

Inter-cropping practices to improve biodiversity can affect yield and quality of organic strawberries

G. Podedworny¹, M. Tartanus¹ and E. Malusá¹

Abstract

*Flowering inter-crops are promising solutions for enhancing ecosystem services (e.g. functional biodiversity, weed control and soil fertility), particularly in organic systems. However, their effects on yield and fruit quality have not been clearly established. A two-year field experiment was carried out to evaluate the impact of a living mulch, a flower strip and flower islands on the agronomic performance of *Fragaria × ananassa* cv. 'Lycia' in an organic farming system. The flower strip (a mixture of various flowering plants grown along one side of the crop edge) and flower islands (the same mixture grown in small patches within the strawberry rows) significantly increased the cumulative marketable yield of strawberries compared to a plot without such arrangements. Both practices also reduced the incidence of fruit damage. On the other hand, white clover living mulch grown in the inter-rows resulted in higher slug damage, as well as delayed fruit ripening. The choice of the inter-cropping practice should therefore depend on the specific effect or ecosystem service to be provided and should be carefully tailored to the crop and its management context.*

Keywords: floral strip, living mulch, cover crop, strawberry yield, fruit marketable quality

Introduction

Despite the relatively high economic viability of organic strawberry production (Resende Filho *et al.*, 2019), its profitability is often limited by lower yields compared with conventional systems, highlighting the need for strategies that could enhance productivity in organic cultivation (Romero-Gámez & Suárez-Rey, 2020).

Inter-cropping practices such as flower strips and living mulches are gaining increasing interest in organic fruit growing for their potential to enhance ecosystem services and crop resilience (Fountain, 2022; Kowalska *et al.*, 2022). Flower strips can improve pollination (Ganser *et al.*, 2018) and reduce pest pressure by supporting natural enemies (Sigsgaard *et al.*, 2013), whilst living mulches help suppress weeds (Bhaskar *et al.*, 2021), supply nutrients (Alexander *et al.*, 2019), as well as increase below-ground biodiversity (Furmańczyk *et al.*, 2025). Despite growing evidence of their ecological benefits, the effects of these practices on strawberry productivity remain insufficiently documented, even though economic performance is a key factor influencing farmers' adoption of inter-crops (Ha *et al.*, 2025). Reliable assessments of agronomic outcomes are therefore crucial for promoting these low-input strategies in fruit production.

This study aimed to evaluate how three kinds of flowering inter-crops — living mulch, flower islands, and a flower strip — affect yield, marketable fruit quality and the proportion and types of fruit damage in organic strawberry production.

Material and Methods

A two-year open-field experiment (2022–2024) was conducted in Skierniewice, Central Poland, on loamy sand soil. Strawberry plants (*Fragaria × ananassa* cv. 'Lycia') were planted in spring 2022 at a spacing of 0.9 × 0.2 m. Four treatments were tested, each represented

¹ National Institute of Horticultural Research, PL-96-100 Skierniewice, gerard.podedworny@inhort.pl

by a single plot of about 200 m², depending on the treatment, to allow planting the same number of strawberry plants: (i.) living mulch (a mixture of *Trifolium repens* and *Festuca ovina* sown in alternate inter-rows), (ii.) flower islands (4 patches of 2 m length each grown within crop rows), (iii.) a one-sided flower strip (along the plot margin), and (iv.) a control without companion plants. The flower islands and strip contained annual species (*Anethum graveolens*, *Tagetes* spp., *Lobularia maritima*, *Tropaeolum majus*, *Matthiola longipetala*) and perennials (*Pulmonaria officinalis*, *Stachys officinalis*). The plantation was managed in accordance with organic production standards: mechanical and manual weeding, annual fertilisation with dried chicken manure, drip irrigation as needed, but no plant-protection products were applied.

Yield was assessed by total and seasonal (early-, mid-, late-season) marketable output and by the weight share of damaged fruit harvesting from all the plants in the plot. Damaged berries were classified as affected by *Lygus* feeding, slug feeding, sunscald or pathogen rot. Continuous variables were analysed using multiple linear regression models incorporating relevant explanatory variables (treatment, year, harvest order), whereas numbers of fruits in particular damage classes were evaluated with chi-square tests followed by multiple comparisons with the Šidák correction at $\alpha = .05$.

Results

Both the flower strip and the flower islands, but not the living mulch, significantly increased the cumulative marketable yield compared with the control (Figure 1). Moreover, the analysis by individual harvest periods confirmed the tendency of the living mulch to delay fruit ripening, reducing early-season yield while increasing late-season yield (data not shown).

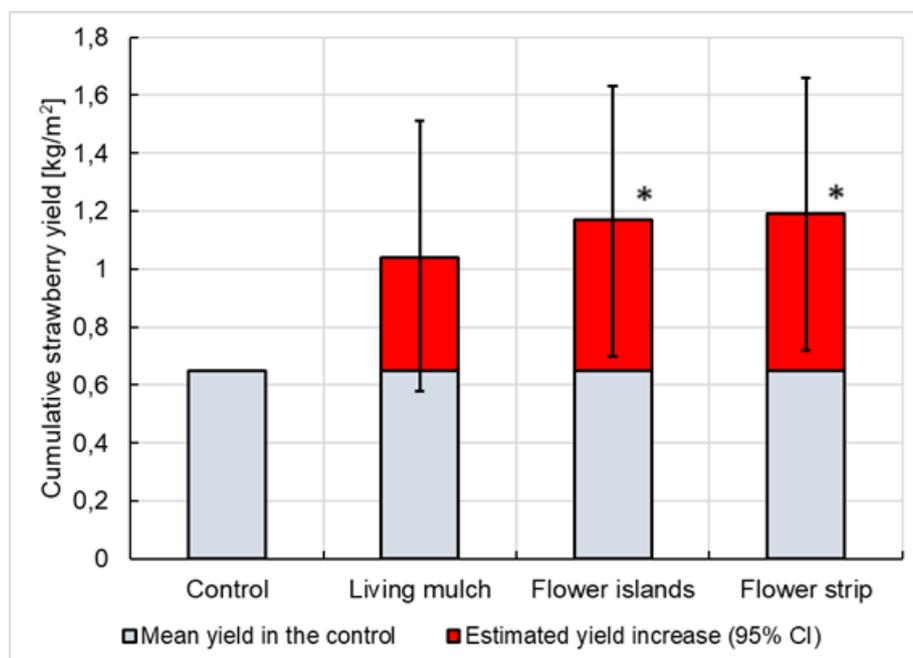


Figure 1: Mean cumulative marketable strawberry yield as affected by three intercropping practices. Red bars represent the expected change relative to the control yield (regression coefficients b) with corresponding 95% confidence intervals. Asterisks indicate statistically significant differences compared with the control ($p < .05$).

The weight proportion of damaged fruit was reduced by both the flower strip and the flower islands compared with the control. However, the estimated decrease in the living mulch treatment was not statistically significant (Figure 2).

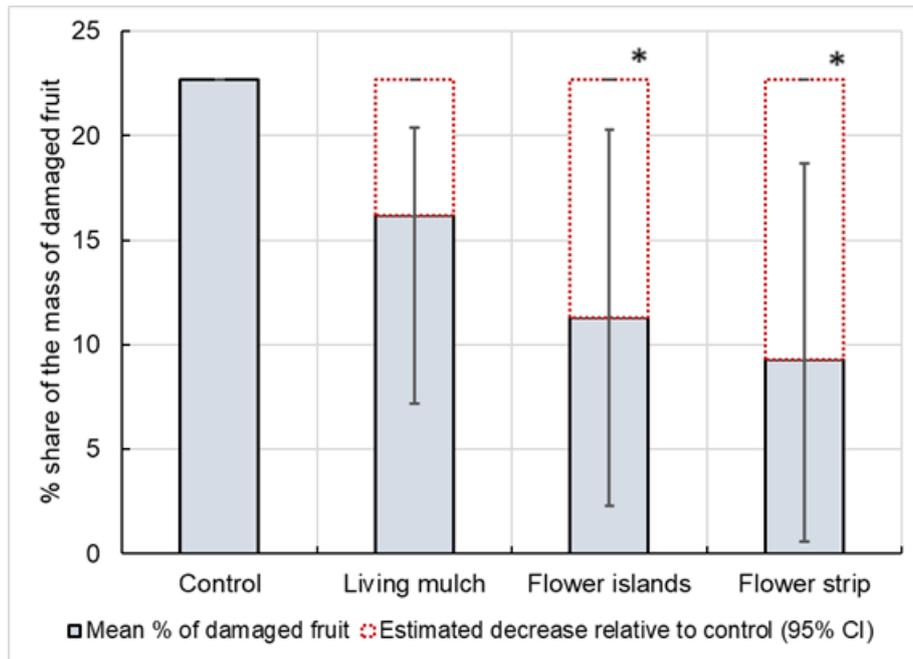


Figure 2: Mean percentage share of the mass of damaged strawberry fruit out of the total yield as affected by three inter-cropping practices. Bars outlined with a dotted red line represent the expected change relative to the control (regression coefficients b) with corresponding 95% confidence intervals. Asterisks indicate statistically significant differences compared with the control ($p < .05$).

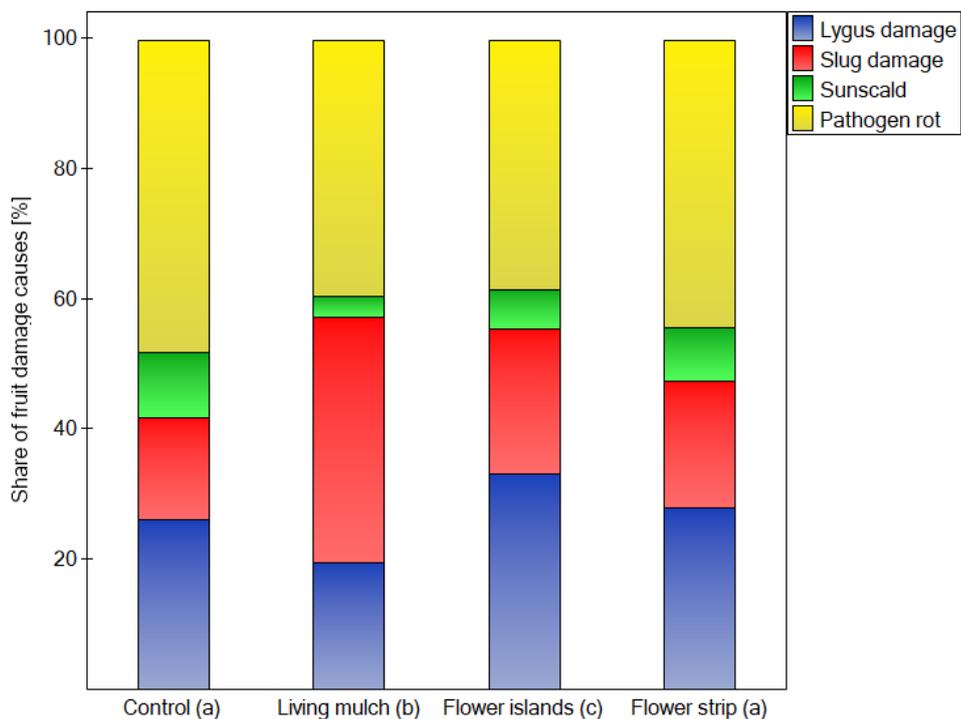


Figure 3: Proportion of strawberry fruit damage causes under different inter-cropping practices. Groups designated with the same letter (given in brackets) are not significantly different ($p < .05$).

Analysis of the two-year dataset showed that the living mulch and flower island treatments differed significantly from the control in the distribution of fruit-damage classes. In the living mulch plots, slug-feeding damage increased, whereas the flower islands showed an increase in damage caused by *Lygus* spp (Figure 3).

Discussion

In this study, both the flower strip and the flower islands increased cumulative marketable yield while simultaneously reducing the mass proportion of damaged fruit. These positive effects can be explained by enhanced natural pest control and pollination resulting from the enrichment of the area with floral resources (Fountain, 2022). However, it should be noted that flower treatments may also produce unintended side effects, such as the increased activity of plant bugs observed herein, and reported also by McCabe *et al.* (2017).

In contrast, neither the increase in cumulative yield nor the reduction in damaged fruit supported the use of clover living mulch; instead, delayed fruit ripening was recorded, which could be due to shading by the cover crop (Neuweiler *et al.*, 2003) and/or excessive, and not synchronised with crop demand, nitrogen supply.

From a practical perspective, these findings suggest that carefully designed floral inter-crops can offer tangible productivity benefits in organic strawberry systems, however, they require cautious use and site-specific evaluation to avoid adverse effects on crop performance.

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