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Eco-physiological behaviors of some apple genotypes (*Malus x domestica* Borkh.) in the hot-and-dry climate of an inner area of Southern Italy

Abstract

The Italian internal areas are distant from the main trade flows and service centers, but have important environmental and cultural resources. The Italian "National Strategy for Inner Areas" represents a novel policy aimed at contrast the abandon of these territories by supporting multiple activities aimed at stimulating economic development and promoting territorial cohesion. The condition of marginality offers the chance to pursue economic development according to the principles of sustainability. These internal areas are often distinguished by a purely rural vocation. Genotypes of fruit crops traditionally grown in inland areas cope often with difficult climatic conditions and low-input farming techniques, showing generally a good tolerance to abiotic tresses. Exploring their eco-physiological behaviors in response to the agri-environmental context is useful for identifying crops capable of stimulating the recovery and expansion of a sustainable agriculture system in inland areas. The present work reports some results of a research conducted on three traditional local apple genotypes grown in an internal hot-arid summer area of Southern Italy, evaluating their water status and the intensity of leaf gas exchange compared to those of a well-known "standard" cultivar, in a hot, dry summer period. The local genotypes tested in this case study proved to be more eco-physiologically performing. The experiment allowed to estimate their probable relative eco-physiological advantages compared to the "standard" apple genotype taken as reference.

Keywords: mountain area, low-input cultivation, water stress, tree water status, leaf gas exchange

Volume 8 Issue 1 - 2024

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Received: April 07, 2024 | **Published:** April 19, 2024

Introduction

The orographic nature of Italy is dotted with hills, mountains and valleys covering more than two thirds of the national territory and where almost a quarter of the population lives. For decades, since the 1950s, many of these areas have been poorly involved in the dynamics of economic and social development, undergoing a process of economic and demographic decline and marginalization from other national territories. The Italian "National Strategy for Inner Areas" represents a novel governmental policy aimed at contrasting this phenomenon by supporting multiple activities to stimulate economic development and promoting territorial cohesion.[1,2]

The Italian inner areas appear profoundly diversified from each other, due to the specific dynamics of the environmental and production systems established over centuries. However, they have in common being distant from the main trade flows and service centers which provide education, health, and mobility; on the other hand, they can count on important environmental and cultural resources. These marginal internal areas are often distinguished by a purely rural vocation; their condition of marginality may offer the chance to pursue economic development according to the principles of environmental, social, and economic sustainability.

Sustainable development is a fundamental principle of the European Union; the EU research support programs, in line with the objectives of the UN 2030 Agenda and with the NextGenerationEU package, offer a large economic sustenance for the development of productive, administrative, social and investigation activities.[3,4] Some of these research lines are focused on the adoption of agroecological principles and the rediscovery of ancient crops and/or on the selection of varieties suitable for specific environments, in order to diversify the food production and sustain the local supply chains by reducing waste, surpluses and environmental impacts.

In the context of the fruit crops, genotypes traditionally grown in internal marginal areas often cope with difficult climatic conditions and are cultivated with low-input techniques since they are quite tolerant to abiotic stresses. Exploring the eco-physiological behaviors of these genotypes in their environment and comparing them with those of some "standard" cultivar widely known and grown, is a tool for identifying crops capable of stimulating the recovery and expansion of a sustainable agriculture in inland areas.

The present work reports the results of a research conducted on three traditional local apple genotypes in an inner area of South Italy, focusing on their tree water status and intensity leaf gas exchange as compared to those of a reference "standard" cultivar, in response to very hot and dry summer conditions.

Material and methods

Study site

The study was conducted in the Monti Dauni (South Italy, Apulia region, Foggia province), one of the territories addressed by the Italian National Strategy for Inner Areas (Figure 1). The climate of the southern part of this territory, where the trial was run, is classified as Csa (hot summer Mediterranean) according to the Köppen-Geiger system.[5] The experimental activities took place in Panni, close to the Campania region, at the apple orchard of Calitri farm (41°13'25" lat. N – 15°15'03" long. E, 446 m a.s.l.). The average annual temperature of that zone is 13.4 °C; the hottest months are July and August (average temperature 23.4-23.5 °C, average minimum 17.1-17.5 °C, average maximum 29.8-29.6 °C, respectively); the annual rainfall is 717 mm, but only 93 mm falls in the June-August period.[6]

Figure 1 Territories addressed by the Italian National Strategy for Inner Areas[2]. The blue arrow indicates the Monti Dauni area.

Plant material and orchard management

Three local apple genotypes typical of Central-South Italy, i.e. Limoncella (medium vigor; designated as a "traditional agri-food product" by the governments of the Campania and the Puglia Region),[7] the locally called Limoncella rossa (medium vigor), and Sergente (high vigor), are grown in the orchard together with some commercial genotypes. Among these latter, Golden delicious (medium vigor, adaptable to a wide range of pedoclimatic conditions) was taken as "standard" reference cultivar, being one of the most popular and grown varieties in Europe. All trees are grafted onto the vigorous rootstock MM111 and trained to palmette system. The soil has a clayey texture (clay 47.3%, sand 17.9%), is deep, but prone to erosion due to the land slope. The orchard is rain-fed, fertilized with organic matter, and managed as a low-input organic cultivation, with spontaneous winter cover crop and summer soil plowing.

Agrometeorogical data

An agrometeorological control unit (EM 50 Decagon-Meter, Pullman, WA, USA) was positioned in the center of the orchard, connected to a sensor of soil temperature and humidity (volumetric water content, VWC, model 5TM) placed at a depth of approximately 50 cm, and a sensor of air temperature and humidity (model VP-3, with anti-radiation shield), placed at a height of 2 m from the ground. The rainfall data were obtained from the pluviometric bulletins of the regional Civil Protection.[8] The crop evapotranspiration was estimated multiplying the reference evapotranspiration, calculated with the Hargreaves method,[9] by the crop coefficient provided by the guidelines for integrated cultivation of Regione Campania,[10] i.e. 0.95 for apple orchards grown on plowed soil.

Eco-physiological measurements

In the orchard three blocks, each including one tree per genotype as single replicate, were individuated to test eco-physiological response of the four cultivars (the three local varieties plus the reference one) to the stressing environmental conditions of summer 2023. In July, on two days of the beginning (1^{st} week) and end of the month (4^{th} week), tree water status was measured as stem water potential[11] (Ψ_{stem}), on 3 leaves per tree, using a Scholander pressure chamber (Soilmoisture, Santa Barbara CA, USA), and leaf gas exchange per unit leaf area (rates of stomatal conductance, transpiration and net photosynthesis) was measured, on 2 sun-exposed mature leaves per tree (Figure 2), using a portable infrared gas analyzer (IRGA, Li-6400XT Li-Cor, Inc., Lincoln, NE, USA) at light intensity of 1000 $\mu mol/m^2/s$. Measurements were taken in the central hours of the day. Data of the three local genotypes were expressed as percentage of the reference cultivar. Data were statistically analyzed by ANOVA; parameters with p value < 0.05 had mean separation by Duncan test.

Figure 2 Measurement of leaf gas exchange on apple trees at the experimental site.

Results

Agrometeorological conditions

Summer 2023 was very hot and dry. The average air temperature recorded at the experimental orchard in the 2^{nd}, 3^{rd}, and 4^{th} weeks of July (Table 1) exceeded that typical for that territory respectively by 2.4, 5.2 and 1.6°C; rainfall was just 8.7 mm. The estimated crop evapotranspiration was 194 mm. Soil moisture progressively decreased from about 34% VWC, which indicates a medium soil water status, to 28.5% WVC, which indicates a low soil water status, being 22% the reference threshold generally considered as the wilting point in clay soils.[12]

Table 1 Average weekly agrometeorological conditions experimentally measured at the trial site, in July 2023

Week	Air Temperature (°C)	Air Humidity (%)	Soil Temperature (°C)	Soil Moisture (%)	Rains (mm)
1	22.70	69.80	22.11	33.90	8.10
2	25.80	55.70	23.93	32.30	0.00
3	28.60	58.90	25.62	30.70	0.00
4	25.00	59.40	24.89	28.50	0.60

Eco-physiological measurements

In early July (1^{st} week of the month), the water status of Limoncella trees was significantly less negative, by approximately 14%, compared to that of the reference cultivar Golden delicious (Figure 3) which Ψ_{stem} was found close to -1.5 MPa, a value below which apple trees may be considered water stressed.[13,14] Limoncella rossa and Sergente showed an intermediate tree water status. Rates of stomatal conductance, transpiration and net photosynthesis were significantly and markedly greater in all local genotypes compared to Golden delicious. Respect to this latter, the stomatal conductance rate increased 1-fold in Limoncella and more than 2.3-fold in

Citation: Antoniciello D, Novello V, de Palma L. Eco-physiological behaviors of some apple genotypes (*Malus x domestica* Borkh.) in the hot-and-dry climate of an inner area of Southern Italy. *Horticult Int J.* 2024;8(1):21–24. DOI: 10.15406/hij.2024.08.00298

Limoncella rossa and Sergente, the transpiration increased 0.8-fold in Limoncella and about 1.5-fold in Limoncella rossa and Sergente, the net photosynthesis increased 0.3-fold in Limoncella and about 0.8-fold in Limoncella rossa and Sergente.

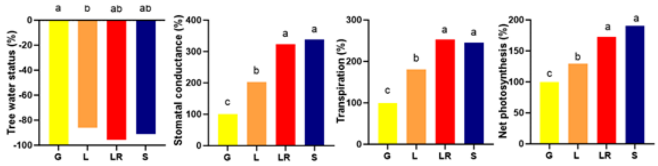

Figure 3 Tree water status and intensity of leaf gas exchange in three local apple genotypes (L= Limoncella, LR= Limoncella rossa, S= Sergente), expressed as percentage of the reference cultivar Golden delicious (G), assessed in early July 2023 (different letters indicate significant differences at $p < 0.05$; mean separation by Duncan test).

In late July (4th week of the month), the tree water status of the local genotypes was still less negative, from 15% in Sergente to 11% in Limoncella rossa, compared to that of the reference variety Golden delicious (Figure 4). In this latter, Ψ_{stem} reached -2.6 MPa, meaning that trees of all genotypes were highly water stressed. The rates of leaf gas exchange were still more active in the local genotypes than in the reference one. The increase was just over 1-fold in Limoncella and Sergente and 1.5-fold in Limoncella rossa as regards stomatal conductance, about 1-fold in Limoncella and Sergente and 1.23-fold in Limoncella rossa for leaf transpiration, about 0.45-fold in Limoncella and Limoncella rossa and 0.60-fold in Sergente for net photosynthesis.

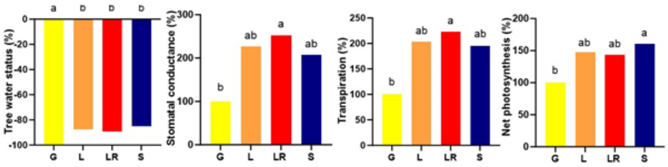

Figure 4 Tree water status and rates of leaf gas exchange in three local apple genotypes (L= Limoncella, LR= Limoncella rossa, S= Sergente), expressed as percentage of the reference cultivar Golden delicious (G), assessed in late July 2023 (different letters indicate significant differences at $p < 0.05$; mean separation by Duncan test).

Discussion

According to data collected by the EU climate and meteorological service 'Copernicus', July 2023 was the warmest July ever recorded globally.[15] The same occurred at the experimental site; therefore, the eco-physiological performance of the apple genotypes were tested under highly stressful summer conditions.

In this agri-environmental context, the local cultivars proved to be able to maintain a better water status and a more active leaf gas exchange compared to the "standard" variety Golden delicious. This behavior was first observed in early July, when trees had still an acceptable water status likely due to the combination of two factors: i) the clayey texture and good depth of the soil, suitable for storing winter rains, and ii) the root system of the vigorous rootstock, capable of exploring deeper and wetter soil layers and extracting moisture from them. This behavior was then confirmed in late July, when trees of all cultivars experienced a very severe water deficit. Since trees of the local varieties showed a less negative stem water potential and, at the same time, a higher stomatal conductance, their better water status was possibly related to a greater capacity for osmotic adjustments compared to that of the reference cultivar. Due to their higher stomatal conductance, the local varieties transpired more water per unit leaf area than Golden delicious, but, on the other hand, they fixed more CO_2. Cv Sergente showed a tendency for a higher rate of net CO_2 uptake among the local varieties.

The pattern of differences in leaf transpiration and net photosynthesis was quite similar to that of stomatal conductance and leaf transpiration, in early July, and to that of transpiration in late July; therefore, in such cases, the stomatal component seemed to have exerted a strong influence on these parameters. In late July, the pattern of differences in net photosynthesis differed from that of stomatal conductance and resembled more that of stem water potential. Therefore, under such highly limiting water conditions, the influence exerted by the mesophyll hydration on the photosynthetic capacity seemed to be greater than that of the stomatal component.

Conclusion

It is generally thought that genotypes typical of inland marginal areas are often "intrinsically" well adapted to local agri-environmental conditions, being more tolerant to abiotic stresses and low-input cultivation than "standard" widely grown genotypes. In this case study, the local genotypes proved to have the most performing water status and leaf gas exchange in the hot, dry, and stressful summer environment of an internal marginal area of Southern Italy; this type of eco-physiological behavior may be at the basis of the best environmental "adaptation" showed by several traditional cultivars in their cultural areas. This research is still ongoing and will include the evaluation of the fruit quality and nutritional features. Although this first survey was concentrated in a single period, given the high severity of the stress conditions that occurred in that period the experimental results can be considered a demonstration of the greater capacity for resilience to the climate crisis and difficult environments possessed by the tested local apple genotypes. The present trial also allowed to estimate the probable eco-physiological relative "gain" of those genotypes compared to the "standard" one taken as reference. Exploring the biodiversity of minor cultivars traditionally grown in internal areas and identifying those that can combine eco-physiological advantages with typicality of their fruit, is a tool to support the development of sustainable agriculture even in difficult environments.

Acknowledgments

The Authors thank Mr. Giovanni Calitri for hosting the trial activities and the invaluable support to this research, and to dr. Nicola Trombetta for his help in field measurements.

Research funding

The research is carried out within the Agritech National Research Center and received funding from the European Union Next-Generation EU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR)-MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 -D.D. 1032 17/06/2022, CN00000022).

Conflicts of interest

None.

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