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# Sustainable mulching with agricultural residues enhances soil properties, fruit quality, growth, and yield of 'Le-Conte' pear

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Recycling plant residues for use as mulch avoids negative environmental impacts and promotes sustainable agriculture by providing a safe and low-cost substrate. Toward this goal, a field experiment was conducted over two successive seasons (2023 and 2024), on 13-year-old 'Le-Conte' pear trees to investigate the effects of different organic mulch materials applied at two coverage areas (1 and 2 $m^2$) on soil properties, vegetative growth, productivity, fruit quality, and weed growth. The results demonstrated an overall positive effect of mulching on evaluated parameters in general. Mulching with sugarcane stalks at 2 $m^2$ showed the highest values of soil nutrients, i.e., P (0.006% and 0.0037%) and K (0.017% and 0.009%) in the first and second seasons, respectively. On the other hand, mulching with rice straw at a 2-$m^2$ coverage area showed the greatest reduction in soil temperature, approximately 3.25°C in the first season and 3.42°C in the second season, while increasing soil moisture content by approximately 3.49% and 5% in both seasons, respectively. In addition, it increased leaf relative water content (RWC) by approximately 42.8% and 22.5% in the first and second seasons, respectively. Moreover, mulching with rice straw at a 2-$m^2$ coverage showed improvements in vegetative growth and also increased tree yield by 60.27% and 43.18% in the first and second seasons, respectively. In addition, it improved fruit quality, including firmness, vitamin C content, and soluble solids content (SSC) in both seasons. The study confirms that recycling agricultural residues into mulch supports key SDGs, including zero hunger (SDG 2) through increased yield and climate action (SDG 13) through improved soil health. Adopting this practice is a significant step toward sustainable food systems.

KEYWORDS
'Le-Conte' pear, organic mulching, rice straw, soil characteristics, sugarcane stalks, weeds, yield

# 1 Introduction

Climate change, which results in increased land degradation, encourages focus on actions that mitigate land degradation. Green and agricultural projects are major contributors to carbon sequestration in soils, thus reducing atmospheric $CO_2$ subsequently mitigating climate change (Hepperly and Setboonsarng, 2015; Holka et al., 2022). Sustainability in the agricultural sector can be recognized through the conservation of water, soil, and the environment (Pang et al., 2020). This can be achieved collectively by recycling plant residues as soil mulch. Using organic mulches involves applying available plant residues that decompose and enhance soil organic carbon and organic matter content (Ranjan et al., 2017). From an environmental perspective, recycling agricultural residues avoids negative impacts associated with improper disposal (Sarkar et al., 2020).

In Egypt, the cultivated pear area covers 5,613 hectares with a total production of 80,993 tons (FAO, 2023), and 'Le-Conte' is the most important pear cultivar in Egypt. Water scarcity is expected to increase as a consequence of climate change, thereby reducing arable land and water resources (Ezzat et al., 2021; Salama et al., 2024). The agricultural production mainly relies on irrigation due to low rainfall, especially in semiarid areas such as Egypt (Fathian et al., 2023). Moreover, approximately 80% of the available water in Egypt is allocated to agricultural practices (primarily irrigation) (Abdelhafez et al., 2020). Consequently, it is a significant challenge for Egyptian farmers to adopt innovative practices that maximize water-use efficiency and minimize water wastage.

Several studies have demonstrated the beneficial effects of organic mulch on chemical and physical soil properties and, thereafter, on crop production (Serry et al., 2019; Iqbal et al., 2020; Zhang et al., 2022; Al-Qthanin et al., 2024). Organic mulch can regulate soil temperature and enhance soil moisture retention. For instance, the application of organic mulches in apple orchard reduced soil temperature and increased moisture content in the root zone (Iqbal et al., 2020), hence enhancing root activity and nutrient uptake (Singh et al., 2020). High soil temperatures in summer (exceeding 35°C) can damage the roots by increasing oxidative stress, inhibiting the photosynthetic process, causing damage to root cells, and even leading to root death (Tokić et al., 2023; Wang et al., 2023; Su et al., 2024). In this context, Du et al. (2022) noted that straw mulch can moderate soil temperature, creating conditions more suitable for plant growth and productivity. Moreover, straw mulch (in 3 cm thickness) positively influenced soil temperature by lowering the maximum temperature and increasing the minimum temperature (Gan et al., 2013; Suo et al., 2019). Several studies reported that mulching with different organic materials, such as paddy straw on pear and wheat straw or corn straw on apple, decreased soil temperature compared with unmulched soil (Liao et al., 2021; Gill et al., 2022; Kiprijanovski et al., 2022). Similarly, straw mulch reduced soil temperature through the shading effect of organic material and conserved soil moisture content by reducing evaporation (Liao et al., 2021), saving 15.4% of irrigation water compared with control (Al-Qthanin et al., 2024). During periods of moisture stress, soil mulched with a wider strip (2 m) retained more moisture than a narrower strip (1 m) (Onwuka and Mang, 2018). Similarly, applying a 10-cm layer of straw mulch in apple orchards increased soil moisture content (2.4%–6.5%), extended irrigation intervals by more than double, and improved water-use efficiency compared with the control (Bakshi et al., 2015). It also improved soil water conservation in pear orchard (Kiprijanovski et al., 2022) and saved 50% of irrigation water in the 'Ruby' grape orchard (Abo-Ogiala and Khalafallah, 2019). Using straw mulching with 4 cm layer in grapevine orchards improved soil physical properties, such as increasing the aggregate stability and enhanced soil structure (Gan et al., 2013). These improvements directly affect minerals availability to the plant, enhance water-use efficiency, and subsequently affect tree growth (Abo-Ogiala and Khalafallah, 2019; Du et al., 2022; Bhan et al., 2025). Utilizing organic mulches adds nutrients to the soil and increases its fertility (Ranjan et al., 2017). In this context, mulching with rice straw (layer of 2.5 and 5 cm thickness) increased available N, P, and K than unmulched soil (Jamir and Dutta, 2020; Van Dung et al., 2022). Rice straw mulching at 1.5 $m^2$ coverage area has been reported to increase N, P, and K uptake with pomelo trees compared with control (Van Dung et al., 2022). It also improved vegetative growth, including shoot length, number of leaves per shoot, and tree volume in 'Ruby' vineyards (Abo-Ogiala and Khalafallah, 2019). Straw mulch exhibited a positive effect on vegetative growth of pear (Kiprijanovski et al., 2022). Additionally, mulching with sugarcane residue (5 cm layer) improved vegetative growth of mandarin trees compared with the control (Bhan et al., 2025). Moreover, Singh et al. (2020) reported that paddy straw mulch resulted in the maximum canopy spread in 'Cv. L-49' guava trees. Regarding organic mulch impact on yield and fruit quality, several studies noticed improved yield and fruit quality with rice straw mulch at 2.4 m wide area on pear (Li et al., 2025) and 10 cm thickness on 'Washington Navel' orange (Ennab, 2023a). As for sugarcane residue, Bhan et al. (2025) reported maximum fruit weight under mulched mandarin trees with sugarcane trash compared to other mulching treatments and control.

Soil mulching is considered as environmentally friendly method for weed management herbicide application (Shehata et al., 2019). Rice straw mulching decreased weed growth in vineyards (Losana, 2022). In addition, Du et al. (2022) reported minimal weed growth with the use of straw mulch. Also, Mohammed (2022) found that mulching an 'Anna' apple orchard with woodchips and peanut shells decreased weed growth and increased weed control efficiency compared to unmulched plots. Based on the available literature, limited information is available regarding the comparative effect of rice straw and sugarcane stalks as mulching materials on vegetative growth and productivity of 'Le-Conte' pear trees, and this research is considered one of the earliest investigations evaluating this subject. Burning or improper disposal of agricultural residues, such as rice straw and sugarcane stalks, causes serious environmental pollution. Therefore, utilizing these organic materials as soil mulch represents an environmentally friendly approach to enhance soil properties, improve tree growth, and increase both yield and fruit quality.

The objectives of the present study were as follows:

1. Evaluate the effects of different organic mulching materials on soil characteristics, growth, productivity, fruit quality, and weeds of 'Le-Conte' pear orchard
2. Monitor the best treatment that can be recommended for general applications

Based on previous studies (Serry et al., 2019; Iqbal et al., 2020; Zhang et al., 2022; Al-Qthanin et al., 2024) and the known beneficial effects of organic mulches, it was hypothesized that applying rice straw and sugarcane stalks as organic mulch would improve soil properties, reduce weed growth, and improve vegetative growth, productivity, and fruit quality of 'Le-Conte' pear trees compared with bare soil, thereby allowing this practice to be recommended for use in pear orchards.

The novelty of this study lies in its systematic evaluation of locally abundant agricultural wastes, not only as mulching materials, but as optimized, scalable solutions for Egyptian pear orchards. It identifies a specific, cost-effective application rate (2 $m^2$ coverage of rice straw) that simultaneously boosts productivity, conserves water, and resolves a critical waste management issue.

# 2 Materials and methods

## 2.1 Study area

The study was conducted on 13-year-old 'Le Conte' pear trees (*Pyrus communis* × *Pyrus pyrifolia*), budded on "*Pyrus betulaefolia*" rootstock, and planted at 3 m × 4 m intervals in sandy soil under a drip irrigation system in a commercial orchard of the 6th October Agricultural Company, located at 32.017069°N, 30.458670°E, 86 km along the Ismailia Desert Road, Egypt (Figure 1), over the course of two consecutive seasons (2023, 2024). Mean monthly temperature, relative humidity, precipitation average, wind direction, and wind speed at the experimental site during the study period were obtained from the NASA POWER Data Access viewer (https://power.larc.nasa.gov/) (accessed on 12/2025) for the study area and presented in Supplementary Table 1. The experimental orchard was managed according to standard practices used in commercial pear orchards. Organic inputs such as compost and organic manure were applied in the winter, while inorganic fertilizers (N, P, and K) were applied during the growing season following an orchard schedule. Common pear orchard practices in the region include winter pruning, irrigation, weed and pest management, and harvesting. The effects of a combination of two distinct organic materials and three distinct mulching areas on soil temperature, moisture, water status, weed growth, vegetative growth, yield, and fruit quality, as well as the nutritional status of the soil and trees, were examined. In this experiment, a 7-cm-thick layer of two organic materials—rice straw and sugarcane stalks—was placed beneath the tree canopy. Strips of 1 and 2 $m^2$ of each material were manually placed, and the results were compared with bare soil (control). Each replication was represented by a single tree, and the treatments were set up in entirely randomized blocks with five treatments [sugarcane stalks (1 $m^2$), sugarcane stalks (2 $m^2$), rice straw (1 $m^2$), rice straw (2 $m^2$), and control] each replicated four times, resulting in a total of 20 trees.

## 2.2 Assessment of soil properties

### 2.2.1 Soil temperature (°C) and moisture (%)

At 10 cm depth, 75 cm distance from the trunk, and on the 1st of April, May, June, and July, soil temperature was measured using a digital soil thermometer (Digital Therm., Lab, System Hi Temp., China), while soil moisture was estimated gravimetrically before irrigation.

### 2.2.2 Soil content of nutrients and organic matter (%)

At the end of each season, soil N, P, K, and organic matter content were determined. The total N, P, and K were measured

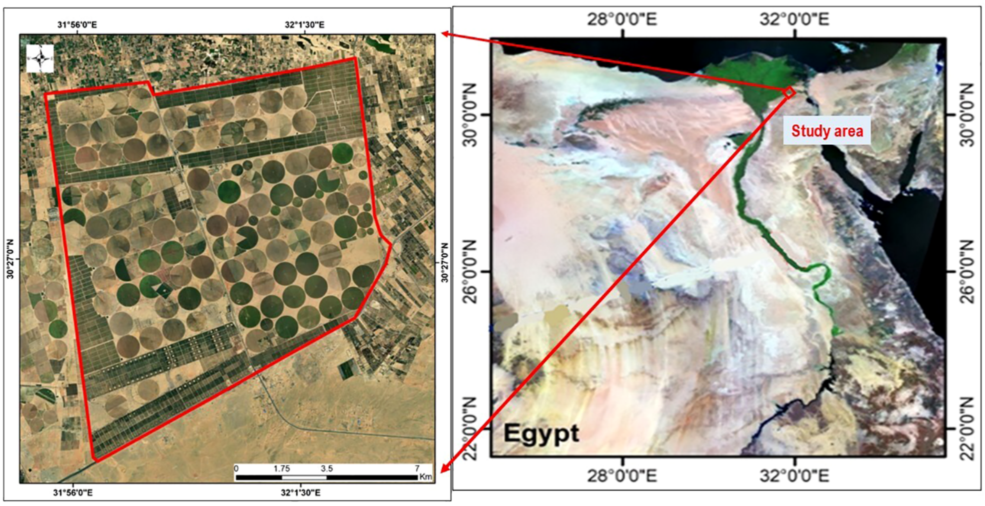


FIGURE 1
Location of the study.

according to Sparks (1996). Soil organic matter was indirectly quantified by determining organic carbon by wet oxidation using the method of Walkley and Black (1934).

### 2.2.3 Relative water content of the leaves

In each season, relative water content (RWC) was determined on the first of April, May, June, and July and calculated according to Equation 1 of Yamasaki and Dillenburg (1999).

$$RWC = \frac{\text{Fresh weight (g)} - \text{dry weight (g)}}{\text{turgid weight (g)} - \text{dry weight (g)}} * 100 \quad (1)$$

## 2.3 Vegetative growth parameters

### 2.3.1 Number of leaves per shoot, leaf area (cm$^2$), shoot length (cm), and number of shoots/ branches

In each season, four main branches, one from each side, were chosen around the tree canopy and tagged to measure the parameters. The measurements were carried on at the end of August. Leaf area and shoot density were calculated according to Equation 2 of Ahmed and Morsy (2023) and Equation 3 of Mohammed (2022), respectively.

$$\text{Leaf area (cm}^2) = 0.73 * (\text{leaf length x leaf width}) + 0.16 \quad (2)$$

$$\text{Shoot density ( \% )} = (\text{shoot number per branch /branch length}) \text{ x100} \quad (3)$$

### 2.3.2 Tree height (m), volume (m$^3$), and canopy diameter (m)

At the end of each season, they were measured; hence, tree volume was calculated using the following Equation 4 according to Mohammed (2022).

$$\text{Tree Volume (m}^3) = (4/3) \text{ x (canopy diameter/2)2 x (tree height)} * (3.14) \quad (4)$$

### 2.3.3 The increment in trunk cross-sectional area

Trunk circumference was measured at 30 cm above the soil surface, and then trunk cross-sectional area (TCSA) was calculated at the beginning and end of each season using the following Equation 5 of Popescu and Popescu (2015), and subsequently, the increase of TCSA was determined.

$$\text{TCSA (cm}^2) = (\text{trunk circumference in cm})^2/(4 \times 3.14) \quad (5)$$

### 2.3.4 Tree productivity

At harvest, the number of fruits and yield/tree were recorded, and the average fruit weight was calculated. Also, yield increment (%) compared to the control was calculated for each treatment using Equation 6 of Kabeel (1999).

$$\text{Yield increment ( \% )} = \frac{(\text{Yield in treatment} - \text{yield in control})}{(\text{Yield in control})} * 100 \quad (6)$$

Moreover, yield efficiency (kg/cm$^2$) was calculated at the end of the growing season as a ratio of yield quantity (kg) of each tree and TCSA (cm$^2$) according to Equation 7 of Westwood (1993).

$$\text{Yield efficiency (kg/}cm^2) = \text{yield per tree (kg)/TCSA (cm}^2) \quad (7)$$

## 2.4 Fruit quality

At harvest, 5 fruits per replicate were randomly selected, and fruit weight (g) using a digital scale and firmness (kg/cm$^2$) using a penetrometer (Magness, Traylor, Yakima, Washington) fitted with an 11-mm tip were measured. Moreover, soluble solids content (SSC %) was measured using an LCII Digital refractometer (Medline Scientific, United Kingdom, SR-95), and juice titratable acidity (%) was titrated against NaOH (0.1 N) and expressed as mg malic acid per 100 mL juice. Also, starch index was measured according to Blanpied and Silsby (1992). Ascorbic acid was determined through titration using 0.1% 2,6-dichlorophenolindophenol, and vitamin C content was expressed as mg/g fruit (AOAC, 1990).

### 2.4.1 Leaf N, P, and K (%)

At mid-August, 10 leaves of each replicate were collected and digested (Chapman and Pratt, 1962), and the digested solutions were used for determination of N, P, and K. Nitrogen (N) % was determined by the micro-Kjeldahl method (Pregel, 1945), phosphorus (P) % was estimated using method of Piper (1945), and potassium (K) % was analyzed using a flame photometer (Brown and Lilleland, 1946).

### 2.4.2 Weed management

At the end of each growing season, the number of weeds was counted in 1 m$^2$ underneath each tree, then the fresh and dry weight of the weeds was estimated. Weed control efficiency was computed using Equation 8 as mentioned by Mohammed (2022).

$$\text{Weed control efficiency ( \% )} = \frac{\text{Dry matter of weeds in control} - \text{dry matter of weeds in treatments}}{\text{Dry matter of weeds in control}} * 100 \quad (8)$$

## 2.5 Statistical analysis

All produced data represent the mean of four replicates per treatment. The statistical analysis was conducted utilizing SPSS V22, Python3.2 software, and differences between treatments were analyzed by one-way analysis of variance (ANOVA) (Steel and Torrie, 1981) using least significant differences (LSDs) ($p < 0.05$

level of probability). Values followed by the same letter(s) in each table column are not significantly different.

# 3 Results and discussion

## 3.1 Soil properties

### 3.1.1 Soil temperature

As shown in Figure 2, in both seasons, at all measurement periods, both rice straw and sugarcane stalks decreased soil temperature compared with the control. The reduction in soil temperature due to organic mulch may result from lower solar radiation absorption by the soil (Onwuka and Mang, 2018) and the shedding effect of the organic materials, which reduces evaporation from the soil surface (Jamir and Dutta, 2020; Liao et al., 2021). Similar results using different organic mulches, such as paddy straw and corn straw, have been reported on pear (Yin et al., 2018; Yang et al., 2019; Liao et al., 2021; Gill et al., 2022; Kiprijanovski et al., 2022). Soil temperature gradually increased with an extended growing season. Moreover, soil temperature decreased with increasing mulching area, with the 2-m$^2$ coverage of either by rice straw or sugarcane stalks being more effective in decreasing the soil temperature.

### 3.1.2 Soil moisture

Data presented in Figure 3 revealed that soil moisture was significantly maintained by using both rice straw and sugarcane stalks as mulching materials compared with bare soil (control), at all measuring periods. The increase in soil moisture under rice straw and sugarcane stalk mulches may be attributed to improve water-holding capacity due to the reduction in evaporation and increment in organic matter content, which improves the soil physical properties (Jamir and Dutta, 2020). These findings were supported by those of Kiprijanovski et al. (2022) on 'Bartlet' pear and Al-Qthanin et al. (2024) on orange. Similarly, Yang et al. (2024) pointed out that the maximum soil moisture of the apple orchard

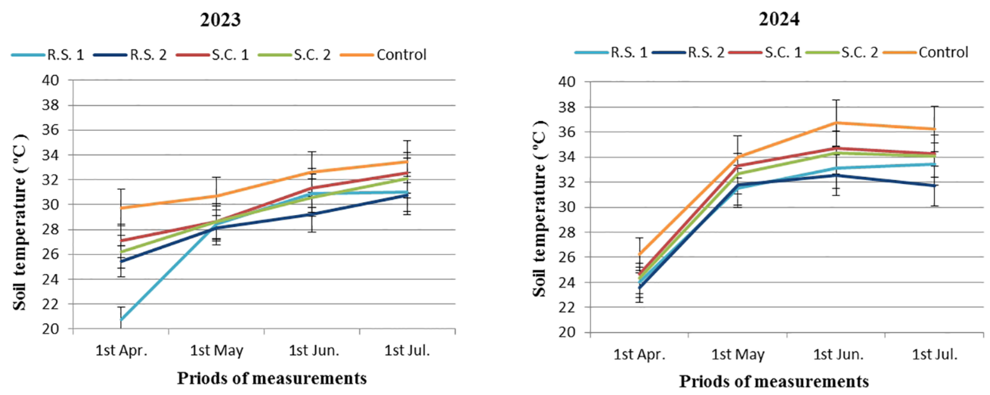


FIGURE 2
Response of soil temperature (°C) to different organic mulching treatments in 'Le-Conte' pear orchard during the 2023 and 2024 seasons. Error bars indicate standard deviation. R.S. 1 = mulching with rice straw at 1 m$^2$ coverage area; R.S. 2 = mulching with rice straw at 2 m$^2$ coverage area; S.C. 1 = mulching with sugarcane stalks at 1 m$^2$ coverage area; S.C. 2 = mulching with sugarcane stalks at 2 m$^2$ coverage area.

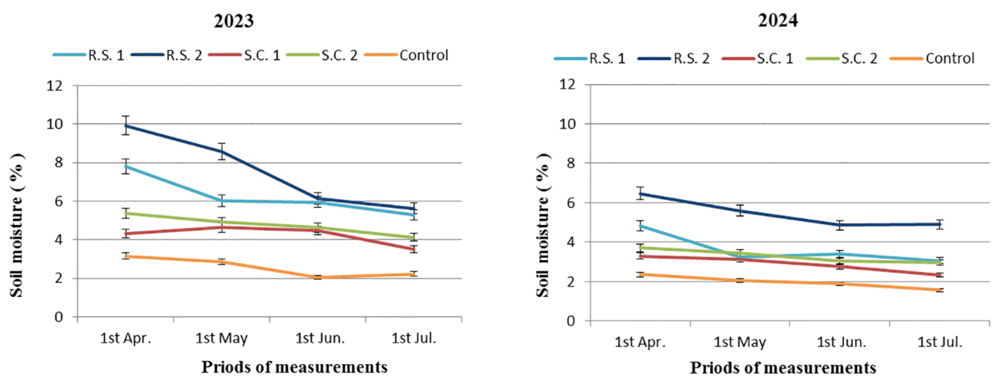


FIGURE 3
Response of soil moisture (%) to different organic mulching treatments in 'Le-Conte' pear orchard during the 2023 and 2024 seasons. Error bars indicate standard deviation. R.S. 1 = mulching with rice straw at 1 m$^2$ coverage area; R.S. 2 = mulching with rice straw at 2 m$^2$ coverage area; S.C. 1 = mulching with sugarcane stalks at 1 m$^2$ coverage area; S.C. 2 = mulching with sugarcane stalks at 2 m$^2$ coverage area.

was obtained by straw mulching. Regarding the mulching layer area, the soil moisture was positively maintained by increasing the area of the mulching layer with either rice straw or sugarcane stalks. Significantly higher soil moisture was obtained in the soil that was mulched with 2 $m^2$ of rice straw mulch than in other treatments and the control.

### 3.1.3 Soil N, P, K, and organic matter content

As shown in Table 1, data revealed that the different mulching materials used in different areas (1 and 2 $m^2$) had positive effects on soil available nitrogen, potassium, phosphorus, and organic matter content compared to unmulched (bare) soil. This effect was continued during the two seasons. In the 2023 season, the data revealed that mulching with rice straw and sugarcane stalks was equally effective in nitrogen, potassium, and soil organic matter content; however, mulching with sugarcane stalks in both 1 and 2 $m^2$ mulching areas had significantly higher phosphorus content (0.0077 and 0.0085 ppm).

In the 2024 season, both rice straw and sugarcane stalk mulching in either 1 or 2 $m^2$ mulching area were equally effective in increasing phosphorus, potassium, and soil organic matter content compared to the control. However, soil mulched with sugarcane stalks in 1 or 2 $m^2$ layer had significantly higher (0.232 and 0.257 ppm) nitrogen content. The enhanced content of soil nutrients and organic matter may be due to the participation of organic mulches in modifying soil physical properties. These modifications create suitable conditions for enhanced activity of soil microorganisms causing an increase in the soil organic matter and nutrient contents (Van Dung et al., 2022), as well as the organic mulches themselves are a source of organic matter, which enhances the availability of soil nutrients for plants (Du et al., 2022). These results are consistent with those reported by Jamir and Dutta (2020) on mandarin and Van Dung et al. (2022) on pomelo. Overall, the results indicate that organic mulching is more effective than unmulching (bare soil) in improving soil physical and chemical properties.

## 3.2 Relative water content of the leaves

Data for both seasons showed that mulching with rice straw and sugarcane stalks significantly increased RWC during all measurement periods (Figure 4). However, it is clear that a 2-$m^2$ layer of rice straw had significantly higher RWC than the other treatments, while the lowest RWC was obtained from the unmulched (control). Relative water content is an important parameter that describes plant water status; it refers to the physiological balance between water supply to the leaf tissue and leaf transpiration. The increment in RWC due to using organic mulches may be attributed to better soil water content in mulched soil, which can affect water absorption by the trees resulted resulting in improved water status (Serry et al., 2019). These results are in agreement with those of Zengin and Sabir (2022) on grapevine and Alhashimi et al. (2023) on mango. Together, these observations pointed out that organic mulching is more efficient in improving water status and the relative water content of the leaves than unmulching (bare soil).

Additionally, soil temperature, moisture, and RWC were analyzed using multicorrelation and regression coefficient, and significant differences were analyzed with LSD. Data in Table 2 revealed a significant negative correlation between soil temperature and soil moisture content or between soil temperature and RWC in both seasons. These results indicated that the increase of 1°C in soil temperature had resulted in a reduction in soil moisture content of approximately −0.863% and −0.946% and in RWC of approximately −0.845% and −0.902% in both seasons, respectively. Moreover, a highly significant correlation among soil moisture content and RWC of the leaves was evident in both seasons.

TABLE 1 **Effect of different organic mulch materials on soil total N, P, K (ppm), and organic matter content (%) on 'Le-Conte' pear orchards during the 2023 and 2024 seasons.**

| Treatments | N (ppm) | P (ppm) | K (ppm) | Organic matter (%) |
|---|---|---|---|---|
| **2023** | | | | |
| R.S. 1 | 0.181 ± 0.027 AB | 0.0043 ± 0.0006 B | 0.026 ± 0.003 A | 0.42 ± 0.057 A |
| R.S. 2 | 0.182 ± 0.028 AB | 0.0045 ± 0.0003 B | 0.028 ± 0.006 A | 0.46 ± 0.015 A |
| S.C. 1 | 0.197 ± 0.030 A | 0.0077 ± 0.001 A | 0.025 ± 0.001 A | 0.37 ± 0.072 A |
| S.C. 2 | 0.154 ± 0.0279AB | 0.0085 ± 0.0008 A | 0.029 ± 0.004 A | 0.41 ± 0.076 A |
| Control | 0.133 ± 0.006 B | 0.0021 ± 0.0009 C | 0.012 ± 0.0008 B | 0.18 ± 0.071 B |
| **2024** | | | | |
| R.S. 1 | 0.195 ± 0.005 B | 0.005 ± 0.0003 B | 0.018 ± 0.001 A | 0.45 ± 0.013 A |
| R.S. 2 | 0.176 ± 0.009 B | 0.0060 ± 0.0003AB | 0.018 ± 0.005 A | 0.42 ± 0.044 A |
| S.C. 1 | 0.232 ± 0.002 A | 0.005 ± 0.0003 B | 0.017 ± 0.0018 A | 0.44 ± 0.022 A |
| S.C. 2 | 0.257 ± 0.022 A | 0.0063 ± 0.0001 A | 0.018 ± 0.0008 A | 0.44 ± 0.017 A |
| Control | 0.133 ± 0.006 C | 0.0026 ± 0.0006 C | 0.009 ± 0.0014 B | 0.23 ± 0.039 B |

Values are expressed as mean ± standard deviation (SD). Values followed by the same letter(s) in each column are not significantly different at the 5% level. R.S. 1, rice straw covering 1 $m^2$; R.S. 2, rice straw covering 2 $m^2$; and S.C. 1, sugarcane stalks covering 1 $m^2$; S.C. 2, sugarcane stalks covering 2 $m^2$.

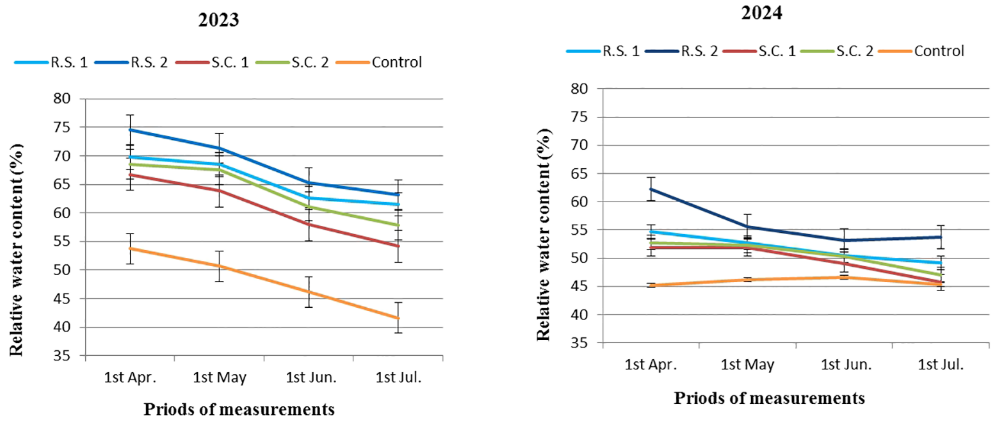


FIGURE 4
Response of leaf relative water content (%) to different organic mulching treatments in 'Le-Conte' pear trees during the 2023 and 2024 seasons. Error bars indicate standard deviation. R.S. 1 = mulching with rice straw at 1 $m^2$ coverage area; R.S. 2 = mulching with rice straw at 2 $m^2$ coverage area; S.C. 1 = mulching with sugarcane stalks at 1 $m^2$ coverage area; S.C. 2 = mulching with sugarcane stalks at 2 $m^2$ coverage area.

## 3.3 Leaf N, P, and K content

Mulching treatments for the 'Le-Conte' pear tree orchard with rice straw and sugarcane stalks in a layer of 1 and 2 m² (coverage area) significantly increased leaf nitrogen content than unmulched trees in both seasons (Table 3). The highest significant value of leaf nitrogen content was detected in the trees with mulching by rice straw in a 1-m² layer and sugarcane stalks in a 2-m² layer in the first season. In the second season, all mulching treatments significantly increased leaf nitrogen content compared to the control without significant differences among these mulching treatments. In both seasons, all mulching treatments in different coverage areas (1 and 2 m²) significantly increased leaf phosphorus content in comparison with the control, and there were no significant differences among different mulching treatments.

As for leaf potassium (K) content, mulching with rice straw and sugarcane stalks significantly increased leaf potassium content than control trees. The highest significant content was obtained in trees with mulching (2 m² coverage area) with sugarcane stalks, while the lowest content was determined in the control trees. The increase in leaf N, P, and K content may be attributed to the positive effect of mulching on improving root regeneration and growth (Bakshi et al., 2015) modifying soil moisture content and temperature, which create appropriate conditions for soil microorganisms (Du et al., 2022), and suppression of weed, which resulted in better translocation of nutrients in plants (Singh et al., 2020). These results are in conformity with the findings of Abo-Ogiala and Khalafallah (2019) on 'Ruby' grapevines and Van Dung et al. (2022) on pomelo. Taken together, these results confirm that organic mulching is more beneficial in improving leaf N, P, and K content than unmulching (bare soil).

## 3.4 Vegetative growth parameters

Rice straw and sugarcane stalk treatments with 1 or 2 m² mulching area had a significant effect on vegetative growth parameters (Table 4). The application of rice straw mulch over a

TABLE 2 Multicorrelation regression coefficient values of soil temperature, moisture, and relative water content (RWC) of 'Le-Conte' pear trees during the 2023 and 2024 seasons.

| Factors | Soil temperature | Soil moisture | RWC |
|---|---|---|---|
| **2023** | | | |
| Soil temperature | 1.00 | −0.863** | −0.845** |
| soil moisture | −0.863** | 1.00 | 0.916** |
| RWC | −0.845** | 0.916** | 1.00 |
| **2024** | | | |
| Soil temperature | 1.00 | −0.946** | −0.902** |
| soil moisture | −0.946** | 1.00 | 0.316* |
| RWC | −0.902** | 0.316* | 1.00 |

Correlation is significant at the 0.01 level (one-tailed).
*= significant at 5%; **= high significant at 1% & 5%.

TABLE 3 Effect of different organic mulch materials on N, P, and K contents (%) of 'Le-Conte' pear leaves during the 2023 and 2024 seasons.

| Treatments | N % | P % | K % |
|---|---|---|---|
| **2023** | | | |
| R.S. 1 | 2.44 ± 0.064 A | 0.643 ± 0.033 A | 1.37 ± 0.015 BC |
| R.S. 2 | 2.41 ± 0.078AB | 0.667 ± 0.031 A | 1.39 ± 0.009 AB |
| S.C. 1 | 2.38 ± 0.027 B | 0.609 ± 0.036 A | 1.40 ± 0.013 AB |
| S.C. 2 | 2.44 ± 0.028 A | 0.631 ± 0.039 A | 1.41 ± 0.015 A |
| Control | 2.34 ± 0.047 C | 0.499 ± 0.079 B | 1.36 ± 0.016 C |
| **2024** | | | |
| R.S. 1 | 2.36 ± 0.129 A | 0.501 ± 0.003 A | 1.37 ± 0.017 AB |
| R.S. 2 | 2.38 ± 0.064 A | 0.500 ± 0.005 A | 1.43 ± 0.055 AB |
| S.C. 1 | 2.46 ± 0.094 A | 0.503 ± 0.005 A | 1.44 ± 0.092 AB |
| S.C. 2 | 2.47 ± 0.22 A | 0.503 ± 0.005 A | 1.51 ± 0.013 A |
| Control | 2.11 ± 0.11 B | 0.458 ± 0.016 B | 1.26 ± 0.071 B |

Values are expressed as mean ± standard deviation (SD). Values followed by the same letter(s) in each column are not significantly different at the 5% level. R.S. 1, rice straw covering 1 $m^2$; R.S. 2, rice straw covering 2 $m^2$; S.C. 1, sugarcane stalks covering 1 $m^2$; S.C. 2, sugarcane stalks covering 2$m^2$.

TABLE 4 Effect of different organic mulch materials on the number of shoots/branch, shoot length (cm), no. of leaves/shoot, total leaf area/shoot ($cm^2$), and shoot density (%) of 'Le-Conte' pear tree during the 2023 and 2024 seasons.

| Treatments | No. of shoots/ branch | Shoot length (cm) | No. of leaves/ shoot | Total leaf area/shoot ($cm^2$) | Shoot density (%) |
|---|---|---|---|---|---|
| **2023** | | | | | |
| R.S. 1 | 8.46 ± 0.15 B | 44.03 ± 0.73 C | 35.90 ± 0.75 C | 755.09 ± 4.56 C | 5.53 ± 0.05 A |
| R.S. 2 | 7.70 ± 0.10 A | 48.83 ± 0.65 A | 39.33 ± 0.64 A | 891.90 ± 7.79 A | 4.12 ± 0.05 C |
| S.C. 1 | 6.46 ± 0.15 B | 43.73 ± 0.61 C | 34.38 ± 0.60 D | 747.37 ± 2.85 D | 4.28 ± 0.10 C |
| S.C. 2 | 7.73 ± 0.20 A | 46.07 ± 0.37 B | 37.37 ± 0.68 B | 865.80 ± 6.19 B | 4.68 ± 0.12 B |
| Control | 6.03 ± 0.05 C | 41.57 ± 0.83 D | 28.27 ± 0.70 E | 636.77 ± 3.63 E | 3.67 ± 0.08 D |
| **2024** | | | | | |
| R.S. 1 | 5.10 ± 0.10 BC | 36.63 ± 0.55 C | 24.20 ± 0.19 C | 653.00 ± 5.76 D | 4.16 ± 0.06 A |
| R.S. 2 | 6.30 ± 0.30 A | 42.23 ± 0.97 A | 28.53 ± 0.47 A | 766.12 ± 5.75 A | 3.74 ± 0.17 B |
| S.C. 1 | 5.23 ± 0.05 BC | 38.17 ± 0.66 B | 22.27 ± 0.30 D | 755.67 ± 2.69 C | 3.42 ± 0.04 BC |
| S.C. 2 | 5.56 ± 0.05 B | 39.23 ± 0.69 B | 26.30 ± 0.26 B | 760.66 ± 2.47 B | 3.58 ± 0.04 BC |
| Control | 4.80 ± 0.43 C | 32.93 ± 0.80 D | 22.00 ± 0.19 D | 609.33 ± 3.47 E | 3.16 ± 0.039 C |

Values are expressed as mean ± standard deviation (SD). Values followed by the same letter(s) in each column are not significantly different at the 5% level. R.S. 1, rice straw covering 1 $m^2$; R. S.2, rice straw covering 2 $m^2$; S.C. 1, sugarcane stalks covering 1 $m^2$; S.C. 2, sugarcane stalks covering 2 $m^2$.

2-$m^2$ area significantly increased the number of shoots/branch, shoot length, shoot density, number of leaves/shoot, and leaf area/shoot followed by sugarcane stalks covering a 2-$m^2$ area. Meanwhile, the lowest values of the aforementioned parameters were observed in the control treatment. The positive effect of organic mulches in improving vegetative growth may be attributed to its beneficial effects on soil temperature and moisture content, which improve soil health and nutrient uptake (Bhan et al., 2025). Similar results of improved vegetative growth due to mulching with rice straw were reported by Abo-Ogiala and Khalafallah (2019) on 'Ruby' grapevines and Kiprijanovski et al. (2022) on 'Bartlett' pear. Also, Bhan et al. (2025) reported that mulching with sugarcane trash improved the vegetative growth of mandarin trees.

Mulching treatments either with rice straw or sugarcane stalks had a significant effect on tree height, volume, canopy diameter, and increment in trunk cross-sectional area (Inc-TCSA) as shown in Table 5. However, rice straw mulch applied over a 2-$m^2$ area gave the highest values of tree height, volume, canopy diameter, and Inc-TCSA, in descending order by application of sugarcane stalks mulch over a 2-$m^2$ area, while the unmulched trees gave the lowest values for all studied parameters. The improved tree characteristics may be due to the increased available soil moisture and nutrients (Bhan et al., 2025) and improved root development, which improved tree growth (Du et al., 2022). Similar results of increased tree volume due to application of organic mulches were reported on pear by Kiprijanovski et al. (2022), on apple by Singh et al. (2020) and

TABLE 5 Effect of different organic mulch materials on tree height (cm), canopy diameter (cm), tree volume ($m^3$), and increment in trunk cross-sectional area ($cm^2$) of 'Le-Conte' pear tree during the 2023 and 2024 seasons.

| Treatments | Tree height (cm) | Canopy diameter (cm) | Tree volume ($m^3$) | Inc. TCSA ($cm^2$)* |
|---|---|---|---|---|
| **2023** | | | | |
| R.S. 1 | 198.33 ± 5.40 B | 261.33 ± 3.21 D | 14.19± 1.10 D | 3.23 ± 0.30 B |
| R.S. 2 | 277.00 ± 2.64 A | 325.00 ± 1.52 A | 25.10± 0.30 A | 3.80 ± 0.2 A |
| S.C. 1 | 223.01 ± 2.64 A | 273.67 ± 3.21 C | 17.48± 0.60 C | 2.73± 0.05 C |
| S.C. 2 | 224.60 ± 6.57 A | 302.67 ± 3.05 B | 21.56± 0.38 B | 3.46 ± 0.20 AB |
| Control | 170.00 ± 8.22 C | 227.33 ± 2.51 E | 9.19± 0.72 E | 1.33 ± 0.15 D |
| **2024** | | | | |
| R.S. 1 | 190.00 ± 4.35 B | 264.33 ± 4.72 B | 13.89 ± 0.40 C | 2.90 ± 0.10 C |
| R.S. 2 | 222.67 ± 2.08 A | 319.67 ± 3.05 A | 23.81 ± 0.27 A | 4.46 ± 0.15 A |
| S.C. 1 | 184.33 ± 5.50 B | 269.33 ± 6.65 B | 13.98 ± 0.26 C | 2.43 ± 0.15 D |
| S.C. 2 | 220.12 ± 3.00 A | 311.00 ± 5.29 A | 22.27 ± 0.68 B | 3.83 ± 0.20 B |
| Control | 173.33 ± 6.65 C | 210.67 ± 2.08 C | 8.04 ± 0.15 D | 1.63 ± 0.05 E |

Values are expressed as mean ± standard deviation (SD). Values followed by the same letter(s) in each column are not significantly different at the 5% level. *increment in trunk cross-sectional area. R.S. 1, rice straw covering 1 $m^2$; R.S. 2, rice straw covering 2 $m^2$; S.C. 1, sugarcane stalks covering 1 $m^2$; S.C. 2, sugarcane stalks covering 2 $m^2$.

Mohammed (2022), and on mandarin by Bhan et al. (2025). Moreover, organic mulches increased the basal girth of guava trees (Singh et al., 2020). When considered as a whole, these results demonstrate that applying organic mulch provides greater improvement in vegetative growth than unmulching.

## 3.5 Yield attributes

Concerning the effect of organic mulching on yield attributes (e.g., fruit weight, number of fruits per tree, yield (kg) per tree, yield increment, and yield efficiency), data in Table 6, obviously, displayed a significant effect of the application of rice straw and sugarcane stalks on the tested yield attributes. It is noteworthy to point out that the heaviest fruit and yield were found at the mulched treatment with rice straw covering an area of 2 m² for both seasons, while the lowest fruit weight and yield per tree were obtained in the control. With respect to the number of fruits per tree, either mulching with rice straw or sugarcane stalks at a coverage area of 1 or 2 m² significantly increased fruit number/tree compared to the control.

Moreover, the highest fruit number was recorded in mulched treatments with rice straw (2 m² coverage area) in the first season and (1 m² coverage area) the second season, while the lowest fruit number was recorded in the control treatment in both seasons. Concerning yield increment, mulching with both rice straw and sugarcane stalks, either at 1 or 2 $m^2$ coverage area, had a significant effect on yield increment compared with the control (Table 6). Application of rice straw mulch over a 2-$m^2$ coverage area had the significantly highest yield increment related to the control. It increased yield by 60.27% and 43.18% in the first and the second season, respectively. As for yield efficiency, mulching with sugarcane stalks at 2 $m^2$ (coverage area) had the highest yield efficiency in the first season, while in the second season, the highest significant yield efficiency was recorded in mulching with rice straw at 1 $m^2$ coverage area. The beneficial effects of organic mulches on yield could be attributed to its effect in maintaining soil moisture content and increasing available soil nutrient content with organic mulches (Bhan et al., 2025), combined with improved root development and microbial activity which led to improved tree yield (Du et al., 2022). These findings of improved yield attributed to mulching with rice straw are in line with those obtained by Li et al. (2025) on pear, Abo-Ogiala and Khalafallah (2019) on 'Ruby' grape, and Ennab (2023a) on 'Washington Navel' orange. Overall, the results confirm that mulched trees with organic materials are superior to unmulched trees in terms of improving tree productivity.

## 3.6 Correlation between leaf and soil N, P, and K content and some vegetative and yield attributes

Generally, as shown in the correlation matrix (Figure 5), in both seasons, there was a positive correlation between soil and leaf N, P, and K content, and vegetative growth parameters, including the number of shoots, leaf area/shoot, tree volume, and increment in TCSA and tree yield. However, some variations in significance and strength were observed between the two seasons due to environmental effects and seasonal nutrient dynamics. In both seasons, there were extremely strong and significant correlations among vegetative growth attributes such as Inc-TCSA, leaf area/shoot, and tree volume with tree yield, emphasizing that improving vegetative growth resulted in higher tree productivity, while these correlations were more significant ($p$ < 0.001) in the first season. This could be attributed to the present relationship between tree yield and vegetative growth especially shoot growth (Hosomi, 2020). These results are consistent with the findings of Rosati et al. (2017) on olive and Fan et al. (2020) on orange, who found that tree yield significantly and positively correlated with increased vegetative growth. Positive correlations were detected among leaf N and K content with tree yield; however, these correlations were

TABLE 6 Effect of different organic mulch materials on fruit weight (g) and numbers, tree yield (kg), yield increment (%), and yield efficiency (kg/$cm^2$) of 'Le-Conte' pear tree during the 2023 and 2024 seasons.

| Treatments | Average weight/fruit (g) | No. of fruits/tree | Yield/tree (kg) | Yield increment (%) | Yield efficiency (kg/$cm^2$) |
|---|---|---|---|---|---|
| **2023** | | | | | |
| R.S. 1 | 146.30 ± 0.36 C | 262.27 ± 6.25 C | 38.37 ± 0.32 C | 45.65 ± 0.38 C | 0.155 ± 0.003 A |
| R.S. 2 | 152.33 ± 0.29 A | 277.23 ± 8.25 A | 42.22 ± 0.20 A | 60.27 ± 0.38 A | 0.151 ± 0.015 A |
| S.C. 1 | 132.53 ± 0.30 D | 254.63 ± 5.15 D | 33.75 ± 0.18 D | 28.10 ± 0.78 D | 0.121 ± 0.002 B |
| S.C. 2 | 149.47 ± 0.45 B | 265.43 ± 6.40 B | 39.67 ± 0.15 B | 50.60 ± 0.70 B | 0.161 ± 0.010 A |
| Control | 118.43 ± 0.40 E | 222.44 ± 4.40 E | 26.34 ± 0.22 E | 0.00 ± 0.00 E | 0.130 ± 0.009 B |
| **2024** | | | | | |
| R.S. 1 | 143.63 ± 0.40 B | 251.23 ± 2.85 A | 36.08 ± 0.22 B | 41.76 ± 0.69 B | 0.162 ± 0.011 A |
| R.S. 2 | 148.53 ± 0.94 A | 245.37 ± 4.13 B | 36.44 ± 0.24 A | 43.18 ± 1.49 A | 0.140 ± 0.006 B |
| S.C. 1 | 136.37 ± 0.70 D | 222.27 ± 5.15 D | 30.31 ± 0.16 D | 19.07 ± 0.25 D | 0.119 ± 0.002 C |
| S.C. 2 | 138.87 ± 0.41 C | 224.30 ± 4.16 C | 31.15 ± 0.32 C | 22.36 ± 1.25 C | 0.126 ± 0.002 C |
| Control | 121.60 ± 0.69 E | 209.33 ± 9.81 E | 25.45 ± 0.19 E | 0.00 ± 0.00 E | 0.123 ± 0.009 C |

Values are expressed as mean ± standard deviation (SD). Values followed by the same letter(s) in each column are not significantly different at the 5% level. R.S. 1, rice straw covering 1 $m^2$; R.S. 2, rice straw covering 2 $m^2$; S.C. 1, sugarcane stalks covering 1 $m^2$; S.C. 2, sugarcane stalks covering 2 $m^2$.

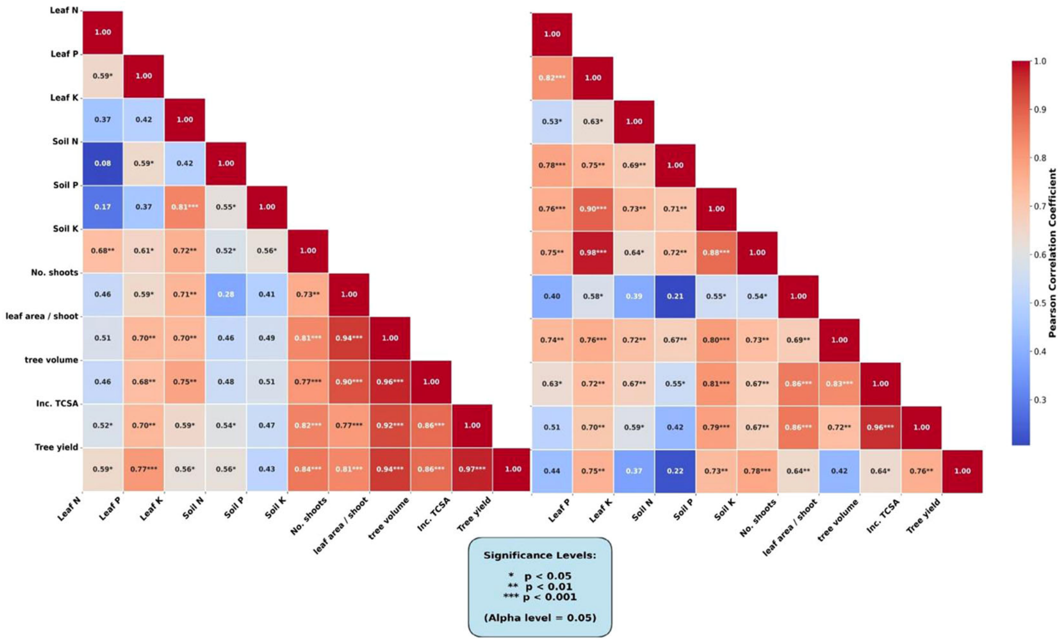


FIGURE 5
Correlation matrix between leaf and soil N, P, and K contents, some vegetative growth parameters, and tree yield during the 2023 and 2024 seasons.

significant ($p < 0.05$) in the first season but not significant in the second season. Similarly, increased leaf N, P, and K resulted in improved tree yield in 'Anna' apple trees (Ismail and Abd El-Hady, 2018) and in orange (Fan et al., 2020). Moreover, a strong positive correlation was obtained among soil K content with leaf K content in the first season ($p < 0.001$), while this positive correlation was less significant ($p < 0.001$) in the second season. A highly significant positive correlation among soil P and leaf P content ($p < 0.001$) was detected in the second season, whereas P correlations were not significant in the first season. The results are in accordance with those of Okba et al. (2025) on 'Anna' apple and Ennab (2023b) on pummelo (*Citrus maxima*), revealing that increased soil nutrient contents, especially N, P, and K, were reflected in enhanced leaf N, P, and K contents. These results showed that increased soil nutrient availability is reflected on its content in the leaves, thus enhancing tree vegetative growth. Leaf P and soil N and K in the first season ($p < 0.05$) and leaf P and soil K in the second season exhibited a highly significant positive correlation with vegetative growth such as the number of shoots ($p < 0.05$), Inc-TCSA ($p < 0.01$), leaf area/shoot ($p < 0.001$), tree volume ($p < 0.01$), and yield ($p < 0.01$ and 0.001 for leaf P and soil K). Moreover, there was a high positive correlation between soil P and the number of shoots ($p < 0.05$), leaf area/shoot, tree volume, Inc-TCSA, and yield ($p < 0.001$). These results confirm the important role of N, K, and P in improving vegetative growth and productivity. Similarly, Okba et al. (2025) found that increased soil content of N, P, and K affected significantly and positively the vegetative growth of 'Anna' apple such as shoot growth and leaf area. A highly positive correlation between vegetative growth parameters such as the number of shoots, leaf area/shoot, and Inc-TCSA ($p < 0.001$) was indicated in the first season; however, the correlations of leaf area/shoot with the number of shoots and Inc-TCSA remained positive but were less significant ($p < 0.01$) in the second season.

## 3.7 Physical and chemical fruit properties

The data presented in Table 7 revealed that the different organic mulching materials had a significant effect on most chemical and physical fruit properties. The greatest significant values of fruit firmness were in direct relationship with the mulched treatment with rice straw covering an area of 2 $m^2$, which exhibited firmer flesh texture fruits than fruits in the other treatments and control in both seasons. However, the differences were only significant in the second season. Fruits of mulched treatment with rice straw at 2 $m^2$ coverage area had significantly higher SSC and SSC/acid ratio and markedly higher vitamin C content than those of other treatments and control. Meanwhile, the lowest values were detected in the unmulched treatment (control). As for titratable acidity, in both seasons, fruits picked from trees treated with mulch with rice straw (2 $m^2$ coverage area) had the lowest significant acid content than those from other treatments and control, while fruits picked from unmulched trees had the highest acid content. However, fruit respiration is an important process during ripening and postharvest life. It is a metabolic reaction that utilizes organic acids during the peak energy requirement of the fruit, which commonly synchronizes with ripening and leads to a decrease in acidity during this period (Sonkar and Ladaniya, 1999). There was no significant response of the starch index to any mulching treatment. The positive effect of organic mulches under study (especially rice straw mulch at 2 $m^2$ coverage area) in improving most fruit physical and chemical properties may be attributed to the suitable soil moisture content (Kiprijanovski et al., 2022) as indicated in Figure 3. The results are in agreement with the findings of Mohammed (2022) using wood chips and peanut shells on 'Anna' apple, Gill et al. (2022) using paddy straw on mandarin, Ennab (2023a) using rice straw on 'Washington Navel' orange, and Bhan et al. (2025) using sugarcane residue on mandarin. Contradictory results were observed by Al-Qthanin et al. (2024) using rice straw on

TABLE 7 Effect of different organic mulch materials on fruit quality of 'Le-Conte' pear tree during the 2023 and 2024 seasons.

| Treatments | Fruit firmness (kg/cm²) | Starch index | Vitamin C (mg/g) | SSC (%) | Titratable acidity (%) | SSC/acid ratio |
|---|---|---|---|---|---|---|
| 2023 | | | | | | |
| R.S. 1 | 4.03 ± 0.20 B | 6.90 ± 0.10 A | 0.880 ± 0.020 A | 12.66 ± 0.20 B | 0.160 ± 0.010 AB | 79.35 ± 4.73 A |
| R.S. 2 | 4.43 ± 0.11 A | 6.71 ± 0.10 A | 0.883 ± 0.020 A | 13.40 ± 0.36 A | 0.153 ± 0.005 B | 87.45 ± 3.54 A |
| S.C. 1 | 4.00 ± 0.09 B | 6.60 ± 0.36 A | 0.846 ± 0.015 AB | 11.46 ± 0.15 C | 0.176 ± 0.015 AB | 65.23 ± 5.81 B |
| S.C. 2 | 3.91 ± 0.10 B | 7.16 ± 0.15 A | 0.870 ± 0.020 A | 11.30 ± 0.30 C | 0.190 ± 0.010 A | 59.63 ± 4.72 B |
| Control | 3.90 ± 0.20 B | 6.76 ± 0.15 A | 0.826 ± 0.018 B | 10.40 ± 0.09 D | 0.193 ± 0.015 A | 53.98 ± 3.66 B |
| 2024 | | | | | | |
| R.S. 1 | 4.63 ± 0.20 AB | 7.36 ± 0.20 A | 0.850 ± 0.030 AB | 12.56 ± 0.20 A | 0.153 ± 0.005 BC | 82.00 ± 2.76 A |
| R.S. 2 | 4.73 ± 0.15 A | 7.46 ± 0.41 A | 0.876 ± 0.015 A | 12.90 ± 0.09 A | 0.146 ± 0.015 C | 88.65 ± 6.10 A |
| S.C. 1 | 3.80 ± 0.09 BC | 7.00 ± 0.2 A | 0.843 ± 0.020 AB | 11.93 ± 0.15 B | 0.183 ± 0.005 A | 65.14 ± 5.69 B |
| S.C. 2 | 4.20 ± 0.43 AB | 7.46 ± 0.15 A | 0.840 ± 0.010AB | 11.46 ± 0.20 C | 0.166 ± 0.005 B | 68.83 ± 7.78 B |
| Control | 3.53 ± 0.32 C | 7.06 ± 0.11 A | 0.813 ± 0.011 B | 10.73 ± 0.37 D | 0.186 ± 0.010 A | 57.49 ± 5.35 B |

Values are expressed as mean ± standard deviation (SD). Values followed by the same letter(s) in each column are not significantly different at the 5% level. R.S. 1, rice straw covering 1 m²; R.S. 2, rice straw covering 2 m²; S.C. 1, sugarcane stalks covering 1 m²; S.C. 2, sugarcane stalks covering 2 m².

'Valencia' orange and Li et al. (2025) using straw mulch on pear. In summary, the results indicate that organic mulching is more beneficial than unmulching (bare soil) in promoting higher fruit quality.

## 3.8 Weed management

Mulching treatments with rice straw and sugarcane stalks significantly affected weed growth (Figure 6). Application of rice straw mulch either at 1 or 2 m² coverage area had the lowest significant weed number per m², fresh and dry weed weight. The highest values of the aforementioned parameters were recorded in the unmulched treatment. The highest weed control efficiency was recorded in mulched treatments with rice straw covering 1 and 2 m² areas, while the lowest values were recorded in unmulched ones. The decreased weed growth beneath mulched trees contributed to the prevention of the germination of weed seeds and seedling

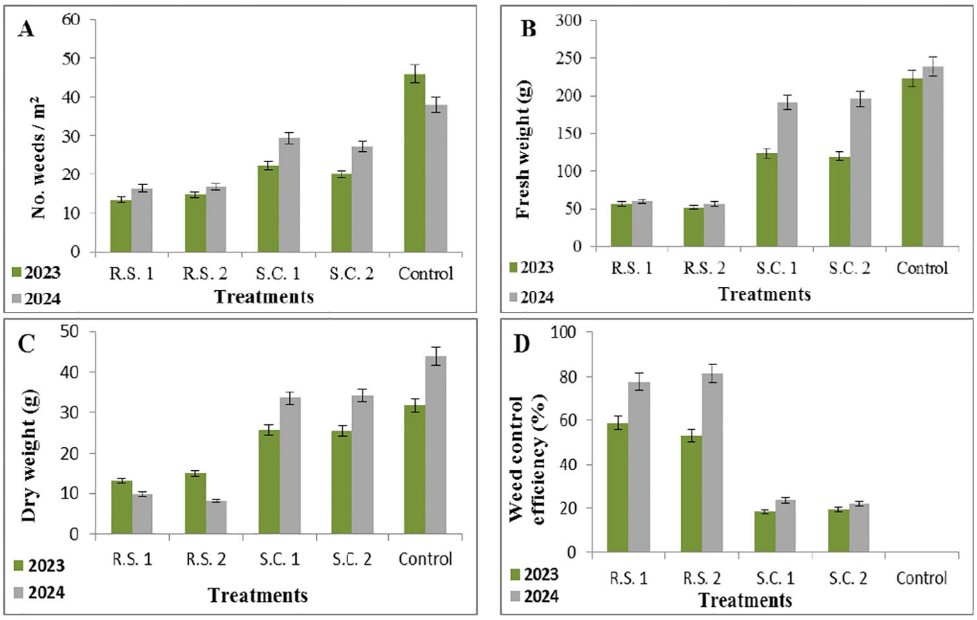


FIGURE 6
Response of weed growth to different organic mulching treatments in 'Le-Conte' pear orchard during the 2023 and 2024 seasons. **(A)** Number of weeds/m²; **(B)** fresh weed weight; **(C)** dry weed weight; **(D)** weed control efficiency. Error bars indicate standard deviation. R.S. 1 = mulching with rice straw at 1 m² coverage area; R.S. 2 = mulching with rice straw at 2 m² coverage area; S.C. 1 = mulching with sugarcane stalks at 1 m² coverage area; S.C. 2 = mulching with sugarcane stalks at 2 m² coverage area.

growth by acting as a physical barrier of light. These results are in agreement with those of Losana (2022) on vineyards. As a whole, the results confirm that organic mulching is superior to unmulching in controlling weed growth and improving weed management.

## 4 Conclusion

This study demonstrates that repurposing rice straw and sugarcane stalks as mulch, specifically, rice straw (over a 2-m² area), in 'Le-Conte' pear orchards was most effective in reducing soil temperature, conserving moisture, enhancing vegetative growth, and increasing yield by 60.27% and 43.18% in the 2023 and 2024 seasons, respectively, compared to bare soil. This treatment also significantly improved fruit quality. Due to its low cost, high availability, and high beneficial effects on tree performance, rice straw mulch at a 2-m² coverage area represents an efficient and sustainable alternative to unmulched soil. Further investigation is warranted to explore the effects of thicker mulch layers on soil physicochemical properties and microbiology.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding authors.

## Author contributions

NEM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. A-MS: Conceptualization, Investigation, Methodology, Resources, Validation, Writing – original draft, Writing – review & editing. NAM: Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. DA: Methodology, Visualization, Writing – original draft, Writing – review & editing. NK: Formal analysis, Methodology, Validation, Writing – original draft. MS: Investigation, Visualization, Writing – original draft, Writing – review & editing. AU: Funding acquisition, Project administration, Writing – original draft, Writing – review & editing. AA-O: Conceptualization, Formal analysis, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing.

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## Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

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## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fagro.2026.1746000/full#supplementary-material

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