Agrovoc descriptors: *Cichorium intybus*, chicory, crop yield, disease resistance, erysiphe cichoracearum, temperature resistance, bolting

Agris category code: F01, F40

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COBISS Code 1.01

Plant characteristics for distinction of red chicory (*Cichorium intybus* L. var. *silvestre* Bisch.) cultivars grown in central Slovenia

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Received: June 24, 2004; accepted: October 8, 2004
Delo je prispelo 24. junija 2004; sprejeto 8. oktobra 2004

ABSTRACT

Eight red chicory (*Cichorium intybus* L. var. *silvestre* Bisch.) cultivars were screened for plant characteristics, yield, resistance to *Erysiphe cichoracearum* and their persistence of bolting over a two-year period (2002 and 2003 growing seasons) in central Slovenia. On two years with meteorologically different conditions the highest total and marketable weight of heads (i.e. total weight – weight of removed damaged leaves) were obtained from cv. 'Averto', followed by cv. 'Mesola' and 'Rubino'. The most compact heads in both years, were produced by cv. 'Palla rossa-super'. Less productive cultivars of red chicory were on average the most infected with the powdery mildew caused by *E. cichoracearum*. In 2002 the fungus occurred in a substantially larger extent than in 2003, which was less favourable for spread of the pathogen. The higher temperatures, prevailing in summer 2003, presumably promoted a greater percentage of bolting in plants. Among eight cultivars studied through two years, cv. 'Castel Franco', 'Averto' and 'Mesola' drew no incidence of bolters.

Key words: *Cichorium intybus*, cultivar, yield, yield components, weather conditions, *Erysiphe cichoracearum*, bolting

IZVLEČEK

ZNAČILNOSTI KULTIVARJEV RDEČEGA RADIČA (*Chicorium intybus* L. var. *silvestre* Bisch.), GOJENIH V OSREDNJI SLOVENIJI

V dveletnem poskusu (v pridelovalnih obdobjih v letih 2002 in 2003) z osmimi kultivarji rdečega radiča smo ugotavljali njihovo primernost za pridelovanje v osrednji Sloveniji glede na njihove značilnosti, višino pridelka, glede na odpornost na *Erysiphe cichoracearum* in glede na odpornost na odganjanje cvetnih stebel. V dveh meteorološko različnih letih je najvišji skupni in tržni pridelek glavic (tj. skupna teža glavic – teža odstranjenih poškodovanih listov) dosegel cv. 'Averto', ki sta mu sledila cv. 'Mesola' in 'Rubino'. V obeh letih pa je

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najčvrstejše glavice imel cv. 'Palla rossa-super'. Kultivarji z najskromnejšim pridelkom so bili v povprečju najbolj dovzetni za pepelasto plesen, ki jo povzroča gliva *E. cichoracearum*. V letu 2002 je bil napad glive znatno obsežnejši kot v letu 2003, ki je bilo manj ugodno za njeno razširjanje. Z visokimi temperaturami, ki so prevladovale poleti 2003, se je povečal odstotek rastlin, ki so pognale cvetna stebla. Med osmimi kultivarji, ki smo jih opazovali v dveh letih, cvetna stebla niso pognala pri cv. 'Castel Franco', 'Averto' in 'Mesola'.

Ključne besede: *Chicorium intybus*, kultivar, pridelek, značilnosti pridelka, vremenske razmere, *Erysiphe cichoracearum*, cvetenje

INTRODUCTION

Throughout Europe, many varietes of *Cichoruim intybus* L. (*Asteraceae*) chicory are quite important agricultural crops, highly appreciated for their bitter taste (Poli et al., 2002). This bitterness is due to the presence of large quantities of sequiterpene lactones, such as lactucin, 8-desoxylactuctin, lactucopicrin and 11ß-dihydro-derivates (Peters and Van Amerongen, 1998). Red chicory, also known as radicchio (*Cichoruim intybus* L. var. *silvestre* Bisch.), may be of greater commercial importance (Rangarajan and Ingall, 2001). The expansion of its cultivation is determined by the marketing success of freshly cut salad mix of which it is a basic component (Bertolini et al., 2003).

Radicchio is a red, broad leaf, heading form of chicory. Its leaf colours range from pink to maroon with white midribs. Some cultivars form loose heads, while others have folded leaves and resemble small cabbages. The red coloration increases during the colder months (Perkins-Veazie, 1991). All the red types of raddichio now being cultivated derive from red-leaved individuals belonging to *Cichoruim intybus* L. var. *foliosum* (Hegi) Bischoff, while the types with spotted or variegated leaves originated from spontaneous or controlled crosses between these individuals and members of the species *Cichoruim intybus* L. var. *latifolium* Hegi, commonly known as broad-leaved endive (Barcaccia et al., 2003).

Production problems including the early stalk development (bolting), greatly reduces the marketable yield (Gianquinto, 1997). Bolting of radicchio depend on vernalisation and photoperiod. Many studies reported about the effect of environmental conditions on bolting and flowering of chicory, but this information comes from in vitro cultivation of root tissue (Badila et al., 1985; Demeulemeester et al., 1995). However, little information is available on the response of radicchio to temperature and photoperiod in natural field conditions. According to Gianquinto (1997) and Pimpini and Gianquinto (1988), low temperature between sowing and germination (below 8^{o}C), long days (above 13 h) and the age of seedlings at transplanting (above 35 days) are known to be a primary environmental factor associated with flower stalk initiation in radicchio. Summer heat can also cause bolting. The crops could not tolerate high ambient temperatures and promote stalk elongation when the temperature exceeded 32^{o}C (Krausenbaum, 1996).

Another important factor to be considered for growing radicchio was resistance to fungal diseases. Considering disease control of chicory in Europe, powdery mildew (*Erysiphe cichoracearum* D.C.) is one of the most observable pathogenic fungi (Žerjav, 2000). A less significant role has been assigned to this fungus (Klemm, 1985)

which has been occurring for a longer period of time in Europe (Braunschweig, Biologische Bundesanstalt für Land- und Forstwirtschaft, 1972) and was determined in North America in the mid-nineties of the 20th century (Koike and Saenz, 1996). This may be true in the case of the pathogen indirect damage, which has a negative impact on photosynthesis and consequently reduced yield of chicory, because symptoms of the disease become especially evident towards the end of the growing season. On the other hand, the exterior leaves ought to be removed from the infected plants due to a powdery mildew coating on the leaves, thus causing a direct loss in chicory yield (Trdan et al., 2004).

Although the radicchio has become an increasingly popular consumed salad vegetable in Europe it is a minor crop for Slovenia and is grown predominantly in the Goriška region (Osvald, 1999). The overall goal was to examine the yield potential of this crop in central Slovenia environment conditions and to test the available commercial cultivars on plant characteristics, yield and bolting. Another objective of present work was to screen radicchio cultivars for field resistance on powdery mildew and evaluate how meteorological conditions can interact with this fungi.

MATERIAL AND METHODS

A field experiment was undertaken at the Experimental Station of the Biotechnical Faculty in Ljubljana, during 2002-03 (46^{o}04', 14^{o}31' E). The soil of the experimental plot was heavy clay loam with pH 6.5. The experimental design was a randomized complete block with plots arranged factorially and replicate four times. Based on available literature and on preliminary studies, eight commercial cultivars of radicchio, 'Averto', 'Castel Franco', 'Dolfina', 'Foresto', 'Maura', 'Mesola', 'Palla Rosa-super', and 'Rubino', were selected. In 2002 and 2003, the experimental crop was planted after lettuce and cabbage, respectively.

Seedlings were grown in unheated plastic greenhouse under natural light conditions. Styrofoam trays with 60 ml volume of each cell, 72 cells per tray, were hand-filled with peat-based growing medium Klasmann Tray substrate (pH 6-6.5; N 180 mg L^{-1}; P_2O_5 210 mg L^{-1}; K_2O 250 mg L^{-1}; MgO 85 mg L^{-1} + microelements). One seed per cell was sown on June 6, 2002 and June 8, 2003. Seedlings were irrigated manually, with no fertilization and no pest and disease control. In all two years of research, ploughing was performed at the beginning of spring at the 30 cm depth. The amount of 350 kg ha^{-1} of 15N-15P_2O_5-15K_2O was spread on the ground and than incorporated into the soil with a cultivar.

Seedling with fourth to fifth true leaves were planted on black polyethylene film on July 8 and July 14, in 2002 and 2003 year, respectively. Distance between rows were 35 cm, while in-row distance were 30 cm. Each experimental plot contained 4 parallel rows of 10 plants in a 2.8 m length of bed, with buffer plants at each end. The plants were irrigated immediately after transplanting to avoid drought stress. All plots were uniformly irrigated using T-Tape systems that delivered 4 L h^{-1} of water per 100 m of tubing with emitting orifices spaced at 35 cm intervals. Additional nutrition was supplied together with the irrigation water, according to normal commercial practice (once per week with 6.5 kg ha^{-1} of KNO_3 and 15.2 kg ha^{-1} 20-20-20). In both years no phytotechnic practises were used.

Plants were harvested manually at commercial maturity of each cultivar, i.e. between October 20 and October 31, 2002, and November 1 and November 10, 2003. Plants were cut from the roots as the time when approximately 80% of the radicchio heads had reached relatively compactness. Head compactness was evaluated by touch on an index from 1 to 10, with 1 beginning very fluffy and 10 a very hard head (Jenni, 2002). Weight of radicchio heads of each individual plant was recorded on a fresh weight basis. Disease (*E. cichoracearum*) severity was visually recorded according to the infected leaf area on both upper and lower surfaces, using a scale of 0-6, where 0 = no infection, 1 = less than 1%, 2 = 2-5%, 3 = 2-5%, 4 = 6-20%, 5 = 21-40%, 6 = more than 40%. The evaluation of the percentage of leaf area

affected was adapted by the EPPO numerical scale for assessing the symptoms of powdery mildews on cucurbits and other vegetables (OEPP/EPPO, 1997) was used.

A sample of eight random plants from each plot was taken to obtain total head weight, marketable head weight, head height, head diameter and compactness of the head. In addition, index of heads damaged by powdery mildews and percentage of plants which showed the flower-stalk formation was determined.

All measured and derived data, were analysed separately for each year by analyses of variance (ANOVA) using Statgraphics Plus for Windows 4.0 computer program. Character means were separated by least significant differences (LSD, $P<0.05$) when sources of variation from ANOVAs were significant ($P<0.05$).

RESULTS AND DISCUSSION

Weather patterns

Weather data was measured in a Meteorological station located in the Biotechnical field, about 300 m distance from the experimental plots. The main meteorological conditions in the course of the investigation period, are given in Table 1. It shows the monthly average temperature, maximum average temperature, rainfall and wet days from July to October 2002 and from July to October 2003. The meteorological conditions experienced by the crops during the two growing seasons were substantially different. The mean air temperatures were almost the same (16.0 and 16.8^{o}C) but the first year's temperatures were lower in the beginning and generally higher in the rest of the growing season. Although the total rainfall received in 2002 was relatively lower than in 2003, there was a significant difference in its distribution over the season. There were only two rainy days in July 2003, immediately after transplanting. While the crop received an appreciable amount of rainfall during August in 2002, only limited rainfall occurred during the corresponding period in 2003 (207 and 65 mm, respectively). In contrast, in 2003 crops received substantial rainfall during September and October while the crops received very little rainfall during the same period in 2002. It should be pointed out that the mean maximum air temperature in 2003 was extremely high, exceeding 32.4^{o}C in August.

Table 1: Weather characteristics (per month) during experiment for the years 2002 and 2003

Month	Mean max. air temperature (^{o}C)		Mean air temperature (^{o}C)		Total rainfall (mm)		Wet days (No.)	
	2002	2003	2002	2003	2002	2003	2002	2003
July	28.7	30.0	20.2	21.2	80.0	113.0	11	11
August	27.8	32.4	19.3	22.6	207.0	65.0	9	7
September	21.2	23.0	14.0	14.0	28.0	118.0	3	8
October	16.3	13.7	10.5	8.0	52.0	184.0	6	14
Sum or Mean	23.5	24.8	16.0	16.8	367.0	480.0	29	40

Yield and yields components

The results show a great variation in yield and its components in relation to the investigated years, which is a consequence of different weather conditions. In autumn 2002 the crops had very dry conditions, whereas in 2003 the opposite appeared, with relatively wet conditions.

Table 2: The total and marketable weight, the height, diameter and compactness of radicchio heads in 2002 growing season

Cultivar	**Total weight of heads** (g)	**Marketable weight of heads** (g)	**Head height** (cm)	**Head diameter** (cm)	**Compact.** (1-10)
C. Franco	238.1 a	131.0 a	26.5 d	25.1 c	6.0 a
Dolfina	272.3 b	169.6 b	17.8 b	17.6 b	8.1 c
Maura	303.0 bc	205.8 bc	13.7 a	13.7 a	9.1 d
P. rossa-s.	304.8 bc	172.6 b	12.2 a	16.7 ab	9.6 e
Foresto	324.6 c	179.4 b	25.4 d	28.8 d	6.6 a
Rubino	332.2 c	218.1 c	16.7 b	18.8 b	9.1 d
Mesola	445.6 d	248.7 d	26.5 d	27.9 d	8.6 c
Averto	465.0 e	290.0 e	19.8 c	25.5 c	7.6 b

Means in column followed by the same letter are not significantly different according to Duncan's Multiple Range test at $P<0.05$.

Table 3: The total and marketable weight, the height, diameter and compactness of radicchio heads in 2003 growing season

Cultivar	**Total weight of heads** (g)	**Marketable weight of heads** (g)	**Head height** (cm)	**Head diameter** (cm)	**Compact.** (1-10)
C. Franco	357.0 a	282.1 a	29.5 c	33.8 c	6.0 a
Dolfina	406.1 b	305.5 b	22.0 b	28.3 b	8.1 c
Maura	427.7 bc	350.9 c	17.9 a	24.3 a	9.1 d
P. rossa-s.	398.0 b	347.4 c	17.4 a	28.4 b	9.5 e
Foresto	411.0 bc	361.3 c	29.5 c	37.4 e	6.6 a
Rubino	446.7 c	373.4 c	21.1 b	29.8 b	9.1 d
Mesola	516.9 d	444.2 d	30.0 c	38.2 e	8.6 c
Averto	542.2 e	476.4 d	24.0 b	35.6 d	7.6 b

Means in column followed by the same letter are not significantly different according to Duncan's Multiple Range test at $P<0.05$.

In spite of irrigation, the total and marketable weight of heads in 2002 was exceptionally low because of a dry spell, resulting in poor stand establishment and growth. In the total weight and in marketable weight of heads in both years

statistically significant differences between the cultivars were found. The results showed that the cv. 'Averto' and 'Mesola' had a significantly greater production in both years (the highest total weight of heads, independent of the diseases infection) compared to the other six cultivars, whereas the lowest yield was in cv. 'Castel Franco'. The highest yield was in the cv. 'Averto', with the mean total weight of the heads 465.0 g in 2002 and 542.2 g in 2003. The cv. 'Averto' had the highest mean net weight (290.0 g in the first and 476.4 g in the second year) even after the infected leaves had been removed. These values were the lowest in the cv. 'Castel Franco' (238.1 g/131.0 g in 2002 and 357.0 g/282.1 g in 2003).

There were significant differences among cultivars in head sizes. The higher mean sizes were highly dependant on greater head weight. In both years cv. 'Castel Franco', 'Foresto' and 'Mesola' had the highest heads, while cv. 'Palla rossa-super' had the lowest head height. The highest head diameter was observed in cv. 'Foresto' and 'Mesola'.

Statistically significant differences were also found in the mean compactness of the radicchio heads. Al-Harbi (2001) reported that compact heads by lettuce were indicated by the lower head diameter and greater head weight. A significantly positive relationship between the compactness of the radicchio heads and total weight of the heads was established ($p = 0.0078$) in 2002, but not in 2003 ($p = 0.1350$). The reasons for the reduction of this relationship in 2003 is not clear.

Disease rating

Under natural infection, only *Erysiphe cichoracearum* D.C. was observed in the field. Two reasons could explain the absence of the other diseases: the environmental conditions were not suitable for the occurrences of some diseases; or radicchio cultivars had good disease resistance.

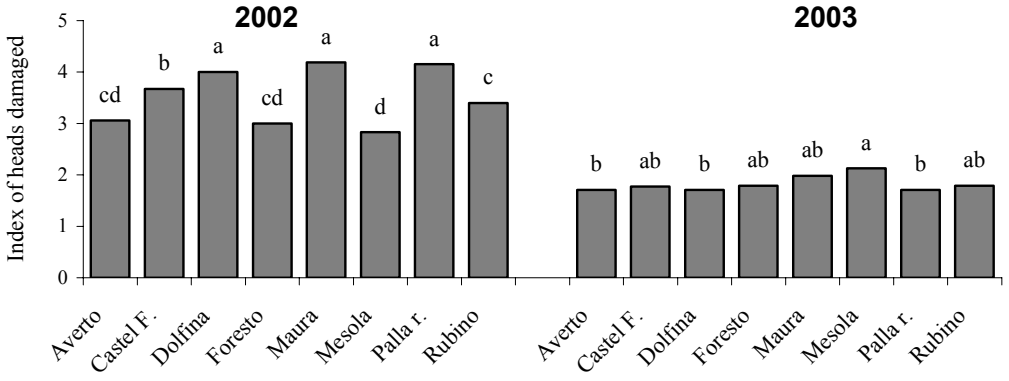

Figure 1: Mean index of heads damaged by *Erysiphe cichoracearum* D.C. Mean values followed by the same letter are not significantly different according to Duncan's Multiple Range test at $P<0.05$.

While climatic conditions during the growing season varied among the years, the mean index of head damaged by *E. cichoracearum* was different in each year, the index in 2002 was significantly higher compared to 2003. Lower temperatures and

vigorous rainfall in August 2002 may have contributed to this. Further the mean index head damage ranged from 2.83 for cv. 'Mesola' to 4.19 for cv. 'Maura' in 2002 and from 1.71 for cv. 'Averto', 'Dolfina' and 'Palla Rossa-super' to 2.13 for cv. 'Mesola' in 2003.

The highest mean degree of infection of radicchio with *E. cichoracearum* in 2002 was determined in cv. 'Palla Rossa-super' (4.15), 'Maura' (4.19) and 'Dolfina' (4.00), which are less productive, but have compact heads. Cv. 'Mesola' had significantly fewer plants with powdery mildew and was the least infected (2.83) in 2002, but it is among the most productive varieties with medium compact heads. In 2003 the same cultivar was, surprisingly, the most infected (2.13). This indicates a specific response of this cultivar to infection with change in climatic conditions. Similar discrepancies in the mean degree of infection of chicory with the fungus in question in both years were also proved in some other varieties, but with these the deviations are slightly smaller. No statistically significant relationships were determined between the infection of chicory with this fungus and the compactness of the heads.

The results show that all of the cultivars tested had a definite reaction to the *E. cichoracearum*, i.e. neither was absolutely resistant. The response was dependent on the environmental conditions. At the harvest time in 2002 and 2003, only a few individuals showed no signs of powdery mildew. The results also show the difference in cultivars response disorder during the warmer and dryer periods.

Bolting

Every ten days, from the beginning of September to the end of the growing season, plants were monitored in both of the growing seasons. The bolting intensity of plants, as determined by the visible flower stalk, was expressed as a percentage according Suhonen (1991). Depending on cultivar, date and growing season the percentage of bolting varied from 0 to 20%.

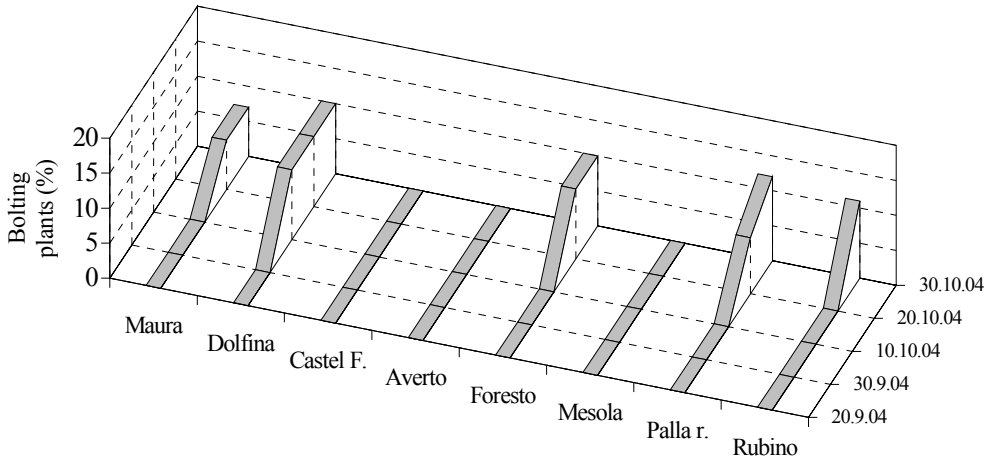

Figure 2: Percentages of bolted plants at ten day intervals, beginning at 25. September in 2002

In 2002, there was a low occurrence of bolting. A small number of plants bolted during the growing season, but the frequency was not significant among the cultivars evaluated. Only few percentage bolters occurred at cv. 'Maura' (7%), 'Dolfina' (10%), 'Foresto' (10%), 'Rubino' (11%) and 'Palla rossa-super' (between 8 to 11%). The flower stalk developing began on 30th September (cv. 'Dolfina'), while the other four bolting cultivars induced to be bolt in October.

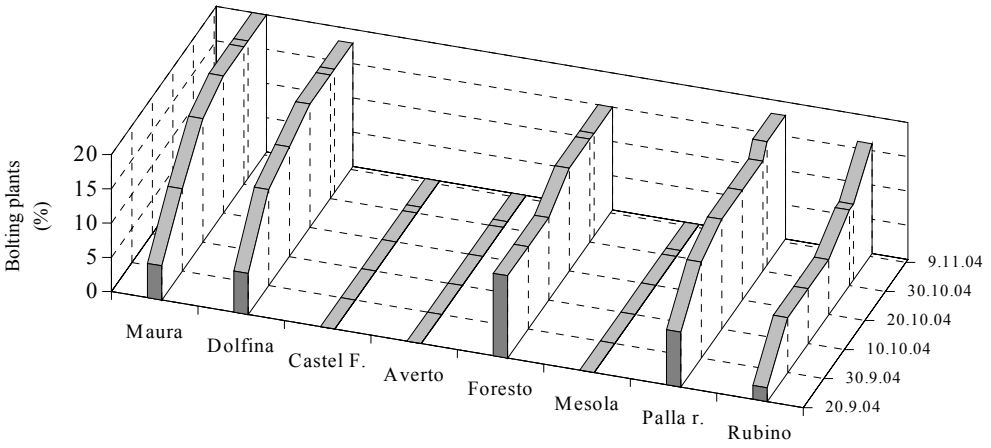

Figure 3: Percentages of bolted plants at ten day intervals, beginning at 20. September in 2003

Competition between vegetative growth and flower stalk initiation has been proposed as a controlling factor in bolting in raddicchio and this competition would be much stronger at high temperatures. The fact that high maximum temperatures increased bolting was practically confirmed in 2003 when high maximum temperature from July to September were view associated with bolting. In all five bolter cultivars, bolting was significantly higher in 2003 comparing 2002. However, the difference was still present from October 10th to the end of the growing season. In 2003, the highest percent of bolting plants reached cv. 'Maura' (20%). Among eight cultivars studied through two years, cv. 'Castel Franco', 'Averto' and 'Mesola' showed no incidence of bolters.

Temperature not only affected bolting, but also its onset. The importance of temperature was clearly seen by comparing the beginning of the crop bolting in 2002 and 2003, to a higher maximum temperature such as 2003. In 2003, five cultivars with intermediate to high bolting tendency (cv. 'Maura', 'Dolfina', 'Foresto', 'Rubino' and 'Palla rossa-super') began producing flower stalks ten (cv. 'Dolfina') to thirty (cv. 'Rubino') days early. The time at which the flower stalk is initiated in relation to the temperature and the date is important for the marketability of the radicchio crop.

CONCLUSIONS

On the basis of two-year investigations of growing the eight cultivars the following could be concluded:

- the radicchio yields were under strongly association with the weather conditions of the area, which was confirmed by pretty high yield fluctuations between the years of investigation. Cv. 'Averto'and 'Mesola' were significantly more productive in

both years (the highest total and marketable weight of heads, independently of the diseases infection).

- occurrence of the *E. cichoracearum* is stronger in humid years. However, neither cultivar was absolutely resistant to powdery mildew but cultivars which reach higher yield are more susceptible to infection with this fungus.
- although, newer radicchio cultivars have good resistance to bolting, high temperatures in summer can promote bolting. Five out of the eight cultivars ('Dolfina', 'Foresto', 'Maura', 'Palla Rosa-super', and 'Rubino') tends to flower stalk formation from last ten days of September to last ten days of October. Cv. 'Averto', 'Castel Franco'and 'Mesola' seem to be more superior in this characteristic because these three cultivars demonstrate high bolting resistance.

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