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**MANEJO DE FRUTOS DOBLES EN CEREZOS A TRAVÉS DE MALLAS
FOTO-SELECTIVAS: ASPECTOS MICROCLIMÁTICOS Y FISIOLÓGICOS.**

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RESUMEN

Los frutos dobles y la sutura profunda son desordenes fisiológicos asociados con altas temperaturas y que afecta negativamente la producción de cerezas en áreas con veranos calurosos, problema que se ha visto incrementado debido al escenario actual del cambio climático. Esta investigación evaluó el uso de mallas con diferentes colores y densidad de hilos para prevenir la incidencia de frutos dobles y sutura profunda en cerezos. Se evaluaron tres diseños de mallas con las siguientes configuraciones de color y distancia entre hilos: perla a 2.12 mm x gris a 4.01 mm (PG); gris a 2.16 mm x azul 5.49 mm (GB) y cristal a 2.7 mm x cristal a 7.37 mm (CR). Se cubrieron 2,726 m² de los huertos de cerezo ‘Santina’, ‘Regina’ y ‘Lapins’ (bloques) con cada tipo de malla, dejando la misma superficie sin malla como control. Se evaluó las condiciones microclimaticas incluyendo la temperatura del aire (T_{aire} , °C); humedad relativa (HR,%); radiación solar (RS, W m⁻²); temperatura de la yema(T_{yema} , °C); déficit de presión de vapor (DPV, kPa) y las características fisiológicas de la planta (intercambio gaseoso de la hoja y potencial hídrico del tallo). Se cuantificó la incidencia de pistilos dobles en floración, y frutos dobles en estados inmaduros y a cosecha, además de la sutura profunda de tipo leve, moderada y severa. Las mallas PG y GB disminuyeron significativamente la incidencia de pistilos dobles a floración ($p=0.0007$) en un 88%, y frutos dobles en estados inmaduros ($p=0.0016$) y frutos dobles a cosecha ($p=0.0001$) en un 79% y 89%, respectivamente respecto al control. La malla CR disminuyó con menor efectividad (44%) y solo a cosecha la incidencia de frutos dobles. El uso de mallas, independiente del diseño (color de los hilos y densidad) disminuyeron con la misma significancia ($p=0.0045$) y magnitud (75%) la sutura profunda, pero solo aquella de tipo severa. Las mallas PG y GB redujeron en un 22% la radiación global, mientras que esta reducción fue de un 10% con la malla CR. La T_{yema} fue entre 1.5 y 2.5 °C menor con mallas PG y GB y entre 0.9 y 1.2 °C más baja con la malla CR. Se encontró una relación significativa de la incidencia de frutos dobles ($R^2=0,62$) y sutura severa ($R^2=0,53$) con la radiación

RS. Sin embargo, la magnitud de variación en respuesta a la RS fue mayor en frutos dobles ($\beta_1=0.02$) que en sutura profunda ($\beta_1=0.0047$). Estos resultados sugieren que ligeras variaciones en el color y densidad de los hilos influyen en la incidencia de frutos dobles en cerezos, afectado por cambios en las condiciones de la RS, siendo las mallas PG y GB las herramientas más prometedoras para prevenir la ocurrencia de este desorden en cerezos. Por el contrario, la sutura profunda dependería de otros factores ambientales y no estaría necesariamente regulada por el diseño de la malla.

SUMMARY

Double fruit and deep suture are fruit physiological disorders associated with high temperatures, which negatively affect cherry production in areas with hot summers, with an increasing impact due to the current climate change scenario. This study evaluated the use of netting of different thread colors and density to prevent double fruit and deep suture incidence in cherry. Three different netting designs were evaluated: pearl at 2.1 mm warp x gray at 4.0 mm weft spacing (PG); gray at 2.1 mm warp x blue 5.4 mm weft spacing (GB); and crystal at 2.7 mm warp x crystal at 7.3 mm weft spacing (CR). Plots of 2,726 m² of 'Santina', 'Regina', and 'Lapins' cherry trees (blocks) were covered using the protective nets under study, whereas a control treatment consisting of non-covered trees (plot of the same size) was also included. Microclimatic conditions, including air temperature (T_{air} , °C), relative humidity (RH, %), solar radiation (SR, W m⁻²), bud temperature (T_{bud} , °C), and vapor pressure deficit (VPD, kPa) were determined, while physiological parameters (leaf gas exchange and stem water potential) were also evaluated. The incidence of double pistils at flowering, double fruit at immature stages and harvest, and deep suture (mild, moderate, and severe damage) were quantified. The results showed that PG and GB nets significantly decreased the incidence of double pistils at flowering ($p = 0.0007$) by 88%, and double fruit at immature stages ($p = 0.0016$) and harvest ($p = 0.0001$) by 79% and

89% with respect to the control, respectively. CR netting decreased the occurrence of double fruits with less effectiveness (44%) and only at harvest. The use of all netting, regardless of netting design (thread color and density), reduced deep suture with the same significance ($p=0.0045$) and magnitude (75%), but only in case of severe damage. PG and GB nets reduced SR by 22%, while the CR net reduced it by 10%. Similarly, T_{bud} was reduced between 1.5 and 2.5 °C under PG and GB nets, and between 0.9 and 1.2 °C under the CR net. There was a significant relationship between the incidence of both physiological disorders, double fruit ($R^2=0.62$) and severe suture ($R^2=0.53$) and SR. However, the magnitude of variation in response to RS was greater for double fruit ($\beta_1=0.02$) when compared to deep suture ($\beta_1=0.0047$). These results suggest that slight variations in thread color and density influence double fruit incidence in cherry, being also affected by changes in SR conditions, with PG and GB nets being the most promising tools to prevent the occurrence of this disorder. Conversely, deep suture incidence would depend on other environmental factors and would not necessarily be regulated by netting design.

CAPÍTULO 1.

INTRODUCCIÓN GENERAL

Bajo la condición actual de cambio climático, el incremento de la temperatura ambiental es un factor crítico que podría afectar negativamente el crecimiento vegetativo y reproductivo de cultivos hortícolas, incluyendo frutales, especialmente en etapas críticas el ciclo de su crecimiento y desarrollo, tales como la floración y fructificación, pudiendo impactar negativamente en el rendimiento (Rehman et al., 2015). En especies como el cerezo (*Prunus avium* L.), se ha reportado que, en la etapa de la diferenciación floral, y específicamente en la etapa de transición de sépalos y pétalos, las altas temperaturas inducen la formación de pistilos dobles, que luego dan origen a los denominados frutos dobles (Beppu et al., 2001). La formación de frutos dobles se atribuye al proceso de fusión de dos carpelos durante la etapa inicial del desarrollo floral. Estos carpelos fusionados, a medida que avanza en su desarrollo y crecimiento, alcanzan dimensiones similares, aunque puede ocurrir que uno de los carpelos fusionados no se desarrolle por completo. Además, otros desordenes como la formación de sutura profunda también se encuentra relacionado a un desarrollo anormal de los primordios florales. En este caso, la sutura profunda se originaría por la falta de fusión en los márgenes del carpelo desde su base, observándose en frutos maduros una hendidura a lo largo de la línea de la sutura, creando, además, un ambiente propicio para la colonización de microorganismos como hongos que dan origen a pudriciones de frutos (Southwick y Uyemoto, 1999).

Existen antecedentes que indican que estos desordenes se inducirían tempranamente en la yema, posterior a la iniciación floral. En su etapa inicial comienza con un aplanamiento del meristema donde se forman individualmente los primordios florales. Luego y transcurrida la iniciación floral, en cada primordio se comienzan a diferenciar secuencialmente los

sépalos, pétalos, estambres y pistilo (Diaz et al., 1981). Se ha reportado que durante la etapa de diferenciación floral el incremento de la temperatura a valores igual o superior a los 30°C es el factor más crítico que induce la formación de pistilos dobles en cerezos. De acuerdo con Beppu y Kataoka (1999), bajo una temperatura promedio diaria de 25°C, los primordios florales se desarrollan con normalidad formando un solo pistilo, mientras que a temperaturas de 30 y 35°C se incrementaría en un 10% y 60% el porcentaje de flores con pistilos dobles, respectivamente.

En el caso de la sutura profunda, se desarrollaría a partir de temperaturas medias por sobre los 20°C, incrementándose hasta en un 50% con temperaturas medias diarias superiores a los 25°C (Southwick y Uyemoto, 1999).

La influencia del incremento de la temperatura como la causa principal de estos desordenes ha sido corroborada a través de investigaciones más específicas desarrolladas a nivel molecular. En este sentido, estudios recientes indican que el mecanismo de formación de frutos dobles en cerezas se encuentra regulado por el complejo genético FRUITFULL (FUL), revelando que el nivel de expresión de gen PavFUL es mayor en cultivares que presentan una alta incidencia de pistilos dobles y cuya expresión se ve incrementada bajo condiciones de verano cálido y cuando la temperatura del aire alcanza valores de cerca de 35°C (Wang et al., 2022).

El rol de la luz solar sobre la incidencia de estos desordenes también ha sido documentada. Así, se ha observado una mayor incidencia de frutos dobles en aquellas zonas del dosel del árbol que se encuentran en mayor exposición a la radiación solar, comparada con las zonas más sombreadas del árbol (Beppu y Kataoka, 2011).

En la actualidad existen una serie de tecnologías para contrarrestar los efectos adversos de la excesiva radiación solar y las altas temperaturas

sobre la superficie de los tejidos vegetales, particularmente dirigidas a protección de frutos, y que podrían ser utilizadas para disminuir la incidencia de frutos dobles y sutura en cerezos (Kuden et al., 2020). Uno de los métodos más empleados es el enfriamiento evaporativo mediante la aspersión de agua de riego sobre los árboles. Aunque esta técnica logra reducir la temperatura en el follaje y los frutos, no tiene control sobre el daño por exceso de radiación, además su implementación conlleva un alto costo energético y consumo significativo de agua de riego (Gindaba y Wand, 2005). Por otro lado, la aplicación de agentes químicos o protectores solares han demostrado ser efectivos en el control de daño foto-oxidativo ocasionado por excesiva radiación solar, pero su efecto sobre el control de la temperatura de la planta es solo relativo (Schrader et al., 2008).

Tomando en cuenta estos antecedentes y considerando que la variación en la temperatura en la superficie de los tejidos vegetales es función de los cambios en la temperatura del aire, la radiación incidente y la velocidad del viento (Hanan, 1970), es que se ha propuesto el uso de malla sombra como método para prevenir el desarrollo de frutos dobles en cerezos a través del principio de reducción en la intensidad de luz solar incidente. En este contexto, la implementación de mallas sombras han demostrado una notable reducción en la incidencia de dobles pistilos. Beppu y Kataoka (2000), demostraron que el uso de mallas de polietileno con intercepción de luz del 78% y 53% reduce la temperatura del aire en 3,2°C y 1,8°C, respectivamente, y la frecuencia de formación de dobles pistilos cuando fue comparada con la condición sin malla en huertos de cerezos '. En duraznero (*Prunus persica* (L.) Batsch) el uso de mallas de color negro y blanco con un 55% y 30% de sombreado logró reducir eficazmente la temperatura de las yemas, lo que también resultó efectiva en reducir la formación de frutos dobles en un 69% y 63%, respectivamente en esta especie (Imrak, 2016).

Durante los últimos años se han introducido nuevos materiales de mallas que integran distintos diseños de tejidos y colores de hilos de polietileno de alta densidad y como una alternativa de mitigación y protección de los cultivos frente a condiciones climáticas adversas (Castellano et al., 2008). Estas mallas poseen la capacidad de modificar el microclima luminoso de los cultivos (Mupambi et al., 2018), modificando de esta manera la temperatura de los tejidos vegetales (Solomakhin y Blanke, 2010; Kalcsits et al., 2017). El efecto de las mallas de colores sobre el microclima dependerá del diseño de la malla, en términos de color y entrelazado de los hilos (Mupambi et al., 2018; Arthurs et al., 2013). Además, dependiendo de la configuración de las mallas el espectro y la intensidad de radiación solar se verá diferencialmente alterado (Shahak et al., 2004a; Shahak et al., 2004b), dando origen a diversas respuestas morfológicas y fisiológicas regulados por una serie de foto-receptores específicos tales como fitocromos, criptocromos y fototropinas (Bastías y Corelli-Grappadelli, 2012). Umanzor et al. (2017) trabajando con manzano (*Malus domestica* Borkh.) demostraron que las mallas de colores roja y perla reducen la intensidad de luz total fotosintéticamente activa total, directa y difusa en distinta proporción dependiendo del color de la malla. Estas diferencias de luz transmitida por las mallas se encuentran en función de la distancia y el color de los hilos (Castellano, 2008), y los cambios de proporción de luz difusa altera la temperatura en la superficie de los tejidos vegetales (Urban et al., 2007; Umanzor et al., 2017).

Por otra parte, la modificación del espectro luminoso también tiene un efecto diferencial sobre la temperatura de los tejidos vegetales. Al respecto, Kalcsits et al., (2017) demostraron que la malla de color perla disminuyó en 3.8°C y 5.6°C la temperatura de la superficie de hojas y frutos de manzano, mientras que la malla de color azul lo hizo en 1.5°C y 4.5°C, respectivamente.

Recientemente se ha incorporado distintas opciones de diseño de mallas, las que se basan en que en el mismo tejido de la malla se combinan hilos de diferentes colores y así como también distintas distancias entre hilos, con el propósito de mejorar su efectividad en el control de daño por excesiva radiación solar y altas temperaturas en huertos de manzano (Bastías et al., 2018; Bastías y Boini, 2022). En huertos de avellano europeo (*Corylus avellana* L.) se demostró que el uso de la malla con la combinación de colores color perla-gris permitió incrementar el rendimiento acumulado del cultivo en un 15% en comparación al uso de malla bicolor azul-gris y de color negro, lo que fue atribuido a cambios en las condiciones de radiación solar y de temperatura que se generan bajo estas mallas (Salazar-Canales et al., 2021). Sin embargo, a la fecha no existen estudios del uso de este tipo de diseño de mallas en huertos de cerezo, y menos aún se conoce acerca de su efectividad en el control de frutos dobles o sutura profunda en este cultivo.

HIPÓTESIS

Esta investigación propone que, dependiendo del color y distancia de hilos de las mallas, distinto será el efecto en la inducción de frutos dobles y frutos con sutura profunda en cerezos, lo que se relaciona a cambios específicos en las condiciones micro-climáticas que se generan debido a los cambios en el diseño de la malla.

OBJETIVO GENERAL

Evaluar la incidencia de frutos dobles y sutura profunda en cerezos y las variables micro-climáticas que se ven alteradas con el uso de estas mallas con las siguientes combinaciones de color y distancia de hilos para trama x urdiembre, respectivamente: perla a 2.12 mm x gris a 4.01 mm (PG); gris a 2.16 mm x azul 5.49 mm (GB) y cristal a 2.7 mm x cristal a 7.37 mm (CR).

OBJETIVOS ESPECÍFICOS

- Evaluar la influencia de los distintos diseños de mallas en la incidencia de pistilos dobles a la floración y estados de frutos inmaduros y maduros, además de la incidencia de distintos grados de sutura profunda.
- Cuantificar el efecto de los distintos diseños de malla en las condiciones ambientales de temperatura, radiación solar, humedad relativa, y otras de relevancia.
- Relacionar estas condiciones ambientales con la incidencia de frutos dobles y frutos con sutura profunda para los distintos diseños de mallas.

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CAPÍTULO 2

Netting design differentially affects double fruit and deep suture development in cherry orchards

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Abstract

Double fruit and deep suture are disorders associated with high temperatures affecting cherry production in the current climate change scenario. This research evaluated the following netting design (colors and density) to prevent double fruit and deep suture in cherry: Pearl at 2.1 mm warp x gray at 4.0 mm weft spacing (PG); gray at 2.1 mm warp x blue 5.4 mm weft spacing (GB); and crystal at 2.7 mm warp x crystal at 7.3 mm weft spacing (CR). Plots of 2,726 m² of 'Santina', 'Regina', and 'Lapins' cherry trees (blocks) were covered using these protective nets compared to non-covered trees as control. Air temperature (T_{air} , °C), relative humidity (RH, %), solar radiation (SR, W m⁻²), bud temperature (T_{bud} , °C), vapor pressure deficit (VPD, kPa), leaf gas exchange, and stem water potential were evaluated. The incidence of double pistils at flowering, double fruit at immature stages and harvest, and deep suture (mild, moderate, and severe damage) were quantified. PG and GB nets significantly decreased the incidence of double pistils ($p = 0.0007$) by 88%, and double fruit at immature stages ($p = 0.0016$) and harvest ($p = 0.0001$) by 79% and 89% with respect to the control, respectively. CR netting decreased double fruits with less effectiveness (44%) and only at harvest.

Irrespective of netting design, all nets reduced deep suture with the same significance ($p=0.0045$) and magnitude (75%), but only in severe damage. PG and GB nets reduced SR by 22%, while the CR net reduced it by 10%. T_{bud} was reduced between 1.5 and 2.5°C under PG and GB nets, and between 0.9 and 1.2°C under the CR net. There was a significant relationship between SR and the incidence of double fruit ($R^2=0.62$) and severe suture ($R^2=0.53$). Magnitude of variation in response to RS was greater for double fruit ($\beta_1=0.02$) when compared to deep suture ($\beta_1=0.0047$). These results suggest that slight variations in thread color and density of netting influence double fruit incidence in cherry, being also affected by changes in SR conditions, with PG and GB nets being the most promising tools to prevent the occurrence of this disorder. Conversely, deep suture incidence would depend on other environmental factors and would not necessarily be regulated by netting design.

Key words: Climate change · High temperatures · Protective fruit growing· Colored nets · *Prunus avium* L.

1 Introduction

The increase in air temperature due to climate change can negatively affect the vegetative and reproductive growth of crops, including fruit trees, particularly at crucial stages of their life cycle such as flowering, and thus reduce yields (Rehman et al. 2015). In cherry (*Prunus avium* L.), there is evidence that high temperatures at flower differentiation can induce double pistil formation, which is attributed to a fusion process of two carpels (Beppu et al. 2001), and other physiological disorders such as deep suture, which causes carpel margins to remain open and not fuse at the base (Southwick and Uyemoto 1999). Specifically, the former occurs at temperatures equal to or higher than 30°C (Beppu and Kataoka 1999), while the latter develops from average temperatures above 20°C (Southwick and Uyemoto 1999).

Recent studies at the molecular level have shown that double fruit formation is regulated by FRUITFULL (FUL), revealing that the level of expression of the PavFUL gene is higher in cultivars with a high index of double pistils and whose expression is increased during the summer, when temperature reaches values of 35°C (Wang et al. 2022). On the other hand, double fruit incidence increases in canopy areas that are more exposed to solar radiation than shaded areas (Beppu and Kataoka 2011).

Netting is being used to prevent double fruit formation in cherry trees by reducing sunlight intensity. A previous study on 'Satohnishiki' cherry orchards revealed that the use of 78% and 53% shade nets reduced air temperature by 3.0°C and 1.8°C, respectively, as well as double pistil development when compared with non-shaded trees (Beppu and Kataoka 2000). In peach (*Prunus persica* (L.) Batsch), black and white netting providing 55% and 30% shade proved effective in reducing bud temperature and double fruit formation (Imrak 2016). Recently, colored nets have been introduced as a modern technology for the mitigation and protection of crops against adverse weather conditions. These types of nets can change orchard light microclimate (Mupambi et al. 2018), and thus modify the temperature of plant tissues (Solomakhin and Blanke 2010; Kalcsits et al. 2017). Their effect on the microclimate will depend on netting design in terms of thread color and density (Mupambi et al. 2018; Arthurs et al. 2013), which differentially alter solar radiation spectrum and intensity (Shahak et al. 2004a; Shahak et al. 2004b), triggering several morphological and physiological responses regulated by specific photoreceptors such as phytochromes, cryptochromes, and phototropins (Bastías and Corelli-Grappadelli 2012). In this sense, Umanzor et al. (2017) showed that red and pearl netting reduced the intensity of total photosynthetically active light (PAR) by 25% and 20%, respectively, whereas the proportion of diffuse PAR under pearl netting increased by up to 21% compared to red netting. Depending on thread color and density, netting alters light transmission differently (Castellano 2008), while a higher proportion of scattered

light promotes a reduction in the surface temperature of plant tissues (Urban et al. 2007; Umanzor et al. 2017). In fact, the reduction in light intensity and changes in light spectrum have a differential effect on the temperature of plant tissues. In apples (*Malus domestica* Borkh.), Kalcsits et al. (2017) found that pearl netting reduced leaf surface and fruit surface temperatures by 3.8°C and 5.6°C, whereas blue netting resulted in reductions of 1.5°C and 4.5°C, respectively.

New netting options have been incorporated in recent years. These include the combination of different thread colors as well as different thread densities, with the purpose of improving effectiveness in preventing fruit damage due to excessive solar radiation and high temperatures as previously described in studies on apple orchards (Bastías et al. 2018; Bastías and Boini 2022). In European hazelnut orchards (*Corylus avellana* L.), the accumulated crop yield increased by 15% under pearl-gray netting with respect to blue-gray and black netting, was attributed to changes in solar radiation and temperature due to the use of protective netting (Salazar-Canales et al. 2021). However, to the best of the authors' knowledge, no studies have evaluated the use of netting of different colors and thread density in cherry orchards. Accordingly, this study hypothesizes that double fruit and deep suture incidence in cherry trees will vary depending on thread colors and density of netting, leading to specific changes in the microclimatic conditions of the orchard. To test this hypothesis, the objective of the present research was to evaluate the effect of netting design (thread color and density) on double fruit and deep suture incidence and on microclimatic variables in cherry. The following net designs were evaluated: pearl at 2.12 mm warp x gray at 4.01 mm weft spacing (PG); gray at 2.16 mm warp x blue 5.49 mm weft spacing (GB); and crystal at 2.7 mm warp x crystal at 7.37 mm weft spacing (CR).

2 Materials and methods

2.1 Plant material and experimental design

The experiment was carried out in the Santa Teresa Ltd. orchard located in Rancagua, Province of Cachapoal, General Bernardo O'Higgins Region (34°07'18.0"S, 70°42'26.3"W) for two consecutive seasons, 2022/23 and 2023/24. The area has a temperate, Mediterranean-type climate, with wet winters and dry summers (Errázuriz et al., 1998). Three cherry cultivars were evaluated: 'Santina', 'Lapins', and 'Regina', corresponding to early, mid-, and late-season varieties, respectively. 'Santina' and 'Lapins' were grafted onto Colt rootstock in a planting frame of 4.8 x 3 m and 4.5 x 2.5 m, respectively. 'Regina' was grafted onto Gisela 6, with a row spacing of 4.3 m and a plant spacing of 2 m. The three cultivars were trained on a central axis system, and plots were irrigated using a drip irrigation system.

During the 2022/2023 season, each cultivar was covered using PG, GB, and CR netting, which were characterized using a digital microscope model PCE-MM200 (PCE Instrument, Spain) (Table 1; Fig. 1). Non-covered trees were used as control. The nets were installed at a height of 3.5 m above the ground, with a total of 5 rows, and covering 2,726 m² per net design. The trial was conducted using a randomized complete block design with 3 replicates, considering 'Santina', 'Regina', and 'Lapins' cultivars as blocks (Fig. 2). To evaluate the effect of the nets in each block and type of net, 9 trees were randomly selected per net and control, and then an exposed, a semi-exposed and a non-exposed branch were selected from each tree, with a total of 36 branches per block.

2.2 Microclimatic conditions

From December 1, 2022, to March 31, 2023, air temperature (°C) and relative humidity (%) were continuously monitored at 15-minute intervals using HOBO MX2301A meteorological sensors (Onset Corporation, Bourne, MA, USA). The meteorological sensors were installed at a height of 1.6 m in each type of netting and block, considering a total of 12 sensors for simultaneous monitoring of

temperature and relative humidity variables. Each sensor was covered with an RS1 solar radiation shield (Onset Corporation, Bourne, MA, USA).

The collected data were used to determine the thermal accumulation (hours) above temperatures of 25 and 30°C, which have been described as critical thresholds for deep suture and double fruit incidence (Southwick and Uyemoto 1999; Beppu and Kataoka 1999). At 50 (January 13, 2023) and 80 (February 17, 2023) days after harvest (DAH), bud temperature (°C) was evaluated on completely sunny days with temperatures above 30°C using an infrared thermometer (Mini IR thermometer 42510A, Extech Instruments, Nashua, NH). Measurements were taken at three time points during the day: 10:00 am, 12:00 pm, and 3:00 pm. Simultaneously, global solar radiation ($W m^{-2}$), air temperature (°C), relative humidity (%), and wind speed ($m s^{-1}$) were measured using automatic weather stations model WatchDog 29000ET (Spectrum Technologies, Inc. Illinois, USA), which were installed at the center of each type of net at a height of 1.5 m from the ground and 2.3 m from the tree canopy. These measurements were made at 1-minute intervals between 10:00 am and 4:00 p.m.

Air temperature (°C) and relative humidity (%) data were used to calculate vapor pressure deficit (VPD, kPa), using the following equation:

$$DPV = e^{\circ} \left(1 - \frac{HR}{100}\right)$$

where HR is a relative humidity value (%) and e° corresponds to the saturation vapor pressure, which was estimated according to the following equation (Allen et al. 1998):

$$e^{\circ} = 0.6018 \exp \left[\frac{17.27 T_a}{T_a + 237.3} \right]$$

2.3 Physiological parameters of the tree

Healthy and sun-exposed leaves of 2-year-old spurs were selected, and the following leaf gas exchange parameters were measured: net photosynthetic rate (A_n , $\mu mol CO_2 m^{-2} s^{-1}$), stomatal conductance (g_s , $mmol m^{-2} s^{-1}$), transpiration rate

(E ; $\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$), and leaf water use efficiency (A_n/E), using a Targas-1 infrared gas analyzer (PP Systems, Massachusetts, USA). Stem water potential (Ψ_{stem}) was measured after harvest (March), using a Scholander pressure chamber (PMS 615, PMS Instruments, Washington, USA) in accordance with the methodology proposed by McCutchan and Shackel (1992). Stem gas exchange and stem water potential were measured between 12:00 and 2:00 p.m.

2.4 Double fruit and deep suture incidence

At full flowering (first week of September 2023) and green-straw yellow fruit stages (November 2023), samples were taken from 5 spurs per branch position, block, and netting design, while the total number of double pistils and double fruits were determined (Fig. 3a, b and c). Subsequently, the occurrence of double fruit (Fig. 3d and e) and deep suture (Fig. 4) was evaluated again by counting the fruits exhibiting the disorders. Deep suture was classified according to the length of the cleft along the suture line, into: i) mild, the cleft starts at the pedicellar zone and extends to less than half of the suture line (Fig. 4a); ii) moderate, the cleft extends from the pedicellar zone to more than half of the suture line (Fig. 4b); and iii) severe, the cleft extends from the pedicellar zone to the distal zone of the fruit (Fig. 4c).

2.5 Statistical analysis

Data were subjected to a mixed model statistical analysis, while 'block' and 'branch position' were treated as random factors. To evaluate if bud temperature and incidence of double pistils, double fruit, and deep suture (response variable) differed between netting designs (fixed factor), a generalized linear mixed model with a significance level of 0.05 was used. Significant differences between means were determined using Fisher's LSD test. Data of microclimatic conditions, leaf gas exchange, and stem water potential were subjected to an analysis of variance, while the separation of means was performed using a Fisher's LSD

multiple comparison test at a significance level of 0.05. A linear regression analysis was performed for deep suture and double fruit incidence with respect to global radiation at 50 and 80 DAH, with a significance level of 0.05. In addition, a function for the variable double fruit and deep suture incidence with respect to global radiation was estimated by calculating an F-statistic and according to the reduced statistical model proposed by Jobson (1991). All statistical analyses were performed using Infostat software (Di Rienzo et al. 2007).

3 Results

3.1 Incidence of double pistils, double fruits, and deep suture

PG and GB netting had a significant effect on the incidence of double pistils ($p=0.0007$) during flowering and double fruit at green-yellow fruit stage ($p=0.0016$) and harvest ($p=0.0001$) (Table 2). With respect to the control (non-covered trees), PG and GB netting reduced the number of flowers with double pistils by an average of 88%, and double fruit incidence by 79% and 89% at the immature stage (green-yellow fruit) and harvest, respectively (Table 2). Conversely, CR netting had a significant effect only on double fruit incidence at harvest (44% reduction), but not on the presence of double pistils at flowering or double fruits at immature stages (Table 2).

Regarding deep suture incidence (Fig. 4c), all netting designs reduced severe damage by an average of 75%. with the same significance level ($p=0.0045$; Table 3) with respect to the control; however, no effect was observed on mild or moderate damage (Fig. 4a and b; Table 3).

3.2 Microclimatic conditions

Between January and March, the nets under evaluation had no significant effect on thermal accumulation above 25 and 30°C compared to the control (Fig. 5a and b). At 50 and 80 DAH, PG, and GB nets reduced incident global solar radiation more significantly than CR nets (Fig. 6). Specifically, radiation was reduced by an average of 22% under PG and GB nets, with a 10% reduction under CR nets at

50 DAH. Similarly, radiation decreased by an average of 23% under PG and GB nets, and by 7% at 80 DAH (Fig. 6a).

Netting had a significant effect on wind speed at 80 DAH, resulting in a 49% reduction compared to the control (Fig. 6d). None of the evaluated nets significantly affected air temperature, relative humidity, or VPD (Fig. 6b, c, and e). However, all nets had a significant impact ($p < 0.0001$) on flower bud temperature at the three-time points evaluated at 50 DAH (Table 4). Compared to the control, PG and GB nets reduced bud temperature by an average of 1.6°C at 10:00 a.m., and by 1.7°C and 1.4°C at 12:00 and 3:00 pm, respectively, whereas CR nets did not significantly affect this parameter (Table 4).

At 80 DAH, PG and GB nets decreased bud temperature by a significantly greater magnitude with respect to CR nets (Table 4). In this sense, bud temperature was 2.3 to 2.5°C lower than that in the control under PG and BG nets for the periods between 10:00 am and 3:00 pm, and 0.9 to 1.2°C lower under CR nets (Table 4).

3.2.3 Relationship between microclimatic conditions and incidence of double fruit and deep suture

Significant statistical relationships ($p < 0.05$) were found between double fruit, solar radiation, and bud temperature (Table 5). At 50 DAH, solar radiation and bud temperature explained variations in double fruit incidence by 58% and 50% (Table 5). At 80, solar radiation significantly explained ($p < 0.05$) the same disorder by 66% (Table 5). Regarding deep suture, only solar radiation explained incidence variations of 55% and 51% at 50 and 80 DAH, respectively (Table 5).

Linear functions show the relationships between double fruit and global solar radiation, and between severe suture and radiation, indicating that, for the same date, both disorders behave differently with the same variation in solar radiation (Fig. 7). This is reflected in the slope of the function (β_1), which was significantly higher for the relationship between double fruits and global solar radiation ($\beta_1 = 0.02$), compared to that between the latter and severe suture ($\beta_1 = 0.0047$) at 50 DAH (Table 5). The same was observed at 80 DAH with β_1 values of 0.02 and

0.0043 for double fruits and deep suture, respectively (Table 5). These results were also corroborated by the straight-line comparison test, which showed a significant difference between the regression lines of both physiological disorders (%) in relation to global radiation at 50 and 80 DAH (Table 6).

3.3 Physiological parameters of the tree

No significant effect of the type of net was observed on leaf gas exchange parameters or stem water potential (Table 7).

4 Discussion

All netting designs, regardless of thread color and density, reduced deep suture development regarded as severe but had no impact on that considered as mild or moderate. With respect to double fruit, only PG and GB nets were more effective in reducing incidence. Differences in effectiveness can be attributed to the modifications in microclimate resulting from the use of netting. At 50 and 80 DAH, PG, and GB netting allowed a higher reduction in incident global radiation compared to CR nets (Fig. 6a). This can be explained by the lower thread density of the latter (Table 1; Fig. 1), allowing for greater light transmission as previously reported with other shade nets (Umanzor et al. 2017; Treder et al. 2016; Bastías et al. 2012). From a physical point of view, the radiation transmitted under netting would be composed of the light that passes directly through the space between threads, and the light that is scattered downwards from the threads due to their reflection (Al-Helal and Abdel-Ghany 2011). In this way, netting designed with more opaque or darker-colored threads absorb more and scatter less light, while threads of lighter colors absorb less and scatter more light, in turn affecting the amount of total radiation that passes under netting (Al-Helal and Abdel-Ghany 2011).

The present research showed that PG and GB netting had the same effect on solar radiation transmission, even though they consisted of different designs in terms of thread color and density (Table 1; Fig. 1). This result may be because

GB netting consisted of more opaque threads (blue and gray), which have been reported to absorb more and emit less available light (Blanke 2010; Solomakhin and Blanke 2010; Shahak 2008). This may explain why the amount of solar radiation transmitted under GB and PG netting was similar despite differences in density, since threads in GB netting are spaced further apart (Table 1; Fig. 1). However, another explanation could be that pearl-colored (clear) threads scatter more available light (Solomakhin and Blanke 2010; Shahak 2008). It is important to note that the lower transmission of solar radiation generated by two-colored netting of different thread densities (PG and GB nets) was more effective in reducing double fruit rather than deep suture (Table 2). The linear regression analysis allowed establishing that differences in the effect of the evaluated netting designs would be partly explained by the intensity of solar radiation transmitted under the protective nets, which varies depending on thread color and density (Tables 5 and 6). In this sense, the results of the study indicate that a reduction of 100 W m^{-2} in solar radiation intensity by netting could decrease double fruit incidence by about 90%, with a lower effectiveness of less than 40% in deep suture incidence (Fig. 7).

A previous study conducted by Beppu and Kataoka (1999) revealed that double fruit occurs when temperatures are higher than 30°C during flower differentiation. Similarly, molecular studies have related high temperatures to a higher incidence of double pistils in locations where the maximum temperature exceeds 40°C , and the average is higher than 30°C (Liu et al. 2019). In the present study, no significant differences were found between air temperature (Fig. 6b) or thermal accumulation for the thresholds of 25 and 30°C (Fig. 5a and b) observed under netting with respect to the control. This may indicate that air temperature could not be considered a determinant factor explaining the differences in double fruit incidence resulting from the use of different netting designs. In this sense, the results of our study suggest that differences in solar radiation intensity and bud temperature would better account for variations in the occurrence of double pistils

and double fruits in cherry orchards under netting (Table 4; Fig. 6). After harvest and at the time when cherry blossom differentiation occurs (Fadón et al. 2015), netting significantly decreased bud temperature at the 3 time points evaluated, with differences of up to 2.5° C with respect to the control, being only achieved with PG and BG nets, i.e., those that were the most effective in reducing double fruit incidence. These findings would confirm that thread color and density affect the reduction of incident solar radiation, which influences bud temperature. Specifically, PG and BG nets were more effective in reducing bud temperature compared to CR nets, with global radiation between 12 - 16% lower (Fig. 6). Similar results were reported by Tinyane et al. (2018), who conducted a study in avocado (*Persea americana* Mill.) and found that white and blue netting reduced canopy temperature by 7.6 and 7.3°C, while red netting resulted in a reduction of 2.3°C. In apple (*Malus domestica* Borkh), Kalcsits et al. (2017) demonstrated that blue, red and pearl netting reduced fruit surface temperature by 4.5, 6.4 and 5.6°C, respectively, due to the solar radiation conditions under netting. In peach (*Prunus persica* (L.) Batsch), the use of black and white netting, 55 and 30% shade, combined with kaolin applications reduced bud temperature by 7°C compared to the control, decreasing double fruit incidence by an average of 66% (Imrak 2016). In the present study, the results indicate that slight differences in light transmission (12–16%) depending on net design (thread color and density) are sufficient to differentially influence double fruit incidence in cherry.

The analysis of the effect of bud temperature and solar radiation on double fruit development at harvest indicates that the higher the bud temperature and solar radiation intensity, the higher the incidence of double fruits (Table 5). These results demonstrate that high bud temperature due to high solar radiation intensity would be the main factor inducing double fruit development, which is reflected in the lower incidence of this disorder under PG and BG netting (Tables 4 and 5). In this sense, it has been indicated that incident global solar radiation determines the amount of net radiation absorbed by plant tissues and their temperature

(Jones and Rotenberg 2011). In apples, PG netting reduced net radiation by 18%, in turn reducing sunburn damage, but with no effect on air temperature, which indicates that the reduced damage would be more related to the variation in global solar radiation rather than air temperature (Bastías et al. 2021). Accordingly, in the present study, the amount of radiant energy directly absorbed by the buds under PG and BG netting would be lower than that under CR netting or the non-covered control. Therefore, the lower effectiveness of CR netting in reducing double fruit incidence would be due to its lower capacity to reduce radiant energy load compared to PG and BG netting (Table 2; Fig. 6a). Therefore, energy balance components of the bud could be a useful tool to more accurately select the most appropriate and effective net designs (thread color and density) to reduce double pistil or double fruit incidence in cherry production under warmer climatic conditions.

It is well established that high temperatures during pistil development and differentiation are the primary cause of double fruit formation in cherry (Beppu et al. 2001). However, the molecular mechanisms behind double pistil formation in this species remain poorly understood. This developmental disorder during flower differentiation might be related to the increased expression of the PavFUL gene (Bastías et al. 2021; Liu et al. 2019; Wang et al. 2022). PavFUL belongs to the AGAMOUS-like (AGL) MADS-box family, expressed in the floral buds of cherries. This transcription factor may play a key role in determining the formation of multi-pistils (Wang et al. 2022). Other MAD-box transcription factors, such as PaMADS3/4/5, also regulate multi-pistil formation triggered by high temperatures in cherry. PaMADS3 is temperature-sensitive, and interactions between PaMADS3-PaMADS5 and PaMADS5-PaMADS4 help regulate multi-pistil formation by forming complexes (Wang et al. 2019). Additionally, PavFUL interacts with other MADS-box genes, including PavAP1, PavSOC1, PavLFY, and PavSEP, which also co-regulate flowering and multi-pistil formation (Wang et al. 2022). These genes, especially PavFUL, could be valuable molecular markers in

cherry breeding programs to select genotypes with low incidence of double fruits under high radiation and temperature. With respect to deep suture, netting design showed no effect on the incidence of severe damage while none of the evaluated protective nets was effective in reducing the incidence of mild and moderate damage. The significant relationship between solar radiation and severe suture indicates that this disorder increases with higher solar radiation. However, the magnitude of deep suture damage was lower in response to solar radiation levels compared to that of double fruit (Fig. 7). These findings indicate that, unlike double fruit, a slight variation in netting design (thread color and density) is not sufficient to generate marked changes in the occurrence of severe suture, suggesting that the induction mechanism triggering this physiological disorder differs from that of double fruit. In addition, severe suture incidence was not significantly related to the variation in bud temperature under netting (Table 5). Southwick et al. (1994) found a significant relationship between mean flower bud temperature and the occurrence of deep suture when a temperature threshold above 22°C was considered. This would explain the null effect that netting had on the presence of deep suture regarded as mild and moderate, as well as the no effect of netting design on severe damage, since all measurements of flower bud temperature were taken at temperatures above 20°C under the different net types evaluated (Table 4).

The slight effect of netting design on the occurrence of deep suture could also be explained by factors associated with the water status of the tree, as early studies found that over-tree sprinkling reduced the incidence of deep suture in 'Bing' sweet cherry trees (Southwick et al. 1991). In this sense, Zayan et al. (2016) carried out a study on peach trees and reported that foliar applications of potassium reduced deep suture incidence, being attributable to the key role of this mineral element in increasing water content and decreasing leaf dehydration. Similarly, in nectarine and peach trees, a higher incidence of deep suture has been associated with conditions in which trees are subjected to water deficit the

previous season (Naor 2006; Handley and Johnson 2000). The occurrence of severe water stress with stem water potential values below -2.0 MPa during flower differentiation has been associated with a high incidence of deep suture in peaches the following season (Naor et al. 2005). In this study, netting had no effect on plant water status parameters, such as stem water potential, g_s , E, and WUE (Table 7). In fact, during the measurement period (after harvest), all plants showed stem water potential values that were representative of well-watered conditions for sweet cherry trees (\sim -1.0 MPa) (Blanco et al. 2018). This agrees with the findings of Salazar-Canales et al. (2021), who conducted a study on European hazel (*Corylus avellana* L.) and reported that PG and GB netting did not significantly affect any of the previously mentioned parameters when plants were under irrigation practices to avoid severe water stress during the season. Conversely, in blueberry plants (*Vaccinium corymbosum* L.), the use of netting reduced the severity of water stress after one week without water application under Mediterranean climate conditions (Calderón-Orellana et al. 2023). Consequently, it is possible that the use of netting in sweet cherry orchards may have a greater effect on plant water status, and thus on deep suture incidence, under water stress conditions rather than under optimum plant water status.

For deep suture, the fact that netting had no effects on the incidence of mild and moderate damage, and that net design did not affect the severe formation of this disorder suggest that the nets used in this research would not be altering tree water parameters influencing the development of this disorder. However, it should be noted that previous studies have reported that the variation in water status of cherry plants due to the effect of deficit irrigation or changes in soil moisture content did not influence the occurrence of double fruits or deep suture (Beppu and Kataoka 1999; Engin et al. 2009). Therefore, the effect of netting on the incidence of deep suture cannot be exclusively attributed to the water status component of the tree. In this regard, research on other fruit species, such as peach, indicates that deep sutures start on doubles, but then one of the fruits

aborts and may not become evident at harvest (Handley and Johnson 2000). Further research is required to get a better understanding of the environmental and physiological aspects that regulate deep suture incidence, with special emphasis on the degree of severity of this disorder in cherry trees, and thus allow developing effective management strategies (e.g., the design of specific netting systems) in commercial orchards.

5 Conclusions

Netting design (thread color and density) affects double fruit incidence to different extent in cherry due to variations in solar radiation intensity and bud temperature. PG and BG netting would be the most promising designs to reduce the damage in commercial cherry orchards.

Netting is a good tool to reduce deep suture incidence in case of severe damage but not in fruits exhibiting mild and moderate damage; netting design would not be a determining factor when deciding which type of netting to use to prevent deep suture in commercial cherry orchards.

The results of this research suggest that the development of double fruit and deep suture in cherry differ in terms of physiological and environmental causes. More in-depth research is required to develop new netting systems that allow for a more effective reduction of both disorders under field conditions.

Author contribution statement

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Contributions

CMA: Data collection and analysis, drafting the article. RMB: Mentoring in the conception and design of the research work and critical revision of the article. JC:

Helping with statistical analysis. ACO: Helping with plant water status analysis.
MG: Critical revision of the article.

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Compliance with ethical standards

The authors declare that they have no conflict of interest. This article does not contain any studies involving human or animal participants performed by any authors.

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Tables

Table 1 Warp and weft color and spacing of pearl-gray (PG), gray-blue (GB), and crystal (CR) netting in cherry

Netting design	Warp color	Weft color	Warp spacing (mm)	Weft spacing (mm)	Thread thickness (mm)
PG	pearl	gray	2.12	4.01	0.34
GB	gray	blue	2.16	5.49	0.36
CR	crystal	crystal	2.74	7.37	0.37

Table 2 Effect of crystal (CR), pearl-gray (PG), and gray-blue (GB) netting on the incidence of double pistils and double fruits at the green-straw yellow fruit stage and harvest in cherry trees

Treatments	Double pistils (%)	Double fruits (%)	
		Green-straw yellow fruit stage	Harvest
Control	7.9 ±2.6a	8.3 ±2.0a	4.8 ±1.3a
CR	5.0 ±1.7a	6.6 ±2.2a	2.7 ±0.6b
PG	1.0 ±0.5b	2.4 ±1.0b	0.2 ±0.1c
GB	0.9 ±0.4b	1.1 ±0.6b	0.9 ±0.4bc
<i>p-value</i>	0.0007	0.0016	0.0001

Table 3 Effect of crystal (CR), pearl-gray (PG), and gray-blue (GB) netting on deep suture (severe, moderate, and mild damage)

Treatments	Deep suture (%)		
	Severe	Moderate	Mild
Control	1.7 ±0.5a	10.8 ±1.5a	56.7 ±2.6a
CR	0.6 ±0.2b	12.4 ±2.6a	55.7 ±3.1a
PG	0.5 ±0.2b	10.6 ±3.3a	52.2 ±3.8a
GB	0.2 ±0.1b	6.0 ±1.8a	54.3 ±4.4a
<i>p-value</i>	0.0045	0.1485	0.7153

Table 4 Effect of crystal (CR), pearl-gray (PG), and gray-blue (GB) netting on bud temperature at 10:00 am, 12:00, and 3:00 pm, and at 50 and 80 days after harvest (DAH)

Treatment	Bud temperature (° C)		
	10:00 a. m.	12:00 p. m.	3:00 p. m.
50 DAH			
Control	24.3 ±0.4a	28.5 ±0.4a	30,5 ±0,4a
CR	23.8 ±0.4a	28.0 ±0.4a	30,4 ±0,3a
PG	22.5 ±0.3b	26.6 ±0.3b	28,9 ±0,3b
GB	23.0 ±0.3b	27.0 ±0.4b	29,2 ±0,3b
<i>p-value</i>	<0.0001	<0.0001	<0.0001
80 DAH			
Control	23.7 ±0.4a	28.3 ±0.5a	31.5 ±0.4a
CR	22.5 ±0.3b	27.4 ±0.4b	30.3 ±0.3b
PG	21.4 ±0.3c	26.0 ±0.3c	29.0 ±0.3c
GB	21.4 ±0.3c	25.7 ±0.3c	29.0 ±0.3c
<i>p-value</i>	<0.0001	<0.0001	<0.0001

Table 5 Regression coefficient for the relationships between double fruits, global radiation ($W m^{-2}$), bud temperature ($^{\circ} C$); and deep suture, global radiation ($W m^{-2}$), and bud temperature ($^{\circ} C$) in cherry trees grown under netting (two-colored and crystal) and no cover (control) at 50 and 80 days after harvest (DAH)

Date	Double fruits (%)		Deep suture (%)	
	Global solar radiation ($W m^{-2}$)	Bud temperature ($^{\circ} C$)	Global solar radiation ($W m^{-2}$)	Bud temperature ($^{\circ} C$)
50 DAH				
β_0	-13.20*	-53.85*	-3.87*	-8.81 ^{ns}
β_1	0.02*	1.88*	0.0047*	0.32 ^{ns}
R^2	0.58*	0.50*	0.55*	0.15 ^{ns}
80 DAH				
β_0	-12.55*	-19.41 ^{ns}	-3.19*	-5.44 ^{ns}
β_1	0.02*	0.72 ^{ns}	0.0043*	0.21 ^{ns}
R^2	0.66*	0.23 ^{ns}	0.51*	0.21 ^{ns}

Regression equation is $Y = \beta_0 + \beta_1 X$

*; ns: significant and non-significant at $P < 0.05$, respectively

Table 6 Regression coefficient of the reduced model for the relationships between double fruit and deep suture incidence and global radiation at 50 and 80 days after harvest (DAH)

Date	Coefficient	F-statistic	F-distribution	p-value
50 DAH				
β_0	-8.54	7.91	3.49	<0.05
β_1	0.01			
R^2	0.37			

80 DAH				
β_0	-7.88	10.39	3.49	<0.05
β_1	0.01			
R^2	0.40			

Table 7 Effect of crystal (CR), pearl-gray (PG), and gray-blue (GB) netting on net photosynthesis rate (A_n), stomatal conductance (g_s), transpiration rate (E) and water use efficiency (WUE)

Physiological parameters	Control	CR	PG	GB	p -value
A_n ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$)	4.9 \pm 0.4	6.0 \pm 0.3	6.5 \pm 0.5	6.8 \pm 1.4	0.4164 ^{ns}
g_s ($\text{mmol m}^{-2} \text{ s}^{-1}$)	75.0 \pm 9.5	102.3 \pm 19.1	86.3 \pm 3.8	114.7 \pm 27.8	0.5859 ^{ns}
E ($\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$)	1.9 \pm 0.2	2.3 \pm 0.2	2.1 \pm 0.0	2.4 \pm 0.5	0.6923 ^{ns}
WUE (P_n/E)	2.6 \pm 0.1	2.7 \pm 0.2	3.1 \pm 0.3	2.8 \pm 0.3	0.5955 ^{ns}
Stem water potential (MPa)	-1.15 \pm 0.1	-1,00 \pm 0.1	-0,97 \pm 0.1	-1,02 \pm 0.0	0,4246 ^{ns}

*; ns: significant and non-significant at $P < 0.05$, respectively.

Figures



Fig. 1 Pearl-gray (PG), gray-blue (GB), and crystal (CR) netting evaluated in cherry

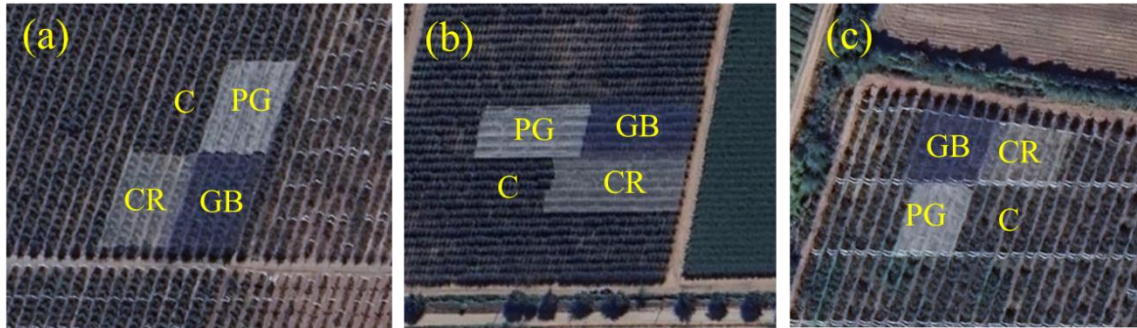


Fig. 2 Aerial view of the pearl-gray (PG) and gray-blue (GB) netting contrasted to crystal (CR) netting and the non-covered control (C) in the blocks of 'Santina' (a), 'Regina' (b) and 'Lapins' (c) cultivars

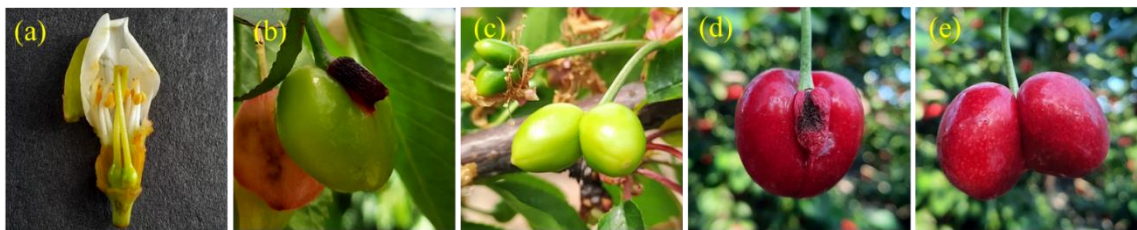


Fig. 3 Symptoms of double pistils in the flowering stage (a), double fruits with aborted ovary and twin fruits at immature stages (b and c) and harvest (d and e) in cherries

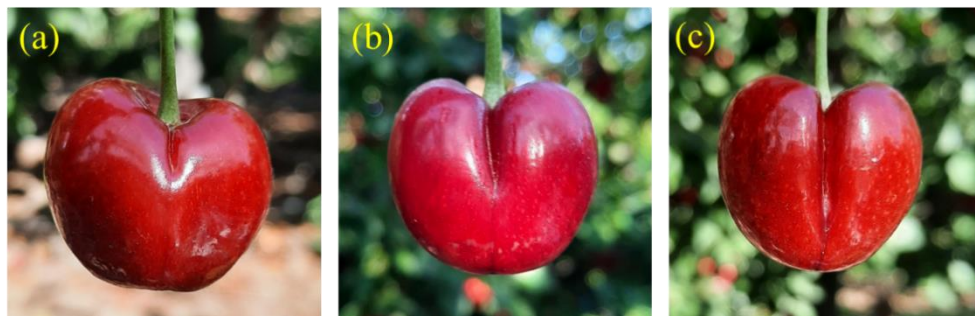


Fig. 4 Symptoms of mild (a), moderate (b), and severe (c) damage in terms of deep suture disorder in cherries

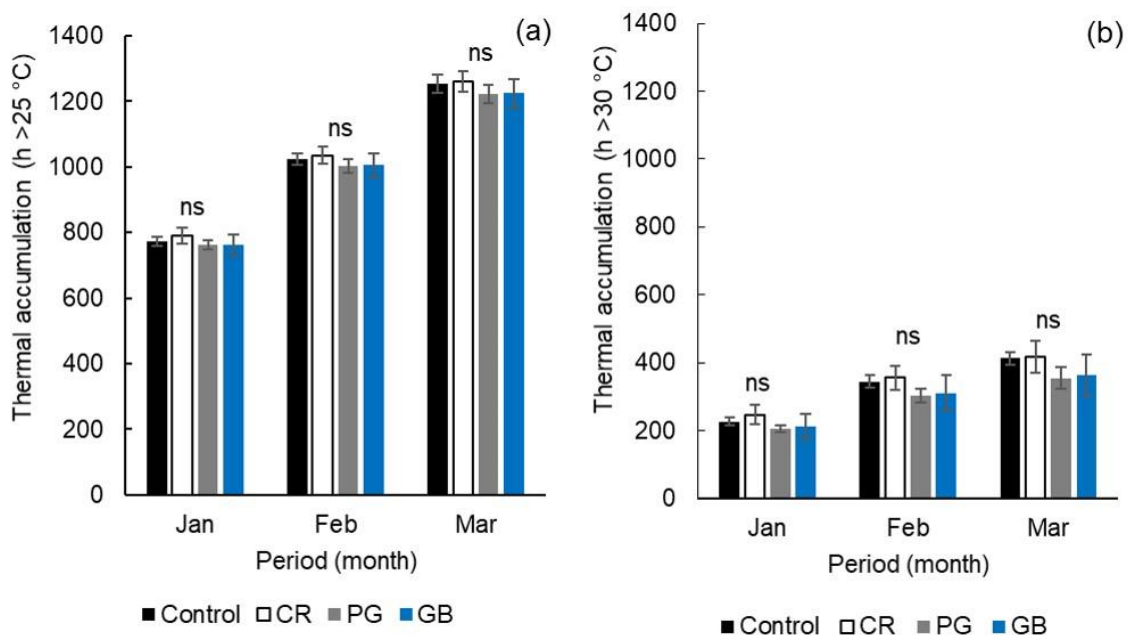


Fig. 5 Effect of crystal (CR), pearl-grey (PG), and gray-blue (GB) netting on thermal accumulation (hours) above 25 and 30°C compared to the non-covered control in cherry orchards

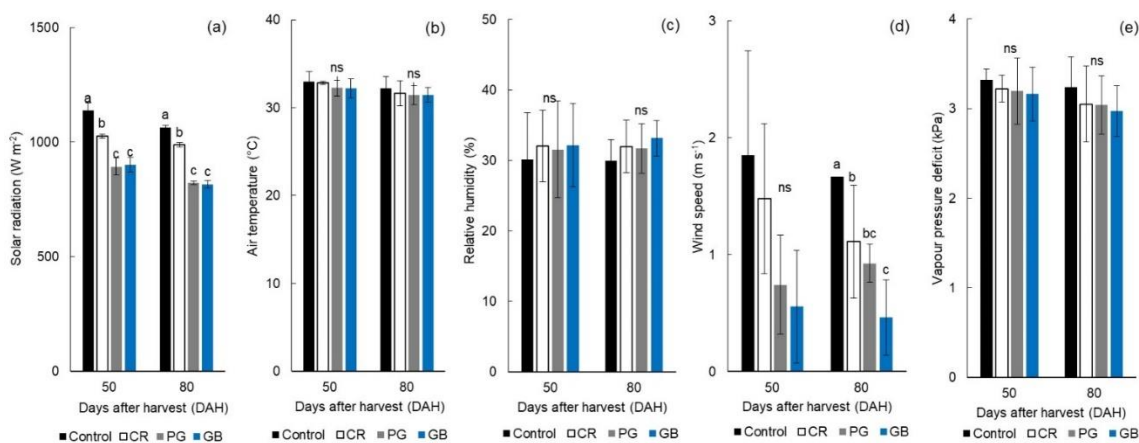


Fig. 6 Effect of crystal (CR), pearl-gray (PG), and gray-blue (GB) netting on global solar radiation (a), air temperature (b), relative humidity (c), wind speed (d) and vapor pressure deficit (e) at 50 and 80 days after harvest (DAH) compared to the non-covered control in cherry

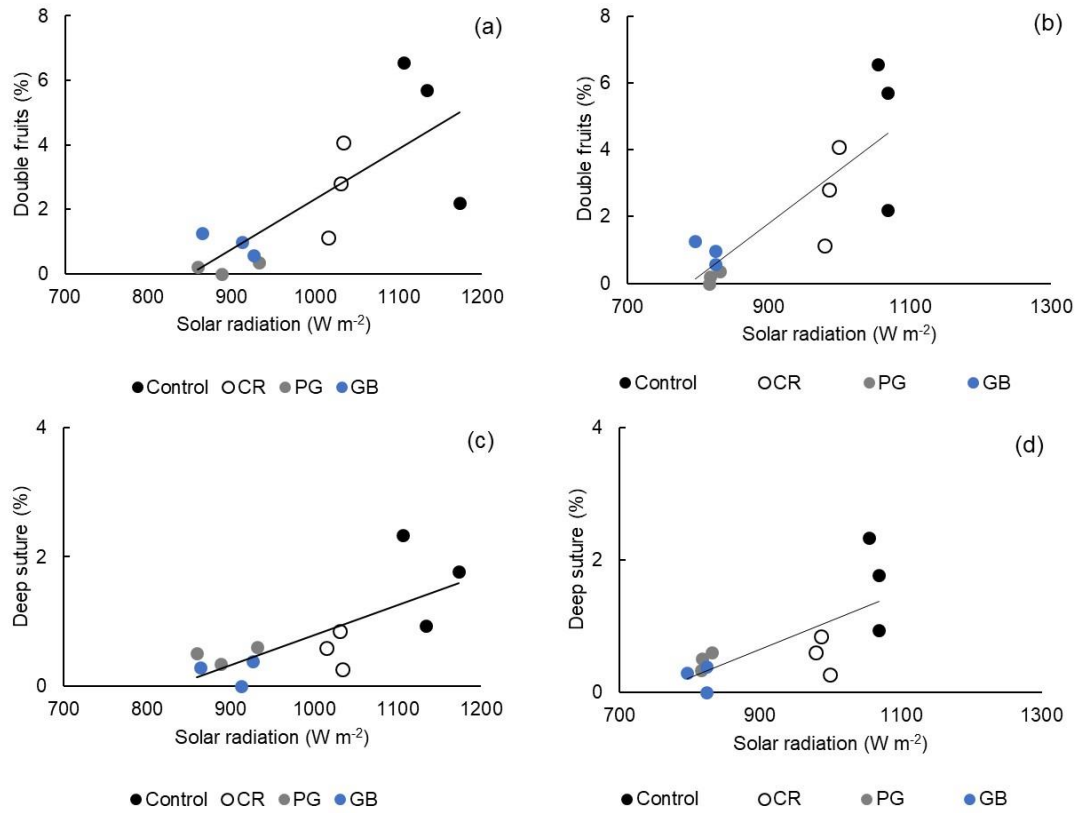


Fig. 7 Relationship between double fruit incidence (%) and global solar radiation at 50 and 80 DAH (a, b); and between deep suture incidence (%) and global solar radiation at 50 and 80 DAH (c, d) influenced by crystal (CR), pearl-gray (PG) and gray-blue (GB) netting compared to the non-covered control in cherry