

Reflective ground-cover film modified canopy microclimate and fruit oil content in an olive orchard in Southern Chile

Gastón Gutiérrez-Gamboa¹, Miguel Araya-Alman², Sebastián Romero-Bravo², Marcos Carrasco-Benavides², Verónica Arancibia-Araya³, Jacqueline Campos-Yáñez³, and Manuel Vial-Alarcón^{4*}

¹Instituto de Investigaciones Agropecuarias, INIA-Cauquenes, Cauquenes, Chile.

²Universidad Católica del Maule, Facultad de Ciencias Agrarias y Forestales, Curicó, Chile.

³Instituto de Investigaciones Agropecuarias, INIA-Intihuasi, Vallenar, Chile.

⁴Instituto de Investigaciones Agropecuarias, INIA-Carillanca, Temuco, Chile.

*Corresponding author (manuel.vial@inia.cl).

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ABSTRACT

Olive (*Olea europaea* L.) cultivation is expanding into non-traditional southern Chilean areas, where lower thermal accumulation and seasonal water constraints may limit fruit development and oil accumulation. This study evaluated the effect of aluminized low-density polyethylene (LDPE) reflective film applied as ground cover for 65 d from fruit development (BBCH 75) until harvest (BBCH 89) in a young 'Arbequina' olive orchard in Los Sauces, La Araucanía Region. The results showed that the reflective film increased photosynthetically active radiation from 510 to 950 $\mu\text{mol m}^{-2} \text{s}^{-1}$ in the lower canopy (+86%) and from 360 to 760 $\mu\text{mol m}^{-2} \text{s}^{-1}$ in the middle canopy (+110%), with nonsignificant effect in the upper or cross-canopy positions. The estimated leaf area index (eLAI) decreased from 2.25 to 0.95 in the lower canopy (-58%) and from 0.72 to 0.50 in the upper canopy (-30%), whereas leaf chlorophyll status remained unchanged. Midday stem water potential decreased from -0.92 to -1.24 MPa (-35%), suggesting increased evaporative demand around solar noon. Reflective film increased fruit DM at 60 °C from 45.55% to 48.00% (+5.4%), dry-basis fat from 39.45% to 43.93% (+11.4%), and fresh-basis fat from 18.17% to 20.07% (+10.5%), without significantly affecting fruit moisture. These results show that reflective film improved light availability in shaded canopy sectors and increased fruit oil percentage in cool-climate olive orchards, although the more negative midday stem water potential suggests that the treatment may also increase evaporative demand.

Key words: Arbequina, dry matter, olive fruit, orchard practices, plant microclimate.

INTRODUCTION

In recent years, there has been growing interest in expanding the cultivation of olive (*Olea europaea* L.) into non-traditional regions as part of public and private efforts to diversify crops and adapt agriculture to climate change (Petrucelli et al., 2022; El-Alakmy et al., 2025). In Chile, while commercial olive production is traditionally concentrated in arid and semi-arid zones of the north-central regions (Ahumada-Orellana et al., 2018), interest has grown in evaluating the commercial feasibility of olive establishment in southern territories, including in La Araucanía Region. In this region, the potential to produce olive oil in one of the southernmost regions globally presents a unique opportunity for growers, as it allows for the development of differentiated, high-value oils with strong territorial identity, an aspect increasingly valued in niche and specialty markets (Moragues-Faus, 2014).

Southern Chilean fruit regions present a temperate-humid climate, with higher annual rainfall and lower winter temperatures compared to conventional olive-growing zones, posing significant challenges such as frost

risk and limited thermal accumulation (Gutiérrez-Gamboa and Mucalo, 2025). In this way, site-specific orchard management strategies, such as careful cultivar selection, north-facing orientation, density planting, and canopy training systems that enhance light interception can help mitigate climatic limitations and improve thermal accumulation in cool-climate environments (Centeno et al., 2019; Fraga et al., 2020). Due to the climatic limitations of the region, technologies that modify plant microclimate may offer valuable support for successful olive establishment in southern Chile. In particular, the application of reflective mulch films and the strategic use of ground covers can enhance local thermal conditions by increasing radiation absorption at the canopy level and improving soil heat retention (Muñoz-Alarcón et al., 2025). These interventions have been shown to promote earlier phenological development and reduce the risk of frost damage during sensitive growth stages, making them a promising tool for optimizing olive production in cool-climate environments.

Reflective mulches modify the light environment, thermal dynamics, and humidity in the crop canopy by altering the radiation balance around the plant (Muneer et al., 2019). This technology redirects solar radiation, including photosynthetically active radiation, back into the canopy, increasing the total light intercepted by lower and inner leaves (Gutiérrez-Gamboa and Mucalo, 2025). Black and transparent film mulches can improve light penetration into shaded areas, enhancing photosynthesis efficiency and overall productivity (Qin et al., 2022). Black and clear mulches raise soil temperatures above ambient, whereas white and aluminized plastics may either raise or lower soil temperature slightly (Muneer et al., 2019; Qin et al., 2022).

Improving photosynthetic efficiency and enhancing oil accumulation in olive fruits are key objectives in orchard management, particularly under cold climate climatic conditions (Centeno et al., 2019). Accordingly, microclimate changes induced by reflective mulches may also affect lipid metabolism and fruit oil accumulation, which is particularly relevant to growers in cold climate regions. These modifications may influence not only fruit composition and oil yield but also harvest timing (Muneer et al., 2019). Thus, this study evaluated the effect of an aluminized reflective ground-cover film on canopy microclimate, tree water status and fruit oil related-trials in a young olive orchard under cool-climate condition.

MATERIALS AND METHODS

Study site and plant material

The study was conducted during the 2024-2025 growing season in a commercial olive (*Olea europaea* L.) orchard located in Los Sauces (37°57'34.15" S, 72°51'54.97" W), Malleco Province, La Araucanía Region, Chile. The site is part of the inland dryland area of Malleco, on the eastern side of the coastal range. The orchard was established in 2021 with 'Arbequina' trees planted on raised beds at a spacing of 4.0 m between rows and 1.5 m within the row. This agroecological zone has a temperate climate with a mean monthly temperature of approximately 12.8 °C and annual rainfall ranging from 800 to 1200 mm, mainly concentrated in autumn and winter, resulting in a dry period of 5 to 6 mo. The sector exhibits a Mediterranean climate characterized by warm-temperate summers and a seasonal semi-arid tendency, classified as Csb₂S_{hs} under the bioclimatic classification system. The soil corresponds to an Alfisol of the San Esteban association, derived from granitic materials of the coastal range, generally characterized by sandy loam texture, good drainage, high sand and gravel contents, and limited water storage capacity.

Reflective film treatment and experimental design

The field trial was conducted using an aluminized low-density polyethylene (LDPE) reflective film as a ground-cover treatment in olive trees and an untreated control without the use of a reflective ground cover. The reflective material consisted of 1.2 m wide aluminized LDPE sheets supplied in 1500 m rolls. The film was placed on the orchard floor along the tree rows, beneath the canopy projection area (Figure 1). The control and reflective-film treatments were arranged in a randomized design with three replicates per treatment that included five olive trees. Each replicate was considered an experimental unit, and the mean of the five trees was used for statistical analysis. The reflective film was installed during the fruit development stage, corresponding to the BBCH stage 75 (Sanz-Cortés et al., 2002) until harvest, equivalent to the BBCH stage 89, accounting 65 d of coverage. The plots were managed under the same agronomic practices, except for the presence or absence of the reflective LDPE film treatment.



Figure 1. Aerial view of the olive orchard used in the experimental trial.

Canopy microclimate and plant physiological measurements

Photosynthetically active radiation (PAR) was measured using an AccuPAR LP-80 PAR/LAI ceptometer (METER Group, Pullman, Washington, USA). Measurements were performed under stable radiation conditions close to solar noon, with the probe positioned horizontally in the lower, middle, upper, and cross-canopy sectors without contacting leaves or branches. Leaf area index was estimated from above-canopy and within-canopy PAR measurements using the instrument radiation model. The resulting estimated leaf area index (eLAI) provides an indirect measure of canopy leaf area based on PAR attenuation.

Leaf chlorophyll status was assessed nondestructively using a SPAD-502Plus chlorophyll meter (Konica Minolta, Osaka, Japan). Measurements were performed on healthy, fully expanded leaves at fruit development. The sensor was placed on the central portion of the leaf blade, avoiding the midrib and major veins. Midday stem water potential (Ψ_{stem}) was determined using a model 600 pressure chamber (PMS Instrument, Corvallis, Oregon, USA). Healthy, fully expanded leaves were enclosed in plastic bags and aluminum foil for at least 2 h before excision to suppress transpiration and allow equilibration between leaf and stem xylem water potential. Leaves were then excised and immediately measured close to solar noon.

Determinations of olive fruit DM, moisture, and fat content

The olive samples (500 g) were collected at harvest from each replicate and transported to the laboratory for compositional analysis. Dry matter and ash content were determined in duplicate using oven-drying and muffle furnace calcination procedures, respectively, according to AOAC methods (AOAC, 1980). Moisture content was calculated from the mass loss during oven drying and expressed as a percentage of the initial fresh mass. Total fat content was determined from dried olive paste by solvent extraction using a Soxhlet system, following the Soxhlet Foss manual procedure. Fat content was expressed both on a dry-weight basis and on a fresh-weight basis since water content may interfere with the estimation and interpretation of fat concentration in olive paste.

Statistical analysis

The variables were subjected to one-way ANOVA, and mean comparisons were performed using Duncan's multiple range test at $p \leq 0.05$. Statistical analyses were performed using Centurion XVI (Statgraphics Technologies, Las Llanuras, Virginia, USA).

RESULTS AND DISCUSSION

The reflective aluminized low-density polyethylene (LDPE) film modified the canopy radiation environment of olive trees, with the strongest effects observed in the lower and middle canopy zones. Photosynthetically active radiation (PAR) increased significantly in the lower canopy, from 510 to 950 $\mu\text{mol m}^{-2} \text{s}^{-1}$, representing an increase of nearly 86% (Figure 2a). A similar response was observed in the middle canopy, where PAR increased from approximately 360 to 760 $\mu\text{mol m}^{-2} \text{s}^{-1}$, equivalent to an increase of 110%. In contrast, PAR did not differ significantly between treatments in the upper canopy or in the cross-canopy measurement. This response indicates that the reflective film was mainly effective in improving radiation availability in the most shaded canopy sectors. This response is relevant because fruit and leaf position within the canopy strongly determine the local microenvironment, particularly light interception and temperature. Connor et al. (2014) emphasized that canopy structure and radiation distribution are key factors regulating olive orchard productivity, especially in dense or hedgerow systems. Similarly, previous studies have shown that upper canopy positions usually present higher light exposure, greater fruit development, and more advanced maturation than lower canopy positions (Grilo et al., 2019).

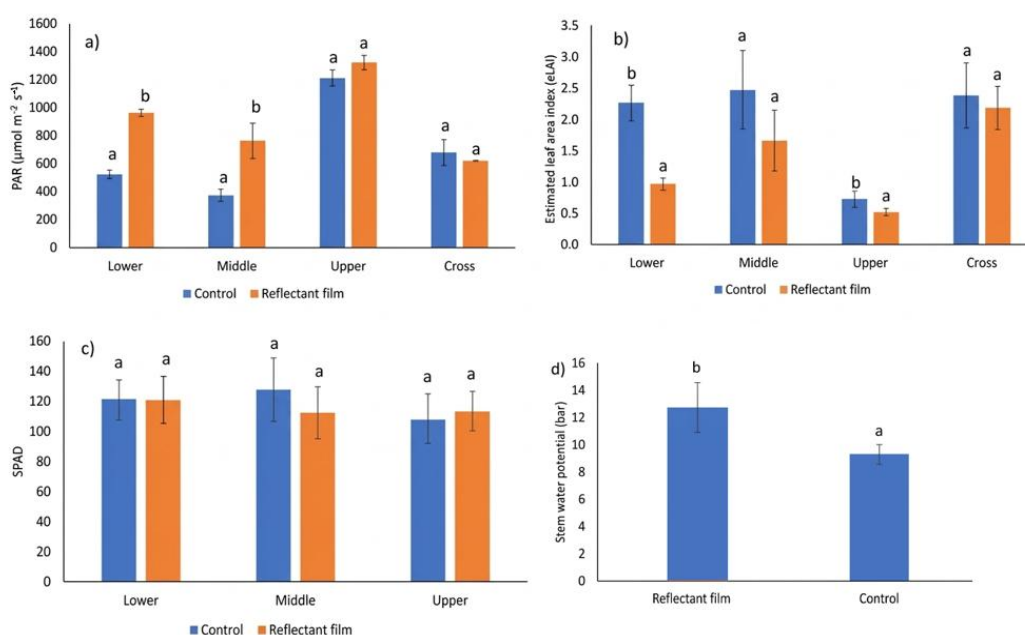


Figure 2. Ecophysiological responses of olive trees subjected to reflective aluminized low-density polyethylene (LDPE) film under southern Chilean conditions. (a) Photosynthetically active radiation (PAR), (b) estimated leaf area index (eLAI), (c) leaf chlorophyll status expressed as SPAD units, and (d) stem water potential measured in control and reflective film treatments.

The estimated leaf area index (eLAI) was also modified by the reflective film treatment in specific canopy sectors (Figure 2b). In the lower canopy, eLAI decreased significantly from approximately 2.25 to 0.95, representing a reduction of about 58%. A similar response was observed in the upper canopy, where eLAI decreased from 0.72 to 0.50, equivalent to a reduction close to 30%. Nonsignificant differences were observed in the middle and cross-canopy positions. The lower eLAI values indicate reduced optical attenuation within the canopy, consistent with the increase in PAR. The observed differences may indicate variation in canopy light attenuation, which may result from changes in leaf area and foliage distribution, but do not providing conclusive evidence of a reduction in actual leaf area. In olive orchards, canopy architecture and light distribution are closely related to the spatial heterogeneity of fruiting zones, leaf activity, and productive performance (Connor et al., 2014). The eLAI reduction observed in the lower canopy under reflective film should be interpreted

together with the higher PAR values, indicating that the reflective surface altered the canopy light environment mainly in the most shaded sector of the olive tree.

Leaf chlorophyll status was not significantly affected by the reflective film in any canopy position (Figure 2c). This result is relevant because chlorophyll index is commonly used as a non-destructive proxy of relative chlorophyll content and, indirectly, of leaf N status, both of which are closely linked to photosynthetic capacity and plant nutritional condition (Kim and Kim, 2024). In olive trees, recent studies using proximal or remote sensing approaches have also considered chlorophyll-related traits as key indicators of canopy physiological status and spatial variability within the orchard (Zhuang et al., 2025). The lack of chlorophyll status response may also be associated with the phenological timing of the measurements. At BBCH 79-80, leaves were fully expanded and physiologically mature, so their chlorophyll status may have been less responsive to a short-term increase in reflected radiation than variables directly related to light interception. Olive leaves exhibit relatively conservative acclimation to changes in the light environment (Ahumada-Orellana et al., 2018). Previous work in high-density olive orchards has shown that leaves from different canopy positions can differ in anatomical, physiological, and photosynthetic traits in response to long-term light gradients, rather than only to short-term changes in radiation exposure (Larbi et al., 2015). High PAR availability in the lower and middle canopy may therefore enhance the photosynthetic potential of leaves located in these comparatively shaded sectors. However, the unchanged SPAD values indicate maintenance of leaf chlorophyll status rather than increased C assimilation. Direct evidence of enhanced photosynthetic activity would require measurements of leaf gas exchange or chlorophyll fluorescence.

Midday stem water potential (Ψ_{stem}) differed significantly between treatments (Figure 2d). Trees subjected to reflective film exhibited a more negative midday stem water potential than control trees with values ranging from -0.92 to -1.24 MPa, corresponding to a difference of 0.32 MPa. This response was consistent with the higher PAR values observed in the lower and middle canopy sectors. The reflective film increased radiation availability within the canopy, but this may also have increased the local energy load around leaves and fruiting zones, particularly because measurements were performed close to solar noon. Under these conditions, higher radiation can increase leaf temperature and atmospheric demand, promoting greater transpiration and a more negative plant water status. In olive orchards, midday stem water potential is considered a sensitive indicator of tree water status, and recent studies have emphasized that its interpretation is closely linked to measurement time, canopy position, and environmental demand during the day (Garofalo et al., 2024). The more negative stem water potential observed under reflective film should therefore be interpreted as a physiological response to the modified canopy microclimate rather than only as a direct effect on soil water availability. The reflective films can redistribute radiation within the canopy, improving light conditions in shaded sectors (Muñoz-Alarcón et al., 2025), but they may also modify the leaf energy balance and increase evaporative demand when radiation and temperature are high (Ahumada-Orellana et al., 2018).

The reflective aluminized LDPE film significantly modified some fruit compositional traits (Table 1). The percentage of DM at 60 °C increased from 45.6% to 48.0% under the reflective film, representing an increase of 5.4%. This response is consistent with the increase in canopy PAR previously observed in the lower and middle canopy sectors, suggesting that the improvement in light availability may have favored fruit DM accumulation. In olive trees, fruit exposure to higher light conditions has been associated with greater dry weight, mesocarp development, maturation, and oil accumulation, whereas shaded canopy positions generally show lower fruit growth and oil-related traits (Grilo et al., 2019). Fruit moisture and DM determined at 105 °C did not differ between treatments, indicating that the reflective film did not markedly alter fruit water content at the evaluated phenological stage. This is relevant because olive fruit water content is strongly influenced by ripening, cultivar, soil water availability, and agronomic background, and changes in moisture are not always directly proportional to changes in oil accumulation (Vicario et al., 2023). The clearest effect of the reflective film was observed in fruit fat content. Dry fat percentage increased significantly from 39.5% to 43.9% under reflective film, equivalent to an increase of 11.4%. Olive fresh fat percentage also increased significantly, from 18.17% to 20.07%, representing an increase of 10.5%. The increase in fruit fat percentage coincided with the marked enhancement of PAR in the lower and middle canopy, suggesting that greater within-canopy radiation availability was the principal measured factor associated with the compositional response. This interpretation is consistent with previous evidence showing that fruits located in well-exposed canopy positions generally attain higher oil concentrations than those developing in shaded sectors (Grilo et al., 2019). The absence of significant differences in fruit moisture indicates that the increase in fat percentage was not explained by

changes in fruit water content. Oil accumulation in olive fruit is regulated by fruit development, source-sink relationships, and C availability (Grilo et al., 2021; Perez-Arcoiza et al., 2022). Increased illumination of the lower and middle canopy may enhance C assimilation and assimilate supply to developing fruits, providing a plausible physiological basis for the observed increase in fruit fat percentage. Confirmation of this mechanism will require direct measurements of leaf photosynthesis, carbohydrate allocation to the fruit, and lipid biosynthetic activity.

Table 1. Effect of reflective aluminized low-density polyethylene (LDPE) film on DM, moisture, and fat content of olive fruits grown under southern Chilean conditions. Distinct letters in the row indicate significant differences according to Duncan's test (p -value ≤ 0.05).

	Control	Reflective film
DM at 60 °C, %	45.55 $\pm$ 2.05 ^a	48.00 $\pm$ 0.46 ^b
Moisture, %	54.45 $\pm$ 2.05 ^a	52.00 $\pm$ 0.46 ^a
DM at 105 °C, %	96.20 $\pm$ 0.75 ^a	95.43 $\pm$ 0.29 ^a
Dry fat percentage, %	39.45 $\pm$ 0.49 ^a	43.93 $\pm$ 1.36 ^b
Fresh fat percentage, %	18.17 $\pm$ 1.29 ^a	20.07 $\pm$ 0.47 ^b

CONCLUSIONS

The aluminized low-density polyethylene (LDPE) reflective film showed potential for improving the canopy microenvironment of olive trees grown under southern Chilean conditions. The main observed effect was the redistribution of radiation toward the lower and middle canopy zones, where light availability is usually more limiting. This improvement in the light environment was achieved without altering leaf chlorophyll status, suggesting that the treatment enhanced canopy illumination without negatively affecting leaf pigment condition during late fruit development. However, the more negative stem water potential observed under reflective film indicates that changes in radiation distribution may also increase plant water demand, particularly around solar noon. The reflective film favored fruit DM and oil-related traits, supporting the importance of light availability for olive fruit composition. Overall, this study suggests that reflective ground-cover materials may be a useful tool to improve within-canopy light conditions and fruit quality in olive orchards of southern Chile, although their use should be integrated with careful monitoring of tree water status.

Author contribution

Conceptualization: M.V.A. Methodology: G.G.G., V.A.A. Software: G.G.G. Validation: M.A.A., V.A.A. Formal analysis: G.G.G., S.R.B. Investigation: G.G.G., M.V.A., G.G.G. Resources: G.G.G., S.R.B. Writing-original draft: G.G.G. Writing-review & editing: M.V.A., G.G.G. Visualization: G.G.G. Supervision: M.V.A. Funding acquisition: G.G.G. All co-authors reviewed the final version and approved the manuscript before submission.

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