SPATIAL DISTRIBUTION OF COFFEE LEAF MINER INFESTATION AND ITS IMPACT ON COFFEE FRUIT MATURATION, YIELD, AND BEVERAGE QUALITY

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Abstract.

Differences in the maturation rate of coffee fruits can be associated with plant stress. The incidence of pests, such as the coffee leaf miner (Leucoptera coffeella), compromises the photosynthetically active area, which can reduce yield and beverage quality. Computer vision can assist in damage reduction by identifying the pest's spatial and temporal behavior.

This study aimed to verify, spatially and temporally, the impact of damage caused by the coffee leaf miner on fruit maturation, yield, and beverage quality. The study was conducted in Indianópolis, Minas Gerais, Brazil, in a 27 ha area at an altitude of 980 m, with Red Latosol (Oxisol). The coffee crop (Coffea arabica), cultivar Topázio, was established four years ago under drip irrigation.

A regular sampling grid of 50 points was defined to obtain data on fruit maturation, coffee leaf miner damage, yield, and beverage quality. Maturation was recorded on five occasions, based on the visual analysis of the percentage of cherries. Yield was quantified by manual harvesting (July 26, 2025) of all fruits from four plants per sampling point. The fruits were dried on a drying patio to approximately 11.7% moisture, then processed and weighed. Sensory analysis of the beverage was performed following the Specialty Coffee Association (SCA) classification methodology, assigning scores from 0 to 100. The evaluation of the coffee leaf miner was performed using computer vision with the OmniAg® embedded computer vision system for pest detection. For each sampling point, images were obtained covering 12 m of the crop row.

The collected data were subjected to descriptive, correlation, and geostatistical analyses. An average yield of 37 bags ha^{-1} was verified, coinciding with the crop's lower biennial yield year, where the CV of 32% indicates variation in productive potential. The average beverage quality score of 81 classifies it as specialty coffee, with variation from 76 to 87 points.

Fruit maturation showed increasing average values from 1.3% (March 2025) to 61% (June 2025), and a CV ranging from 150% to 31% for the period. Coffee leaf miner damage recorded in the images increased from 13 (April 2025) to 20 (June 2025). Geostatistical analysis recorded spatial dependence for all attributes, with the range varying from 110 m for beverage quality to 340 m for fruit maturation.

The maps indicated a concentration of coffee leaf miner damage values in the central region of *the plot. This region partially coincides with higher fruit maturation values (r = 0.26), and a visual spatial correspondence between pest incidence and fruit maturation can be observed in the central portion of the field. Yield was higher in the upper region of the plot, showing low correlation with the pest (r = 0.23). For beverage quality, the highest values were recorded in the left region, showing no correlation with the pest (r = 0.02).*

It is concluded that coffee leaf miner damage showed low correlation with fruit maturation, yield, and beverage quality at the field scale, despite a localized spatial correspondence with fruit maturation in the central region of the plot.

Keywords.
Precision agriculture, Leucoptera coffeella, Geostatistics, Computer vision, Foliar diseases.

Introduction

Brazilian coffee farming can have its yield reduced by the incidence of pests such as the coffee leaf miner (Leucoptera coffeella) (Almeida et al. 2020), which can affect fruit maturation and final beverage quality by reducing the photosynthetic capacity of the plants (Dantas et al. 2021). The efficient control of this pest requires rigorous phytosanitary monitoring. The traditional assessment method, based on visual field inspections, is time-consuming and subjective, potentially leading to chemical control applications at non-ideal times and locations (Esgario et al., 2020). Pest monitoring can be enhanced through precision agriculture tools by regularly acquiring images of the plant canopy and utilizing algorithms alongside artificial intelligence. Computer vision techniques, based on the training of robust models, assist in identifying active lesions caused by the coffee leaf miner. The present study aimed to verify, spatially and temporally, the impact of damage caused by the coffee leaf miner on fruit maturation, yield, and beverage quality.

Materials and Methods

The study was conducted in a commercial field cultivated with coffee (Coffea arabica L.), cultivar Topázio, in the municipality of Indianópolis, Minas Gerais, Brazil. The 27 ha area, located at an elevation of 980 m with Red Latosol (Oxisol) soil, was established with the crop four years ago under a drip irrigation system. A regular sampling grid of 50 points was established in the field to collect data on coffee leaf miner foliar damage, fruit maturation, grain yield, and beverage quality. Foliar damage was monitored using computer vision through the OmniAg® embedded pest detection system, capturing 12 canopy images at each of the 50 grid points. Maturation progress was recorded on five occasions (between March and June 2025) based on the visual analysis of the percentage of cherry-stage fruits. Harvesting was performed by manual stripping of all fruits from four plants at each sampling point. Final yield was determined after the fruits were sun-dried on a patio to a moisture content of approximately 11.7%, processed, and weighed. The sensory analysis of the coffee followed the Specialty Coffee Association (SCA) methodology. The data were subjected to descriptive statistical analysis, Pearson's linear correlation, and geostatistics, culminating in the generation of spatial distribution maps.

Results and Discussion

The average yield of 37 bags ha^{-1} was representative of the values found for the crop's low-yield biennial year. The CV of 31.5% indicates the presence of variability in the field's productive potential. The maturation of cherry-stage fruits evolved over time from 1.3% (March 2025) to 61% (June 2025), showing a decrease in CV from 150% to 31% over the same period. In turn, the use of computer vision (OmniAg®) evidenced an increase in foliar damage caused by the coffee leaf miner, rising from 13 detections (April 2025) to 20 detections per sample (June 2025). Beverage quality showed values ranging from 76 to 87 points, with an average score of 81 out of 100 points, classifying the coffee as specialty (SCA).

Geostatistical analysis demonstrated spatial dependence for the evaluated attributes, with ranges varying from 110 m (beverage quality) to 340 m (fruit maturation). The maps revealed a concentration of foliar damage caused by the coffee leaf miner in the central region of the field (**Fig. 1**). Visually, damage areas partially coincided with higher fruit maturation, with r = 0.26. Conversely, higher yield in the upper field showed low correlation with pest incidence (r = 0.23). Beverage quality showed no correlation with foliar damage (r = 0.02).

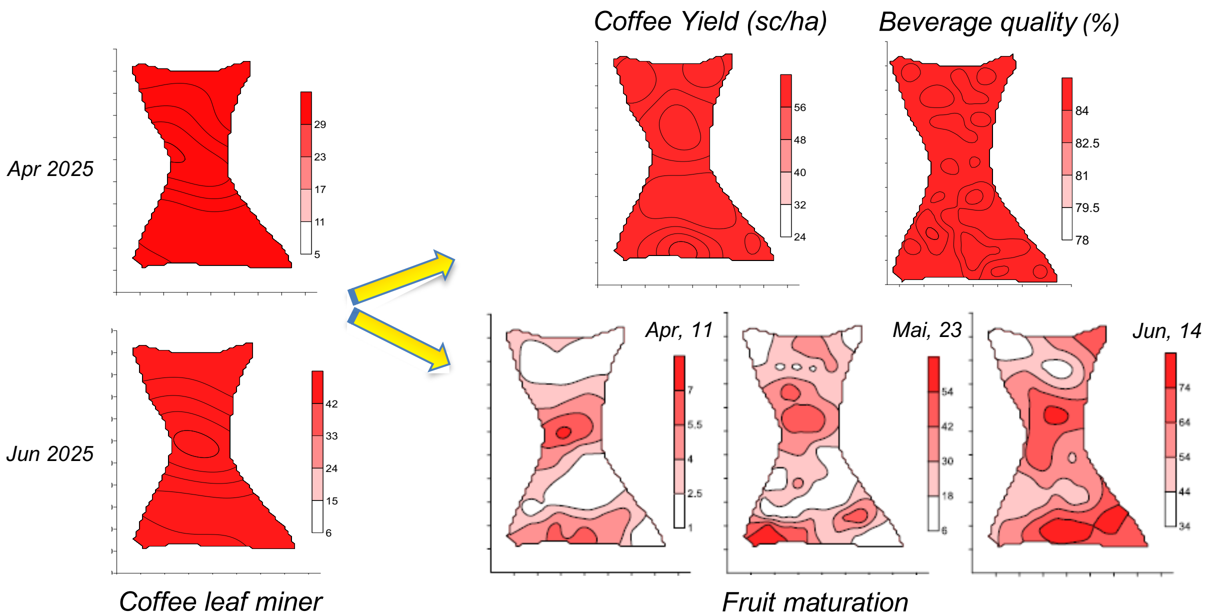

Fig. 1 Spatial distribution maps evaluating coffee leaf miner incidence, fruit maturation, crop yield, and final beverage quality within the experimental field.

Conclusion

Coffee leaf miner damage showed a low correlation with fruit maturation, yield, and beverage quality at the field scale, despite a localized spatial correspondence with fruit maturation in the central region of the field. Geostatistical analysis revealed the spatial behavior of L. coffeella incidence, fruit maturation, yield, and coffee beverage quality. The use of artificial intelligence based on computer vision proves to be a supportive tool for the spatial monitoring of the pest, enabling site-specific interventions and the mitigation of crop physiological stress.

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