroma or also called terroir, which must be taken into consideration by the breeder (VAN HOLLE et al., 2021).

Thus, the selection of improved genotypes for flavor can enable the development of special beers with greater added value, compensating for the low production rates initially obtained or without the use of lighting, which, thanks to the development of LEDs, has demonstrated an increase in yield, but increase the cost of production (LELES et al., 2023). Therefore, there is a need to evaluate the sensory and production analyses of hops grown in various harvests, in order to provide a zoning or geographical indication that could make the cultivation of hops economically viable in the Planalto Catarinense region.

CONCLUSION

There is variability between the hop genotypes evaluated. The Hallertauer showed significant differences for the characters of fresh mass of plants, green mass of cones, dry mass of cones and production, when compared to the genotypes acclimatized by farmers (Cascade, Chinook and Columbus). Although, the genotypes have demonstrated low productive performance, in the edaphoclimatic conditions of the Planalto Catarinense region, there is potential for using these genetic constitutions in directed crosses in the region.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHORS' CONTRIBUTIONS

Conceptualization: MDS, LLDV and AFG. Data acquisition: MDS. Design of methodology and data analysis: MDS, and JLMC. Prepared the draft of the manuscript: MDS, CZJJ, PMOP and LLDV. All authors critically revised the manuscript and approved of the final version.

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