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Garlic vernalization and planting dates in Guarapuava

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ABSTRACT

Several attempts have been made in order to produce garlic out of season in Southern Brazil, aiming to reduce dependence on imports. The use of cold storage before planting is a possible alternative. Another possibility could be forward planting dates using early cultivars, more tolerant to diseases and less demanding in temperature and photoperiod conditions. The objective of the present study was to evaluate the effects of three vernalization periods (30, 40 and 50 days) and three planting dates (23/03, 23/04 and 23/05) on the yield of two garlic cultivars (Caçador and Quitéria). A randomized block design with three replications was used. The assessed traits were plant emergence, plant height, secondary plant growth, total yield and classification of marketable bulbs. The plant emergence and plant height increased in the first cultivation period. The yield of marketable bulbs of the Quitéria cultivar increased on the first two planting dates and the Caçador cultivar showed the highest yield of marketable bulbs on the second planting date. The third planting date provided a decrease in the secondary growth of the Caçador cultivar plants. The 30-day vernalization period promoted lower secondary growth of Quitéria cultivar plants. The 40-day vernalization period, which allowed better adaptation of both cultivars to photoperiod and temperature, resulted in good vegetative and productive development in the region of Guarapuava, Paraná State, Brazil.

Keywords: *Allium sativum*, cold storage, early production.

RESUMO

Vernalização e épocas de plantio de alho em Guarapuava, PR

Diversas tentativas têm sido feitas com intuito de produzir alho na entressafra na região sul do Brasil, objetivando diminuir a dependência de importações. Uma alternativa é a utilização de frigorificação em pré-plantio. Outra possibilidade seria a antecipação do plantio com cultivares precoces, mais tolerantes a doenças e menos exigentes em temperatura e fotoperíodo. O objetivo desse experimento foi avaliar os efeitos de diferentes períodos de vernalização e épocas de plantio sobre a produtividade de duas cultivares de alho (Caçador e Quitéria), submetidas a três períodos de vernalização pré-plantio de bulbilho-semente (30, 40 e 50 dias) e três épocas de plantio (23/03, 23/04 e 23/05). O delineamento experimental utilizado foi em blocos casualizados, com três repetições. Avaliou-se a emergência e a altura média de plantas, o superbrotamento, a produtividade total e classificação comercial de bulbos. Houve aumento da emergência e altura média de plantas na primeira época de cultivo, sendo que a produção de bulbos com maior padrão comercial foi obtida nas duas primeiras épocas para a cultivar Quitéria e na segunda época para a cultivar Caçador. A terceira época reduziu o superbrotamento para a cultivar Caçador e menor superbrotamento foi observado com 30 dias de vernalização para a cultivar Quitéria. O período de 40 dias de vernalização foi o que permitiu melhor adaptação de ambas as cultivares às condições de fotoperíodo e temperatura, proporcionando um desenvolvimento vegetativo e produtivo satisfatório na região de Guarapuava.

Palavras-chave: *Allium sativum*, frigorificação, produção precoce.

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The economic importance of the garlic crop (*Allium sativum* L.) has increased considerably in Brazil in recent years. Between 2004 and 2008 garlic production increased 7.32% as a result of the growth in domestic consumption. These increases have occurred because of the generalized use of garlic as the main seasoning in Brazilian cooking and the greater exploitation of its therapeutic and functional characteristics (Watanabe, 2009).

Research has shown positive results for increase in production, as for example, development of more adapted cultivars, application of the vernalization technique to noble garlic, determination of the ideal harvest point, proper storage, correct irrigation management, fertilization and plant health treatments (Mota, 2003).

One of the main problems currently encountered by garlic producers in the central southern region of Brazil has been competition with imported garlic, especially from China and Argentina, which has highly competitive quality and prices on the Brazilian market. To solve this problem, in addition to increasing productivity, it is necessary to produce better quality bulbs and widen the period of Brazilian garlic offer on the domestic market. The state of Paraná, according to Watanabe (2009), accounted for only 4.09% of the Brazilian garlic production in 2008 but accounted for 7.37% of the planted area.

Garlic is a crop resistant to low temperatures and not very intense frosts. Temperature and light period are important environmental conditions for

good development of the crop (Filgueira, 2008). Maintaining the bulbs before planting at temperatures from 0 to 10°C for a period of two months accelerates the cycle and substitutes the initial climatic requirements of the crop (Jones & Mann, 1983). In the case of Brazil, the vernalization periods range from 45 to 60 days at temperatures from 3 to 5°C for vernalization (Resende *et al.*, 2004). Exposing the bulbs to low temperatures in pre-planting stimulates cytokine and giberelin accumulation, modifying the hormonal balance and leading the seed bulbs to early development (Rakhimbaev & Ol'Shaskaya, 1976). Seed bulbs without vernalization develop only when they receive suitable light period and temperature conditions for their requirements, whereas vernalized seed bulbs begin to develop more quickly at high temperatures than at low temperatures (Racca *et al.*, 1981).

Garlic cultivars respond in physiologically different ways to vernalization because of variation resulting from dormancy (Blesdale, 1976). In this sense, according to Pyo *et al.* (1979), the most striking effect of vernalization is of the increase in earliness, especially in cultivars with greater low temperature requirement for development (Motaz *et al.,* 1971). However, there are many contradictions about the effects of vernalization on the garlic yield; some researchers have observed increases (Ferreira *et al.,* 1980) while other reported no significant differences (Pyo *et al.,* 1979) and yet others have reported depressive effects (Biasi & Mueller, 1984).

The lack of good-quality bulbs to supply the bigger and more demanding markets, such as those in Rio de Janeiro, Belo Horizonte and São Paulo, has contributed to the entry of the imported product from March to November. This fact results from the excessive concentration of production from August to October in the southeastern region and from November to December in the southern region of Brazil. Only noble garlic from southern Brazil, especially from Santa Catarina and Rio Grande do Sul States, and produced under vernalization in Minas Gerais, Bahia and Goiás States, meets the quality requirements of the most demanding markets (Pereira, 2000).

There have been several attempts to produce garlic in the fallow in Southern Brazil to reduce imports. One of the possibilities is using cold storage in the pre-planting. Another possibility is forward planting with early cultivars that are more tolerant to *Alternaria* and require less light. In this sense, scheduling planting by managing the vernalization period allows the extension of the planting periods and harvesting throughout the year.

The objectives of the present study were to assess the effects of different vernalization periods and cultivation periods on the emergence and mean plant height, secondary plant growth, yield and commercial classification of bulbs of the Caçador and Quitéria cultivars, cropped in the central south of Paraná State, Brazil.

MATERIAL AND METHODS

The experiment was carried out in the Vegetable Cultivation Sector of the Central West State University (UNICENTRO), located in Guarapuava, Central-Southern Paraná, in 2004. The climate of the region is classified as Cfb (wet subtropical mesothermic) without a dry season, with cool summers and moderate winters according to the Köppen classification. The mean altitude is 1.100 meters and the soil is classified as a typical clay-textured Bruno Distrofic latosoil (Embrapa, 2006). The mean maximum (16,9 to 26,5^{0}C) and minimum temperatures (8,8 to 15,7^{0}C) and average rainfall (138 mm) were observed during the execution of the experiment.

A soil sample, composed of 10 subsamples, was removed from the 0 to 20 cm layer for chemical analysis and showed the classification: pH ($CaCl_2$)= 5.7; $H^+ + Al^{+++}$= 3.46 $cmol_c$ dm^{-3}; Ca^{++}= 6 $cmol_c$ dm^{-3}; Mg^{++}= 4.3 $cmol_c$ dm^{-3}; P= 10.1 mg dm^{-3}; K^+= 0.43 $cmol_c$ dm^{-3}; organic matter = 51.00 g dm^{-3}; CTC= 14.19 $cmol_c$ dm^{-3}; and V%= 75.6%.

Fertilization was carried out based on the soil analysis using 800 kg ha^{-1} of the NPK 04-14-08 formula at planting and about 10 t ha^{-1} of cattle manure three days before planting. Fifty days after planting zinc sulfate (1%) and copper sulfate (2%) were applied in a leaf spray and 100 kg ha^{-1} urea as top dressing were applied in three lots, at 30, 60 and 90 days after emergence.

A randomized block design was used with three replications in a split plot arrangement where the main treatments (plots) were three cultivation periods (23/03, 23/04 and 23/05/2004). The subplots consisted of a 2 x 3 factorial arrangement consisting of the two cultivars (Caçador and Quitéria) and three pre-planting seed bulb vernalization periods (30, 40 and 50 days). The seed bulbs were vernalized in a cold chamber at 4°C, 2°C and 80% humidity.

The seed bulbs were planted at a depth of 5 cm, with 20 cm between row spacing and 10 cm between plant spacing. The plot area was defined by a 1 x 2 m bed, with five planting rows.

A microspray irrigation system was used and the quantity of water applied was sufficient for the soil to return to field capacity in the layer corresponding to the effective depth of the root system. Irrigation was stopped between five and 15 days before the harvest.

Before planting, the seed bulbs were treated with a 2.5% Iprodione solution to prevent possible attack from soil pathogens. Plant health was controlled with products based on Maneb for preventive control of Alternaria and rust. Thiometon-based insecticides were used to control mites and thripes as necessary. The crop was kept weed-free by manual weeding.

The characteristics plant emergence, mean plant height, secondary plant growth (%), total yield and marketable bulb classification were evaluated.

Emergence was determined by counting the number of emerged plants 20 days after planting. The mean plant height was determined 60 days after emergence, in 10 plants sampled randomly per plot, measured from the base of the pseudo-stem to the tip of the longest leaf.

The harvest time was determined by the yellowing and partial drying of the canopy and/or plant falling. After harvesting, the plants were submitted to

the cure process for 50 days and then the total yield in ha^{-1} and the percentages of bulbs with secondary plant growth were determined.

The marketable bulbs were distributed in size classes according to the transversal diameter: 7 (>56 mm), 6 (47-56 mm), 5 (42-47 mm), 4 (37-42 mm) and 3 (32-37 mm), according to decree nº 242, 17th September 1992, of the Ministery of Agriculture, Livestock and Supply (MAPA) (Menezes Sobrinho, 1997).

The obtained data were submitted to analysis of variance and the means of the treatments were compared by the Tukey test at 5% probability. Several regression models were fitted for cultivar response to the vernalization period. The choice of the most suitable model was based on the significance fit of the performance of the variables to the regression equations (F test, 5%) and its coefficients (t-test, 5%).

Table 1. Average plant height, total yield and oversprouting of garlic cultivars Caçador and Quitéria in three planting dates and three periods of vernalization (altura média de plantas, produtividade total e superbrotamento das cultivares de alho Caçador e Quitéria em três épocas de plantio e três períodos de vernalização). Guarapuava, UNICENTRO, 2004.

Cultivar	Planting date			Vernalization (days)		
	Mar 23	Apr 23	May 23	30	40	50
	Plant average height (cm)					
Caçador	46.61 aA	34.68 aB	32.60 aB	38.54 aAB	39.30 aA	36.06 bB
Quitéria	46.61 aA	36.59 aB	30.45 bC	37.96 aAB	35.55 bB	40.15 aA
C.V. (%) = 6.68.						
	Total yield (t ha^{-1})					
Caçador	9.26 aB	12.73 aA	8.43 aB	10.46 aA	11.25 aA	8.56 aA
Quitéria	12.95 aA	12.84 aA	8.25 aB	11.77 aA	13.71 aA	8.68 aB
C.V. (%) = 23.63.						
	Oversprouting (%)					
Caçador	42.00 aA	40.67 aA	20.33 aB	31.67 aA	33.00 aA	38.33 aA
Quitéria	49.66 aA	22.67 bB	26.00 aB	19.33 bB	39.33 aA	39.67 aA
CV (%) = 23.98.						

Means followed by the same small letter in the column and capital letter in the lines did not differ from each other by Tukey test at 5% (médias seguidas pela mesma letra minúscula nas colunas e maiúscula nas linhas não diferem entre si pelo teste de Tukey (α=0,05)).

RESULTS AND DISCUSSION

The cultivation period and vernalization period interaction was significant for the characteristics mean plant height, total yield and secondary plant growth (Table 1). Significant differences were observed among the cultivars for mean plant height, in the planting on 23/05 with vernalization of 40 and 50 days and for the secondary plant growth, in the 23/04 planting date with 30 days vernalization.

Generally, a greater percentage of emerged bulbs was observed on 23/03 compared to the other dates, and some treatments reached about 90% sprouting, for example, the Quitéria cultivar when submitted to a 40-day vernalization period (Figure 1). These results were in line with those observed by Silva & Casali (1987) and Seno *et al.* (1993), who reported early plant emergence in early planting, that is, in February and March. Late planting resulted in reduced cycle and less yield, because the plants received stimulus for bulb development before reaching full vegetative development (Ferreira, 1989).

The 40-day vernalization period seemed to be the period that influenced most effectively the seed bulb emergence of the Quitéria cultivar. The 30-day period presented the lowest percentage of emerged plants on the planting dates 25/03 and 23/04 for the Quitéria cultivar. On 23/04, all the treatments presented 60-80% emergence index and the Quitéria cultivar with 30 days vernalization presented the lowest emergence (60%). For the 23/05 planting date, the treatments performed similarly for the plant emergence trait except for the Quitéria treatment, which presented the lowest emergence (58%) with 50 days in cold storage (Figure 1c).

A significant effect was detected for the cultivation period x vernalization period interactions for mean plant height, that is, the cultivars performed differently depending on the cultivation period and the vernalization period. Considering the cultivation period effect for each cultivar, the 23/03 planting date enabled greater plant height for both the cultivars assessed (Table 1).

Pereira (2000) worked with the Gravatá and Roxo Pérola de Caçador cultivars and observed that there was no influence of cultivation period on the mean plant height. However, Seno *et al.* (1993) observed that early planting reduced growth of parts of the Caçador cultivar. However, presumably, environmental factors such as temperature and light period may have favorably influenced the trait, because in the central southern region of Brazil in March high temperatures were observed that permitted early seed bulb emergence and accelerated vegetative development. The increase in the light period has a direct relationship with increase in the canopy dry matter, especially during the vegetative phase (Carvalho, 1975). Relatively high temperatures and long light period promoted greater photosynthesis and resulted in a greater photoassimilate accumulation that contributed to a greater canopy development (Taiz & Zeiger, 2004).

Seno *et al.* (1993) observed increase in plant height in function of the increase in the vernalization period from 40 and 60 days. These results were in line with those obtained in the present study for the Quitéria cultivar (Table 1) that presented greater mean plant height when submitted to the 50-day vernalization period. However, Leal (1998) did not report effect of the vernalization period (25, 35 and 45 days) on plant height when assessed at

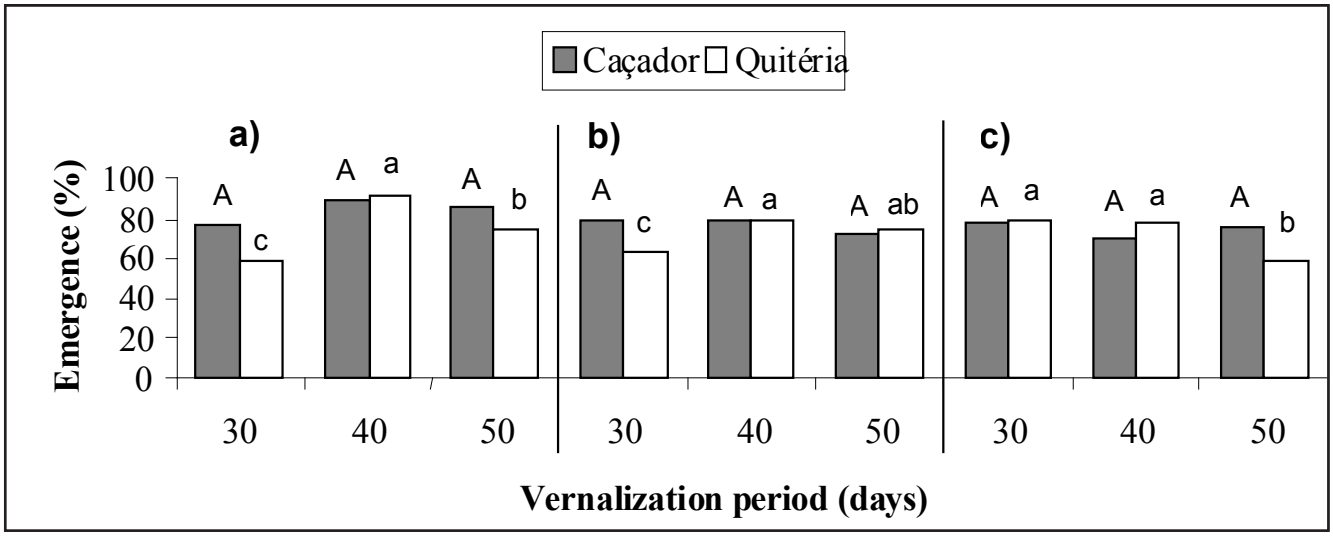

Figure 1. Emerged plants (%) of garlic cultivars Caçador and Quitéria, 20 days after planting, vernalizated during 30, 40 and 50 days and planted on 23/03/2004 (a), 23/04/2004 (b) and 23/05/2004 (c) [plantas emergidas (%) aos 20 dias após o plantio, cultivares de alho Caçador e Quitéria, vernalizadas por 30, 40 e 50 dias e plantadas em 23/03/2004 (a), 23/04/2004 (b) e 23/05/2004 (c)]. Guarapuava, UNICENTRO, 2004.

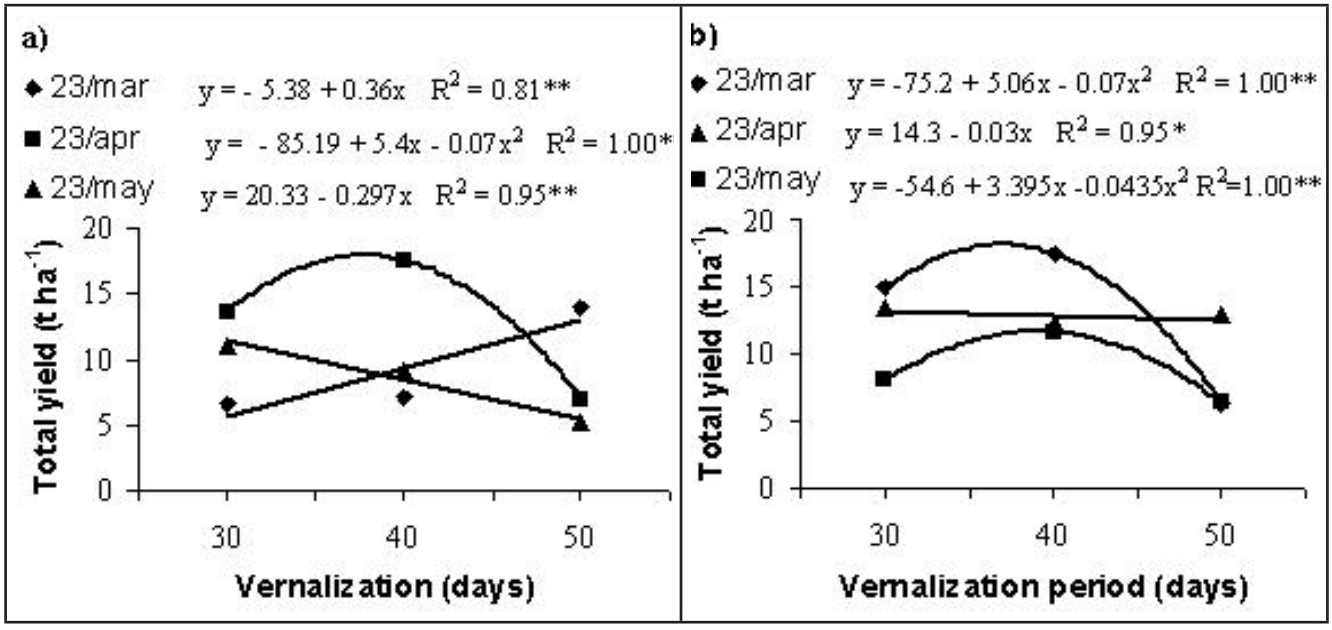

Figure 2. Total yield of bulbs of garlic cultivars Caçador (a) and Quitéria (b) subjected to 30, 40 and 50 days of vernalization and three planting dates [produtividade total de bulbos das cultivares Caçador (a) e Quitéria (b) submetidas a 30, 40 e 50 dias de vernalização em três épocas de plantio]. Guarapuava, UNICENTRO, 2004.

53 and 90 days after planting. This fact was due to the climatic conditions of the cold storage) and the climatic conditions of the cropping location.

The greater plant height was due to the early seed bulb emergence (Silva 1982) allied to the fact that, at the start of development, the plant depends on its own reserves for the canopy and root system development, that will later be an important source of reserve and nutrient exportation that translates into fast growth (Magalhães, 1985).

For the total bulb yield, the cultivars performed differently depending on the cultivation period x vernalization period interaction. The Caçador cultivar presented higher yield on the 23/04 planting date when vernalized for a period estimated by the regression curve of 38.6 days (Figure 2a), resulting in a yield of up to 18.96 t ha^{-1}. When cultivated on the 23/03 planting date, the vernalization period showed linear performance, indicating the need to remain more than 50 days in cold storage. Inverse performance was

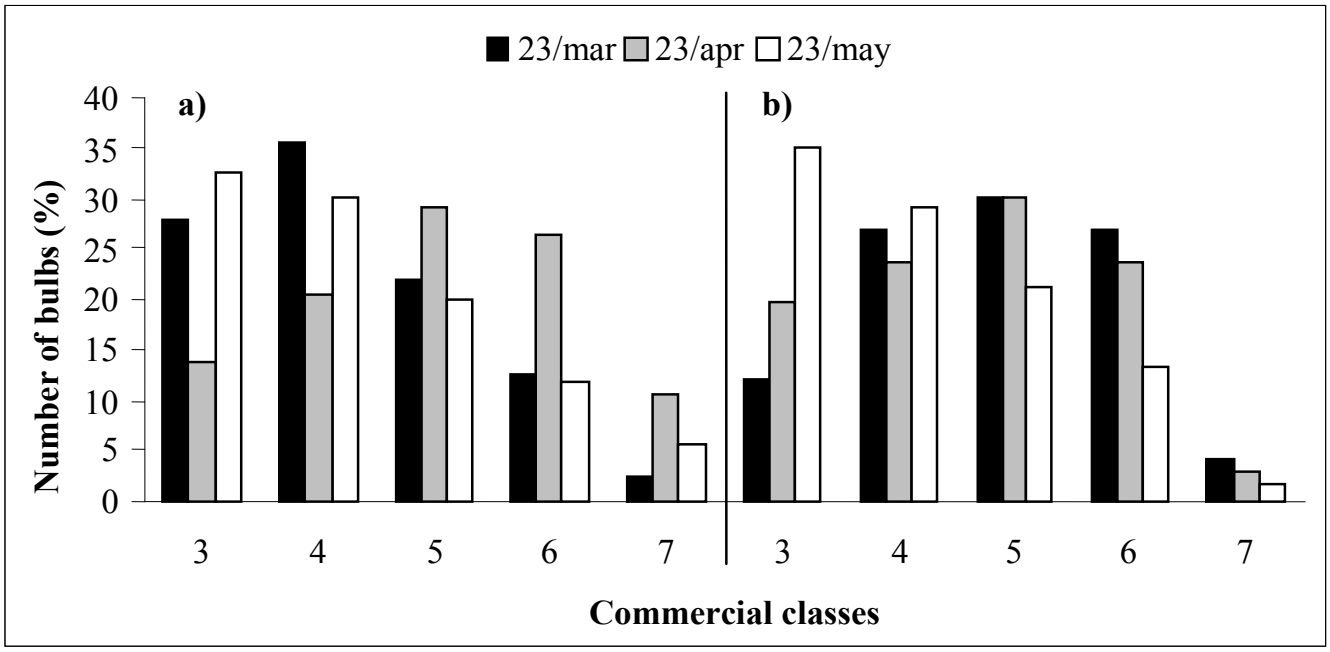

Figure 3. Distribution of the yield of bulbs of garlic cultivars Caçador (a) and Quitéria (b) in marketable class based on three planting dates (distribuição da produção de bulbos das cultivares Caçador (a) e Quitéria (b) em classes comerciais em função de três épocas de plantio). Guarapuava, UNICENTRO, 2004.

observed for the 23/05 planting date, when production decreased linearly as time spent in cold storage increased, indicating that the vernalization period should not exceed 30 days (Figure 2a). These results were in agreement with those reported by Ferreira *et al.* (1991), Reghin & Kimoto (1998) and Pereira (2000) for the Caçador cultivar and were due to the earliness of the cultivar, where the decrease in the environmental temperature with the advance of the cultivation period reduced the vernalization time necessary to obtain good yields compared to the later cultivars.

When the performance of the Quitéria cultivar was assessed in relation to the cultivation period x vernalization period interaction it was observed that the greatest bulb production was obtained on the 23/03 planting date. Following the quadratic model fitted for this cultivation period, a maximum production was obtained of 16.24 t ha^{-1} with 36 days in cold storage. However, the 23/04 planting date altered little due to the vernalization period, because a slightly decreasing linear performance was observed in the production among the vernalization periods (Figure 2b). The results obtained corroborated with those reported by Seno *et al.* (1993) who observed higher yields in planting carried out in April, that is, between the 3/03 and 23/04 planting dates of the present experiments.

Bulb production by the Caçador cultivar on the 23/04 planting date was greater than in the other cultivation periods (Table 1). The Quitéria cultivar presented best productive performance on the 23/03 and 24/04 planting dates, that differed statistically from the 23/05 planting date (Table 1), so that it could be recommended for forward planting, implying an early harvest at least three months earlier than the normal time in the region, that would be in November and December. This fact is relevant, because it allows the producers to place their product in the fallow of the region, reducing the need to import the product. The production results obtained were compatible with those observed for garlic cultivars in the central southern region of Brazil by Seno *et al.* (1993) and Pereira (2000).

These results indicated that scheduling planting among the cultivars is an excellent alternative for producers, because the Quitéria cultivar can be planted in March and the Caçador cultivar in April, implying a prolongation of the harvest in the fallow period of the region.

The Caçador cultivar presented the greatest percentage of bulbs with good marketable standard on the 23/04 planting date, that is, bulbs in classes 5, 6 and 7. The other cultivation periods resulted in a greater percentage of bulbs in classes 3 and 4 (Figure 3a). A similar fact was observed for the Quitéria cultivar, where the two first cultivation periods accounted for the greatest production of bulbs with good marketable standards (Figure 3b).

Secondary plant growth was influenced by cultivation period and vernalization period, and was one of the factors responsible for damaging the marketable quality of the bulb. The Caçador cultivar presented a smaller percentage of bulbs with secondary plant growth when cultivated on the 23/05 planting date, regardless of the vernalization period (Table 1). In the later planting in the southern region, the bulbs were differentiated in a longer light period, contributing to inhibition of the secondary plant growth process (Burba, 1983). However, the Quitéria cultivar was more influenced by the vernalization periods, where a lower percentage of bulbs with secondary

plant growth was observed when the bulbs were vernalized for a short period (30 days) regardless of the cultivation period (Table 1). The Quitéria cultivar is later than Caçador and more susceptible to secondary plant growth, therefore, a shorter vernalization period reduces secondary plant growth pressure. These results are in line with those observed by Silva (1982) and Ferreira *et al.* (1993) who reported a linear increase in the percentage of bulbs with secondary plant growth in function of the increase in the vernalization period.

As moisture is one of the factors that induces secondary plant growth (Filgueira, 2000), it is pointed out that even with interrupting irrigation close to 100 days after planting, the rainfall remained relatively high throughout the experimental period (Table 1), that associated to the practice of vernalization, contributed effectively to the high occurrence of secondary plant growth.

Vernalization for a 40-day period was shown to be efficient in increasing the yield of the garlic crop in Guarapuava, PR, contributing to improvement in agronomic characteristics such as plant emergence, plant height and commercial production. The cultivation period equivalent to the month of March was preponderant to obtain bulbs with desirable marketable characteristics and higher marketable standard.

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