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Susceptibility to *Bactrocera oleae* (Gmelin) of some Sicilian olive cultivars

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Abstract: Genetic resistance of olive germplasm could be an important tool in the control of *Bactrocera oleae* (Gmelin), the key pest in Mediterranean Basin olive groves. Up to now, no study carried out on olive varieties stressed a complete resistance to the attack of *B. oleae*, although differences among olive cultivars in the susceptibility to olive fruit fly could be usefully considered both in organic and conventional olive cultivation, to obtain quality productions and to reduce insecticides use.

The present study was carried out at Castelvetrano (Trapani province, Sicily), in the olive germplasm collection of Ente di Sviluppo Agricolo of the Sicilian Region. From 2002 to 2005, the assessment of susceptibility was made recording infestation levels on 18 cv, representing the most widely cultivated in Sicily. Samplings were carried out every 11-20 days, starting from the second half of August to the end of October. Moreover, from 2003 to 2005 infestation levels were correlated with hardness and size of the olives, while in 2004-2005 further data on olive colouration were collected at different ripening stages. A positive correlation between infestation and olive sizes was found, resulting in higher infestation levels recorded on the cultivars producing larger olives. A negative correlation between hardness and infestation was found in the early olive growing, until they reached almost definitive sizes. *B. oleae* showed to have a clear preference for green drupes, instead of reddish or blackish ones. Among the cultivars producing larger olives, Nocellara del Belice resulted the susceptible to the olive fly attacks, while Nocellara messinese was the less infested. Among cultivars with medium and small-sized fruits Moresca, Vaddarica, Nasitana frutto grosso, Minuta and Bottone di gallo were the less suceptible.

Key words: olive fruit fly, fruit size, fruit hardness, organic farming.

Introduction

The olive fly, *Bactrocera oleae* (Gmelin), is considered the olive key pest in Mediterranean Basin. As a consequence of ECC incentives, during the last five years many olive growers changed cultivation strategy from conventional to organic method, although the olive fly control is very difficult, because of the limited availability of effective products as permitted by Council Regulation (EEC) No 2092/91.

Several studies were carried out on the effectiveness of allowed products or of new natural substances (Belcari & Bobbio, 1999**;** Tsolakis & Ragusa, 2002; Petacchi & Minnocci, 2003; Saour & Makee, 2004) and on the susceptibility of different cultivars to the olive fly attacks (Donia, 1971; Neuenschwander *et al*., 1985; Iannotta, 1999).

In Sicily many local cultivars are well characterized and regularly cultivated; nevertheless their resistance to the olive fly infestation is not yet deeply investigated.

The aim of the present research is to assess the susceptibility of the most widespread Sicilian cultivars, to better control the olive fly and to give useful information for new olive groves planting.

Materials and methods

From 2002 to 2005, the research was carried out on 18 Sicilian cultivars, in the experimental olive grove "Campo Carboj" of ESA (Ente Sviluppo Agricolo, Regione Siciliana), located at Castelvetrano (Trapani Province). A list of the 18 cultivars is reported in Table 1; La Mantia *et al.* (2005) now consider Pizzo di corvo as junior synonym of Giarraffa. In the different years, the cultivars with not enough drupes for the minimum sampling were not included in the research.

Each thesis consisted of three untreated plants for each cultivar, subjected to the same cultural practices.

Male olive fly population was monitored by wing traps baited with the specific pheromone (1.7-dioxaspiro [5.5] undecane). During each year, two-three traps were placed in the field from the end of July-beginning of August to the end of October. Traps were checked every week, and pheromone dispensers were replaced every 30 days.

Table 1. Sicilian olive cultivars tested in the research; cultivars are listed in descending order of size

No	**CULTIVAR**	**2002**	**2003**	**2004**	**2005**	SIZE*(cm^3)	
1	Pizzo di corvo (= Giarraffa)	X	X	X	X	11.1	l
2	Giarraffa	X	X	X	X	9.6	l
3	Tonda Iblea		X			8.2	l
4	Nocellara messinese	X	X	X	X	7.7	l
5	Nocellara del Belice	X	X	X	X	6.6	l
6	Carbucia		X			6.6	l
7	Moresca	X	X	X	X	5.3	m
8	Vaddarica	X	X	X	X	4.5	m
9	Nasitana frutto grosso	X	X	X	X	4.3	m
10	Cerasuola di Sciacca	X	X	X	X	4.2	m
11	Biancolilla Caltabellota frutto grosso	X			X	4.1	m
12	Calatina		X		X	3.0	m
13	Piricuddara	X	X	X	X	2.5	s
14	Biancolilla Caltabellotta frutto piccolo	X		X		2.2	s
15	Bottone di gallo	X	X	X	X	2.1	s
16	Castricianella rapparina	X	X	X	X	1.9	s
17	Minuta	X	X	X	X	1.9	s
18	Olivo di Mandanici	X	X	X	X	1.5	s
TOTAL No PER YEAR		**15**	**16**	**14**	**15**		

*average size ([(π/6) x max.D.] x min.$D.^2$) at the end of October calculated from 2003 to 2005; l = large, m = medium, s = small.

From August to October, samples of 60 drupes (20 per tree) in 2002-2004 and 90 drupes (30 per tree) in 2005 were randomly collected every 11-20 days, at a 1.70 m height and around all the tree. In the laboratory olives were examined under a steromicroscopy, to check

the presence of oviposition punctures. Olives were also sectioned to record the presence of the different preimaginal stages.

The number of eggs, larvae of the different stages, pupae and exit holes was recorded to calculate the total infestation. Furthermore, sterile stings (punctures not followed by oviposition) and empty galleries were counted.

Moreover, during 2003-2005, on 30 sampled drupes of each cultivar, the following biometric data were recorded: hardness, maximum diameter (max.D.), minimum diameter (min.D.). The latter two measurements were used to calculate the olive volume ([(π/6) x max.D.] x min.D.^{2}).

A visual analysis of olive colour was carried out on 30 drupes of the last sample collected on 2003 and of all the 2004 samples, and on all the 90 olives collected during 2005. Three different colouration classes were adopted to classify olives: green, reddish (mostly during viraison), and blackish (completely mature olives).

Climatic data from the agrometeorological station located at Castelvetrano (30 m a.s.l., Trapani Province) were kindly provided by S.I.A.S. (Servizio Informativo Agrometeorologico Siciliano of Government of the Sicily Region).

Data on total infestation recorded at each sampling date were statistically evaluated by ANOVA followed by Tukey post-hoc test at confidence level $p<0.05$. Pearson linear correlation ($p<0.05$) total infestation/olive volume and total infestation/hardness was calculated at each sampling data from 2003 to 2005.

Results

2002

In all samplings the four cultivars with a large fruit were among the most infested cultivars with the exception of Nocellara messinese whose infestation did not statistically differ from the four smaller cultivars (Table 2).

Table 2. Total infestation in 15 Sicilian olive cultivars (listed in descending order of size) and statistical analysis (ANOVA 1-way followed by Tukey post-hoc test; $p<0.05$). Year 2002.

CULTIVAR	03/09/02	18/09/02	01/10/02	15/10/02	29/10/02
Pizzo di corvo	0.17 b c	0.73 a b	2.09 a	1.63 a b	1.59 b
Giarraffa	0.43 a	0.94 a	1.47 b	1.29 b c d	1.41 b c d
Nocellara messinese	0.04 c	0.26 c d	0.56 f	0.54 h	0.78 e f
Nocellara del Belice	0.29 a b	0.46 b c	1.18 b c	1.64 a b	1.50 b c
Moresca	0.13 b c	0.15 c d	0.59 d e f	1.13 c d e	0.22 f
Vaddarica	0.11 b c	0.71 a b	0.60 e f	1.09 c d e f	0.79 e f
Nasitana f.g.	0.19 b c	0.70 a b	1.01 c d e	1.04 d e f g	0.97 e
Cerasuola di Sciacca	0.17 b c	0.70 a b	1.19 b c	0.59 g h	1.14 c d e
Biancolilla Caltab. f.g.	0.03 c	0.10 d	1.06 b c d	1.81 a	1.14 c d e
Piricuddara	0.03 c	0.24 c d	0.51 f	0.89 d e f g h	2.16 a
Biancolilla Caltab. f.p.	0.07 b c	0.31 c d	1.13 b c	1.54 a b c	1.03 c d e
Bottone di gallo	0.03 c	0.30 c d	0.49 f	0.70 e f g h	1.02 d e
Castricianella rapp.	0.00 c	0.10 d	0.43 f	0.66 e f g h	1.17 c d e
Minuta	0.01 c	0.26 c d	0.44 f	0.61 f g h	0.91 e
Olivo di Mandanici	0.04 c	0.14 d	0.30 f	1.03 d e f g	0.86 e

In the last two sampling dates Moresca, Vaddarica and Nasitana f.g. probably because of their early dark colouration resulted among the less infested cultivars in the last two sampling dates.

In the last sampling date Piricuddara, with olives still green in that moment, reached the hightest infestation although its small size.

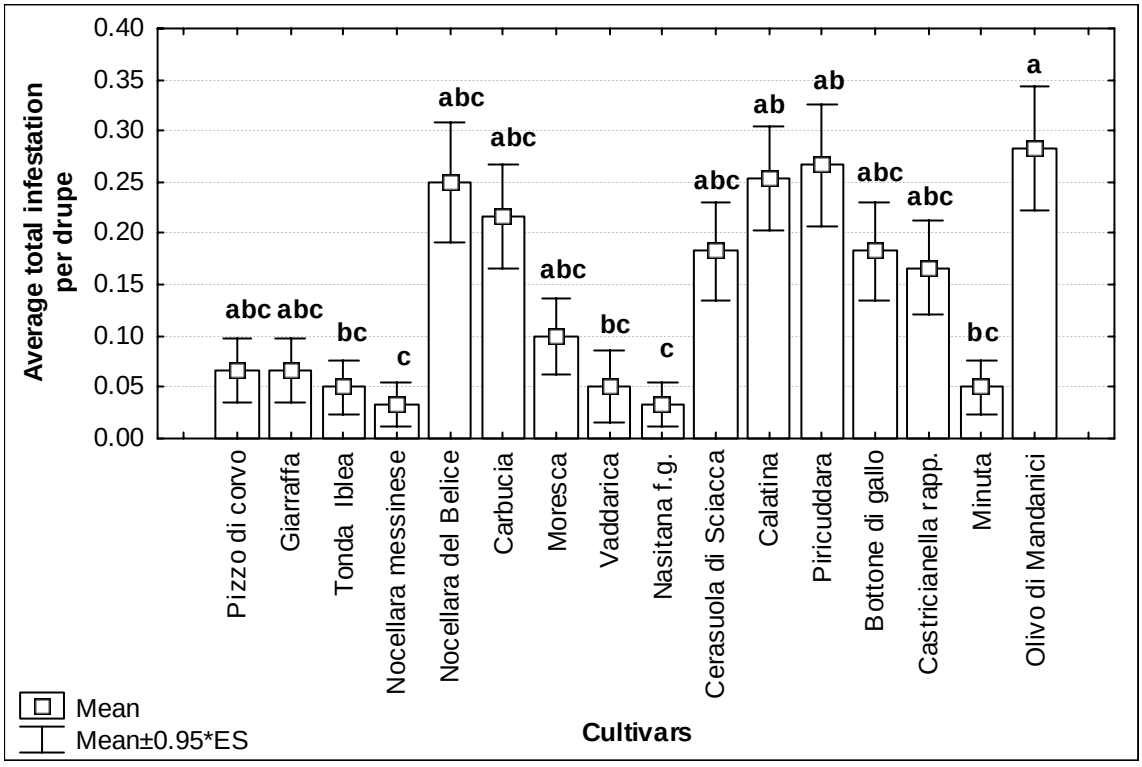


Figure 1. Total infestation level in 15 Sicilian olive cultivars (listed in descending order of size) on October 31st 2003 (Different letters denote statistically significant differences; ANOVA 1-way followed by Tukey test; $p<0.05$)

2003

During this year, *B. oleae* infestation was very low, mostly due to the high temperatures. Significant differences among the cultivars were recorded only at the last sampling date October 31st (Figure 1).

Eight out of sixteen cultivar did not show any statistical difference from other cultivars also in this date.

The highest infestation level was recorded on Olivo di Mandanici, Piricuddara and Calatina, which differed from only 5 cultivars, and also on differing from Nocellara messinese and Nasitana f. g. least infested cultivars.

Sterile stings were more abundant than the total infestation, in the first five sampling dates, while in the last date they were at the same level of total infestation, due to the need of adult females to get liquid food (Girolami, 1978).

Biometric analysis on hardness and size of drupes from the different cultivars showed significant differences among them. The two cultivars with highest hardness values resulted Nocellara messinese and Piricuddara, characterized by large and small size of olives, respectively.

Correlations infestation/hardness and infestation/size were not significant, until the last sampling date. At this date (30/10/2003), a significant positive correlation was found between infestation and hardness, while a significant negative correlation was found between infestation and size (Table 3).

Table 3. Pearson linear correlation infestation/size and infestation/hardness of variously coloured drupes of 16 sicilian olives cultivars in 2003. (Values in bold indicate statistically significant correlation; $p<0.5$)

	SIZE	**HARDNESS**
INFESTATION 4 September	-0.05	0.03
INFESTATION 23 September	0.06	-0.03
INFESTATION 15 October	0.00	-0.03
INFESTATION 30 October	**-0.17**	**0.10**

Table 4. Total infestation in 14 Sicilian olive cultivars (listed in descending order of size) and statistical analysis (ANOVA 1-way followed by Tukey test; $p<0.05$) – Year 2004

CULTIVAR	**03/09/04**	**20/09/04**	**06/10/04**	**26/10/04**
Pizzo di corvo	0.00 b	0.28 b c	0.73 a b c	2.25 a
Giarraffa	0.06 b	0.55 a	0.70 a b c d	1.38 b
Nocellara messinese	0.00 b	0.02 d	0.88 a b	0.75 b c
Nocellara del Belice	0.07 b	0.32 a b	0.95 a	2.80 a
Moresca	0.18 a	0.08 b c d	0.28 d	0.73 b c
Vaddarica	0.03 b	0.25 b c d	0.60 a b c d	0.80 b c
Nasitana f.g.	0.00 b	0.08 b c d	0.53 a b c d	0.82 b c
Cerasuola di Sciacca	0.00 b	0.13 b c d	0.50 b c d	1.18 b c
Piricuddara	0.00 b	0.05 c d	0.37 c d	0.95 b c
Biancolilla Caltab. f.p.	0.00 b	0.22 b c d	0.87 a b	0.83 b c
Bottone di gallo	0.00 b	0.12 b c d	0.48 b c d	1.05 b c
Castricianella rapp.	0.00 b	0.15 b c d	0.35 c d	0.93 b c
Minuta	0.00 b	0.18 b c d	0.48 b c d	0.53 c
Olivo di Mandanici	0.02 b	0.02 d	0.45 b c d	1.13 b c

2004

In all samplings cultivars with large drupes were the most attacked, excepting Nocellara messinese on September 20th. In the last date Nocellara del Belice and Pizzo di corvo recorded the highest infestation significantly differing from all cultivar, while Minuta was the least infested without significant differences from ten other cultivars (Table 4).

In this year, in all the sampling dates, a significant positive correlation was found between the infestation levels and the olive size, indicating that olive flies prefer to oviposit

on larger drupes. The correlation between infestation and hardness resulted statistically negative on the 20th of September, and positive in the last date (Table 5).

Moreover, limiting the analysis to the green olives, a significant positive correlation was confirmed between infestation and olive size, while a significant negative correlation was found only on September 20th (Table 6).

Table 5. Pearson linear correlation infestation/ size and infestation/hardness of variously coloured drupes of 14 Sicilian olives cultivars in 2004

INFESTATION	SIZE	HARDNESS
3 September	**0.12**	-0.07
20 September	**0.21**	**-0.13**
6 October	**0.14**	0.10
26 October	**0.17**	**0.27**

Table 6. Pearson linear correlation between infestation/size and infestation/hardness of green drupes of 14 Sicilian olives cultivars in 2004

INFESTATION	SIZE	HARDNESS
3 September	**0.12**	-0.07
20 September	**0.23**	**-0.16**
6 October	**0.16**	-0.03
26 October	**0.26**	0.11

Values in bold indicate statistically significant correlation ($p<0,05$)

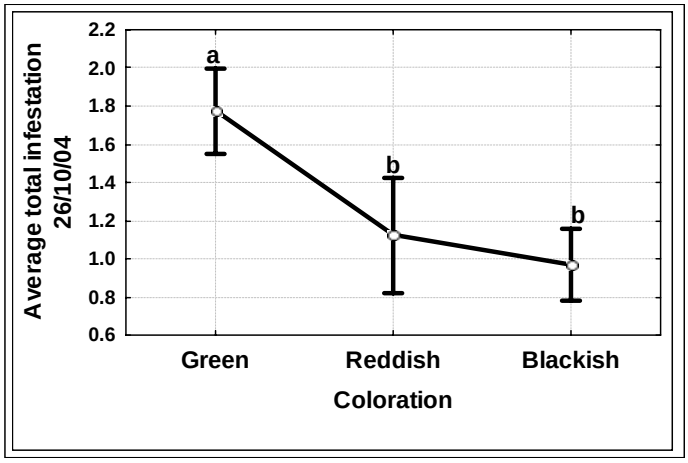


Figure 2. Total infestation of differently coloured drupes of 14 Sicilian olives cultivar (Different letters denote statistically significant differences; ANOVA 1-way followed by Tukey post-hoc test; $p<0.05$)

The different results obtained in the last sampling date indicates that olive fly females prefer larger and green olives for oviposition; on October 26th, green olives resulted statistically more infested than the reddish and blackish ones (Fig. 2).

2005

During the first three sampling dates, infestation levels were low on all cultivars. Only on Nocellara del Belice the infestation resulted significantly higher at the first sampling date.

Excluding September 9th in all samples the infestation level of Nocellara del Belice was the highest of large-sized of cultivars, with the following statistically significant differences from: Nocellara messinese in all dates, Giarraffa in all dates except September 23rd, Pizzo di corvo in all dates except September 23rd and October 7th.

Table 7. Total infestation in 15 Sicilian olive cultivars (listed in descending order of size) and statistical analysis (ANOVA 1-way followed by Tukey test; $p<0.05$). Year 2005

CULTIVAR	26/08/05	8/09/05	23/09/05	7/10/05	20/10/05	31/10/05
Pizzo di corvo	0.00 b	0.00 a	0.15 a b	0.49 a b c	0.63 e f g h	2.85 b c
Giarraffa	0.00 b	0.03 a	0.12 a b c	0.46 b c d	0.88 d e f g	2.36 c
Nocellara messinese	0.00 b	0.00 a	0.00 c	0.16 e f	0.92 d e f	1.51 d
Nocellara del Belice	0.05 a	0.00 a	0.17 a	0.71 a	2.43 a	5.24 a
Moresca	0.00 b	0.00 a	0.07 a b c	0.14 f	0.30 h i	1.15 d e
Vaddarica	0.00 b	0.00 a	0.00 c	0.13 f	0.50 g h i	0.64 e
Nasitana f.g.	0.00 b	0.02 a	0.10 a b c	0.09 f	0.21 h i	0.88 e
Cerasuola di Sciacca	0.00 b	0.02 a	0.03 a b c	0.48 a b c d	1.68 b	3.52 b
Biancolilla Caltab. f.g.	0.02 a b	0.02 a	0.13 a b c	0.52 a b	1.62 b	2.12 c
Calatina	0.00 b	0.00 a	0.02 b c	0.39 b c d e	0.54 f g h i	1.31 d e
Piricuddara	0.00 b	0.00 a	0.02 b c	0.27 c d e f	1.57 b c	1.36 d e
Bottone di gallo	0.00 b	0.05 a	0.02 b c	0.24 d e f	0.24 h i	1.13 d e
Castricianella rapp.	0.00 b	0.00 a	0.00 c	0.20 e f	0.98 d e	2.56 c
Minuta	0.00 b	0.00 a	0.00 c	0.07 f	0.20 i	1.01 d e
Olivo di Mandanici	0.00 b	0.02 a	0.00 c	0.08 f	1.17 c d	2.19 c

In the last three dates Nocellara del Belice showed an infestation higher than that one in all other cultivars excepting Biancolilla Caltabellotta f. g. and Cerasuola di Sciacca on October 7th.

Among medium and small size cultivars these last two cultivars plus Piricuddara, Castricianella rapparina and Olivo di Mandanici were the most attacked.

In variously coloured olives the positive correlation between infestation and olive sizes resulted statistically significant from September 23rd to the end of samplings; the correlation between infestation and drupe hardness was significantly negative on the August 26th, September 8th, October 20th and 31st, while it was significantly positive on the October 7th (Table 8).

In green olives positive correlation between infestation and size is confirmed as statistically significant from September 23rd to the last sampling date. Differently from analysis in variously coloured fruits, infestation and hardness in green olives resulted positively correlated on October 20th, and not significant on October 7th and 31st (Table 9). These data to indicate that, when the olives are all unripe and green, *B. oleae* preferably oviposits on softer olives. When olives are completely grown in size, oviposition occurs mostly on larger and still green drupes.

Infestation on olives characterized by different colouration (Figures 3-4) resulted statistically higher on green olives than on reddish and blackish ones, on October 20th and 31st.

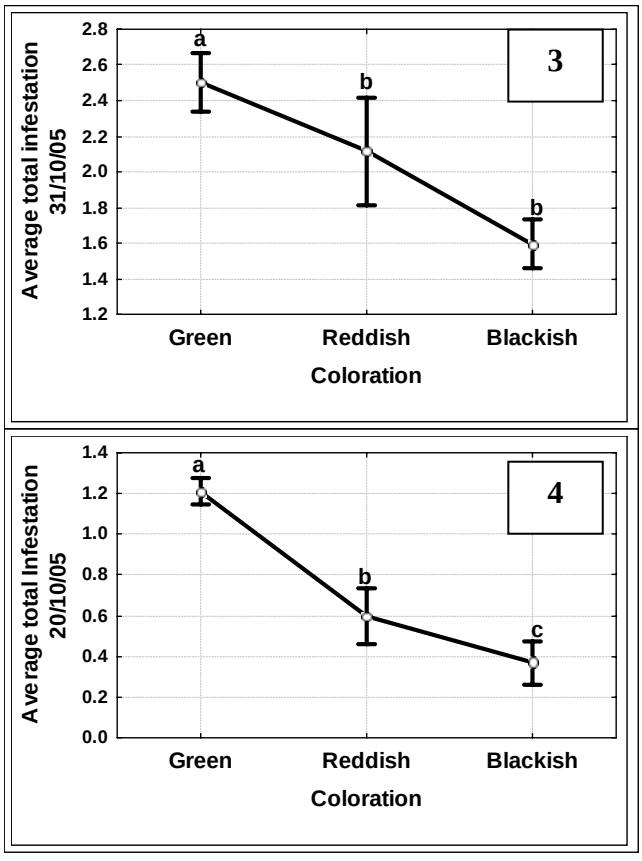
Table 8. Pearson linear correlation infestation /size and infestation/hardness of variously coloured drupes of 15 Sicilian olive cultivars in 2005

INFESTATION	SIZE	HARDNESS
26 August	0.09	**-0.09**
8 September	-0.11	**-0.11**
23 September	**0.10**	-0.04
7 October	**0.25**	**0.10**
20 October	**0.14**	**-0.30**
31 October	**0.26**	**-0.13**

Table 9. Pearson linear correlation infestation /size and infestation/hardness of green drupes of 15 Sicilian olives cultivar in 2005

INFESTATION	SIZE	HARDNESS
26 August	0.09	**-0.09**
8 September	-0.01	**-0.11**
23 September	**0.11**	-0.03
7 October	**0.29**	-0.05
20 October	**0.23**	**0.15**
31 October	**0.57**	-0.11

Values in bold indicate statistically significat correlation (p<0,05)



Figures 3-4. Total infestation of differently coloured drupes of 15 Sicilian olives cultivar (Different letters denote statistically significant differences; ANOVA 1-way followed by Tukey post-hoc test; p<0.05)

Discussion

The results of our research confirm that none of tested Sicilian olive cultivars is resistant to olive fly attack. Nevertheless, a range of susceptibility among the different cultivars was found.

The sizes of drupes is considered by several authors one of the most important factors in the choice of olives by *B. oleae* female (Pucci & Ambrosi, 1981; Jimenez, 1988). The positive significant correlation between infestation levels and olive sizes seems to confirm this relationship. Moreover, the infestation level on cultivars characterized by large drupe size resulted usually higher than that one recorded on cultivars bearing small olives (Figure 5).

Olive hardness was proved to be another important factor in determining the choice of drupes for oviposition by *B. oleae* females (Martin, 1948; Orphanidis *et al*., 1958). The occurrence of a negative significant correlation between infestation and hardness was confirmed mostly during the early developing and ripening period of the olives, when all drupes are completely green, showing that hardness play an important role until the end of August- half of September.

Afterwards, when olives reach their nearly final sizes and become softer, they turn dark-coloured. Also the olive colouration seems to play a role in females choice (Katsoyannos, 1989). Indeed, green olives resulted more infested than brown ones, as found also by Orphanidis *et al.* (1959) and Cirio (1971).

As a result, cultivars such as Giarraffa and Pizzo di corvo, charachterized by large olives and early ripening period, were the most infested in September. Afterwards, the complete viraison of olives from these two cultivars, lead the olive fly females to prefer other cultivars for oviposition.

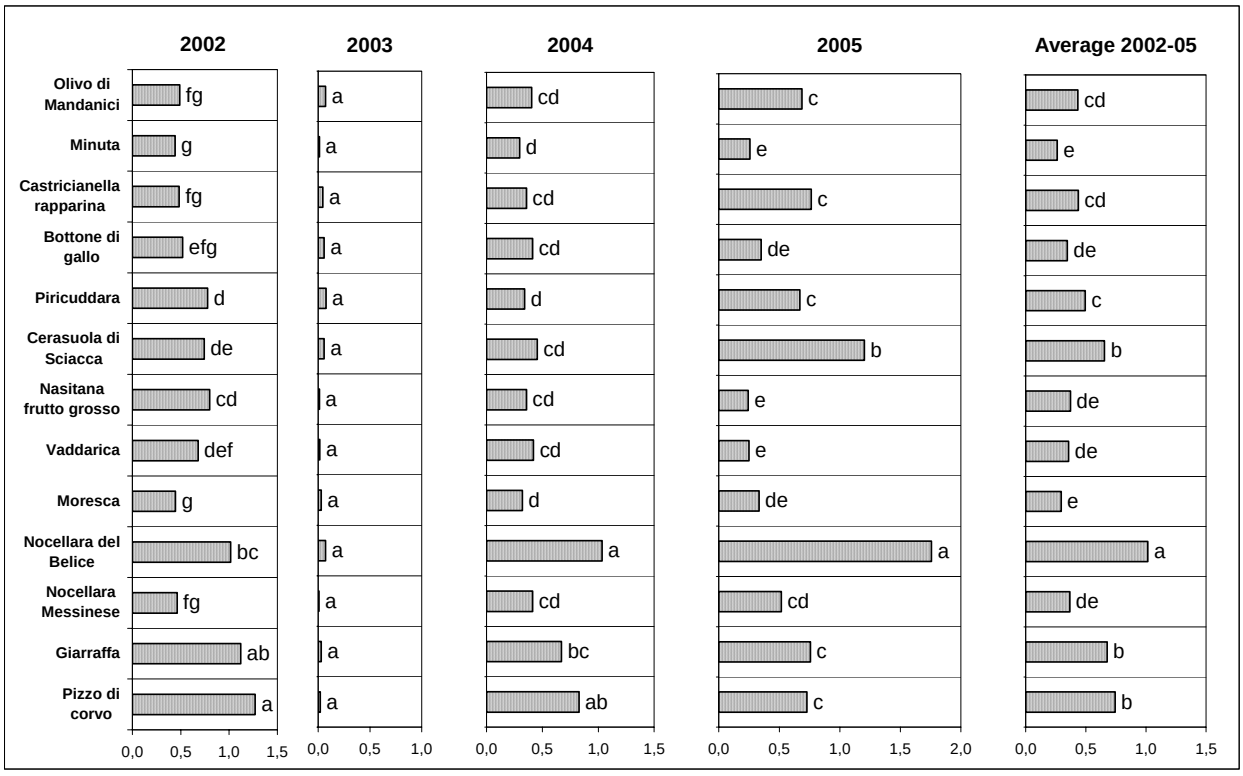


Figure 5. Mean values of total infestation in September and October in 13 Sicilian olive cultivars (listed in ascending order of size) from 2002 to 2005, and statistical analysis (repeated measurements ANOVA followed by Tukey test, $p<0.05$)

In the cultivars Moresca, Nasitana f. g. and Vaddarica, characterized by medium size olives and early maturation, almost 50% of olives on the trees is already blackish, in the first week of October; these three cultivars thus avoided the most harmful olive fly attack, commonly occuring at the end of October.

Among the tested cultivars, Nocellara del Belice resulted the most susceptible to the olive fly attack, both for the large olive size and the still green colouration at the end of October. On the other hand, Nocellara messinese, in spite of the large olive size, resulted one of the less attacked cultivar, with infestation levels similar to the small cultivars (Figure 5). As Nocellara del Belice and Nocellara messinese have also in common a high fruit hardness and a green colouration until the end of October, but their susceptibility is highly different, other (physical, chemical) factors are surely involved in determing this difference.

Also in the susceptibility to *B. oleae* attacks Giarraffa and Pizzo di corvo did not show statistically significant differences in mean values of the all the years, according to La Mantia *et al*., (2005) considering them synonyms.

Among the cultivars producing small olives, Minuta showed the lowest susceptibility, probably due to both the small olive size and to the brown colouration that more than 50% of olives had in the first half of October.

The wide range of susceptibility level shown by tested cultivars could be useful in organic olive growing. In the most susceptible cultivars, to limit damages due to *B. oleae* early harvesting and effective interventions are necessary; less susceptible cultivars (Nocellara messinese, Moresca, Vaddarica, Nasitana f. g., Minuta, Bottone di gallo) could be suggested for new organic olive plantings for oil or table olives production.

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