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ORIGINAL RESEARCH ARTICLE

Performance of cauliflower cultivars under different phytosanitary management in summer/autumn crops, under no-till in Santa Catarina

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ABSTRACT

The performance of five cauliflower cultivars in conventional and alternative phytosanitary management—without the use of synthetic pesticides—was evaluated. Two experiments were conducted at Epagri, Ituporanga Experimental Station in February 2018 and 2019. A randomized block design with four repetitions was adopted, with twenty plants of each cultivar as plots. The seedlings were transplanted on millet and mucuna straw at a spacing of 0.5 m × 0.8 m. We evaluated agronomic yield, inflorescence quality, pest damage and plant diseases, especially bacterial and fungal rots. The cauliflower hybrids Vera, Verona and Serena stood out in productivity and quality, being the most indicated for sowing in off-season crops, in the Alto Vale do Itajaí region. The most productive cultivars were less damaged by bacterial diseases and defoliating caterpillars and without interference of whitefly infestation on yield. The results also reveal that it is possible to control pests and diseases with phytosanitary products of lower toxicity, i.e., with lower residues of synthetic pesticides.

Keywords: Brassica Oleracea Var Botrytis; Yield; Production Systems; Pesticides

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1. Introduction

Cultivated predominantly on small farms, cauliflower (*Brassica olerácea var. botrytis*) represents an important economic activity for Santa Catarina. In 2016 the volume of commercialization of this vegetable in Ceasa, SC, was 6,842 tons, which moved about R$ 6.4 million. In the state, the largest supply of cauliflower occurs in the months of July to January, since the Santa Catarina crop is characterized by harvests in the fall/winter and winter/spring. The off-season of this vegetable occurs from February to June, a period when supply is reduced, which allows for the best average prices per kilogram. In 2016, there was an increase in the average prices charged in the off-season period of 102% for cauliflower, compared to the average prices charged in the harvest. The prices of these products are defined by the Santa Catarina market, since practically 100% of cauliflower is produced in the state.

One of the factors responsible for the reduced supply of cauliflower in the off-season is related to the lack of technical information in the recommendation of cultivars adapted to the soil and climate conditions of the growing regions. Given this, there was the development of cultivars that present adequate production conditions in warmer climates, which allows its cultivation throughout the year[1].

Silva *et al*.[2] studied the seasonal variation of supply and prices of cauliflower practiced in Minas Gerais, represented by the units of CEASAMINAS, as well as the components of this supply for each main supplying region of the state, in the period from 2005 to 2009. Seasonal variations in cauliflower supply clearly reflected the limitations of currently available cultivars and the need for new genotypes that can tolerate the large temperature oscillations in the mid-season months[2]. Summer weather with high precipitation causes higher losses by diseases at tillage and post-harvest in cauliflower. Peruch and Silva[3] reported the lack of research to study hybrids constantly launched in the market. These authors evaluated the performance of cabbage, cauliflower and broccoli hybrids for the coastal region of Santa Catarina, under organic cultivation, resulting in the indication of more promising hybrids for cultivation in two seasons, spring and fall.

However, for brassicas, cultivation in conventional production system predominates, with frequent use of synthetic pesticides. The main targets in phytosanitary management are the control of diseases caused by fungi, bacteria and insects[1,4], mainly including: Alternaria, Alternaria brassicicola, black rot, Xanthomonas campestris pv. campestris, soft rot, Pectobacterium carotovorum subsp. Carotovorum[3], brassica moth, Plutella xylostella, curuquerê-do-couve, Ascia monuste orseis, medfly caterpillar, Trichoplusia ni, whitefly, Bemisia tabaci, aphids, Brevicoryne brassicae and Myzuspersicae[4]. This practice would provide negative impacts to the environment and the health of farmers and consumers[5].

Recently in the country, there is a concern for the production of safe food for the consumer, and integrated and organic production systems have been promoted[6,7]. Epagri, Ituporanga Experimental Station, SC, has developed information for the production of vegetables in organic system[8], and alternative, without the use of synthetic pesticides[9,10]. In 2014, with support from FAPESC, and in 2015, with support from MAPA, a project for integrated onion production began. Therefore, it is essential to develop technologies that are technological benchmarks for these processes.

The objective of the work was to evaluate the performance of cauliflower cultivars in conventional and alternative phytosanitary management systems, without the use of synthetic pesticides, in the summer/autumn period, aiming to offer products in more opportune times for commercialization and to obtain better prices.

2. Material and methods

The experiments were conducted in Epagri, Ituporanga Experimental Station, located in Ituporanga, SC, latitude 27º38' S, longitude 49°60' W and altitude 475 meters above sea level. According to Koeppen's classification, the local climate is of Cfa type.

The treatments consisted of five cauliflower cultivars with respective recommended growing seasons: Alpina (Topseed, winter), Vera (Tecnoseed, mid-season), Barcelona (Seminis, mid-season), Serena (Tecnoseed, mid-season), Verona (Seminis, summer) in two phytosanitary management systems, conventional and alternative, without the use of synthetic pesticides. The treatments, cultivars, were conducted independently in each phytosanitary management system.

In the conventional system, preventive and curative phytosanitary treatments were performed, with products recommended for crops by the Ministry of Agriculture, Livestock and Supply Department[11]. In the alternative phytosanitary management, natural products recommended by specialized literature and allowed by Normative Instruction No. 46[7], which establishes the technical regulations for organic production systems, as well as the lists of substances and practices allowed, were used.

Conventional phytosanitary management in pest control was performed with two sprays with 0.15 ml/L of Eleitto® (acetamiprid, 167 g/L + etofenproxi, 300 g/L), three with 0.3 ml/L of Decis®

25 EC (deltamethrin, 25 g/L) and three with 2 ml/L of Provado® (imidacloprid, 200 g/L). In conventional disease control, four sprays were made with 0.2 ml/L of Score® (difenoconazole, 250 g/L) and four with 1.25 ml/L of Revus® (mandipropamide, 250 g/L). In the alternative phytosanitary management for pest control there were four sprays with 2 ml/L of Azamax® (Azadirachtin, 12 g/L), four sprays with 3 ml/L of Assist® (Mineral oil, 756 g/L) + 5 g/L of Bugran® (diatomaceous earth) and for disease control, two applications with 2 ml/L of Sulfur (S, 450 g/L,) and six with 3 g/L of copper sulfate. In both managements preventive applications were made weekly. The active ingredients and chemical groups were alternated throughout the crop cycle. The control targets were mainly the occurrences of stem and inflorescence rots, whitefly, and defoliating caterpillars. The products were applied with a manual knapsack sprayer, using approximately 300 ml of syrup per plot.

A randomized block design with four repetitions was adopted in each management. The plots were composed of 20 plants of each cultivar, and the useful area consisted of six central plants. The seedlings were produced in expanded polystyrene trays, filled with commercial substrate (Maxfértil®). In February 2018 and 2019, at the stage of four to five definitive leaves, the seedlings were transplanted at a spacing of 0.5 m x 0.8 m.

The experiments were established in no-till system over millet and mucuna straw, sown in October 2017 and 2018, in the amounts of 80 kg seed ha^{-1} for each species. One week before planting the cauliflower seedlings, the cover plants were bedded with a knife roller. Soil analysis was performed in the Soil Laboratory of Epagri, Experimental Station of Ituporanga, SC. The results were: Clay = 29%; pH(H_2O) = 5.9; pH (SMP index) = 6.1; M.O. = 3.1%; P (Mehlich1)= 182.4 mg dm^{-3}; K = 268 mg dm^{-3}; H+Al = 3.9 $cmol_C$ dm^{-3}; CTC (pH 7.0) = 14.8 $cmol_C$ dm^{-3}; Al = 0.0 $cmol_C$ dm^{-3}; Ca = 7.8 $cmol_C$ dm^{-3}; Mg = 2.4 $cmol_C$ dm^{-3}; S = 15 mg dm^{-3}; B = 0.2 mg dm^{-3}; Cu = 0.7 mg dm^{-3}; Zn = 12.3 mg dm^{-3}; Fe = 44 mg dm^{-3}; Mn = 25.1 mg dm^{-3}. Fertilization was based on the recommendations of the Commission for Soil Chemistry and Fertility[12] for no-till farming. The base fertilization consisted of 20, 40 and 0.0 kg ha^{-1} of N, P_2O_5 and K_2O, respectively, distributed to the soil in the planting furrow one week before planting, together with 10 kg ha^{-1} of B and 1 t ha^{-1} of poultry litter manure (with 2% N). In top dressing, in the planting row, 160 and 50 kg ha^{-1} of N and K_2O were added, respectively, in three plots at 15, 32 and 46 days after transplanting (DAT). Foliar fertilization was also performed with boric acid (100 g 100 L^{-1}) + ammonium molybdate (50 g 100 L^{-1}), at 32, 39, 46 and 53 DAT. The products were applied with a manual knapsack sprayer, using approximately 300 mL of syrup per plot.

The control of weeds was performed with three manual weeding between plants in the rows of cultivation at 6, 27 and 53 DAT of the seedlings, in between the rows, the straw of the cover crops was kept. During the execution of the experiments, temperatures and relative humidity of the air were monitored by means of an automatic meteorological station, present in the Experimental Station of Ituporanga (**Table 1**).

The harvests were carried out weekly, when the inflorescences presented commercial size suitable for packing in Styrofoam trays with dimensions of 15 cm × 15 cm × 2 cm. The following productive characteristics were evaluated: Yield (number of heads harvested per ha^{-1}); productivity (t ha^{-1}); average weight of heads (kg $plant^{-1}$). The visual quality index of inflorescences[13] was determined with a scale of scores ranging from 1 to 5, being 1 = not

Table 1. Monthly averages for minimum temperature (min.T), average temperature (A.T), maximum temperature (max.T) and relative humidity (RH%)

	2018				**2019**			
Month	**T.min. (°C)**	**A.T. (°C)**	**T.max. (°C)**	**RH%**	**T.min. (°C)**	**A.T. (°C)**	**T.max. (°C)**	**RH%**
Jan.	18.3	22.1	28.4	81.5	20.2	24.2	31.2	80.1
Feb.	17.1	21.3	28.7	78.0	18.0	21.6	28.0	82.2
Mar.	18.6	22.0	28.0	80.7	9L1	21.2	26.7	81.9
Apr.	15.8	661	26.7	81.5	16.2	19.9	25.5	84.5
May	16.5	19.3	24.9	998	14.9	17.9	22.4	87.1
Average	17.3	21.1	27.3	81.7	17.4	21.0	26.8	83.1

commercial, extremely defective, 2 = commercially defective, 3 = moderately defective, 4 = slightly defective, 5 = no apparent defects. The variables referring to phenology were the cycle (number of days from sowing to last harvest); average precocity (number of days between sowing to first harvest); and the harvest period, obtained by the difference, in days, between the last and first harvest performed. The variables with phytosanitary data were the incidence of diseased plants (stem and head rot); average number of leaves per plant with more than 10% of damage caused by defoliating caterpillars (Defol) and average number of leaves per plant (random sample of 3 leaves per plant) with infestation above 15 nymphs and adults of whitefly (Infest.). The data collected were submitted to analysis of variance and the means were compared using the Scott-Knott test at 5% probability, using the free software "*R*"[14].

3. Results and discussion

The results of the variance analysis indicated differences between the cultivars for all variables, in both management systems evaluated, conventional (**Table 2**) and alternative (**Table 3**).

Table 2. Averages of two 2018/19 crops for number of heads per hectare (Rend.), average head weight (AHW), productivity (PRO), visual aspect index of inflorescences (VAI), cycle, average precocity (AP), harvest period (HP), percentage of diseased plants (PD), defoliation by caterpillars (Defol), whitefly infestation (Infest.) for cauliflower cultivars under conventional phytosanitary management system

Treatments	Yield (heads ha^{-1})	BMP(kg)	PRO t ha^{-1}	VAI	Cycle	AP	HP	PD(%)	Defol	Infest.
					(Days after sowing)		Dias			
Alpina	18.333b	0.280c	5.1c	4.5a	99b	74b	15c	26.7b	5.0a	1.3b
Barcelona	10.261c	0.370b	3.8c	4.5a	106b	70b	36a	59.0a	3.8b	1.0c
Serena	21.70la	0.380a	8.2a	4.2c	107b	91a	16c	13.2b	2.0c	1.6a
Vera	21.667a	0.310c	6.7b	4.6a	124a	95a	29a	13.3b	3.0b	9'1
Verona	23.438a	0.300c	7.0b	4.4b	119a	93a	26b	6.2c	2.5c	1.7a
CV%	12.34	6.05	12.50	1.53	4.12	6.17	16.32	39.84	16.16	8.95

Averages not followed by the same letter in the column differ by the Scott-Knott test at 5% probability. NS: Not significant by the F test at 5%.

Table 3. Averages of two 2018/19 crops for number of heads per hectare (Rend.), average head weight (AHW), productivity (PRO), visual aspect index of inflorescences (VAI), cycle, average earliness (AP), harvest period (HP), percentage of diseased plants (PD), defoliation by caterpillars (Defol), whitefly infestation (Infest.) for cauliflower cultivars under alternative phytosanitary management system

Yield.	Treatments (heads ha^{-1})	AHW (kg)	PRO t ha^{-1}	VAI	Cycle	AP	HP	PD (%)	Defol.	Infest
					(Days after sowing)		Dias			
Alpina	16.346b	0,340b	5,6b	4.4a	113b	102a	21b	34.6b	3.6a	1.4b
Barcelona	9.115c	0,390a	3,6c	4.5a	104c	71c	33a	63.5a	3.la	1.0c
Serena	19.760a	0.330b	6,5b	4.5a	107b	88b	19b	21.0b	2.1b	1.3b
Vera	21.188a	0,320b	6,8a	4.4a	124a	89b	35a	15.2c	2.2b	1.7a
Verona	23.825a	0,290c	6,9a	4.2b	118a	93a	25b	4.7c	2.6b	1.7a
CV%	14.07	4.88	10.43	1.24	3.20	5.70	11.98	36.50	10.36	9.29

Means not followed by the same letter in the column differ between them by the Scott-Knott test at 5% probability.
NS: Not significant by the F test at 5%.

The cultivars Verona, Serena and Vera showed higher yields in conventional management, reaching production between 21,667 to 23,438 heads ha^{-1}, reflecting an estimated productivity of 6.7 to 8.2 t ha^{-1} (**Table 2**). These cultivars also stood out in the alternative management with production and productivity ranging from 19,760 to 23,825 heads ha^{-1} and 6.5 to 6.9 t ha^{-1}, respectively (**Table 3**). Regardless of the management adopted for cauliflower, the least productive cultivars were Barcelona and Alpina, with respective 10,261 and 18,333 heads ha^{-1} and 3.8 and 5.1 t ha^{-1}, in the conventional (**Table 2**) and 9,115 and 16,346 heads ha^{-1} and 3.6 and 5.6 t ha^{-1}, in the alternative (**Table 3**).

Although there was a significant difference between the cultivars regarding the visual aspect index of the inflorescences, in both management systems, the average scores were above 4.0, indicating high commercial quality for all materials evaluated (**Tables 2** and **3**). In this aspect, the cultivars Vera, Alpina and Barcelona stood out in both management systems. Seabra *et al*.[15] stressed the importance of the visual aspect in broccoli plants for reflecting the quality of the material and its acceptance by consumers. Although this inflorescence quality scale was not applied to cauliflower by those authors, in the present study the scale was adopted, because according to Melo *et al*.[13] this scale was originally developed to evaluate defects described in the cauliflower classification by CEAGESP. It is worth noting that the average yields apparently low, when compared to values obtained by other authors are due to the methodology adopted in this work, since the inflorescences were harvested in standard size for packaging in Styrofoam tray with dimensions of 15 cm x 15 cm x 2 cm. Thus, the variations observed between the average weights of cauliflower heads, 0.280 to 0.390 kg^{-1} (**Tables 2** and **3**) reflect more the density of their mass than their size.

Regarding the cycle, inflorescence emission and harvest period, it is possible to observe great variation among the most productive cultivars within each management studied. The cultivar Serena presented the earliest cycle, both in conventional and alternative management, of 107 days (**Tables 2** and **3**), being relatively shorter than Verona (119 and 118 days) and Vera (124 days). The cultivar Serena started the emission of inflorescence a little later, at 91 and 88 days after sowing, when compared to the earliest cultivar for inflorescence emission (Barcelona with 70 and 71 days), but had the harvest concentrated in 16 and 19 days (**Tables 2** and **3**). The concentration of the harvest period, observed in the Serena cultivar, was quite expressive, with an anticipation of 13 to 16 days, compared to the other cultivars of better performance. Morais *et al*.[1] and Monteiro *et al*.[16] observed average earliness values of 112 and 119 days, respectively, for Verona, slightly lower than those observed in the present study, but still being classified as a medium cycle cultivar (110 to 130 days), by the criterion proposed by Maluf and Corte[17], cited by Morais *et al*.[1] However, Peruch and Silva[3] recorded a cycle of 96 days for Verona in spring organic cultivation, which according to the aforementioned criterion, would be classified as an early cycle cultivar (80 to 110 days). Morais *et al*.[1] considered the precocity of cauliflower cultivars to be a characteristic highly influenced by the environment, and it can oscillate considerably between regions and seasons.

Regarding the damage caused by diseases, it was verified that the percentage of diseased plants for the most productive cultivars in conventional and alternative management were, respectively, Verona (6.2 and 4.7%), Vera (13.3 and 15.2%) and Serena (13.2 and 21.0%) (**Table 2 and 3**). In the less productive cultivars, Alpina and Barcelona, the percentage of losses by diseases ranged from 26.7 to 59.0%, in the conventional management, and from 34.6 to 63.5%, in the alternative. Thus, the most productive cultivars were less damaged by diseases. Morais *et al*.[1] found significant differences for both incidence and severity of black rot, X. campestris pv. campestris, on six summer cauliflower cultivars. The cultivar Verona, along with early Piracicaba, showed the lowest mean incidence (25%) and severity of the disease (0.25%). Besides, it stood out in productivity (34.17 t ha^{-1}), being considered a promising material for cultivation in the southeastern region of Goiás. Peruch and Silva[3] evaluated the intensity of foliar diseases in hybrids Barcelona AG-324, Julia F1, AF-919, Verona, AF-1182 and Sharon F1. Although the materials did not show significant differences regarding the incidence of black rot, the authors considered Verona to be promising for cultivation on the coast of Santa Catarina, because it presented an intermediate index of alternariosis intensity (45%) and reached good productivity (20.8 t ha^{-1}).

Hernández and Mendes[18] reported that one of the factors responsible for the reduction in broccoli and cauliflower volume, observed in the off-season, is related to the damage caused by diseases incident on the plants, especially bacterial and fungal rots, favored by high temperatures and high humidity, typical of summer, with the presence of free water and injuries in plant tissues. In the present study, maximum temperatures above 25 °C were observed in the months of January to April and relative humidity was always above 70% in the two years of evaluation (**Table 1**). The differences observed between the cultivars evaluated in the present study, regarding the percentage of diseased plants, may be due to the presence of a thicker waxy layer (epicuticle) in the less affected cultivars, since there are no commercial materials resistant or tolerant to alternaria blotch and soft rot[18,19]. Silva *et al.*[20] observed that areas with more than 10 years of cultivation with Chinese cabbage, Brassicapekinnensis, and plants older than 50 days showed higher incidence of soft rot, which indicates that the history of the area, as well as the stage of plant development are also factors to be considered in the management of the disease in brassicas.

During the experimental evaluations, the presence of defoliating caterpillars, Plutella xylostella and Trichoplusia ni, and of adults and nymphs of the whitefly, Bemisia tabaci, was observed. The most productive cultivars Serena and Verona, were also less damaged by defoliating caterpillars in both management systems (**Tables 2** and **3**). In contrast, in a laboratory experiment, the cultivar Verona showed high survival of P. xylostella caterpillars and Barcelona was considered of higher susceptibility[21]. The genotypes Barcelona and Verona were not considered as resistant in non-preference test for P. xylostella caterpillar in the laboratory[22]. It should be noted that cauliflower has been indicated as susceptible to the P. xylostella caterpillar[23]. However, the cultivars Barcelona and Verona were less preferred for oviposition with chance of choice[24]. The infestation by whitefly was even higher in the most productive cultivars. This suggests that the damage by defoliating caterpillars has an influence on productivity and infestation by whitefly does not interfere with this variable. During the experiments, neither aphids nor leafminers were observed. However, in general, the damage caused by these insects did not significantly affect the commercial quality of the inflorescences of the most productive cultivars. This suggests that the management methods adopted were efficient in controlling these insects.

4. Conclusions

The experimental results indicate that, among the cultivars evaluated, Vera, Verona, and Serena stood out in productivity and quality, being the most suitable for sowing in off-season, summer/autumn, crops in the Alto Vale do Itajaí region, SC.

The most productive cultivars were less damaged by bacterial diseases and defoliating caterpillars and no whitefly interference on yield.

The results also reveal that it is possible to control pests and diseases with phytosanitary products of lower toxicity. The practice of no-till farming in straw represents an important component of this production system.

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Conflict of interest

The authors declared no conflict of interest.

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