Development of the hazelnut chain in Tuscany: the case of the integrated project “Loacker, Hazelnuts of Maremma”

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Abstract

The recent market impulse affecting the nut sector has led to a new expansion of Italian hazelnut farming, involving both traditional areas and areas new to hazelnut production. Among these, of particular interest is the recent introduction of hazelnuts to Tuscany, where the most promising area for the development of a new hazelnut district is the province of Grosseto. In this area, under the aegis of the Loacker company, the “Maremma” hazelnut supply chain is emerging, which is also supported by the Integrated Supply Chain project financed by the Tuscany region and called “Loacker, Hazelnuts of Maremma”. The experimental part of the project is supported by the sub-project “FIL.CO.T. - Development of the hazelnut supply chain in Tuscany”. Two irrigated farms owned by Loacker, covering a total of 360 ha, were planted to hazelnuts in 2014 with ‘Tonda di Giffoni’, ‘Tonda Gentile Romana’, ‘Nocchione’, ‘Camponica’, ‘Barcelona’ and ‘Tonda Francescana’®, some of which were grafted to *C. colurna* seedlings. The plantations are intended for both commercial and experimental purposes. In addition, a collection of the main hazelnut cultivars recently released by the Oregon State University hazelnut breeding program was established in November 2020. The FIL.CO.T., structured in ‘work packages’, aims to carry out experimental activities to assess the adaptability of hazelnut cultivars in the new growing area. The most relevant results obtained during the trials are reported, with a focus on the introduction of new hazelnut cultivars released from OSU into the selected environment, soil mapping to determine its spatial variability and develop a new protocol for monitoring sub-irrigation water distribution in the orchard, and the development of improved protocols for high-efficiency kernel storage using appropriate ozone concentrations.

Keywords: *Corylus avellana*, cultivar choice, apparent electrical conductivity, sub-irrigation system, ozone treatment

INTRODUCTION

World hazelnut cultivation has shown constant growth over the last decade, reaching 1.2 million t of in-shell nuts in 2021 (INC, 2021). The increase of the hazelnut cultivation area involves both new and traditional countries, including Italy (Silvestri et al., 2021), where in addition to its expansion in the traditional areas of cultivation, hazelnuts have been introduced to new regions such as Tuscany (Botta et al., 2019). In this region, new plantations are mainly in the southern provinces of Grosseto and Siena, and in 2020, the region had 750 ha of hazelnut orchards, of which 370 ha were in production, and produced about 550 t of in-shell nuts in the same crop year (ISTAT, 2020).

The most promising region for developing a new hazelnut district is the province of Grosseto, where, under the aegis of Loacker company, the hazelnut sector of “Maremma” is being set up, supported by the Integrated Supply Chain project funded by the Tuscany Region

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and called “Loacker, Hazelnuts of the Maremma” (Furlan et al., 2021). Here, two irrigated farms owned by Loacker, a total of 360 ha, have been planted with hazelnut since 2014 using ‘Tonda di Giffoni’ for around 60% of the plantations, ‘Tonda Gentile Romana’ and ‘Nocchione’ for 15% each, and ‘Camponica’ and ‘Tonda Francescana’® for the remaining 10%. Portions of the plantations are destined for experimental purposes, with plots established according to different planting layouts and plant training systems, and planting the ‘Tonda di Giffoni’, ‘Tonda Gentile Romana’, ‘Camponica’, ‘Tonda Francescana’® and ‘Barcelona’ grafted on *C. colurna* seedlings. Moreover, in November 2020, a collection of the main cultivars recently released by the Oregon State University (OSU) Hazelnut Breeding Program was established (Smith et al., 2018).

With the aim of supporting the introduction of new commercial hazelnut orchards, a number of trials are currently underway for the sub-project “FIL.CO.T. - Development of the Hazelnut Supply Chain in Tuscany”, structured in “work packages”, both to assess the adaptability of hazelnut cultivars to the new cultivation area and to optimize orchard management and hazelnut storage techniques. In this contribution, the most significant results obtained during the trials are presented.

MATERIALS AND METHODS

Following the guidelines of the Integrated Supply Chain project, different work packages were established dealing with four main topics, which are briefly described following this list:

1) Cultivar choice and suitability;
2) High detail soil characterization and clusterization;
3) Monitoring of water distribution in sub-irrigated orchards;
4) Ozone treatments of kernels to preserve shelf-life.

Following a brief description of the trials implemented is given.

Cultivar choice and suitability

A cultivar collection was established in 2018 at the experimental farm when trees of the main Italian hazelnut cultivars and some local ones were planted. The plants, in single rows of 20 plants per cultivar, were spaced 5×4 m, and grown with a single trunk. Furthermore, in late 2020, a second collection field was established and trees of hazelnut cultivars from OSU (Table 1) were planted at a spacing of 5×3 m. The spatial variability of the soil in the collection fields was determined by proximal sensing using an electromagnetic induction sensor (Mini-Explorer, GF instruments, Czech Republic). The sensor measures the apparent electrical conductivity (ECa) at three depths: 0-50, 0-100 and 0-150 cm. ECa is usually correlated to clay content, stoniness, bulk density, soil moisture and eventual salinity (Corwin and Lesch, 2003) and in the last decade has been often used to map soil features for site-specific agricultural purposes (Priori et al., 2013; Caruso et al., 2022). The sensor detected a wide area with low ECa, mainly due to a high sand fraction, and a smaller area with high ECa due to clay loam soil, and higher soil moisture at greater depth. After the data processing and soil clusterization according to its electrical conductivity, soil samples were collected from each cluster to be analyzed in the lab for soil texture, bulk density, water retention, etc. Furthermore, during the growing seasons of 2020-2021, phenological and agronomic traits were investigated to start highlighting the more suitable introductions from OSU for the new growing area.

Soil characterization and clusterization

In order to develop optimized orchard management protocols, such as irrigation and nutrition, in the experimental farm, highly detailed soil mapping and clusterization into homogeneous zones (HZs) was carried out. Three growing areas of 4 ha each were selected, and the soil profiles were described and analyzed according to the map of farm soil typological units (STUs). In the subsurface horizons, undisturbed soil samples were collected for the measurement of bulk density and for analysis of the water retention curves. The latter have been used to determine the amount of water available for plants that specific kind of soil was able to retain (AWC). Furthermore, the highly detailed soil mapping of the experimental plots (about 50 ha) was carried out using the GF Mini-Explorer electromagnetic induction sensor, which allows mapping of the soil's apparent electrical conductivity (ECa), or its inverse electrical resistivity (ER), at three different depths (0-50, 0-100 and 0-150 cm). The measurements were continuously geo-referenced via GPS and are recorded using a hand-held device.

Table 1. First observations on vegetative behavior of the OSU hazelnut cultivars in the collection field established at "Loacker Tenuta Corte Migliorina". Vegetative traits were measured in late August 2021 and 2022.

Cultivar	TCSA (mm^2)		Plant height (cm)	
	2021	2022	2021	2022
Wepster	65.41±8.37	79.31±14.45	82.00±4.35	94.17±13.26
Jefferson	53.60±13.61	83.03±25.09	81.33±4.16	101.23±12.17
Yamhill	44.86±10.87	99.97±31.34	72.00±6.92	101.18±11.78
Tonda Pacifica	40.61±5.32	76.32±18.33	77.66±6.42	98.33±16.27
Dorris	37.54±6.10	75.05±19.67	75.33±6.43	106.34±20.64
McDonald	28.39±1.29	66.44±19.29	67.66±5.50	96.25±14.46
York	59.69±21.72	97.15±29.62	78.33±6.50	106.50±12.28
Theta	55.77±3.51	96.41±31.59	85.33±6.02	109.05±19.24
Felix	53.73±1.23	88.22±24.58	80.33±7.23	104.25±14.53
Eta	38.37±9.12	82.41±15.91	82.67±9.86	99.25±16.93

TCSA = trunk cross-sectional area measured at 20 cm above the ground.

Orchard sub-irrigation: monitoring water distribution

Optimization of water supply is mandatory in hazelnut orchards characterized by limited water availability and uneven distribution of rainfall over the growing season. To this end, a trial was established in early summer 2022 to monitor the efficiency of irrigation water distribution through the sub-irrigation system installed by burying the dripline at a depth of 30 cm and positioned at 50 cm from the rows on both sides, with drippers spaced 80 cm apart (single dripper flow rate of 1.6 L h^{-1}). The protocol provided an initial soil map using the EMI sensor described above (GF Mini-Explorer), before the irrigation system was seasonally activated. The same sensor acquisition was then conducted after about 5 h of irrigation (the first seasonal water supply). Two macro-areas were revealed, where two soil profiles emerged. Area 1 was characterized by loamy texture, rich in gravel, and Area 2 was a clay texture, poorly drained soil, and with periodic waterlogging.

Ozone treatments of kernels to preserve shelf-life

In this trial, an objective method for quality determination of fresh shelled hazelnuts and their storability was tested. Samples of hazelnut kernels were subjected to ozone application, a very promising technique for food preservation that improves food safety without compromising quality or endangering the environment (Carletti et al., 2013). Three hazelnut kernel sample sets were treated at different ozone concentrations and times of exposure (8 ppm for 1 h, 600 ppb and 200 ppb for 2 h), while one was used as the untreated control. After the treatments, the kernels were stored in a cold room at +4°C (±0.5) for a total of 40 days. Every ten days, kernels were sampled for destructive (i.e., oil peroxides and oil acidity) and non-destructive (NIR spectroscopy, results not presented here) analyses to evaluate the effect of the different ozone treatments on kernel quality during storage under controlled temperatures.

RESULTS AND DISCUSSION

Cultivar choice and suitability

Table 1 reports the vegetative behavior of ten hazelnut cultivars recently released by the OSU breeding program and planted in late 2020 in the experimental farm. Unpruned plants of 'Yamhill', 'York' and 'Theta' were the most vigorous, with mean TCSA values of almost 100 mm^2 in late August 2022, whereas 'McDonald', 'Dorris' and 'Tonda Pacifica' were the least vigorous, with mean values in the same year of 66.44, 75.05 and 76.32 mm^2, respectively. Similar to TCSA, plant height showed a range of values related to cultivar with 'Theta', 'York', 'Felix' and 'Dorris' having mean heights greater than 105 cm in late August 2022, while 'Jefferson', 'Yamhill', 'Eta' and 'Tonda Pacifica' had mean values close to 100 cm, and 'Wepster' and 'Mc Donald' had the shortest trees. The soil ECa maps obtained in the hazelnut collection field (Figure 1) showed the same pattern at the three different depths, with higher conductivity in the northeastern part of the experimental field (in blue). A manual augering, performed in this area, revealed the presence of water around 70 cm deep. The presence of water increases the soil ECa. The rest of the field showed moderately low values of ECa, corresponding to loamy and loamy sand texture, with no water table shallower than 1 m.

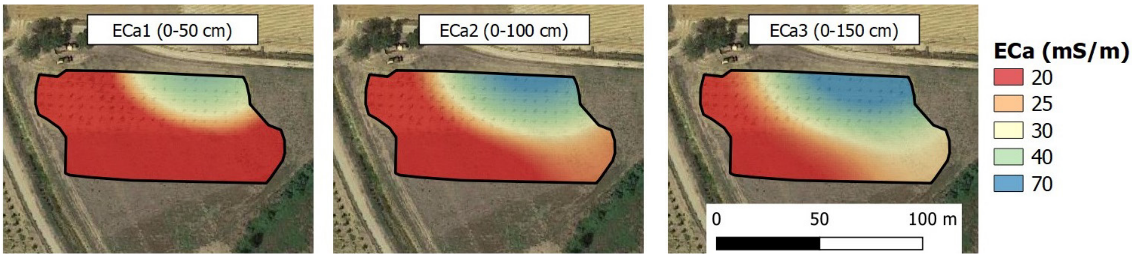

Figure 1. Highly detailed soil map of the hazelnut collection field according to the electrical conductivity (ECa) of the soil at three different depths (50, 100 and 150 cm, respectively).

Soil characterization and clusterization

Study of the soil profiles in the areas under stress (profiles 8, 10 and 13) revealed that the most evident limiting factor was the presence of one or more subsurface horizons (from 10 to 50-55 cm), compacted (bulk density generally greater than 1.6 g cm^{-3}), not very porous, sometimes even very stony (P8, P10), which physically limit deep root growth (Figure 2). The hydrological analyses revealed that this limiting horizon decreases the water available for the plants (AWC from 75 to 79 mm, compared to 111-130 mm in the non-stressed areas) and the drainage speed, especially in the P10 and P13 profiles (K_{sat}<2.1 mm h^{-1}).

Orchard sub-irrigation: monitoring water distribution

Following an initial mapping, two macro-areas were revealed, where two soil profiles emerged. Area 1 was characterized by loamy texture, rich in gravel; Area 2 had a clay texture and slower water internal drainage. The variation of Eca after 5 h of sub-irrigation compared to ECa before irrigation (Figure 3), showed two lines with positive delta (about +6-10 mS m^{-1}) for ECa2 (left figure), not confirmed in the shallower ECa1 (0-50 cm) or in the deeper ECa3 (0-150 cm, right figure). The direction of these two lines corresponds to the sub-irrigation pipelines (depth about 40-50 cm). Further studies will be done to validate the method to check the efficiency of sub-irrigation pipelines by ECa proximal sensing.

Ozone treatments of kernels to preserve shelf-life

The highest ozone concentration (8 ppm) leads to, from the outset and as expected, a much higher quantity of peroxides than the other treatments and the control. The differences were evident after just two days. On the other hand, the mildest treatments (600 and 200 ppb) and the control (CK) were not significantly different at the initial stages of storage. Starting from 30 days of storage, an increase of peroxides was observed in these samples, especially in the 600 ppb-treated kernels. CK and 200 ppb maintained very similar trends throughout storage and up to 40 days (Figure 4). During cold storage, the acidity values of ozone-treated kernels at 8 ppm were twice as high as in the other treated samples. This evidence can be explained because high ozone treatment provoked higher fatty acid oxidation, as already observed in the peroxide results, which were significantly affected by a stronger release of free fatty acids.

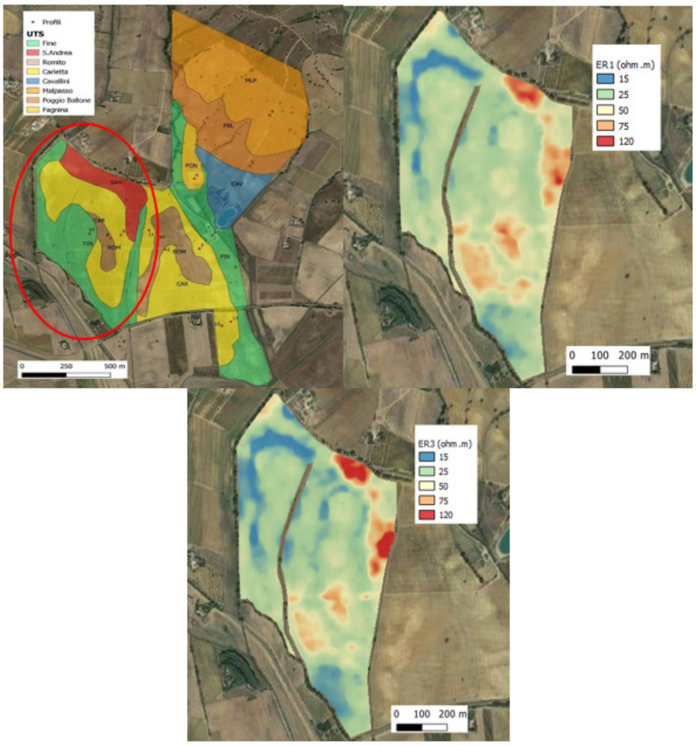

Figure 2. Map of the soil typological units of the farm (left). Electrical resistivity (ER) maps at the shallowest (ER1, 0-50 cm) and deepest levels (ER3, 0-150 cm), obtained by the Mini-Explorer proximal sensing. The highest ER areas (in red) corresponded to stony and shallow soils, whereas the lowest ones (in blue) correspond to deeper soils with high-clay sub-horizons.

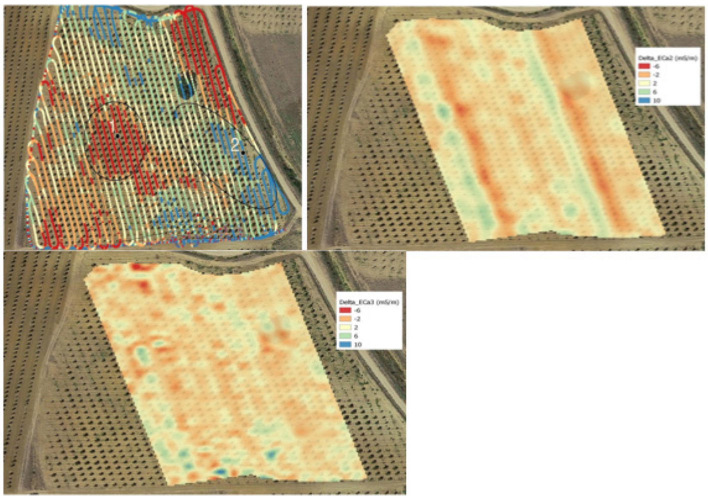

Figure 3. Maps of ΔEca = ECa after irrigation - ECa before irrigation. Initial soil mapping using the EMI sensor (on the right) before the irrigation system was seasonally activated. ΔECa2 (0-100 cm; in the middle) and ΔECa3 (0-150 cm; on the left).

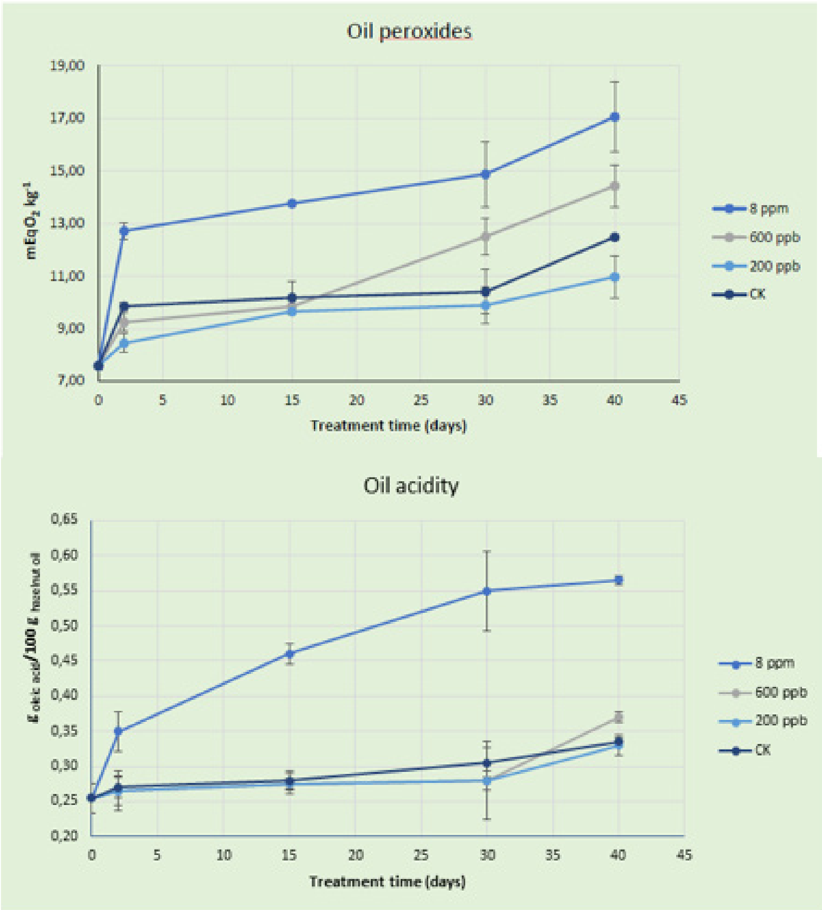

Figure 4. Peroxide content (left) and total acidity (right) of oil extracted from kernels treated with different ozone concentrations after different numbers of days in storage.

Absolutely overlapping trends were instead observed in CK, 200 and 600 ppb treated samples, from 0 to 40 days of storage (Figure 4). In addition, kernel moisture in the treated samples decreased during cold storage (data not shown). At the end of the trial, residual hazelnut moisture was dependent on the treatment. No significant differences were observed between control and ozone-treated (at 200 and 600 ppb) samples. On the other hand, slightly higher moisture loss was observed in kernels treated with 8 ppm. The residual moisture content was consistent with the higher protein content, noticed in the same samples (data not shown). Hence, ozone is able to break the phospholipid membranes (not only of microorganisms, but also of treated fruits) favoring the release of internal constituents, including water and enzymes, leading to an increase in protein concentration (Pryor et al., 1995; Khadre et al., 2001; Brodowska et al., 2018). Interestingly, control kernels at 40 days showed a much higher protein concentration than the initial untreated sample, which was slightly higher than that observed in the 200 ppb treated kernels and almost equal to the 600 ppb ones. All considered, these preliminary results suggest that low concentrations of gaseous ozone (such as 200 ppb) could be considered effective in preserving kernel quality during storage and therefore increasing the shelf-life. Additionally, when applied at an adequate concentration, it can have germicidal effects on fungal contaminants by oxidizing their vital cellular components (e.g., lipid membranes, amino acids, and proteins), and thereby reducing their growth as already reported in the literature (Forney, 2003). Particularly, ozone acts against unsaturated lipids in the microbial cell membranes causing a leakage of their contents, and eventually microbial lysis (Guzel-Seydim et al., 2004).

CONCLUSIONS

The hazelnut work packages developed in the FIL.CO.T. project for the in-field and postharvest chains, will contribute to consolidation of the new hazelnut district in southern Tuscany, as a new area for Italian hazelnut cultivation. Of particular interest are i) the introduction in the selected environment of the new hazelnut cultivars released by OSU; ii) the method to determine the soil spatial variability, which then drives the spatial variability of plant responses; iii) the new protocol proposed for monitoring the irrigation water distribution in the orchard trough sub-irrigation; iv) improved protocols for high-efficiency kernel storage using proper ozone concentrations. The outputs of the research project will be properly disseminated in the district to support farmers wishing to invest in hazelnut cultivation.

ACKNOWLEDGEMENTS

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