



HUMULUS LUPULUS L. IN CAMPOS DE CIMA DA SERRA / RS / BRAZIL

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ABSTRACT

Objective: The general objective of this research was to evaluate the adaptation of hop plants in the Campos de Cima da Serra region – RS - Brazil.

Theoretical Framework: Although small cultivations of hops (*Humulus lupulus* L.) are already occurring in Brazil, there is little information about production, quality and factors faced by producers.

Method: The methodology was organized by hop management, vegetative evaluations and post-harvest analysis.

Results and Discussion: The plants showed very slow vegetative growth, several deaths and little production, probably due to excessive rainfall, which caused several problems for the cultivars, compromising their health and development. Excess precipitation caused the soil to become waterlogged, resulting in a decrease in the amount of oxygen available to the plant roots, which may have caused their death. There were also numerous episodes of pests and diseases. Thus, among all the varieties analyzed, we found that the Northern Brewer and Mapuche cultivars were the ones that best adapted to the climatic conditions and pests in the region.

Research Implications: Therefore, it is expected that this work will be a contribution to the development of this culture in the study region.

Originality/Value: The cultivars analyzed are in their third year of production, they have not yet expressed their full potential, some factors were observed such as intense and prolonged rains during the period of plant development and some pests and diseases, which may have caused this low productivity and performance.

Keywords: Experiment, Sustainability, Technology, Agriculture.

HUMULUS LUPULUS L. NOS CAMPOS DE CIMA DA SERRA / RS / BRASIL

RESUMO

Objetivo: O objetivo geral dessa pesquisa foi avaliar a adaptação de plantas de lúpulo na região dos Campos de Cima da Serra – RS - Brasil.

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Referencial Teórico: Apesar de pequenos cultivos do lúpulo (*Humulus lupulus* L.) já estarem ocorrendo pelo Brasil, são poucas as informações sobre a produção, qualidade e fatores enfrentados pelos produtores.

Método: A metodologia foi organizada pelo manejo do lúpulo, avaliações vegetativas e análise pós-colheita.

Resultados e Discussão: As plantas apresentaram um crescimento vegetativo bastante lento, várias mortes e pouca produção, provavelmente pelo excesso de chuvas, o que ocasionou diversos problemas para as cultivares, comprometendo sua saúde e desenvolvimento. O excesso de precipitação, ocasionou o encharcamento do solo assim havendo uma diminuição da quantidade de oxigênio disponível para as raízes das plantas o que pode ter ocasionado a sua morte. Também ocorreu inúmeros episódios de pragas e doenças. Assim, dentre todas as variedades analisadas verificamos que as cultivares Northern Brewer e Mapuche, são as que mais se adaptaram as condições climáticas e pragas na região.

Implicações da Pesquisa: Assim, espera-se que este trabalho seja uma contribuição para desenvolvimento dessa cultura na região de estudo.

Originalidade/Valor: As cultivares analisadas encontram-se no seu terceiro ano de produção, ainda não expressaram todo seu potencial, foram observados alguns fatores como chuvas intensas e prolongadas no período de desenvolvimento das plantas e algumas pragas e doenças, o que podem ter ocasionado essa baixa produtividade e rendimento.

Palavras-chave: Experimento, Sustentabilidade, Tecnologia, Agricultura.

HUMULUS LUPULUS L. EN CAMPOS DE CIMA DA SERRA / RS / BRASIL

RESUMEN

Objetivo: El objetivo general de esta investigación fue evaluar la adaptación de plantas de lúpulo en la región de Campos de Cima da Serra – RS - Brasil.

Marco Teórico: Aunque ya se están realizando pequeños cultivos de lúpulo (*Humulus lupulus* L.) en Brasil, hay poca información sobre la producción, la calidad y los factores que enfrentan los productores.

Método: La metodología se organizó mediante manejo del lúpulo, evaluaciones vegetativas y análisis poscosecha.

Resultados y Discusión: Las plantas mostraron un crecimiento vegetativo muy lento, varias muertes y poca producción, probablemente debido al exceso de lluvias, lo que causó varios problemas a los cultivares, comprometiendo su salud y desarrollo. El exceso de precipitaciones provocó que el suelo se encharcara, lo que provocó una disminución de la cantidad de oxígeno disponible para las raíces de las plantas, lo que pudo haber provocado su muerte. También se produjeron numerosos episodios de plagas y enfermedades. Así, entre todas las variedades analizadas encontramos que los cultivares Northern Brewer y Mapuche fueron los que mejor se adaptaron a las condiciones climáticas y plagas de la región.

Implicaciones de la investigación: Por lo que se espera que este trabajo sea un aporte al desarrollo de esta cultura en la región de estudio.

Originalidad/Valor: Los cultivares analizados se encuentran en su tercer año de producción, aún no han expresado todo su potencial, se observaron algunos factores como lluvias intensas y prolongadas durante el período de desarrollo de la planta y algunas plagas y enfermedades, que pueden haber provocado esta baja productividad y actuación.

Palabras clave: Experimento, Sostenibilidad, Tecnología, Agricultura.

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1 INTRODUCTION

Hops (*Humulus lupulus*) belong to the Cannabaceae family (Almaguer *et al.*, 2014). The species is believed to have originated in Mongolia about six million years ago, migrating to Europe a million years ago, and in North America hops appeared around half a million years later (Rocha, 2005).

H. lupulus L. primarily occurs in temperate regions around the globe. The plant grows in a clockwise direction around any available support with the help of its robust downward pointing trichomes (hairs) and can reach a height of over 10 meters (Korpelainen; Pietiläinen, 2021). The leaves are opposite or alternate and have 3 to 5 lobes with serrated edges. The root system is large and requires deep, fertile, well-drained soil. Horizontal roots tend to grow with many fine rootlets (Amoriello *et al.*, 2020).

The plant is perennial and can live for about 50 years, with its root system potentially penetrating up to 4 meters deep into the soil. It is considered a climbing plant, meaning that during its growth stage, it relies on surrounding structures (Dagostim, 2019). Its root system is permanent, and its above-ground part is renewed annually (Sposito *et al.*, 2019).

It has an annual flowering, vigorous climbing habit, typically found in temperate climate regions but also cultivated in tropical climates such as Brazil (Marcusso; Müller, 2019). The height of the hop plant can vary significantly depending on factors such as plant variety, growing conditions, and the environment in which it is cultivated. It requires a space of 8 m² per plant, composed of stems, leaves, and inflorescences known as cones (Jezek *et al.*, 2013).

Hops require a large amount of water during the growing seasons to optimize yield and quality. Additionally, the soil should be rich in nutrients, light, well-drained, adequately moist but free from waterlogging, with an ideal pH range between 6.0 and 6.5, although hops also grow in soils with a pH of 4.8 to 8.0 (Amoriello, 2019; Amoriello *et al.*, 2020).

Amoriello *et al.* (2020), used biochar as a fertilizer for hop production in their study. The results showed that biochar significantly improved root growth ($p < 0.0001$). About the above-ground part, no variability was observed among genotypes during the vegetative period, while small differences occurred before plant dormancy, especially for the *Hallertau Magnum* cultivar. No differences were observed in the number of leaves or branch length between the two treatments for all cultivars. The addition of biochar to the soil significantly improved yield (number of cones) (Amoriello *et al.*, 2020).

Hops flowers are small, and wind pollinated. Female plants have cone-like structures that are 2.5 to 5 cm long and develop soon after pollination. They consist of overlapping green-



yellow braces attached to an axis. It may take up to three years before female plants begin to flower and produce strobiles. Each brace encloses a small fruit, which is an achene, a dry fruit that does not open at maturity. Mature strobiles contain various chemicals in their lupulin glands (glandular trichomes) at the base of the bracts, which can be used in various industries, the most well-known being the brewing industry (Korpelainen; Pietiläinen, 2021).

Alonso–Esteban *et al.* (2019), analyzed the phenolic composition of hop seeds and evaluated their antioxidant, cytotoxic, and antimicrobial activities against oxidizable substrates, human tumor and non-tumor cell lines, and different bacteria and fungi, respectively. This study is significant as the bioactive potential of seeds found in hop cones remains unexplored.

Most hops plants used today do not have seeds, although pollination is generally known to increase yield. Seed oil can alter the flavor of beer if the seeds are crushed during processing. However, due to their small size, seeds tend to remain intact in hop pellets or lipophilic extracts, which are preferred by the industry (Alonso–Esteban *et al.*, 2019).

Vegetative propagation of hops occurs when parts of the parent plant are used to form seedlings. “Seedlings produced this way are similar plants (clones) to the parent plant, bringing all the characteristics of the variety and facilitating the formation of a uniform and productive orchard” (Sposito *et al.*, 2019, p. 51). Vegetative propagation is essential to ensure that the resulting plants are clones of the chosen parent (Dodds, 2017).

Hops are quite resilient when dormant but challenging for growers, with severe frosts killing young shoots. Climate change and increasing droughts have already stagnated yields in some cultivation areas around the world (Van Holle *et al.*, 2019).

The evaluation of crop varieties regarding specific characteristics can be useful in the reproduction and agricultural practice of hops. Inter-varietal differences in xylem structure can significantly affect water transport, as well as susceptibility to cavitations and, therefore, crop yield (Jupa *et al.*, 2013).

Additionally, there are specific times of the year when climatic conditions affect the alpha-acid content of hop plants. The most significant periods influencing alpha-acid levels in hops during the growing season are identified as attributes of air temperatures, rainfall, sunshine, and air humidity (Pavlovic *et al.*, 2013).

Van Holle *et al.* (2019), analyzed genetic and biochemical fingerprinting methods to fully characterize hop batches. They found that biochemical marker information provided added value in characterizing hop samples from a particular variety grown in different geographic locations. They demonstrated the power of combining genetic and biochemical fingerprints for



quality control of hop batches in the brewing industry. The long cultivation of this plant has resulted in different cultivars.

The hop flower, also known as the cone, is the part of the hop plant used in beer production. These are the cone-shaped, green structures that grow on the female hop plant, rich in resins, which provide bitterness through alpha and beta acids, polyphenols with antioxidant properties, and essential oils that impart aroma (Rettberg *et al.*, 2018).

Although hop inflorescences are known to be the raw material that provides bitterness and characteristic aromas in the production of different types of beer, hops can also be used as a medicinal plant and have significant effects on human health. Hops have antioxidant and anti-inflammatory properties, and their oils and resins are known for their sedative properties, as well as antibacterial and antifungal effects (Sposito *et al.*, 2019).

Hops can be considered a viable cultivation alternative for family farming, as the growing beer market in Rio Grande do Sul, especially that fueled by craft breweries, demands larger quantities of high-quality hops, almost entirely imported from countries like Germany and the United States, which raises the cost of this raw material. Since its production in Brazil is recent, it is extremely important to have incentives for hop cultivation and research on *H. lupulus* L. This would result in fewer imports, consequently reducing production costs and increasing profitability for growers (Oliveira, 2016).

The Campos de Cima da Serra region has great potential to consolidate hop cultivation. With lower average temperatures in winter and hot summers in this region of Rio Grande do Sul, one of the main issues is the lack of theoretical information, scientific definitions, and up-to-date and coherent statistical data about its scale and integration into the economy, which poses a serious difficulty in formulating policies to stimulate the growth of this sector.

In this context, the objective of the present work was to analyze the development and management of hop cultivation in an experimental area in the municipality of Vacaria, located in the Campos de Cima da Serra region, in the State of Rio Grande do Sul, Brazil.

2 METHODOLOGICAL PROCEDURES

The chosen methodological procedures were standardized data collection techniques with systematic observations (Marconi; Lakatos, 2010). This approach allowed for the exploration and analysis of all the objectives proposed in this study.



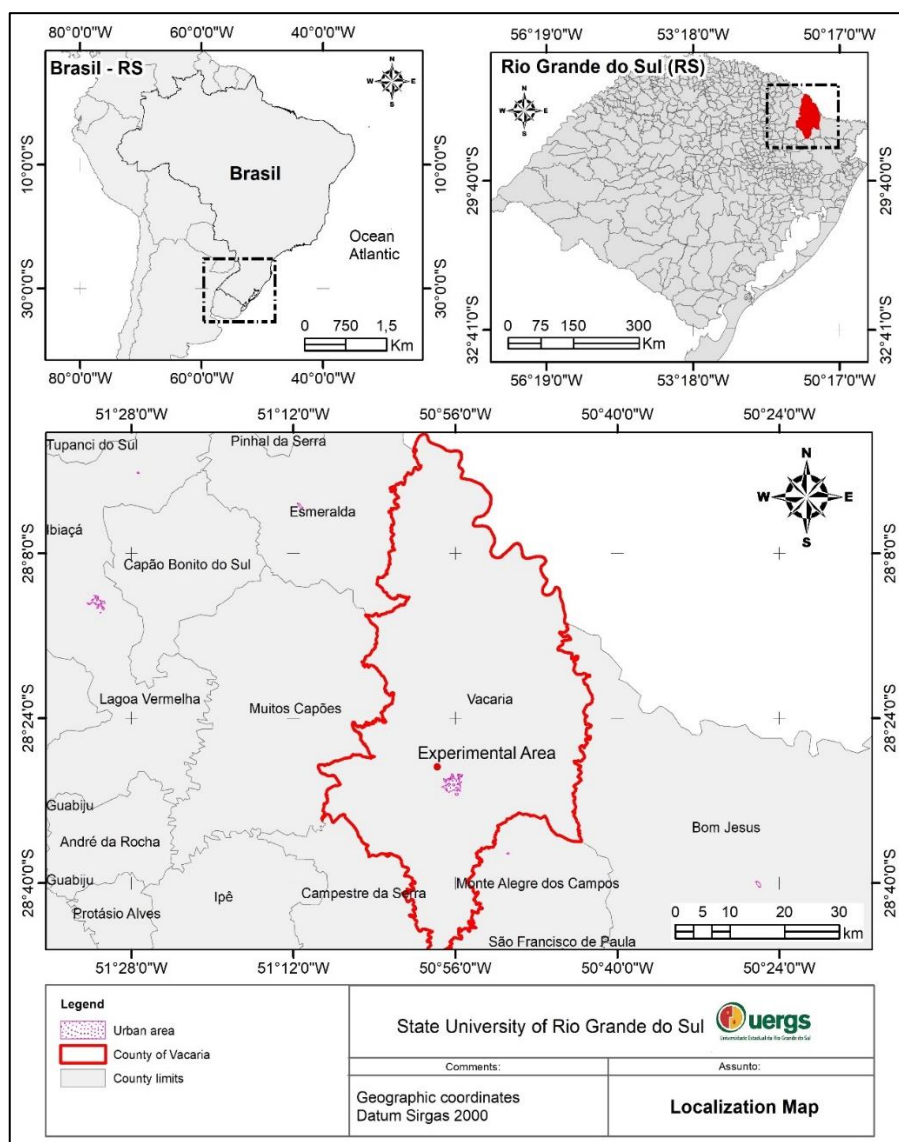
2.1 HOP CULTIVATION

The experiment was conducted in the municipality of Vacaria, RS, at the experimental area of the Federal Institute of Education, Science, and Technology – *Campus Vacaria*, which has a total area of 60 hectares, approximately 3 kilometers from road BR 285 (Figure 1).

The experiment began in 2021, where a 30-meter by 10-meter area was marked out and prepared, including soil liming according to technical recommendations. The project involved planting 90 seedlings of 6 plant varieties: Cascade, Chinook, Northern Brewer, Hallertau Mittelfrüh, Mapuche, and Spalt Spalter, in 3 randomized blocks, with 5 plants per experimental unit. The irrigation system used was drip irrigation.

Figure 1

Location map.





To support the plants, a support structure was installed. This involved the use of 9 stakes, with 3 in each block, each measuring 5.4 meters long and buried 1 meter in the ground, leaving 4.4 meters above ground for the plant's development.

In 2023, some seedlings were replaced due to plant mortality, leaving 7 plant varieties: Triumph, T. Pearl, Saaz, Fuggle, Chinook, Northern Brewer, Hallertau Mittelfrüh, and Mapuche, in 3 randomized blocks (Table 1), totaling 64 plants.

Table 1

Organization of planting in the year 2023.

Blocks	Varieties						
Block 1	Triumph	T. pearl	Chinook	Northern brewer	Halertan	Saaz	Fuggle
Block 2	Fuggle	Halertan	Triumph	T. pearl	Saaz	Northern brewer	Chinook
Block 3	T. pearl	Saaz	Mapuche	Northern brewer	Saaz	Chinook	Triumph
	Fuggle	Halertan	-	-	-	-	-

2.2 VEGETATIVE EVALUATIONS

For these analyses, the following was assessed:

Plant Height (m): Measured with a tape measure, from the base of the plant to the insertion point of the last leaf produced.

Possible Damage to Leaves or Cones: Observed throughout all stages of the plant's cycle, to identify damage caused by pests or diseases.

2.3 POST-HARVEST EVALUATIONS

For these analyses, the following were recorded: - Harvest Date (per plant/block); - Fresh Weight; - Final Drying Date; - Dry Weight; - Number of Cones; - Average Cone Size (cm); - Moisture Content. Additionally, the entire storage process was organized.

3 RESULTS AND DISCUSSIONS

The results were organized from the monitoring of the 2023/2024 harvest, including the appropriate management at different growth stages, planting of new seedlings, harvesting, and processing of the crop.



3.1 ANALYSIS OF CROP GROWTH AND DEVELOPMENT

In August 2023, the maintenance and control process for hops in the experimental area began. Proper management was implemented at different production stages in the field, and the development of the plants was periodically assessed.

The installed irrigation system was drip irrigation, using a "Venturi" type (Figure 2). This system delivers water at low flow rates and high intensity near the root system, thus reducing the soil surface that is wet and exposed to evaporation losses. According to Esteves *et al.* (2012), the systems are set up with pipes installed along the rows of crops. These pipes are called lateral lines. In addition to improved sanitary control, this system allows for water savings, increases fertilization efficiency, and adapts to different soil types and topographies.

This technology is commonly used in the production of vegetables, fruit trees, and ornamental flowers, regardless of property size. Drip irrigation provides greater profitability for the producer and is both a sustainable and economical technology (Rodrigues; Domingues, 2017).

Guimarães (2020), emphasizes that the importance of water supply during the development phase of hops through irrigation has been utilized in cultivation areas since the 19th century. In the context of irrigation, water quality is a critical factor that, if not properly managed, can cause detrimental effects on the irrigation system, soil, and plant. The author highlights that hop cultivation requires adequate water supply, especially during the development phase, which includes the formation and growth of lateral branches, flowering, formation of inflorescences, and maturation of the cones (Guimarães, 2020).

Figure 2

Irrigation system.





Growth measurements of the cultivars began when the plants were a few centimeters tall (Figure 3). These measurements are crucial as they identify hop cultivars with productive and qualitative potential for the Campos de Cima da Serra region, RS.

Since 2020, several studies have been conducted in Brazil to assess hop growth. Oliveira (2016) found that hop (*Humulus lupulus* L.) is sensitive to phosphorus fertilization and liming in the soil of the Southern Plateau of Santa Catarina.

Righi *et al.* (2023) note that cold winter temperatures, low wind intensity, high altitude, and specific latitudes are ideal for hop cultivation. However, hops can still be productive outside these ideal conditions. Vacaria, RS, with its high altitude, cold winters, and adequate sunlight, is suitable for hop cultivation. Yet, there is a lack of research results and information available to local farmers regarding this crop.

Figure 3

Hop plants a few centimeters tall.



In October, maintenance was performed, including bed cleaning and the use of cultivar identification plaques (Figure 4). These identification plaques are useful for farmers, agronomists, and other professionals involved in managing the agricultural area, as they provide a quick and easy way to access important information about the crop and field.



Figure 4

Cleaning of beds and cultivar identification plate.



In addition to cleaning the spaces and maintaining the plants, some cultivars were identified with symptoms of pests or diseases (Figure 5). A sample was sent to the Plant Health Clinic Laboratory of UERGS – Vacaria for disease identification. The sample showed small, circular leaf spots of light brown color, surrounded by a dark brown halo. These signs and symptoms are typical of brown spot disease caused by *Alternaria spp.* In some severe cases, plants have deteriorated.

The field guide “Field Guide for Integrated Pest Management in Hops,” developed by various technicians from different U.S. universities (Gent *et al.*, 2010), describes several pests that damage hop crops. Notable pests include mites, aphids, California prionus beetle, caterpillars, root beetles, and slugs.

According to the guide, *Alternaria* is caused by the fungus *Alternaria alternata*, which is common in hop fields and other agricultural systems worldwide. The disease can occasionally damage the cones and reduce harvest quality. It is more commonly reported in late-maturing varieties exposed to wind damage, wet conditions, and prolonged periods of moisture in the cones. Cone darkening caused by powdery mildew and downy mildew is often misdiagnosed as *Alternaria* cone disorder (Gent *et al.*, 2010).

The disease progresses rapidly, causing dead tissue to turn dark brown and making it easily confused with powdery mildew damage. Affected bracts and bracteoles showed slight distortion or wilting of the diseased tissues.



Figure 5

Disease symptoms in plants in the experimental area.



To combat *Alternaria alternata*, a Bordeaux mixture was applied. This homemade fungicide is effective against many phytopathogens and acts against mollusks, algae, lichens, mites, and certain beetles, among other benefits. Copper sulfate is considered low in toxicity and is still allowed in organic agricultural production as part of Bordeaux mixture (Rebelo *et al.*, 2018).

The Bordeaux mixture was prepared with 100g of copper sulfate in 5 liters of water and 100g of hydrated lime in 5 liters of water. After separate preparation, the solutions were mixed and applied to the plants using a sprayer, ensuring thorough coverage of all parts, including leaves and stems. This process was repeated every 30 days until February.

The potential impacts of pests and diseases on hop cultivation in Brazil remain uncertain. However, the growing importance of hop cultivation in the country necessitates vigilance for any new diseases that may be transmitted through infected planting material (Pereira; Barreto, 2023).

Internationally, several studies are refining methods to identify diseases and pests in hop cultivars. Tanrikulu, Sazlı, and Parça (2022) analyzed images of downy mildew (*Pseudoperonospora humuli*) and powdery mildew (*Podosphaera macularis*) in hop plants using a highly successful Convolutional Neural Network (CNN) model. The model, trained with a small number of selected images, detected diseases with high performance.

In November, maintenance of the area and installation of the trellis system were carried out. Nylon wires were fixed in a "V" shape between the plant and galvanized wire attached to wooden posts (Figure 6). This system supports the weight of the plants and reduces wind speed (Marcos *et al.*, 2011).



Righi and Bitencourt (2022) observe that the predominant wind directions in the study area are North and East, with an annual average speed of approximately 7.5 m/s. Such winds are unsuitable for this perennial crop as they can cause loss of lupulin in the hop cones, which imparts bitterness to beer.

Figure 6

Fixing system.



In December, new seedlings were purchased for transplantation, including Saaz, Fuggie, Triumph, and T. Pear (Figure 7). The seedlings spent 16 days in the greenhouse at the Federal Institute of Rio Grande do Sul, Vacaria *campus*, where they received two applications of the foliar fertilizer "Plenan Bio" at a dosage of 5ml per 5 liters of water, with each application being 2.5 liters.

Several studies show that foliar applications increase leaf micronutrient levels more rapidly than root absorption (Araya, 2008; Boaretto *et al.*, 2002).

Vegetative propagation through rooted cuttings reduces the juvenile phase of the plant, speeding up production, and ensures uniform plants with characteristics identical to the parent plant (Fachinello *et al.*, 2005). Hops can be propagated through seeds, rhizomes, cuttings, and micropropagation. Seeds produce plants of both sexes with varied genetic traits (Fagherazzi *et al.*, 2018; Fagherazzi; Rufato, 2018).

Choosing the right variety for your market and location, propagation is a practical method to enhance production, especially in the absence of cost-effective alternative supply options (Dodds, 2017).



Figure 7

Hop seedlings.



In hop seedling production in Russia, one of the main problems is the survival rate of hop seedlings (averaging 50-55% over the years). Among other reasons, the incidence of rooted cuttings of hops is significant (Dementiev *et al.*, 2020). Therefore, several researchers conduct tests with biological fungicides and growth stimulants for hop seedlings from cuttings.

Cuttings "can be collected at different stages of the plant's vegetative growth; however, cuttings taken between late spring and early summer (before the onset of flowering) tend to show better rooting. Several cuttings can be taken from an herbaceous hop stem" (Sposito *et al.*, 2019, p. 53).

Thus, in December, the preparation of the beds and planting of the new seedlings was carried out. They were distributed across 3 blocks in a randomized manner, in locations where some of the cultivars planted in previous years had died.

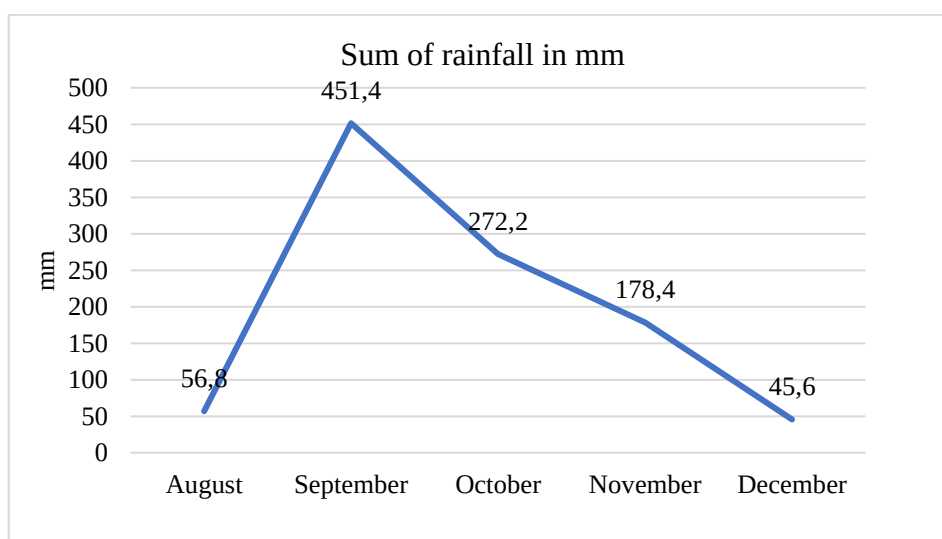


Also in December, maintenance was carried out on the beds and symptoms of rust (*Puccinia ssp*) were found, which initially appeared on the lower leaves and are characterized by the formation of pustules approximately 2 mm long that are distributed parallel to the veins, mainly on the dorsal part of the leaves due to mild temperatures and high humidity. On the same day, the beetle (*Lagria villosa*) was found, whose adults can cause the destruction of the leaves, thus reducing their photosynthetic area, leading to a drop in production (AGROLINK, 2022). For rust (*Puccinia ssp*) and the beetle (*Lagria villosa*), Bordeaux mixture was applied.

In January, it was observed that some plants had died, and others were developing very slowly, primarily due to excessive rainfall in the region (Figure 8). Data from the National Institute of Meteorology (INMET) from the “VACARIA A880” automatic station indicated a total of 1004.4 mm of rainfall from August to December 2023. Well-distributed precipitation during the vegetative period is more effective for good production than a higher but poorly distributed total (Fagherazzi, 2020).

Figure 8

Rainfall analyzed in Vacaria-RS.



Source: Organized by the Authors (2024) – INMET (2023).

In January 2024, it was found that only 4 plants had grown to a large size (6.25%), with some already showing the formation of flowers/cones. By February, several phytosanitary problems and damaged plants were detected due to the presence of the leafcutter ant (*Atta sexdens rubropilosa*). Leafcutter ants are known for their habit of cutting and transporting plant material into their nests, causing serious damage by cutting tender branches, leaves, shoots, and clusters. The damage caused by ants is harmful at any stage of the cycle, but it is more severe



during the plant formation stage, as it halts growth (Botton *et al.*, 2003). To control these ants, “Grão Verde” baits were applied, distributed next to the bed, and reapplied every day after rain.

From the development of the plants to the harvest of the first cones, tracking spreadsheets were organized (Tables 2, 3, and 4). The experiment included several plants, with 7 varieties remaining: Triumph, T. Pearl, Saaz, Fuggle, Chinook, Northern Brewer, Halertan Mittelfree, and Mapuche, distributed in 3 randomized blocks, totaling 64 plants.

Table 2

Monitoring of block 1.

Block 1		August	September	October	November	December	January	February	March
Cultivar	No. Plants	Height	Height	Height	Height	Height	Height	Height	Height
TRIUMPH	1	0	0	0	0	28	31	122	198
	2	0	0	0	0	19	27	135	169
T. PEARL	1	0	0	0	0	31	47	140	152
	2	1	1	0	0	28	39	129	133
CHINOOK	1	6	7	32	0	0	0	0	0
	2	6	7	30	60	167	171	183	185
	3	6	6	19	33	148	155	168	173
NORTHERN	1	0	2	6	8	72	102	165	195
	2	5	7	7	9	85	110	169	215
	3	4	5	6	8	77	99	152	193
HALERTAN	1	3	4	5	38	57	183	245	183
	2	3	4	4	10	0	0	3	0
	3	4	5	6	12	0	0	0	0
SAAZ	1	0	0	0	0	22	0	0	198
	2	0	0	0	0	41	0	0	203
	3	0	0	0	0	33	0	0	0
FUGGLE	1	0	0	0	0	35	0	0	198
	2	0	0	0	0	18	0	0	203
	3	0	0	0	0	22	0	0	0

Table 3

Monitoring of block 2.

Block 2		August	September	October	November	December	January	February	March
Cultivar	No. Plants	Height	Height	Height	Height	Height	Height	Height	Height
FUGGLE	1	0	0	0	0	22	35	45	62
	2	0	0	0	0	16	27	0	0
	3	0	0	0	0	18	23	0	0
HALERTAN	1	1	2	4	10	35	98	127	174
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0
TRIUMPH	1	0	0	0	0	19	30	74	141
	2	0	0	0	0	23	36	70	143
T. PEARL	1	0	0	0	0	35	58	87	104
	2	0	0	0	0	44	71	110	157
	3	0	0	0	0	42	69	99	150
SAAZ	1	0	0	0	0	20	25	0	0
	2	0	0	0	0	24	29	0	0
NORTHERN	1	4	5	7	18	42	77	132	168
	2	2	4	6	16	39	65	110	155
	3	0	0	0	0	0	0	0	0



CHINOOK	1	4	5	7	8	45	0	0	0
	2	2	2	3	5	40	0	0	0
	3	0	0	0	0	0	0	0	0

Table 4

Monitoring of block 3.

Block 3		August	September	October	November	December	January	February	March
Cultivar	No. Plants	Height	Height	Height	Height	Height	Height	Height	Height
T. PEARL	1	0	0	0	0	15	24	57	92
	2	0	0	0	0	16	19	43	85
	3	0	0	0	0	12	15	0	0
SAAZ	1	0	0	0	0	22	35	47	56
	2	0	0	0	0	24	39	0	0
MAPUCHE	1	3	9	15	27	78	363	442	452
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0
NORTHERN	1	1	5	7	12	36	265	279	284
	2	2	6	9	15	42	90	110	131
	3	1	5	8	16	41	260	272	280
SAAZ	1	0	0	0	0	16	22	44	56
	2	0	0	0	0	17	25	45	57
	3	0	0	0	0	20	26	42	50
CHINOOK	1	0	2	2	9	25	120	180	184
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0
TRIUMP	1	0	0	0	0	20	27	62	93
	2	0	0	0	0	19	25	60	90
	3	0	0	0	0	19	16	60	91
FUGGLE	1	0	0	0	0	23	0	0	0
	2	0	0	0	0	22	0	0	0
	3	0	0	0	0	15	0	0	0
HALERTAN	1	1	2	2	8	23	0	0	0
	2	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0

The plants exhibited very slow vegetative growth, numerous deaths, and low production, likely due to excessive rainfall which caused various issues for the plants, affecting their health and development. The excess precipitation led to soil saturation, reducing the oxygen available to the plant roots, which may have caused their death. Additionally, there were numerous pest and disease episodes. Among all the varieties analyzed, Northern Brewer and Mapuche were found to be the most adapted to the climatic conditions and pests in the region.

3.2 HARVEST AND POST-HARVEST ANALYSIS

In March, one plant was ready for cone harvest. During the harvest, the hop plants were cut, and all above-ground biomass was removed from the experimental area. While the cones were harvested, dried, and packaged for craft beer production in the laboratory, the stems and



leaves (post-harvest hop biomass) were discarded in a nearby area. Table 5 shows all the steps performed for the Northern Brewer cultivar. These processes were repeated for all harvested cultivars.

The harvest of all cultivars was conducted after 9 a.m., following the guidelines of Aquino *et al.* (2022, p. 130).

“It is recommended that hops be harvested during the coolest hours of the day, but that the cones have lost the moisture provided by the dew, preferably after 9:00 a.m., which may vary according to the relative humidity of the air, the time of year and the region. It is recommended to wait 2 to 3 days after a rainy season, so that the moisture accumulated inside the cones can be eliminated naturally. The harvested cones should be left protected from sunlight until they are transported to the post-harvest handling location. This step should be carried out as quickly as possible, since hop flowers are extremely perishable and the rate of degradation and oxidation of the chemical components of interest in the region is still unknown.”.

Table 5

Harvesting and processing process of hop cones.

Harvesting of the entire aerial part of the plant.



Removal of cones.

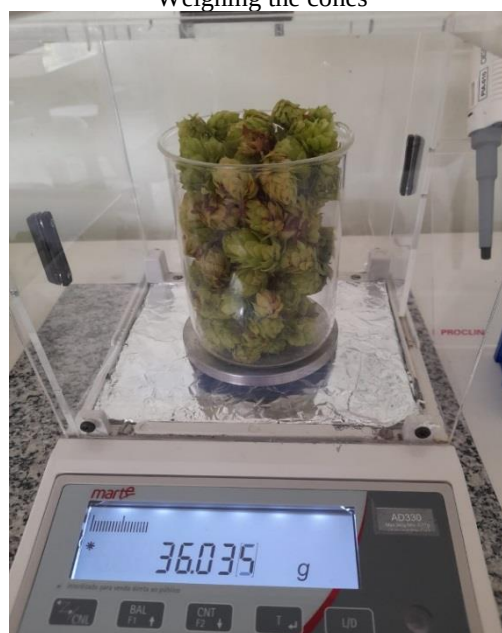




Cone counting



Weighing the cones



Left on trays at room temperature to dry for a period of 15 days and then the dry weight was checked.

Size of cones.



According to Creuz and Kretzer (2022), freshly harvested hops have a field moisture content of around 80%, which decreases to 8-12% when dried. On March 13, 2024, the first weighing of the dried cones was conducted, and they were then stored in sealed plastic bags. All packages were properly labeled and placed in the freezer (Figure 9). According to Aquino *et al.* (2022), vacuum-dried hops can maintain their quality for up to a year if kept refrigerated (5°C) or frozen (-15°C).



Figure 9

Packaging with hop cones.



On March 20, 2024, the Mapuche variety was harvested, yielding 74 cones with an average size of 2.5 cm. The smallest cones had a fresh weight of 43.39 g, which decreased to 12 g after drying, resulting in an average moisture content of 2.86% (Table 6).

The Northern Brewer variety was harvested between March 6, 2024, and March 20, 2024. A total of 1,102 cones were collected, with an average size of 2.92 cm. The fresh weight was 393 g, which reduced to 105.19 g after drying, resulting in an average moisture content of 2.72% (Table 7).

Table 6

Harvest data for the Mapuche variety.

Variedade: Mapuche								
Plant (No.)	Block	Harvest date	Fresh weight (g)	Final drying date	Dry weight (g)	Amount of cones	Average cone size (cm)	Moisture (%)
1	3	03/20/2024	45.395	04/02/2024	12	74	2.5	2.866695
			45		12	74		

Table 7

Harvest data for the Northern Brewer variety.

Variedade: Northern brewer								
Plant (No.)	Block	Harvest date	Fresh weight (g)	Final drying date	Dry weight (g)	Amount of cones	Average cone size (cm)	Moisture (%)
2	1	03/20/2024	93.205	04/02/2024	25	152	3	2.782363



1	3	03/06/2024	131.530	03/14/2024	36	458	2.87	2.69674
3	3	03/20/2024	168.597	04/02/2024	45	492	2.9	2.7496
			393		105.19	1102	2.92	

The total number of cones harvested and processed was 1,176 cones, with the Northern Brewer cultivar being the highest producer. This cultivar made a significant difference compared to the other cultivars, which did not reach even 7% of the harvested cones. The total weight collected was 117.19 grams, with Northern Brewer again being the highest producer. The other variety represented an average of 10.2% of the total weight of the harvest.

In the Czech Republic, Šrédľ *et al.* (2020) note that hop production in t/ha is also influenced by climatic or meteorological changes. For instance, in 2017, there was a 3.39% increase in hop cultivation areas compared to 2016, but an 11.86% drop in production due to frost and drought led to an overall 14.75% decrease in hop yield per hectare.

In studies by Nakawuka *et al.* (2017), it was found that hop yield increased with higher irrigation levels in the Yakima Valley in Washington, USA. The yield decrease was less significant for hop plants once they had a well-developed root system. They evaluated the cultivars Mt. Hood, Columbus, Chinook, and Willamette under three irrigation levels: 60%, 80%, and 100% of the crop's irrigation needs, using both drip and subsurface irrigation.

A global study conducted between 1990 and 2019 found that the global hop cultivation area decreased significantly, by more than a quarter. However, global hop production only grew slightly due to a substantial increase in hop yields (Kubeš, 2021).

4 CONCLUSION

Regarding the observed results, we can highlight the Northern Brewer and Mapuche cultivars as the most vigorous, best adapted to the region, and highest producers. The analyzed cultivars are in their third year of production and have not yet reached their full potential. Factors such as intense and prolonged rainfall during the plant development period, as well as some pests and diseases, may have contributed to the low productivity and yield.

Various influences and variables can positively or negatively affect agricultural activities. For the consolidation of the production chain with good management and to obtain high-quality hops, it is important to conduct further research on this crop.



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