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PHENOLOGICAL CYCLE OF HOPS CULTIVARS, IN THE SECOND PRODUCTION YEAR IN PARANÁ STATE

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ABSTRACT - The hops (*Humulus lupulus* L.) are a perennial herbaceous plant. Commercially, cultivars are classified as plants of American and European origin. Considering that there is no scientific data on the cultivation and productive capacity of hops in Toledo, the aim of this study was to study the phenological cycle of three cultivars in their second year of production. The research was carried out in the second year of cultivation, 2023/2024, at the Experimental Farm of the Pontifical Catholic University of Paraná, Toledo *Campus*. Plants of three hop cultivars (Magnum, Hallertauer Mittelfrüeh and Comet) were grown in a V system in a randomized block design, with six plants in each plot. After the stimulus to overcome dormancy in September/October, sprouting began and the phenological stages of the crop were assessed weekly from October/2023 to May/2024. The parameters assessed were: the start of sprouting, the emission of lateral branches, the start of flowering, the formation of cones and the start of the harvest, following a phenological scale. The phenological characterization showed that the Mittelfrüeh cultivar had the longest vegetative period compared to the other cultivars, while the Comet and Magnum cultivars were similar in terms of the total number of days to complete the cycle, with a difference between the number of days for their phenological phases. From the data obtained, it can be concluded that the hop cultivars Comet and Magnum both completed their cycle after 126 days, and H. Mittelfrüeh showed a longer period to complete its cycle, 139 days, under the soil and climate conditions of Toledo-Paraná, Brazil.
Keywords: *Humulus lupulus* L., adaptation, phenology, growth.

CICLO FENOLÓGICO DE CULTIVARES DE LÚPULO NO SEGUNDO ANO DE PRODUÇÃO NO PARANÁ

RESUMO - O lúpulo (*Humulus lupulus* L.) é uma planta herbácea, perene. Comercialmente as cultivares são classificadas em plantas de origem americana e europeia. Uma cultura originária de regiões de clima temperado, dessa forma considerando que não há dados científicos quanto ao cultivo e capacidade produtiva de lúpulo em Toledo, o presente estudo teve como objetivo estudar o ciclo fenológico de três cultivares, no segundo ano produtivo. A pesquisa foi realizada na Fazenda Experimental da Pontifícia Universidade Católica do Paraná, campus Toledo, safra 2023/2024. Para o presente estudo, plantas de três cultivares de lúpulo (Magnum, Hallertauer Mittelfrüeh e Comet) foram conduzidas em sistema V em delineamento experimental em blocos casualizados, contendo seis plantas por parcela. Após o estímulo para a superação da dormência, no período de setembro/outubro, a emissão de brotação iniciou, e os estádios fenológicos da cultura foram avaliados semanalmente a partir de outubro/2023 a maio/2024. Os parâmetros avaliados foram: início da brotação, emissão de ramos laterais, início da florada, formação dos cones e início da colheita, seguindo escala fenológica. Na caracterização fenológica observou que a cultivar Mittelfrüeh apresentou o maior período vegetativo ao comparar com as demais cultivares. Comet e Magnum apresentaram semelhança em relação ao número total de dias para completar o ciclo, porém se diferenciam no número de dias para suas fases fenológicas. A partir dos dados obtidos, conclui-se que as cultivares de lúpulo Comet e Magnum apresentaram um ciclo de 126 dias, enquanto H. Mittelfrüeh necessitou de maior período para finalizar seu ciclo, sendo 139 dias, em condições edafoclimáticas de Toledo-Paraná, Brasil.
Palavras-chave: *Humulus lupulus* L., adaptação, fenologia, crescimento.

INTRODUCTION

The hop plant (*Humulus lupulus* L.) is native to temperate regions, with the largest producers being countries located in the Northern Hemisphere (RIGHI; BITENCOURT, 2022), herbaceous, perennial with a climbing character, belonging to the order Rosales and family Cannabaceae, with only two genera, *Humulus* and *Cannabis* (SPÓSITO et al., 2019). Commercially, cultivars are classified into two groups, with plants of American and European origin. According to brewers, cultivars belonging to the European group are more aromatic and milder than the American group (AQUINO *et al.*, 2022).

In Brazil, hop production began with the arrival of German and Polish immigrants, who settled in Rio Grande do Sul around the 1960s, but the crop was not maintained for long and was replaced by other economic activities

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(FAGHERAZZI; RUFATO, 2018). According to the same authors, cultivation has been growing in several Brazilian states, due to the increase in the number of microbreweries. Despite reports of an increase in hop-growing areas, information on production, Brazilian productivity and the qualitative characteristics of the cones produced is still incipient.

There is a huge diversity of hop cultivars in Brazil, according to data provided by the Ministry of Agriculture, Livestock and Supply, with a total of 48 registered by the National Register of Cultivars (RNC). These cultivars are divided into two classes: those without a certificate of genetic origin (COG), such as Alpharoma, Brewers, Gold, Bullion, Centennial, Columbus and Crystal, and those with a COG, such as Cascade, Chinook, Cluster, Comet, Hallertauer Mitterfrüeh, Tradition and Hersbrucker (CREUZ; KRETZER, 2022). Among the cultivars that have COG, the southern region of the country is home to the largest number of properties that invest in its cultivation, with the Cascade cultivar present in 85% (FAGHERAZZI; RUFATO, 2018). In general terms, the most planted cultivars in Brazil, in descending order, are: Cascade, Comet, Chinook, Columbus, Nugget, Saaz, Hallertauer Mitterlfrüeh, Hallertauer, which account for 68.9% of the cultivars planted in the areas, with Cascade (13.6%) and Comet (10.2%) standing out (APROLÚPULO, 2021). Commercial hop cultivars have different and relevant characteristics in relation to the bitterness and aroma of the cones, essential elements for the composition of different types of beer, and there are also those that have dual aptitude.

The hop plant is very demanding in terms of climatic conditions, requiring dry weather and warmth during flowering and during the growth and development of the umbels (DODDS, 2017), as well as developing and flowering in a wide range of photoperiods (at least 8 to 10 h of light, the ideal being 16 h), allowing it to be grown at different latitudes. In Brazil, it can be grown at low latitudes, between 15º and 30º, where the shorter photoperiod influences flowering time and the crop cycle (SPÓSITO *et al*., 2019).

Still on the subject of proper crop development, in the spring and summer, the temperature range should be between 20ºC and 30ºC. An increase in temperature during the growing season can lead to a reduction in productivity due to the shortening of the hop development period, as well as changes in the concentration of alpha-acids, due to unseasonable rainfall or adverse temperatures during the development of the cones (CREUZ; KRETZER, 2022). The accumulation of chill hours also interferes with the development of the crop. Hop plants go through a period of rest at the end of summer and beginning of fall and, in response to the shortening of the days, begin to go dormant. Conversely, with a lack of accumulated chill hours, dormancy may be inadequately overcome (DODDS, 2017).

As hops originate from temperate climate regions, all the knowledge and management of the crop studied is currently based on studies carried out in regions with similar climate characteristics to its center of origin. Therefore, regionalized field trials are necessary in order to select more adapted cultivars, obtain technical data and develop new management practices that will lead to greater productivity and quality of the hops produced (CREUZ; KRETZER, 2022).

Considering that there is no scientific data on the cultivation and productive capacity of hops in Toledo, this study aimed to study the phenological cycle of three hop cultivars in the municipality of Toledo-PR in the second productive year.

MATERIAL AND METHODS

The research was carried out at the Experimental Farm of the Pontifical Catholic University of Paraná (PUCPR), Toledo Campus, with geographic coordinates of 24º42'49" S and an altitude of 574m. The soil of the experimental unit is classified as typical RED LATOSSOL Eutroférrico, with gentle undulating relief and a very clayey texture (EMBRAPA, 2012). The municipality has a humid subtropical climate, type *Cfa*, according to Köppen (MAACK, 2009), with average minimum temperatures of 14°C, maximum temperatures of 28°C and average annual rainfall of 1,800 mm (IAPAR, 2017).

Initially, the soil was collected and sent to a commercial laboratory for chemical analysis of nutrients. The interpretation and recommendation of liming was carried out according to Lahnel and Fagherazzi (2019), who recommend a pH for growing hops of between 6 and 6.5. The soil was prepared by subsoiling and harrowing to a depth of 40 cm. The vertical plant management system was then installed, with an open "V" trellis system, using treated eucalyptus poles, 7.0 m long and 25 cm in diameter, which were buried 2.0 m deep in open pits using a soil drill, 2 mm galvanized wire and sisal twine, according to the activities described in Figures 1A, 1B and 1C.

At the beginning of September 2022, the hop seedlings were obtained from a commercial nursery in Gramado (RS), and at the end of the same month they were transplanted to the experimental area, in 20 x 20 x 20 cm holes, with a spacing of 1.0 m between plants and 3.0 m between rows and soil previously fertilized with 150 kg ha^{-1} of P_2O_5, totalling 45 g/hole, 200 g of tanned sheep manure per hole and 250 g of gypsum per hole (Figure 2A).

The experimental design used was randomized blocks, containing three hop cultivars (Magnum, Hallertauer Mittelfrüeh and Comet) and three blocks, with 6 plants per block, for a total of 72 plants. The Magnum cultivar is of German origin, bitter, with a concentration of 11% to 16% alpha-acids. The Hallertauer Mittelfrüeh cultivar also originated in Germany, however, it is classified as aroma hops (SPÓSITO et al., 2019), while the Comet cultivar originated in the United States, with a concentration of 9.4% to 12.4% alpha-acids and high vigor (OREGON STATE UNIVERSITY, 2015).

The plants were guided with 2 branches and tutored in a clockwise direction, up to a height of 2 m, in order to facilitate their development. After this height, the plants were left to grow naturally. For the top dressing of the plants, the recommendation described by Aquino et al.

(2022) was used, with doses of nitrogen and potassium applied according to the physiological stages of the hops. For both years of cultivation, drip irrigation (200 mL per plant/day) was used throughout the cycle.

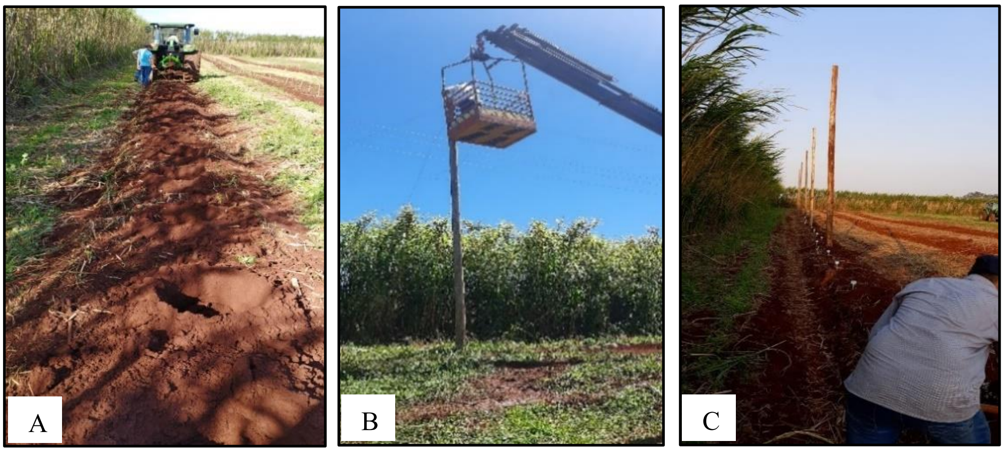


FIGURE 1 - (A) Opening the holes when planting and growing three hop cultivars. (B) Installing the posts when planting and growing three hop cultivars. (C) Installing the wire when planting and growing three hop cultivars.

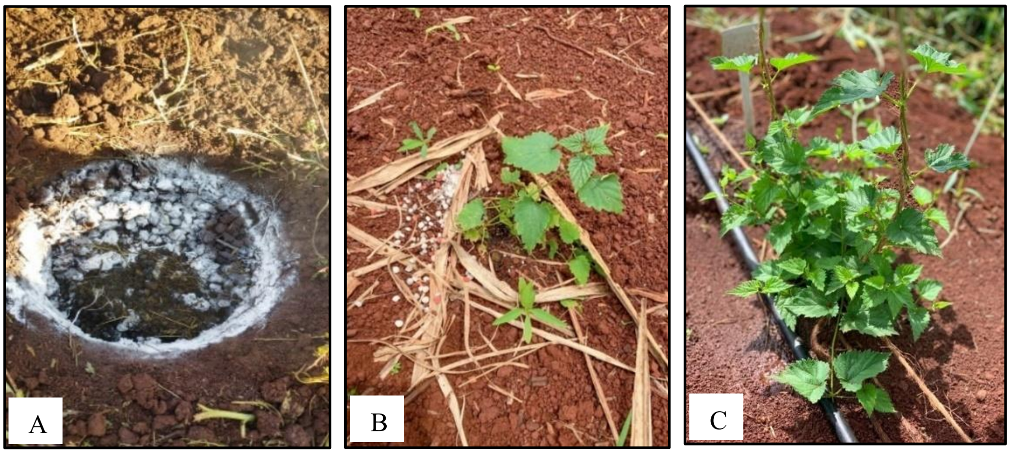


FIGURE 2 - (A) Fertilizing the pits during the planting and cultivation of three hop cultivars. (B) Foliar development during the planting and cultivation of three hop cultivars. (C) Plant sprouting phase during the planting and cultivation of three hop cultivars.

To control weeds, manual weeding was carried out every two weeks, in addition to crowning the plants at a radius of 50 cm and pine shavings were used as ground cover. Emerald grass (*Zoysia japonica*) was planted between the rows, covering a total area of 200 m^2. Pests and diseases were constantly monitored, and the causal agents were identified and controlled immediately. In the period of approximately 30 days after the seedlings were planted in the field, there were significant climatic changes, between very hot, dry and rainy periods, favoring the incidence of mildew (*Pseudoperonospora humuli*), which was controlled with an application of Unizeb Gold (3 g L^{-1}) and an application of Bordeaux mixture.

From October 2023 until May 2024, weekly assessments were made of the start of budding (days) (Figures 2B and 2C), the emission of lateral branches (days), the start of flowering (days), the formation of cones and the start of the harvest (days), following the phenological scale proposed by the BBCH (ROSSBAUER, 1995). In addition, at the end of the harvest, using 6 plants from each block, measurements were taken of the height of the main branches, the number of branches, the longitudinal length of the lateral branches, the number of lateral branches, the diameter of the cones, the length of the cones and the biomass of fresh and dry cones.

The height of the main branches and the length of the lateral branches were obtained using a tape measure on a bench in the Institution's Experimental Farm Laboratory. The number of cones was obtained by counting them individually, and the diameter and length of the cones were obtained with a precision caliper, using 10 cones per branch and averaged. Fresh biomass was obtained by weighing the green biomass of the freshly harvested plant, including all the leaves and branches, on an analytical balance. The dry biomass was obtained after drying the green biomass in a circulation oven at 65ºC for 48 h until constant weight.

The average values were analyzed to see if they met the assumptions of the normality test for residues, according to the Shapiro-Wilk test (5%). They were then subjected to analysis of variance (ANOVA) using the F test (p<0.05) and when significant, they were compared using the Tukey test, at a 5% probability of error, using the Sisvar statistical computer program (FERREIRA, 2011).

RESULTS AND DISCUSSION

Under the conditions of Toledo (PR), according to the data shown in Figure 3, the plants of the three hop cultivars began to sprout between September and November, when two main branches were selected and tutored, while the other branches, emitted from the base of the plant, were removed.

The growth of the tutored main branches lasted for 2.5 months, followed by the start of flowering and development of the cones at the end of December, with ripening taking place in January and continuing until the beginning of February (Figure 3). Therefore, the cycle of hop cultivars in the soil and climate conditions of Toledo (PR) can be seen to be earlier than those described by Spósito et al. (2019), in soil and climate conditions in Piracicaba, São Paulo.

According to the aforementioned authors, hop plants start sprouting in October and plant growth ceases when they reach 5-6 m (maximum height of the support structure) at the end of December and the flowering phase begins in January. In February, inflorescences were observed in various stages of development, while in March, these floral structures were already fully formed. Full maturation of the cones was completed in a short period, lasting a maximum of 15 days, and the harvest was scheduled for the period between the end of March and the beginning of April 2024.

Month/week	September				October				November				December				January				February				Cycle
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	Days
Comet																									126
Hallertauer Mittelfrüeh																									139
Magnum																									126

	Sprouting
	Growth of the main branch and formation of lateral branches
	Emergence of inflorescences
	Flowering
	Cone development
	Cone ripening

Source: The authors, 2024.

FIGURE 3 - Phenological cycle of different hop cultivars in the municipality of Toledo - PR during the growing cycle from September/2023 to February/2024.

The weather data obtained from the weather station at PUC-PR, Toledo Campus, during the experimental period (September 2023 to February 2024) is shown in Figure 4, with an average maximum temperature of 33.1ºC and an average minimum of 17.5ºC.

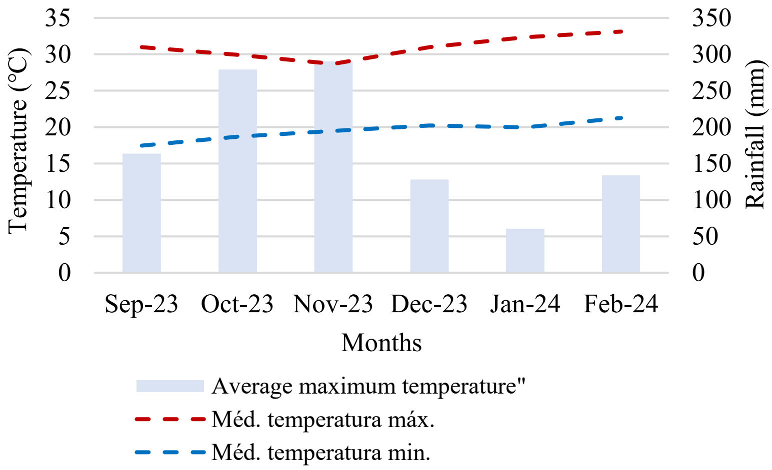
During the vegetative phase, hop plants developed at average maximum temperatures of 31, 29.9 and 28.7ºC, respectively, for the months of September, October and November. During the period from December/23 to February/24, which corresponded to the reproductive period and cone maturation, higher average maximum temperatures were observed (31; 32.3 and 33.1ºC, respectively), verifying that the temperatures in Toledo were above those required by the crop. According to Creuz and Kretzer (2022), the proper development of the hop crop in the spring and summer must occur with temperatures in the 20 to 30ºC range.

This rise in temperature during the beginning of the reproductive phase (December) may have had a negative influence, especially on cultivars of European origin (Magnum and H. Mittelfrüeh), causing excessive growth of the branches and reducing flowering and, consequently, lower cone production. According to Dagostim (2019) and Gonsaga (2021), very high temperatures can reduce carbon assimilation, causing excessive branch growth and negatively influencing the flowering process by weakening the development of the first flowers, thus reducing production.

Spósito et al. (2019) pointed out that, in regions where the seasons are not clearly defined, air temperatures remain high during the summer without a large thermal variation and winter does not present low temperatures (as was the case in Toledo, PR), plants undergo significant physiological changes. With warmer nights, plants consume more carbohydrates produced in the leaves during the day through respiration. This increase in energy expenditure results in a reduced accumulation of carbohydrates, promoting accelerated development of these plants, which can lead to a reduction in the plant's lifespan, due to the depletion of resources and accelerated wear and tear.

In this phenological study, it was possible to observe that among the cultivars studied, the cultivar H.

Mittelfrüeh cultivar needed more days (139 days) to complete its cycle, with a longer vegetative period (100 days) when compared to the other cultivars studied (Table 1). This result corroborates research carried out by Sasso (2021), who, when studying the phenology of hop cultivars in the conditions of Curitibanos (SC), also found that the cultivar H. Mittelfrüeh cultivar had the longest period among the other cultivars studied, totaling a cycle of 173 days, of which 106 days were for the vegetative phase, 67 days for the reproductive phase (30 days for the cone maturation phase).



Source: PUC-PR Meteorological Station, Toledo *Campus*, Paraná, Brazil.

FIGURE 4 - Weather data obtained during the experimental period (September 2023 to February 2024).

TABLE 1 - Phenology of hop cultivars: number of days in the vegetative phase (NDV), number of days in the reproductive phase (NDR), number of days in the cone development phase (NCD), number of days in the cone maturation phase (NDM) and total number of days (TN), in the second year of cultivation in Toledo, Paraná.

Cultivars	NDV	NDR	NCD	NDM	TN
Comet	80	20	7	19	126
Hallertauer Mittelfrüeh	100	20	7	12	139
Magnum	80	12	22	12	126

When the data was analyzed, it was found that it met the assumptions of normality, but the coefficient of variation of the parameters analyzed was high, possibly due to the genetic variability of the plants and because this was a study of the adaptation of cultivars.

The Comet and Magnum cultivars were similar in terms of the total number of days needed to complete the cycle (126 days), but there were differences in their phenological phases. Both cultivars had the same period for budding and inflorescence emergence (80 days), but the Comet cultivar had a longer reproductive period (20 days) and cone maturation (19 days), while the Magnum cultivar had 12 days for the reproductive phase and a longer period for cone development, with 22 days.

It is important to note that the number of plants sampled from the Magnum cultivar was low, mainly due to plant mortality, which possibly influenced the fact that similar results were obtained for those from different centers of origin (American and European). According to Gonsaga (2021), hop cultivars are classified in terms of their production cycle, being early, medium or late, so their cycle can be altered according to the climate and different growing locations. It is therefore possible to identify that, for this study, the cultivars Comet and Magnum had an early production cycle of 126 days, while the cultivar H. Mittelfrüeh had a late cycle of 139 days.

The description of cultivars drawn up by Oregon State University (2015) shows that the Magnum cultivar has very good vigor and medium/medium late maturity. The Comet cultivar has excellent vigor, with medium/late ripening and the Hallertauer Mittelfrüeh has poor/medium vigor, depending on the location, with early ripening in the United States and late ripening in Germany.

With regard to plant vigor, for the conditions of Toledo (PR), it was possible to verify that the Comet cultivar was late ripening, the Magnum cultivar maintained its characteristic of medium/medium late ripening, with good vigor, and H. Mittelfrüeh was medium/medium late ripening. Therefore, the hop cultivars studied in this study showed different growth and development to that described by Oregon State University (2015). This result may be related to the different soil and climate conditions in which this work was carried out. According to Acosta-Rangel et al. (2021) and Jastrombek et al. (2022), these changes can influence growth rates, multiple annual reproductive cycles and lack of dormancy in plants, the latter of which was not observed in the three cultivars studied.

In order to understand these singularities of the crop, it is essential to carry out an analysis of the plant's response to meteorological elements in order to establish the crop's agroclimatic parameters. Among these factors, air temperature plays a crucial role, significantly impacting the growth and development of the plant, and is therefore an element to be taken into account (FERREIRA et al., 2019). In this study, the meteorological data showed that high temperatures did not favor the cultivars (Hallertauer Mittelfrüeh and Magnum), where, in the absence of cold, they showed lower yields in the temperate climate growing region. This result was observed in Table 2, with statistically lower cone yields compared to the Comet cultivar.

Relating the phenology of the cultivars to their growth, it can be seen that the Comet cultivar had the highest average plant height (251 cm), followed by H. Mittelfrüeh with 116 cm and Magnum with 31 cm, where all the cultivars differed from each other statistically at a 5% probability of error. This result is much lower than that obtained by Jastrombek et al. (2022), who found the height of the Mapuche cultivar to be higher, reaching 4.62 m, having exceeded the top of the 4.50 m shoot, as did the other cultivars studied. It is possible that the plants used in this study did not reach a high height due to the high temperatures obtained during their development.

TABLE 2 - Plant height (PH), number of lateral branches (NLB), lateral branch length (LBL), number of cones per main branch (NCPB) and number of cones per lateral branch (NCPLB), in hop cultivars, in the second growing season, in Toledo (PR).

Cultivars	PH (cm)	NLB	LBL (cm)	NCPB	NCPLB
Comet	251.15 a*	6.01 a	29.03 a	20.13 a	4.86 a
Hallertauer Mittelfrüeh	116.95 b	4.60 a	19.45 a	5.60 b	1.10 b
Magnum	31.14 c	0.90 b	3.89 b	2.91 b	0.72 b
Average	131.96	3.80	17.31	9.47	2.21
CV(%)	91.85	141.09	129.23	117.67	251.29

*Equal lowercase letters do not differ from each other in the column, according to the Tukey test, at a 5% probability of error.

The delay in installing the wires and securing the branches occurred at the beginning of December, causing the branches to grow sideways or downwards and not to stick to the nylon wire (SPÓSITO et al., 2019). Therefore, it is ideal to keep only two branches per plant when guiding the branches to the wires, choosing the healthiest and most vigorous ones, while the rest should be thinned out. In view of the above, in this study, only the surplus branches were thinned, as the remaining branches may have influenced the growth of the productive branches.

According to Spósito et al. (2019), the recommendation for fertilization in the 2nd year of cultivation was three applications of NPK per plant, of 100 to 150 g and complementary nitrogen fertilization between September and November. In addition, according to the same authors, potassium fertilization should be carried out in December in order to intensify flowering. Thus, in this study, not enough fertilization was carried out as recommended, directly influencing the growth and flowering results.

The plant height parameter was obtained from the main branch, which has nodes and internodes, where each node has a pair of leaves (Figures 5A and 5B), or the formation of a lateral branch, also called a secondary branch, which can have only leaves or a mixture of leaves and inflorescences (Figures 6A, 6B and 6C).

Plant height is directly related to productivity. According to Gonsaga (2021), the hop plant can reach a height of over 5 m, with cones along this length. Fagherazzi and Rufato (2018) also point out that the height of the conduction system is considered extremely important, as it is the height from which the plant expresses its productive potential.

With regard to the number and length of lateral branches, the Comet cultivar stood out, with an average number of 6 lateral branches per plant and a length of 29 cm, respectively, and H. Mittelfrüeh with 4.6 lateral branches per plant and a length of 10.45 cm, respectively, which did not differ statistically from each other. On the other hand, the Magnum cultivar had lower averages, with 0.9 lateral branches and a length of 3.8 cm.

According to Spósito et al. (2019), the inflorescences develop in greater quantity on the secondary branches formed from the buds located in the axils of the leaves, mostly in the upper third of the plant. In this study, the greatest length of lateral branches was achieved in the Comet and H. Mittelfrüeh cultivars, with 29 and 10.15 cm, respectively, which differed statistically from each other.

When analyzing the number of cones produced by the cultivars on the main and lateral branches, Comet stood out, with the highest averages, differing from the others, at a 5% probability of error level, being 20.13 and 4.86, respectively, while the H. Mittelfrüeh and H. Mittelfrüeh cultivars differed statistically from each other. Mittelfrüeh and Magnum were similar, with the lowest averages. The higher cone production of the Comet cultivar, in addition to being linked to its height and number of lateral branches, has an American center of origin, i.e. it has genetics that can withstand high temperatures, such as those that occurred in Toledo during the crop's development period.

In addition to its demand for temperature, hops are also demanding in relation to light, so the intensity and time of exposure are crucial aspects for the crop's development, and a relevant aspect for planting location. Hops are classified as a plant that is sensitive to a lack of light, where the length of the day can interfere in various ways, but the most important is its response to the start of flowering, since low light can result in fewer flowers (FAGHERAZZI; RUFATO, 2018; DAGOSTIM, 2019).

The onset of flowering can occur on days with up to 16 h of light, requiring a minimum period of 8 to 10 h for flowering to be induced (SPÓSITO et al., 2019). On the other hand, Leite and Pandolfo (2022) detailed that the crop is flexible in terms of inducing flowering, with a wide photoperiod range of 10 to 16 h, justifying the possibility of growing it in areas with different latitudes. According to Arruda et al. (2019) and Fagherazzi and Rufato (2018), Brazil does not have a geographical location where the sunlight reaches the period that the plant needs, approximately 15 h, which is a variable that needs to be controlled, in addition to high temperatures.

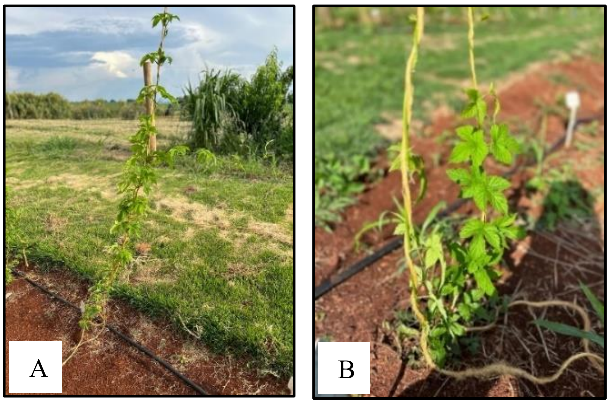


FIGURE 5 - Detalhe no crescimento dos ramos de plantas de lúpulo (A e B), no segundo ano de cultivo, em Toledo (PR).

FIGURE 6 - Details of the development stages of hop plants (A, B and C), in the second year of cultivation, in Toledo (PR).

As well as producing more cones, the Comet cultivar also obtained cones from the main branch with greater fresh and dry biomass, diameter and length when compared to the other cultivars (Tables 3 and 4). The lateral branch cones of the Comet and H. Mittelfrüeh cultivars had similar fresh and dry biomass averages.

Based on comparisons of productivity in other study sites, Sasso (2021), conducting a study in Curitibanos (SC) with different hop cultivars, using H. Mittelfrüeh, obtained an average of 15.16 g and 168.08 g (average of 454.9 cones/plant) of cones per plant in the first and second year of cultivation, respectively, making it the most productive of the genetic materials studied.

In the present study, the same cultivar, H. Mittelfrüeh, obtained a total of 3.08 g of cones per plant in its second year of production. This is a possible response to climatic conditions, given that the region where the study took place had an average temperature of 18.2ºC for the 170 days of cultivation, located at a latitude of 27ºS, with the longest daylight hours being around 13 h in summer and 10 h in winter. According to Raut et al. (2021), each cultivar has specific characteristics in terms of the size and composition of the cones, which can vary between cultivars, in different harvests and growing locations.

To obtain the best yield results for hops, the annual demand for water is based on up to 600 mm, with lower levels (300 mm) leading to a decrease in productivity. In fact, it is of great importance that the water supply is well distributed, regardless of its supply (rain or irrigation), not exceeding the plant's needs, that is, supplying the demand according to the phases of the annual cycle of these plants, appropriate to the absorption capacity of the soil (DAGOSTIM, 2019). Pavlovic et al. (2012), studying the influence of climatic characteristics on the cultivation of hops, stated that the accumulated rainfall in the vegetative period of 500 to 600 mm favored the vegetative development of the crop. Rybacek (1991) considered that the accumulated water consumption should be 482 mm, with a daily average of 3.85 mm, noting that in the warmer months in the Northern Hemisphere (July and August), water consumption is higher, at around 100 mm/month.

In this study, there was a total accumulation of 1,055 mm of rainfall between September 2023 and February 2024, but this was not evenly distributed between the months of crop development, with the highest levels in October and November, with 280 and 290 mm. For the other months, there was little rainfall and it was necessary to irrigate daily with 200 mL/plant.

Throughout the development of the crop, it was possible to observe that the results of the coefficient of variation (CV%) in the Tukey test (comparison of means), at a 5% probability of error, showed a high value, which can be justified by the fact that the plants were harvested on three different dates, with an interval of up to 32 days between the start and end of data collection. Another factor that may have interfered significantly was the lack of standard pruning of the lateral branches, which originated at the base of the plant. According to Guimarães (2021), the point of harvest is a determining factor, because if it occurs at the beginning of the ripening period, there is a reduction in the quality of the cones. In addition, the production of oils is lower; once present in the cones, they are volatile and can be lost over time or undergo a degradation process, even under storage conditions (RAUT et al., 2021). The composition of hop cones is influenced by genetic characteristics, cultivars, harvest point, post-harvest processing, climatic and geographical conditions (RETTBERG et al., 2018).

TABLE 3 - Length and diameter of cones of the main branch, in plants of hop cultivars, in the second year of cultivation, in Toledo (PR).

Cultivars	Length of cones of the main branch (mm)	Diameter of cones of the main branch (mm)
Comet	1.53 a*	1.02 a
Hallertauer Mittelfrüeh	0.71 b	0.52 b
Magnum	0.26 b	0.18 b
Average	0.83	0.57
CV(%)	102.62	103.87

*Equal lowercase letters do not differ from each other in the column, according to the Tukey test, at a 5% probability of error.

TABLE 4 - Fresh and dry biomass of the cones on the main branch and fresh and dry biomass of the cones on the lateral branch, in plants of hop cultivars, in the second year of cultivation, in Toledo (PR).

Cultivars	Fresh biomass of cones on the main branch (g)	Dry biomass of main branch cones (g)	Fresh biomass of lateral branch cones (g)	Dry biomass of lateral branch cones (g)
Comet	8.86 a*	2.46 a	1.53 a	0.39 a
Hallertauer Mittelfrüeh	2.68 b	0.76 b	0.40 ab	0.11 ab
Magnum	1.45 b	0.35 b	0.22 b	0.04 b
Average	4.30	1.18	0.71	0.18
CV(%)	126.61	122.47	274.96	275.77

*Equal lowercase letters do not differ from each other in the column, according to the Tukey test, at a 5% probability of error.

In this study, the plants were harvested on the dates: 24/01, 06/02 and 25/02, both with differences in maximum and minimum temperatures and rainfall, as shown in Table 5, thus influencing the results of the parameters obtained. This research was the result of the second year of cultivation. It is worth pointing out that for an adaptive study, at least 3 years of research is recommended, so that it is possible to indicate genetic materials that show better agronomic performance in the western region of Paraná. It is therefore necessary to continue the research in the coming years.

TABLE 5 - Average maximum temperature, minimum temperature and rainfall on the dates the hop cones were harvested.

Harvest dates	Maximum temperature average (T°C)	Minimum temperature average (T°C)	Precipitation average (mm)
24/01/2024	28.9	17.1	11.5
06/02/2024	34.0	20.9	9.8
25/02/2024	32.7	22.4	9.9

CONCLUSION

From the data obtained, it can be concluded that the hop cultivars Comet and Magnum had a cycle of 126 days, while H. Mittelfrüeh needed a longer period to complete its cycle, 139 days, in the soil and climate conditions of Toledo-Paraná, Brazil.

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