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FRUIT PRODUCTION BY *VACCINIUM SPECIES* IN THE TUSCAN-EMILIAN APENNINES AND A NEW *VACCINIUM VITIS-IDAEA* L. SITE IN THE AREA

Abstract - Si. Vergari, G. Dondini, I. Nerozzi, F. Sabatini, G. Sabatini, Se. Vergari, *Fruit production by* Vaccinium species *in the Tuscan-Emilian Apennines and a new* Vaccinium vitis-idaea *L. site in the area.*

Three species of blueberry grow in the Pistoia Apennines: European blueberry (*Vaccinium myrtillus* L.), Bog bilberry (*Vaccinium uliginosum* L.) and Lingonberry (*Vaccinium vitis-idaea*). *Vaccinium* vegetation develops maximally above the tree line. The ecological and economic importance of these species highlights the need to monitor and analyze aspects of their biology. Here we present our findings relating to the vegetation structure of a large population of *Vaccinium*, dominated by *V. vitis-idaea*, recently discovered on the Pistoia Apennines. Furthermore, we provide quantitative data on fruit production, soil pH, microclimate and biometry of fruits in *V. myrtillus*, *V. uliginosum* and *V. vitis-idaea*. A program of monitoring should be carried out over several years to verify any quantitative trends and determine whether increasingly marked climate changes may influence the relative abundance, distribution and fruit-production capacity of these *Vaccinium* species.

Key words - Blueberries, *Vaccinium* sp. pl., mountain ecology, Tuscan-Emilian Apennines, Italy

Riassunto - Si. Vergari, G. Dondini, I. Nerozzi, F. Sabatini, G. Sabatini, Se. Vergari, *Produzione di frutti di specie del genere* Vaccinium *L. sull'Appennino Tosco-Emiliano e una nuova stazione di* Vaccinium vitis-idaea *L.*

Le formazioni vegetali dominate da specie del genere *Vaccinium* trovano il loro massimo sviluppo sopra il limite della vegetazione arborea. Sull'Appennino Pistoiese sono presenti tre specie di mirtillo: mirtillo nero (*Vaccinium myrtillus* L.), falso mirtillo (*V. uliginosum* L.) e mirtillo rosso (*V. vitis-idaea* L.). La loro importanza ecologica ed economica necessita un approfondimento conoscitivo su alcuni aspetti della biologia. Sono qui presentati i risultati relativi alla produzione di frutti, pH del suolo, microclima. Si sottolinea l'importanza di elaborare un monitoraggio su più anni per verificare eventuali andamenti quantitativi anche in previsione di cambiamenti climatici che ne potrebbero influenzare abbondanza relativa, distribuzione e produzione.

Parole chiave - Mirtilli, *Vaccinium* sp. pl., ecologia montana, Appennino Tosco-Emiliano, Italia

Introduction

On the Tuscan-Emilian Apennines, above the vegetation essentially consisting of beech forest, grows the so-called blueberry heath, dominated by the European blueberry (*Vaccinium myrtillus* L.) and the Bog bilberry (*Vaccinium uliginosum* L.) (Pirola and Corbetta, 1971; Foggi *et al.*, 2007). This type of vegetation is peculiar to the alpine areas of Italy and can be considered a relic from the last glacial era, although its distribution and abundance has been modified by centuries of human activity (Chiarugi, 1936; Bertolani-Marchetti, 1963; Losacco, 1982; Foggi *et al.*, 2007; Vescovi *et al.*, 2010). *Vaccinium* sp. pl. are distributed significantly on the ipsophilous prairies of the Northern Apennines, where they are extremely important to the protection of the thin and unstructured soils that are typical of these high-altitude habitats. For example, the extensive rhizome network found in whortleberry can aid in preventing soil erosion (Ferrarini, 1977; Ferrari, 1978; Vander Kloet & Hall, 1981). The whortleberry plant provides cover for small birds and mammals, and the berries are eaten by many birds and mammals including hares, voles, grouse and partridges (Ritchie, 1956).

On the basis of floristic differences, two types of bilberry phytocoenosis have been defined: one, similar to the Alpine type, is characterized by the dominance of *Empetrum hermaphroditum* Hagerup and *V. uliginosum*; the other, typical of the Apennines, is dominated by *V. myrtillus* and *V. uliginosum* (Ferrari, 1978; Ferrari & Piccoli, 1997; Foggi *et al.*, 2007). European blueberry has considerable local economic importance, with the fruit being harvested both for direct sale and subsequent processing into other food and phytotherapeutic products (Modena, 1939; Ciatti, 1977; Ronchieri & Mazzei, 1997).

In the Pistoia Province, Lingonberry (*Vaccinium vitis-idaea* L.) was originally reported in 1891 near Boscolungo (Levier & Sommier, 1891), where it was present "in large bushes, but for the most part sterile" and where it has not been found since. The only confirmed site, which is limited in size, is one on Mount Gomito (1892 m a.s.l.) (Ronchieri & Mazzei, 1997; Romagnoli & Foggi, 2005; Gabellini *et al.*, 2006). However, another site containing this species was discovered near Croce Arcana (San Marcello-Piteglio Municipality), allowing fruit production to be estimated.

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No data on European blueberry production are available for Tuscany, except for estimates with values of 180 quintals of saleable product (see Ciatti, 1977). Besides being of economic value in Tuscany as a whole (4060 Natura2000 code), this species are of very significant local economic value (Vampa *et al.*, 1978; Alessandrini *et al.*, 2003). Despite its importance, information about fruit production in the area remains limited, and, furthermore, proposals for management strategies to ensure sustainable crop production are required. The purpose of this work was to provide data on the production of fruit by the three *Vaccinium* species in the Tuscan-Emilian Apennines.

Material and methods

Study area

On the Tuscan-Emilian Apennines, the area dominated by Blueberry phytocoenosis is divided into two geographical districts (Ronchieri & Mazzei, 1997): the first constitutes the ridge between the Libro Aperto and Gennaio Mount, while the second is between Alpe delle Tre Potenze and Foce di Campolino (upper Sestaione Valley) (Fig. 1). The area included in this survey was between the Passo della Croce Arcana (1669 m a.s.l.) and Gennaio Mount (1813 m a.s.l.), San Marcello-Piteglio Municipality, Pistoia Province, within the borders of the Special Areas of Conservation (SAC) IT5130006 "Monte Spigolino-Monte Gennaio". The dominant geological substratum consists of the arenaceous formations of Macigno, Modino Mount and Cervarola Mount Sandstone (Bortolotti, 1992; Losacco, 1982). Rainfall exceeds 2000 mm per year with snow cover that in some years continues for 100 days. In particular, the rainfall during the 3 months prior to fruit ripening (May, June and July) was 328 mm in 2018, 463.8 mm in 2019 and 410 in 2020 (Melo-Cutigliano station, Settore Idrologico e Geologico Regionale, https://www.sir.toscana.it/). The new site of *V. vitis-idaea* growth, found in Croce Arcana, is located almost completely in the territory of the municipality of San Marcello-Piteglio, with a small portion in the municipality of Abetone-Cutigliano (Pistoia Province, 44° 7' 35'' N - 10° 47' 1'' E; SCI Monte Spigolino - Monte Gennaio, code IT5130006). It occupies an area of over 1100 m^2, with prevalent exposure to the east, south-east and a predominant inclination between 25° and 45°, at an altitude between 1620 and 1650 m a.s.l.

Fruit production estimation

Fruit production was estimated by randomly selecting a total of 65 × 1 m^2 phytocoenoses of the three investigated species. Each area was at least 95% covered by one of the species. In particular, 30 areas were selected for the presence of *V. myrtillus* (10 in 2018, 10 in 2019 and 10 in 2020); 20 areas for the presence of *V. uliginosum* (10 in 2019 and 10 in 2020) and 15 areas for the presence of *V. vitis-idaea* (five in 2019 and 10 in 2020). In each area, all fruits were collected at the time of maximum fruiting and weighed (wet weight). The average wet weight (Ww ± SD) values were calculated. A sample of 100 g of each type of berry was placed in a ventilated oven at 105 °C for 24 h and subsequently weighed (dry weight, Wd). The percentage of water in the samples was calculated.

Figure 1. Study area (black dot) in the municipality of San Marcello-Piteglio (Province of Pistoia, 44° 7' 35'' N - 10° 47' 1'' E).

Soil pH

Soil samples were taken at a depth of 10 cm from 10 sites distributed between plant formations dominated by European blueberry, Bog bilberry and Lingonberry; 10 g of soil were added to 25 ml of distilled water; after stirring and resting for at least 15 min to reduce the turbidity of the suspension, the pH was measured using a pH meter (PCE-PHD model 1) with a suitably calibrated glass electrode.

Table 1. Fruit production in the three species of blueberries. N=number of sampled 65 m^2-plots. SD= standard deviation of the mean.

	Vaccinium myrtillus			*Vaccinium uliginosum*			*Vaccinium vitis-idaea*		
Year	**N**	**mean (g/m^2)**	**SD**	**N**	**mean (g/m^2)**	**SD**	**N**	**mean (g/m^2)**	**SD**
2018	10	40.2	41.0	- - -	- - -	- - -	- - -	- - -	- - -
2019	10	225.3	140.3	10	171.5	111.3	5	18.0	7.5
2020	10	68.9	45.5	10	45.6	70.2	10	74.2	118.2

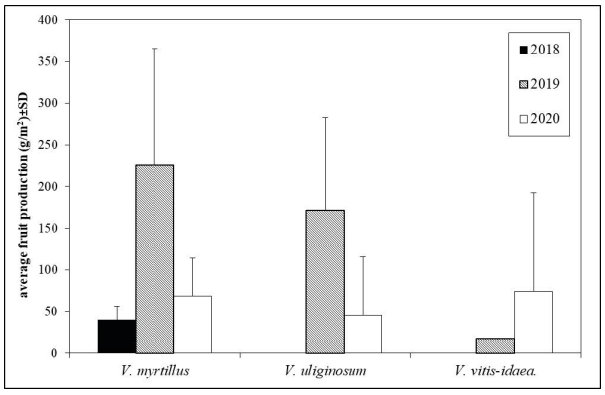

Figure 2. Fruit production for the three species of blueberries. For the European blueberry the production of 2018 is compared with that of 2019 and 2020.

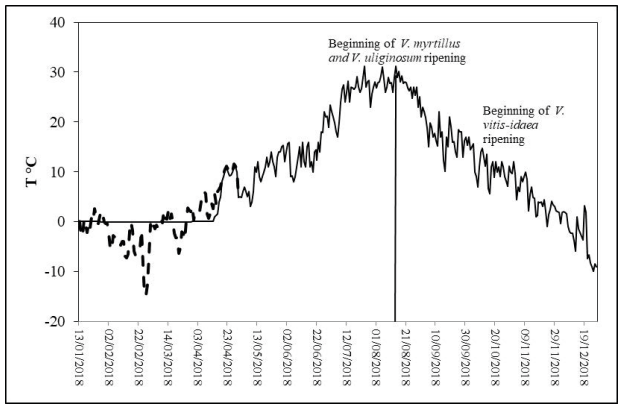

Figure 3. Mean daily ground-level (solid line) and above-ground (broken line) temperatures based on the data collected by the dataloggers in the codominant Lingonberry and European blueberry station. The above-ground temperature was measured at 1.5 meter above the ground from January to April, during which period the ground temperature (under a continuous snow cover) remained constant at 0 °C.

Microclimatic characterization

A datalogger sensor U23-001 from HOBO was placed on the ground to measure temperature (°C). An automatic measurement was taken every 4 h from January 2018 to January 2019. The collected data were downloaded regularly via an Optic USB Base Station BASE U-4 and analyzed with Hoboware pro 3.1 software. The chosen site (1640 m s.l.m., 44° 7' 25'' N - 10° 46' 26'' E) had a south-west exposure, dominated by *V. myrtillus* and subordinately by *V. vitis-idaea*. From 15 January 2018 to 15 April 2019, temperature measurements were also taken over the snow cover with a HOBO datalogger sensor U23-001 located about 1.5 m above the ground.

Biometry of fruits.

The weights of 80 fruits for each of the three randomly selected blueberry plants collected in 2019 were measured with a Sartorius electronic scale (± 0.01 g), and the diameters were measured with calipers (± 0.1 mm). The viable seeds from 80 fruits of each species were counted.

Each type of measurement was tested for normality distribution and analyzed using parametric statistics (one-way ANOVA and Tukey's test), according to the normality test results, with PAST 3.06 software (http://folk.uio.no/ohammer/past/).

RESULTS

Fruit production estimation

The estimate of fruit production showed both annual and species variations (Tab. 1, Fig. 2). In *V. myrtillus* in particular, there was a difference in fruit production over the course of the 3-year study, with a peak in 2019. The average rate of fruit production over the 3 years in this species was 92.3 g/m^2 (± 92.6). A similar difference was observed in *V. uliginosum* between 2019 and 2020 (Tab. 1). The average rate of fruit production over 2 years was 74.7 g/m^2 (± 95.6). In *V. vitis-idaea* the average rate of fruit production over 2 years was 27.5 g/m^2 (± 43.2). The percentage of water in the fruits was 84.4% in *V. uliginosum*, 85.2% in *V. myrtillus* and 84.2% in *V. vitis-idaea*.

Soil pH

The observed values of soil pH ranged from a minimum of 4.1 to a maximum of 5.7 with an average of 4.72 (± 0.44).

Table 2. Biometry of fruits in three blueberry species, tested with one-way ANOVA followed by Tukey's test. Mean values ± standard deviation are given (N = 80, sampled in 2019, for all measurements). D = diameter (mm; F = 164.1, p < 0.001), W = weight (g; F = 169.1, p < 0.001), S = number of seeds per fruit (F = 129; p < 0.001). Different letters show significant differences in pairwise comparisons.

Species	D (mm)	W (g)	S (n)
V. myrtillus	**8.78** ± 0.89[a]	**0.35** ± 0.10[a]	**23** ± 6.9[a]
V. uliginosum	**8.35** ± 0.76[ab]	**0.27** ± 0.07[ab]	**23** ± 6.7[b]
V. vitis-idaea	**6.53** ± 0.83[b]	**0.13** ± 0.05[b]	**11** ± 5.7[ab]

Microclimatic characterization

The measurement of the temperature within the vegetation highlighted the insulating effect of the snow cover. With an outdoor temperature of -17 °C, constant temperatures of around 0 °C were measured under the layer of snow at ground-level (Fig. 3). In the summer, direct exposure to the sun led to temperatures of around 30 °C at ground-level under the blueberry plants. These high temperatures were recorded during the period of fruit ripening for both *V. myrtillus* and *V. uliginosum*, between the end of July and the first two weeks of August. The maturation of *V. vitis-idaea* took place between the end of September and the first week of October, when the temperatures were significantly lower (Fig. 3).

Biometry of fruits

The diameter and weight of the fruits from the three species were significantly different (Tab. 2). In particular, fruits from *V. myrtillus* exhibited the highest values compared with those of *V. uliginosum* and *V. vitis-idaea*. The average numbers of viable seeds in *V. myrtillus* (23) and *V. uliginosum* (23) fruits were not significantly different. A significant difference was, however, found in comparison with the fruits of *V. vitis-ideae* (Tab. 2).

Discussion

Fruit production exhibited significant differences among the three species and over the years of study. In particular, a significant difference in fruit production by European blueberry was observed between 2018, 2019 and 2020. The production of fruits increased significantly in 2019 and decreased drastically in 2020. Moreover, fruit production in *V. uliginosum* decreased significantly between 2019 and 2020. For *V. vitis-idaea*, it was not possible to highlight significant differences between 2019 and 2020, perhaps due to the high variability of the samples, which may have been caused by the different levels of rainfall during the three seasons included, especially during the period between May and July, just before fruit ripening. In fact, the highest amount of rainfall was registered in 2019, the year in which both *V. myrtillus* and *V. uliginosum* bore the most fruit. The findings led us to suggest that fruit production was poor when the winter snow cover was less than 20 cm in depth. Flower buds were then vulnerable to damage by cold winter temperatures. In some areas, flower bud development may be greatly reduced when January temperatures reach -32 to -34 °C (Raatikainen & Vanninen, 1988). Unfortunately, no precise data about snow levels are available in order to enable more precise correlations with the amount of fruit produced. Further investigation is therefore necessary to determine which ecological factors can positively or negatively influence this parameter and enable more careful management.

In *V. myrtillus* the mean number of fully ripe seeds per berry was 23, higher than the value of 17.9 previously observed in the UK (Ritchie, 1956). In *V. uliginosum*, the average number of viable seeds varies. For example, in Iceland a value of 13 was reported (Guitian *et al.*, 1994), while a value of 14 was reported in Canada (Kloet & Hill, 1994) and 25 in Sweden (Ehrlèn & Eriksson 1993). The maximum diameter of the fruit was reported to be on average 7.32 mm in Iceland and 7 mm in Canada, while our measurement was 8.35 mm. Jacquemart (1996) reported a maximum fruit diameter of between 7 and 10 mm (Jacquemart, 1996). For *V. vitis-idaea*, Ritchie (1955) reported an average of 6-7 viable seeds per fruit, while in our sample the average was slightly higher at 10. These data relating to the size and weight of the fruits and the number of seeds were in line with those found for other geographical areas.

The type of vegetation provided by the species of the genus *Vaccinium* plays fundamental roles in the conservation of biodiversity and soil protection (Maubon *et al.*, 1995) in high altitude environments where these species normally grow. These species also provide a local economic resource (Benini, 1990). *V. myrtillus* is deciduous and its foliage is richer in nutrients than most other members of the Ericaceae. Its soft leaf litter decays easily despite a high tannin content (Gallet & Lebreton 1989, 1995). This aspect underlines the importance of developing correct forms of management for these species in this area (Ronchieri & Mazzei, 1997).

This work has focused on fruit production to obtain data on the capacity of these heaths to produce fruit. It would be desirable to monitor the trend in fruit production over a period of years to enable predictive models to be implemented in anticipation of increasingly marked climate changes that could influence relative fruit abundance, distribution and production.

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