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Cauliflower hybrids for spring production in southern mediterranean area

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Abstract

New cultivars (F_1 hybrids) of cauliflower (*Brassica olearacea* L. var. *botrytis* L.) were evaluated at four crop densities (1.3, 1.7, 2.2 or 3.3 plants m^{-2}) for spring harvest crop in a Southern Mediterranean area (western coast of Sicily). The F_1 hybrids ('White-Flash', 'Milky-Way' and 'White Excel') having white head, usually cultivated in Northern Italy and Europe in the autumn, were used. The aim was the introduction of new varieties which can fill the gap from mid May to mid July, now existing in the Sicilian cauliflower production, which is based on autochthonous ecotypes of green head varieties, *e.g.* 'Cavolfiore Verde di Palermo'. Crop density significantly influenced the growth and the phenology of the new hybrids. It was positively correlated to earliness, total marketable yield and inversely to unmarketable product percentage and head size. The best crop density was found to be 2.2 plants m^{-2}. Among the cultivar tested 'White Flash' and 'Milky Way' appeared particularly suited for a spring harvest in the experimental environment. They gave high yields with a minimum discard and uniform heads of approximately 1 kg of weight each.

Key words: *Brassica olearacea* L. var. *botrytis* L., planting density, cultivars, quality

Introduction

According to FAO statistics (2000-2005), Italy is the third producer (500,000 t) of cauliflower (*Brassica olearacea* L. var. *botrytis* L.) in the world, after China and India (7,250,000 and 4,800,000 t, respectively), followed by Spain, USA and France. Italian production has always been commercialized also abroad, but in the last thirty years exports gradually decreased (Liguori,1985; Franca, 1985; Renzoni 2004). France and Spain are particularly strong competitors. They are offering cauliflowers of better and more constant quality standards. Moreover their farms are generally larger than in Italy and this helps in reducing management costs. Nowadays even traditional European importers, *i.e.* The Netherlands, Great Britain and Germany, are becoming new exporters, particularly with the introduction of cold resistant hybrids (Ranco, 1985; Franca, 1985; Renzoni, 2004).

In the past, Italian production was based on ecotypes with loose corymbs. Generally they lacked colour and size uniformity and their ripening period was prolonged, aspects that heavily affected commercialization and reduced customer satisfaction (Baldoni, 1982; Liguori, 1985; Acciarri *et al.*, 2004). Exceptions were rare. For example 'Romanesco' and 'Verde Maceratese' were appreciated in the North European market for the typical shape and for the green colour of their heads, respectively. In the last few years Italian ecotypes lost importance, although many of them have been genetically improved, maintaining their typical organoleptic properties and particular taste. In Italy, most of the cauliflower production comes from central and southern regions (ISTAT, 2005). Campania is the first producer, followed by Puglia, Calabria, Abruzzo, Marche and Sicily (Table 1). Marche's crops has always been focused towards the export. On the contrary, most of the Sicilian products are commercialized on the home market. Sicilian farmers generally use local varieties which are less appreciated abroad. Their heads are usually coloured, too heavy (about 2.5-3 kg head^{-1}) and often scarcely uniform. In western Sicily, the typical cultivar is 'Cavolfiore Verde di Palermo' which has green, compact and medium-large corymbs, while in the oriental part of the island there is a predominance of 'Cavolfiore Violetto di Catania' that is characterized by large and purple heads (Branca and Iapichino, 1997; Acciarri *et al.*, 2004). The 'Cavolfiore Verde di Palermo' has several ecotypes with different earliness of production (Incalcaterra and Iapichino, 2000). These types, selected by growers during the centuries, are now well identified and are called with the name of the harvest month. They allow a continuous production sequence from August to April, with a unique gap that goes from the middle of May to mid July (Branca and Iapichino 1997, Incalcaterra and Iapichino 2000). The goal of this research was the introduction of new cauliflower cultivars in the occidental part of Sicily for a spring harvest in order to cover this productive gap. Today most of the new available varieties of cauliflowers are F_1 hybrid that were bred in localities quite different from the Sicilian environments. The adaptability of these species to many climates is confirmed by several studies. For example, according to Wurr *et al.* (1993) head formation requires a vernalization period at 9- 21°C. Grevsen and Oelsen (1994) indicated a range between 0 and 26°C, while Wiebe (1990) suggests maximum vernalization stimulus at 16 to 30°C. A further proof is provided by the cauliflower crops in tropical regions, with about 25°C as yearly mean temperature. However, the fitness of a new cauliflower variety to a particular environment (and market) should always be thoroughly evaluated. In this instance, a good cultivar for a spring cultivation in the Southern Mediterranean area like Sicily should produce smaller heads than the indigenous ecotypes in order to be appreciated on the international market. Moreover, it should be precocious and tolerate hot temperatures during head formation. Only thus it can give new chances to the Sicilian cauliflower production and marketing. The aim of the study was to explore the hybrid cauliflower production during mid may to mid July in Northern Italy and Europe.

Material and Methods

The research was carried out at the experimental farm of the Horticulture and Floriculture branch of the Department of Agronomy of the University of Palermo in the north-western coast of Sicily (38°7' N; 13°22' E), Italy . The field experiment was conducted on a typical Mediterranean litosoil. It consists of a 50 cm deep layer of sandy-clayey textured soil, lying on dolomitic limestone rock, with the following main characteristics: sand 53.7%, lime 30.3%, clay 16.0%, pH 7.9, active limestone (Ca) 4.3%, Kjeldahl nitrogen (N) 1.2%, organic matter 3.1% (Lotti Method), Olsen phosphorous (P_2O_5) 0.3% and exchangeable potassium (K_2O) 0.1%. Climatic parameters were continuously recorded by a meteorological station situated at the experimental farm. The experimental field was previously cropped with winter melon (*Cucumis melo* L. var *inodorus* Naud.). In February 2000, a ploughing to 0.35 m was carried out, followed by flexible harrowing. Before transplanting, mineral fertilizer (11-22-16 NPK) was applied at 0.6 t ha^{-1} as a basal dressing. On March 19th 2000 the cauliflower seeds were sown in plastic trays with 45 mm diameter holes (Dufault and Waters, 1985a) and filled with dark peat; the plantlets were placed first in a nursery and then outdoor for a slow acclimatizing. Transplanting was made on April 14th with 4-5 leaves/plant. The crop was hand weeded and was irrigated throughout the season according to its need: one irrigation per week starting from the middle of May.

The experiment consisted of a factorial comparison between three cauliflower cultivars and four crop densities. The cultivars were commercial F_1 hybrids: 'White-Flash', 'Milky-Way' and 'White Excel', obtained by Sakata Co. (Japan). All of them have white head and are widely used for autumn harvest in Northern Italy and all over Europe. Compared densities were 1.7, 1.3, 2.2 or 3.3 plants m^{-2}. They were obtained by maintaining constant distance (1 m) between row and changing that along the row: 0.30- 0.45- 0.60 and 0.75 m.

Experimental plots were 18 m^2 of area and were randomized according to a complete randomized block design with three replicates. At harvest, border plants within each plot were discarded to avoid interferences between treatments. During the growing season the rate of leaf appearance was assessed by leaf counts on 15 plants for each plot at 15, 30 and 45 days after transplanting. Moreover the time of head formation was recorded when the change of the apices became visible and heading earliness was expressed as number of days from transplanting. At harvest**,** cauliflower heads were hand collected as soon they were reached marketable stage *i.e.* sufficiently large, but still compact. Head collection implied three passages in each plot, throughout June**.** Collected corymbs were sorted into 5 diameter classes: Ø<0.11m; 0.11-0.13m; 0.14-0.155m; 0.156-0.18m and Ø>0.18m. This classification is linked to the number of heads that can be placed in a standard commercial box and represents the base of the selling price of cauliflowers in the Italian market. Each box contains 24 corymbs of the 0.11-0.13m class, 18 pieces of the 0.14-0.155m class, 12 pieces of the 0.156-0.18m class and 9 heads with Ø>0.18m. Ø<0.11m cauliflowers are considered not marketable.

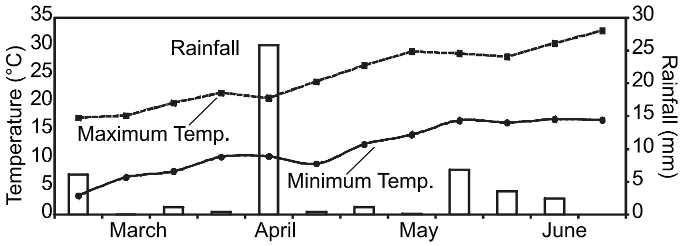

Fig. 1. Air temperatures and rainfalls from March to July 2000.

Data were analysed by a Two-Way ANOVA (cultivar x crop density) procedure and the differences between means were evaluated by Duncan's multiple range test (SAS®, ProcAnova/ DuncanTest).

Results

During the experiment climate was very favourable to cauliflower growth (Fig. 1**).** Minimum temperature varied from 3.4°C in the first part of March to 19.5°C in last days of June, while maximum temperature ranged between 17.0 and 34.6°C in the same periods, respectively. Total rainfall was about 50 mm distributed during the growing season. In particular, 26.65 mm fell soon after transplanting (April 10 and 20) and two rainfall (8 and 6 mm) happened during fertile stem elongation and head ripening, respectively.

Leaf appearance rate: Leaf appearance rate was strongly reduced by increasing crop density (Table 2). This effect can be easily explained by considering the higher competition at root and shoot level of densely grown plants. The parameter tested significantly varied among cultivars. Fifteen days after transplanting 'White Flash' showed more leaves per plant (1 or 3 more than the other cultivars) and this difference was particularly marked in denser crops. After 30 days 'White Flash' again had the maximum number of leaves. In this instance, however, the differences with the other cv. were significant only at the lowest density. Regardless of the planting density, 45 days after transplanting, 'Milky-Way' produced the highest number of leaves per plant.

Head formation: The passage from vegetative to reproductive phase varied widely (from 36.0 to 55.5 d from transplanting) and depended mainly on genotype (Table 3). On average, 'Milky Way' was the first hybrid to develop corymbs, followed by 'White Excel' and 'White Flash'. Heading response to crop density was variable as well. The competition stress that is typical of a dense stand accelerated head formation. However this effect was marked in 'White Excel' (approximately one week between the highest

Table 1. Regional distribution of Italian cauliflower production (ISTAT, 2005)

Regions	Area (ha)	Production (t ha^{-1})
Puglia	2692	15.30
Campania	2858	29.61
Calabria	2316	33.31
Abruzzo	2117	23.73
Marche	1943	23.25
Sicilia	1804	21.86
Italian	17950	24.10

Table 2. Influence of cultivar and crop density on the leaf appearance assessed 15, 30 and 45 days after transplanting

Crop density (plant m^{-2})	Number of leaves plant^{-1}		
	'White Flash'	'Milky Way'	'White Excel'
15 days			
3.3	8.7^{D}	5.4^{G}	6.7^{F}
2.2	10.8^{B}	8.6^{D}	7.8^{E}
1.7	9.6^{C}	9.3^{C}	9.5^{C}
1.3	11.6^{A}	11.5^{A}	10.8^{B}
30 days			
3.3	16.5^{BE}	14.8^{DF}	14.4^{DF}
2.2	19.6^{AB}	15.6^{CE}	15.0^{DF}
1.7	17.3^{BE}	16.1^{BE}	16.3^{BE}
1.3	20.8^{A}	18.7^{CE}	18.2^{AD}
45 days			
3.3	20.9^{D}	24.3^{BC}	18.4^{E}
2.2	21.7^{C}	24.8^{B}	21.3^{D}
1.7	24.8^{B}	25.2^{A}	23.6^{BC}
1.3	27.3^{A}	28.2^{A}	24.4^{C}

Means followed by different letters are significantly different according to Duncan's test at $P<0.05$

Table 3. Cauliflower heading time as affected by genotype and crop density

Crop density (plant m^{-2})	Heading time (Days after transplanting)		
	'White Flash'	'Milky Way'	'White Excel'
3.3	36.0^{H}	53.2^{B}	41.8^{F}
2.2	39.2^{G}	54.6^{A}	43.3^{E}
1.7	39.3^{G}	55.3^{A}	44.8^{D}
1.3	39.6^{G}	55.5^{A}	48.1^{C}

Means followed by different letters are significantly different according to Duncan's test at $P<0.05$

Table 4. Influence of genotype and crop density on the yield of marketable cauliflower heads

Crop density (plant m^{-2})	Marketable cauliflower heads (t ha^{-1})		
	'White Flash'	'Milky Way'	'White Excel'
3.3	21.77^{A}	15.40^{CDE}	21.42^{A}
2.2	16.07^{CD}	18.28^{B}	17.28^{BC}
1.7	15.06^{DE}	13.99^{DE}	10.27^{G}
1.3	13.24^{EF}	11.54^{FG}	8.20^{H}

Means followed by different letters are significantly different according to Duncan's test at $P<0.05$

and lowest density) and less noticeable in the other two hybrids (2-3 days of difference, Table 3).

Head yield: For each hybrid, the harvest period lasted less than 15 days and all heads were collected in three harvests. 'White Flash' was the first cultivar to give a marketable production (in the first part of June), followed by 'Milky Way' and then by 'White Excel', which started to be collected at the end of June.

The highest yields of marketable heads (Table 4) were obtained with 'White Flash' and 'White Excel', both at the densest stand (21.8 and 21.4 t ha^{-1}, respectively). 'White Excel' at the lowest density gave unsatisfactory production (8.2 t ha^{-1}). On average, marketable yield was positively correlated to plant density. This implies that, even at the highest compared density, the plant competition was not so strong as to impair the high yield potential of the new hybrids. Only for 'Milky Way' the highest density slightly reduced yield, probably because its large plants are better suited to less dense plantings.

Head quality: As expected, the weight of single heads (Table 5) was negatively correlated to plant density, but genotypic influence was equally important. 'Milky Way' always produced the heaviest corymbs, which exceeded 1.3 kg head^{-1} at the lowest density. The head size was most sensitive to density in 'White Excel'. From the lowest to the highest density the weight of its heads decreased more than half a kg.

Unmarketable heads were mainly due to bolting. Internode elongation, less leaves, thicker leaf lamina and thinner stem are all symptoms of competition stress that predispose the plant to bolting (Table 6). Thus this adversity was clearly associated to crop density. However genotype also had significant effect. In particular, the discard of 'White Flash' was always inferior to 20%, even at the highest density (Table 6). On the contrary, in 'White Excel' it consistently represented more than a quarter of collected heads, with a slight variation in response to crop density. 'Milky Way' showed an intermediate behaviour. In general, the increase of crop density augmented the frequency of small cauliflowers reducing the number of the extra-large ones (Fig. 2). In 'White Flash' Ø<0.11m corymbs were very few (10.8 %) at 1.3 plants m^{-2} compared to 35.0% that were found at 3.3 plants m^{-2}, while the opposite happened for Ø>0.18m (31.3 and 5.4 %, respectively). Also, in 'Milky Way' the extreme classes were markedly influenced by plant density: the percentages of corymbs belonging to the smallest class were 28.6 and 4.2% at 3.3 and 1.3 plants m^{-2} density, respectively, while those with Ø>0.18m were 0.9 and 35.2%, respectively. A similar pattern, even more

Table 5. Influence of genotype and crop density on the unit weight of collected cauliflower heads

Crop density (plant m^{-2})	Unit head weight (g head^{-1})		
	'White Flash'	'Milky Way'	'White Excel'
3.3	774^{GH}	893^{G}	711^{H}
2.2	993^{F}	1023DE	796^{G}
1.7	959^{EF}	1186^{C}	1015DE
1.3	1053^{D}	1353^{A}	1270^{B}

Means followed by different letters are significantly different according to Duncan's test at $P<0.05$.

Table 6. Percentage of unmarketable cauliflower heads as affected by genotype and crop density

Plant density (plant m^{-2})	Percent unmarketable heads		
	'White Flash'	'Milky Way'	'White Excel'
3.3	19.3EF	24.5CD	32.1A
2.2	11.4G	22.1DE	28.3B
1.7	8.5H	19.1F	25.4BC
1.3	6.7H	17.5F	26.6BC

Means followed by different letters are significantly different according to Duncan's test at $P<0.05$

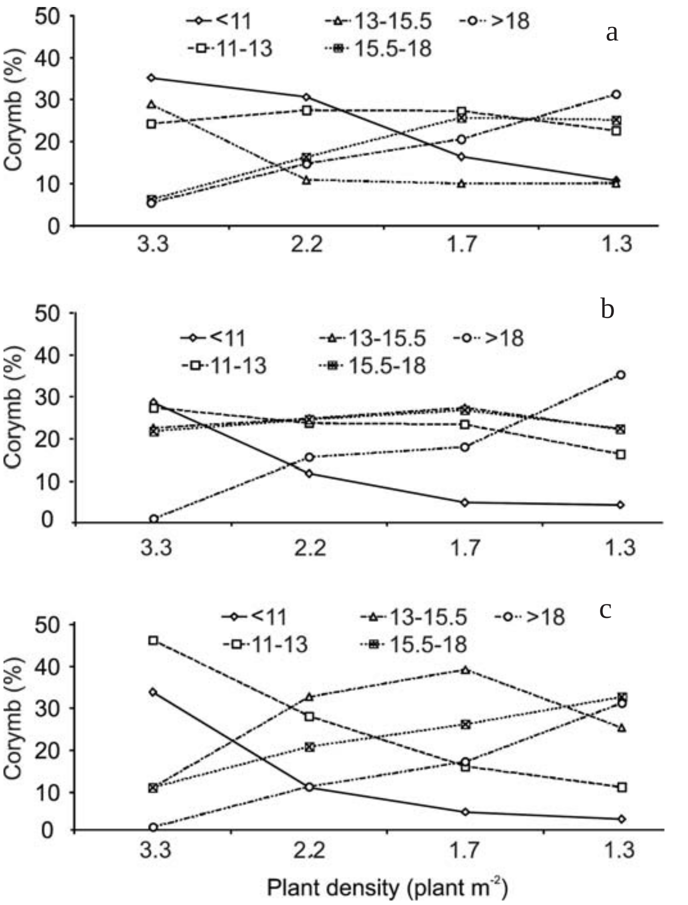

Fig. 2. Distribution of collected heads into diameter classes (<11, 11-13, 14-15.5, 15.5-18, >18 cm) as affected by hybrid and planting density: (a) White flash (b) Milky Way, (c) White Excel.

marked, was observed for 'White Excel'. The percentage of its corymbs belonging to the smallest class ranged from 2.6 to 33.2% when density increased from 1.3 to 3.3 plants m^{-2}, while the largest heads decreased from 30.5 to 0.7%. On the whole, the percentage of intermediate diameter classes was more stable over crop densities and hybrids.

Discussion

In this study, the increasing plant density significantly augmented the marketable yield as already observed by Salter and James (1975) in cauliflower. Our results are also consistent with those obtained by Dufault and Waters (1985), who found that high plant density reduced head weight in cauliflower cultivar Snow Crown. 'White Excel' appeared highly influenced by density, as at the highest stand it gave heads that were so small (less than 800 g $head^{-1}$) as to be scarcely appreciated both by home and international customers. 'White Excel' gave the most suitable weights for the international market (1 kg $head^{-1}$) at 1.7 plant m^{-2}, whereas 'Milky Way' and 'White Flash' gave satisfactory head weight with high productivity even at 2.2 plant m^{-2}. Higher percentages of too small (Ø<0.11m) and too large (Ø>0.18m) corymbs were obtained at 3.3 and 1.3 plants m^{-2}, respectively.

Among the cultivar tested, 'Milky Way' can be considered the best responsive with medium sized head of even uniformity over a wide range of densities. 'White Flash' was the earliest hybrid, followed by 'Milky Way' and 'White Excel'. This earliness was due to faster development, particularly during the initial stages of growth, where it showed the fastest leaf formation. An increase of crop density sped up growth. This influence, combined with the genotype growth characteristic, can be used to achieve an earlier production at the end of spring, which is particularly imporant for the Sicilian cauliflower market.

The amount of unmarketable product was affected by density through bolting; indeed at the highest density the discarded head percentages was high. But bolting effect was influenced by hybrid susceptibility as 'White Excel' (being later producing) was more prone than 'White Flash' (being earlier producing).

The results indicate that the tested hybrids can be successfully cropped in a Mediterranean climate area such as the western coast of Sicily. Indeed, they can almost completely fill the gap in the Sicilian cauliflower production (mid May- mid July) with a high productivity, that was confirmed in our agronomic environment. Both, the high productivity and the quality standard that the tested cultivar showed might be greatly appreciated on the international market, opening the export market to local growers.

Planting density influenced both plant growth and phenology: denser stands promoted earliness and augmented yield, but implied smaller corymbs and high proportion of discardable heads. Thus medium densities are recommended. On the whole, the better quantitative and qualitative results were obtained with 'White Flash' and 'Milky Way' transplanted at a density of 2.2 plants m^{-2}: this density seems thus to be the best choice as reference for further experiments.

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