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Application of a statistical forecast model on the olive fruit fly (*Bactrocera oleae*) infestation and oil analysis in Albania

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Abstract

In our paper we evaluated a statistical-mathematic forecast model on the seriousness of the infestation of *Bactrocera oleae* (Rossi) which is in some years particularly favourable to Tripetidae, and can cause considerable qualitative and quantitative damage. Three cultivars which represent the Albanian olive-growing environment were taken into consideration: "Boçi", "Kalinjot" and "Ulliri i Bardhë i Tiranës". It was necessary to do treatment only for the Boçi cultivar while the Ulliri i Bardhë i Tiranës and Kalinjot were not treated because the intervention threshold (Z) was not reached. At harvest, Ulliri i Bardhë i Tiranës and Kalinjot showed slight levels of infestation (about 7%) and the oils obtained were of outstanding quality (extra virgin). The untreated Boçi cultivar, instead, had 67% infested drupes at harvest and the oil extracted showed serious defects and an acidity of 1.97. 2010 was marked by a high intensity of infestation detected in the Boçi cultivar that has allowed us to prove the validity of the mathematical forecast model on the seriousness of the infestation. It is worth noting that in years of low intensity of infestation, we would not have significant responses, as we have highlighted in several olive groves in Italy and abroad. The results indicated that the applied model accurately forecasts the trend of the infestation regarding the average catches of females/trap/week and the average temperature of the same week. In light of the present results, we suggest extending research to other native cultivars and in different olive-growing environments; this will allow us to single out more suitable cultivars which can be included in the development programs of the Albanian olive-growing.

Key words: *Bactrocera oleae*, statistical model, IPM, olive oil analysis, Albania.

Introduction

The olive, typical of the tradition of Albanian agriculture, is mainly found in the hilly areas that extend along the Ionic and Adriatic coast from Saranda to Scutari. Today the crops cover a surface of 41.000 ha with approximately 5.300.000 plants. The areas involved are in Valona, Berat and Tirana, which have respectively 36.1, 16.0 and 11.0% of the total of the plants existing in Albania. The annual production is around 20.000 and 50.000 tons of olives, with an average production of oil equivalent to 6.000 tons. It is interesting to notice that only 10% of the oil produced is extra virgin quality, which can be attributed to the old-fashioned cultivation techniques of extraction and conservation. There are 23 oil cultivars now described from a morphological point of view (Thomaj and Panajioti, 2005). The plants which do not usually undergo appropriate cultivation techniques, present very variable planting layouts and in several cases are more than a hundred years old.

Olive cultivation is now continually developing, fostered by today's agricultural policies which aim to promote the production and bedding of new groves.

For this, a modern nursery complex was inaugurated in October 2010, managed by the Agricultural University of Tirana and capable of producing 500.000 plants per year.

The first step to take, however, is to increase the value of the production of native cultivars in order to get precise indications of those which are most suitable. Therefore, preliminary work is absolutely necessary to verify the quantitative and qualitative characteristics of the product. In our paper the relative results of the production defence technique are given as well as the qualitative characteristics of the oil obtained from three native cultivars. With regard to this, a statistical mathematic forecast model was applied in this paper concerning the seriousness of the *Bactrocera oleae* (Rossi) infestation seen in the olive areas of central and southern Italy as well as in Croatia and Spain, since the Tephritidae was certainly the key insect capable of producing a considerable amount of quali-quantitative damage (Zuzic *et al*., 1993; Castoro and Pucci, 1996; Pucci *et al*., 1997, 2006; Speranza *et al*., 2003; Alilla *et al*., 2009).

Materials and methods

In June 2010 two olive groves, typical of the Albanian olive environment, were singled out around Tirana, in the Sauk region at 400 m a.s.l. The cultivars studied were: "Ulliri i Bardhë i Tiranës" (white olive of Tirana) and "Boçi" in one olive grove, "Kalinjot" in another bordering grove. The first olive grove mainly includes plants of the Boçi and Ulliri i Bardhë i Tiranës cv (late-blooming variety) which are 50-60 years old, as well as the Kalinjot cv (late-blooming variety) 16-20 years old. The planting layouts for Kalinjot are 6 × 6 meters and 8 × 8 per the Boçi and Ulliri i Bardhë i Tiranës cv. The latter two cultivars were heavily trimmed in 2008. The

second olive grove has mainly Kalinjot and different cv such as Frantorio, Koreneiki, Kalamon and even Kokërrmadh Berati (The big fruit of Berati).

The plants have not received pesticide treatments or other crop procedures for many years. The olive harvest is usually done by hand pole beating and the olives are stocked for more than a week before being milled. Research covered the study of the flight dynamics and an examination of the infestation of *B. oleae* (Ballatori *et al*., 1980), along with the possibility of pesticide treatments and the analysis of the qualitative characteristics of the oil obtained.

In order to assure olive health, we organized the use of an effective pesticide for eventual pesticide interventions. For this reason, dimethoate was used at a dose of 40 grams of a.i. per hl of water.

The harvest in the two olive groves in our experiment was done manually at 89 BBCH code and oil extraction within 24 hours (Neuenschwander and Michelakis, 1978). The oil mill used was the two-phase Pieralisi and the crushing temperature was maintained constant around 27 °C; the oil obtained, distinctly per cultivar, underwent chemical and organoleptic analysis.

Climatic parameters were also identified by weather detectors at the Faculty of Agriculture of the University of Tirana.

Trapping of adults

For each of the three cultivars examined, 24 representative plants were singled out; in each of them a yellow chromotropic trap (wavelength, 560-570 nm) 15 × 20 cm was installed, made sticky with Temocid® glue (Kollant company in Padua, Italy) exposed to the south, at halfway the height and tangent to the foliage. At a weekly rate, starting end July, the number of females caught were counted both on the internal and external sides of the trap in the 24 traps used.

Fruit infestation

Every week, samples of 25 olives per plant were picked at random from the foliage. In all, one hundred olives per cultivar were dissected in the plots eventually to be treated and one hundred from the control plot. The samples were transferred to the laboratory and dissected and examined with a stereomicroscope to confirm the active infestation in the following categories: egg + first-instar larvae (L1), second and third-instars larvae (L2 + L3), pupae + empty puparia + abandoned galleries (p + ep + ag).

Model application

The study of the relationship between females caught with chromotropic traps and drupe infestation done in the olive environment of northern Latium for the Canino cultivar, allowed us to formulate a precise equation via the elaboration of a statistical model of canonical analysis, once the average number of females caught per trap and per week is known, and the subsequent evolution of the infestation (Pucci *et al*., 1990; Pucci and Paparatti, 1994).

In particular, the strictly related variables found were: on one hand, the number of females reported at a certain date and the average temperature registered during the trapping week (Z) and on the other hand the infestation distinguished in: eggs + L1, L2 + L3, pupae + empty puparia + abandoned galleries reported on the hanging fruit and falling fruit (W). The W variable is to be considered an index of infestation, above all in reference to the L2 + L3 and pupae + ep + ag stages which are closely connected to this canonical variable (both in reference to the foliage and the fruit falling) and which determine the most serious damage. To calculate the Z value in reference to a certain date (included in the period before the hardening phase of the fruit stone in the first ten days of October), the following expression/formula needs to be applied:

$$Z = 0.039\ (Fm - 9.7) - 0.186\ (Tm - 22.1)$$

Where Fm is the average number of females/trap/week and Tm is the average temperature reported in the week of catches. Only if the threshold value Z is greater than 0.10 is it advisable to intervene in order to block the evolution of the infestation.

This model was developed in the olive environment of central Italy (Pucci *et al*., 1997; 2006; Speranza *et al*., 2003; Alilla *et al*., 2009) and successfully applied in Croatia and southern Italy (Zuzic *et al*., 1993; Castoro and Pucci, 1996). The application of the above-mentioned model allows us to avoid the expensive sampling and dissection of the drupes to verify the infestation.

To develop the projected statistical model in other olive environments, some methodological requirements need to be respected in order to make some observations:

- It is absolutely necessary to use chromotropic traps (made sticky with Temocid® glue, yellow colour, size 15 × 20 cm.), in numbers of 4 in the first hectare and one per each following hectare, placed one for each plant and arranged towards the south, at tangents and halfway height of the foliage;
- It is advisable to verify the infestation just before completing the phenological stages of stone hardening by taking casual samples of 200 drupes from 10 representative plants per hectare (Pucci *et al*., 1990). The sampled olives must be dissected to verify the entity and type of infestation;
- The count of the number of caught females on the internal and external side of the traps must be done synchronously with the drupe sampling;
- The data of average weekly temperature must be recorded.

In order to proceed with the application of the model, it is necessary to record the average number of caught females in a certain week (Fm) and the value of the average temperature (Tm); then insert these data into the above-mentioned equation via the use of a specific software to determine the value of Z. Treatment can follow only if this value Z exceeds 0.10.

It is appropriate to point out that the statistical model described expresses the seriousness of the infestation only if females are caught. Furthermore, if the threshold value of $Z > 0.10$ is exceeded after the first ten days of October, it is no longer necessary to use insecticide treatment because after this date the weather conditions are generally unfavourable to the evolution of the infestation and also in this period the autumn generation is dying out.

Chemical analysis of the oils

The following qualitative parameters on the oils were given: acidity, number of peroxides, extinction coefficients K232, K270, percentage composition of the methylic esters of the fatty acids according to official methodologies (Reg. EC 2568/1991).

Determination of the biophenols was done according to the norms of the International Olive Oil Council (IOOC/T.20/Doc.n.29, Nov 2009). The methodology is based on an extraction of the minor biophenol polar compounds directly from the olive oil via a metabolic solution and subsequent quantitative determination via HPLC with a 280 mm UV receptor. The internal standard was made up of syringic acid. The content was expressed in mg/kg of tyrosol.

Sensory analysis of the oils

The sensory analysis was done with the help of the form printed out by the panel of The Olive Growing and Olive Product Industry Research Centre (CRA-OLI), obtained on the base of indications of the International Olive Oil Council (IOOC) for the sensory characterisation of the oils. The analyses were conducted in the panel room of the CRA-OLI, coordinated by Massimiliano Pellegrino, head of the panel (CRA-OLI).

Results

The average catches per trap, for the three cultivars examined, were quite low until September 27, with a maximum peak of 7 units for the Boçi cv on September 13 (figure 1). This was determined by the high temperatures recorded (figure 2), hostile to the development of the olive fruit fly (Pucci *et al*., 1982).

After this date, from September 25-29, there were 50.4 mm of rain recorded, with a consequent lowering of the average temperatures. This influenced the dynamics of the flights with a maximum peak, for the Boçi cv, of 54 females/average/trap; this led to a significant downswing in the number of females caught. For the other two cultivars, the catches were distinctly inferior to the previous ones, with a maximum of 14 females, for the Kalinjot cv, on October 23. It should be highlighted that for the Ulliri i Bardhë i Tiranës cv, the catches were zeroed on October 17. Regarding the trend of the catches of the only treated cultivar (Boçi), a significant decrease was recorded in the number of females caught until October 23, with an average of 2 females per trap. The total number of females catches per trap has been for the cultivar Boçi not treated of 128 insects, for the Ulliri i Bardhë i Tiranës 41, for the Kalinjot of 31 and for the Boçi treated of 27 insects.

Infestation

Boçi cultivar (untreated)

In tune with the trend of the catches, even the infestation dynamics (figure 3) was quite limited until October 4. After this date, as a consequence of the rains and the lowering of the temperatures, there was a sudden increase with approximately 40% in eggs and first-stage larvae, 11% in second and third-stage larvae and 8% in pupae and abandoned galleries. In the following sampling dates the overall infestation was maintained at about the same levels but varying, as was expected, in percentages regarding the presence of the single development stages.

During the year of study, the infestation should be considered average late. During the harvest the infestation has reached the 67% of olive damaged by third larval stage, pupae and abandoned galleries.

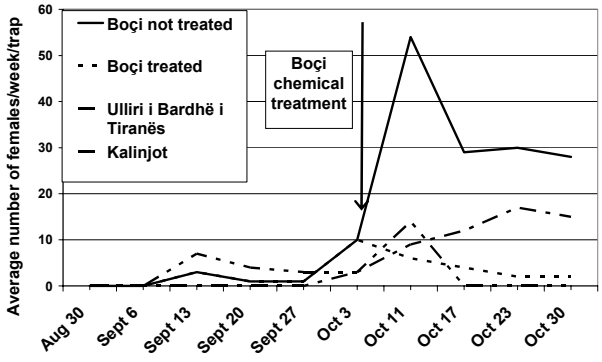

Figure 1. Trend of the weekly catches of females/trap of *B. oleae* for the three cultivars under observation.

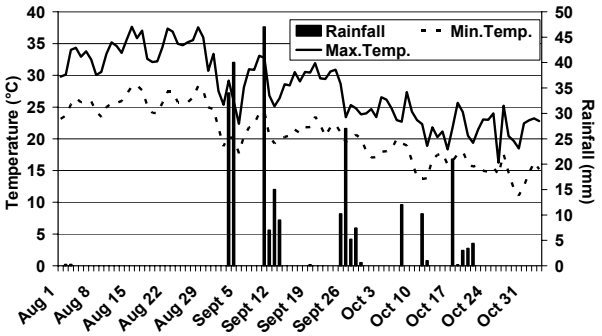

Figure 2. Weather data (rain, maximum and minimum temperature) for the sampling period.

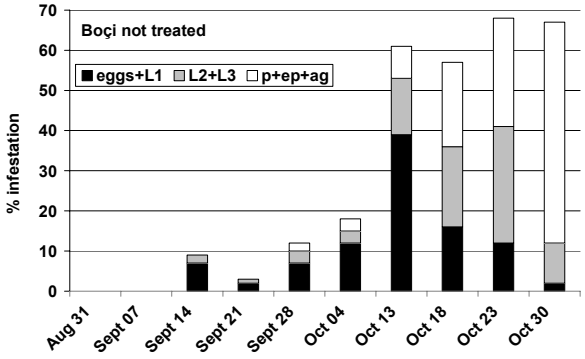

Figure 3. Weekly trend of the active infestation, differentiated in the various development stages, for the untreated Boçi cultivar.

Boçi cultivar (treated)

A trend of total infestation (figure 4) shows up similar to the previous one with a maximum value of 30% represented mostly by eggs and first-stage larvae on October 3, when the Z index was exceeded and therefore the insecticide treatment was done with dimethoate (October 4), which determined a significant and progressive decrease in the infestation which on October 30 stopped at around 5%.

Ulliri i Bardhë i Tiranës cultivar (untreated)

Up to September 28 (figure 5), no infestation of the drupes was recorded from examining the weekly samples. Starting from October 4, the date in which an infestation of 3% was recorded and attributable to eggs and first-stage larvae, a subsequent growth was seen in the following week when it reached 12%, then followed by a slight decrease until claiming a 7% rate at harvest (October 30). No insecticide treatment was done since the Z > 0.1 threshold was not exceeded.

Kalinjot cultivar (untreated)

By examining figure 6, the first signs of infestation are shown only in the last two dates of sampling with values at 2% attributable to eggs and first-stage larvae. This is a late ripening cultivar like Ulliri i Bardhë i Tiranës which eludes the infestation due to the fact that it is a late receptor to the fly attack. No insecticide treatment was done, as for the Ulliri i Bardhë i Tiranës cv.

Statistical analysis on infestation at harvest showed the highly significant difference ($P \leq 0.05$) between the not treated Boçi cultivar and the other ones.

Application of the statistical mathematical forecast model on the seriousness of the infestation

As can be seen in figure 7, the application of the statistical forecast model on the seriousness of the infestation, already mentioned, anticipated the use of treatment only when the seriousness index exceeds Z > 0.10. This situation came about exclusively for the Boçi cultivar on October 3. The next day, therefore, the insecticide treatment was done. For the other two cultivars (Ulliri i Bardhë i Tiranës and Kalinjot), even though the "Z" index was exceeded the following week (October 11) we did not see the need for intervention since previous studies (Pucci *et al.*, 1990) showed that after that date the infestation will not suffer successive and significant increases which justify the use of an insecticide, and also because treatment cannot be done when the harvest date is drawing near.

Qualitative characteristics of the oil

Analysis of the oil

All the samples studied (table 1) were positive regarding their commodity category, and classified as "extra virgin", as defined in Vossen and Devarenne (2011), with the exception of the untreated Boçi sample for which there was a high value of acidity recorded, equivalent to 1.97 ("virgin" category). This recorded defect can be attributed to the high number of abandoned galleries from the mature larvae present in the drupes, with consequent fermentation processes.

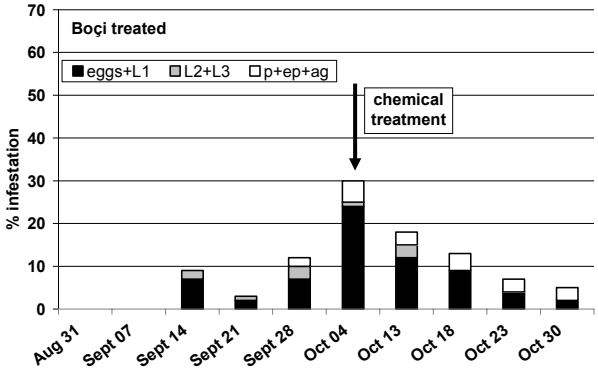

Figure 4. Weekly trend of the active infestation differentiated in the various development stages, for the treated Boçi cultivar (the arrow indicates the treatment date).

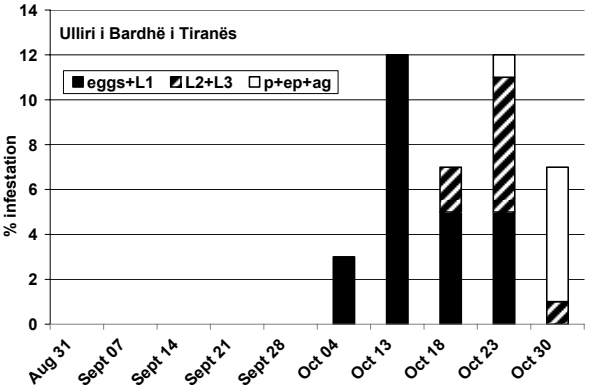

Figure 5. Weekly trend of the active infestation for the Ulliri i Bardhë i Tiranës cultivar.

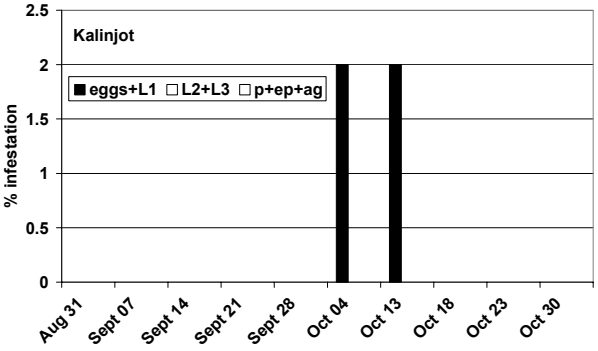

Figure 6. Weekly trend of the active infestation for the Kalinjot cultivar.

Among the cultivars examined, Kalinjot was of excellent quality thanks to the panel test score (7.80), sensory intensity, fatty acid composition, with values in oleic acid of 76.84. Kalinjot also showed a better amount of biophenols (316 mg/kg). From a sensory point of view, the cultivar showed pronounced and persistent bitter and spicy hot scents.

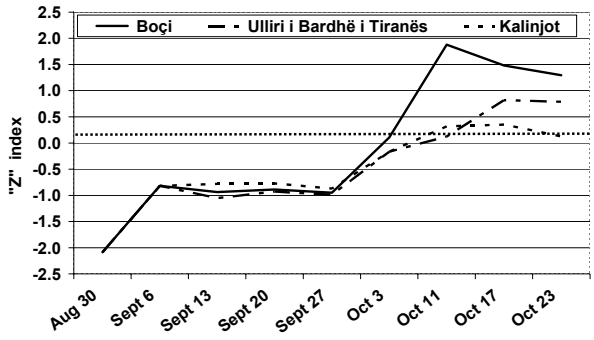

Figure 7. Weekly trend of the forecast of the seriousness of the infestation expressed by the "Z" index.

The Ulliri i Bardhë i Tiranës recorded the lowest value of free acidity (only 0.42) and a good content of oleic acid (76.92) while the levels of biophenols (115) were more limited. The superb panel test score places the oil of this cultivar among those of outstanding quality with medium intensity but with pronounced bitter and spicy hot scents, besides those of aromatic herbs and walnut.

The oil of the "treated Boçi" has less quantity of oleic acid (68.50) compared to the others which were tasted, not a high quantity of total polyphenols (146) and an outstanding score for the taste test (7.40), medium intensity and a medium fruity taste with herb and walnut scents.

Overall, for Ulliri i Bardhë i Tiranës, Kalinjot and treated Boçi, the respective oils examined are to be considered of outstanding quality and able to compete on the international market in the high and medium intensity fruity categories. Considerable defects and a high level of acidity were found for the Boçi without insecticide treatment.

Discussion

The 2010 experiment in Albania regarding the Ulliri i Bardhë i Tiranës, Kalinjot and Boçi cultivars showed that it is possible to obtain good quality oils able to compete at an international level. In particular, it should be noted that for the 2010 olive oil year, it was only necessary to intervene chemically on the Boçi cultivar, while the Ulliri i Bardhë i Tiranës and Kalinjot cultivars did not need intervention as the Z index was not exceeded.

2010 was marked by a high intensity of infestation detected in the Boçi cultivar that has allowed us to prove the validity of the mathematical forecast model on the seriousness of the infestation. It is worth noting that in years of low intensity of infestation, we would not have significant responses, as we have highlighted in several olive groves in Italy and abroad.

Even though interventions were not done for the latter two, good quality oils (extra virgin) were obtained,

Table 1. Chemical and sensory analysis of the oils of the examined cultivars.

	Kalinjiot	Ulliri i Bardhë i Tiranës	Boçi not treated	Boçi treated
Acidity	0.56	0.42	1.97	0.56
Peroxide number	5.20	6.40	8.20	7.60
K232	1.78	1.51	2.20	2.44
K270	0.15	0.07	0.19	0.15
Δ K	0.00	0.00	0.00	0.00
C14:0 myristic acid	0.01	0.01	0.01	0.02
NI R.T. 6.9	0.04	0.06	0.02	0.02
NI R.T. 7.4	0.05	0.03	0.02	0.07
C16:0 palmitic acid	9.35	9.98	11.16	13.24
C16:1 *cis*-palmitoleic acid	0.09	0.06	0.10	0.09
C16:1 *trans*-palmitoleic acid	0.25	0.30	0.48	0.53
Σ C16:1	0.34	0.36	0.58	0.62
C17:0 eptadecanoic acid	0.12	0.12	0.09	0.12
C17:1 eptadecenoic acid	0.20	0.19	0.19	0.22
C18:0 stearic acid	2.66	2.59	1.84	1.86
C18:1 oleic acid	76.84	76.92	71.67	68.50
C18:2 linoleic acid	8.78	8.16	12.86	13.81
C20:0 arachic acid	0.40	0.43	0.31	0.35
C18:3 linolenic acid	0.79	0.74	0.78	0.69
C20:1 eicosenoic acid	0.19	0.18	0.27	0.29
C22:0 behenic acid	0.15	0.13	0.11	0.12
C24:0 lignoceric acid	0.06	0.07	0.07	0.06
Total	100.00	100.00	100.00	100.00
Phenols	316.00	115.00	254.00	146.00
Category	extra virgin	extra virgin	virgin	extra virgin
Intensity	intense	medium	light	medium
Panel test score	7.80	7.50	5.00	7.40

therefore we hope for the proliferation of the new plantings. The economic future of Albanian olive growing depends on the production efficiency and above all on the quality of the oil produced.

This paper should be considered an initial contribution in the hope of extending the research to other native Albanian cultivars so as to single out which other cultivars are able to produce good qualitative and quantitative production that promote adequate development programs which interest the production chain starting from the cultivation to the commercialization of oil. Only in this way can the Albanian olive growing place itself at the same levels of the current producers of quality oil.

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