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Effect of Flowering Strips in Associated Broccoli and Lettuce Crops on Increasing Land Use Efficiency

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Abstract: Diversifying agroecosystems enhance the sustainability of agricultural production and reduce input dependency during agroecological transitions. To achieve this objective, a study was conducted to assess the impact of intercropping and the introduction of flowering plant strips on land use efficiency and crop damage in a lettuce and broccoli association. The results indicated that the introduction of flowering plant strips alone led to a significant increase in land use efficiency, while intercropping alone did not have any such effect. The efficiency was measured using the land use equivalent ratio (LER), which consistently showed values greater than 1, suggesting a significant increase in efficiency. It should be noted that the presence of flower strips in the crop fields were found to increase the incidence of molluscs and *Plutella xyllostella*. Additionally, the competitive ratio analysis revealed that broccoli was more competitive than lettuce in the intercropping system. Therefore, farmers can increase the efficiency of land use and profitability by incorporating flower strips in the intercropping systems of broccoli and lettuce.

Keywords: agroecology; diversification practices; horticultural crops; responsible consumption and production; sustainable agriculture

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1. Introduction

Vegetable production in Colombia, South America, is mainly carried out in areas of less than 3 hectares, which represents 75% of farms [1]. About 40% of these farms have a production area of less than 1 hectare, and this sector generates around 117,000 direct jobs and 233,000 indirect jobs [1]. Lettuce is one of the primary leafy vegetables produced in Colombia for consumption. In the year 2022, the country produced 122,235 tons of lettuce in 5072 hectares, with an average yield of 24 $t.ha^{-1}$ [2]. Broccoli is another vegetable of significant economic and food security importance, with a yearly production of 2422 tons [3]. Most of this production relies on external inputs such as fertilisers and pesticides, whose residual effects can negatively impact both producers and consumers [4].

In some regions of Colombia, peasant family farmers specialise in growing cruciferous crops in monocrop or as part of crop rotation systems where broccoli, cauliflower, and cabbage are rotated four times per year [1,5]. However, cruciferous growth is being hindered by Clubroot disease caused by the obligate pathogens *Plasmodiophora brassicae (Protista: Phytomyxea)* which can cause early plant death, resulting in nearly 100% yield loss [5,6]. This is partly due to the low adoption of diversification practices such as rotation and intercropping, given that sequentially planting the same crop species increases the likelihood of accumulating soil-borne pathogens and insect pests, resulting in negative plant–soil feedback [7]. It is crucial to implement better farming practices to ensure the sustainability of cruciferous crops. Introducing non-susceptible crop species is one solution to prevent disease attacks.

The intentional addition of functional biodiversity to crop systems at multiple spatial and or temporal scales, or agricultural diversification, potentially reduces the negative impacts of intensive production while enhancing agroecosystem's resilience and sustainability [8,9]. This process involves the introduction of plants within the crop, known as "crop diversification" (e.g., rotations, polyculture, companion planting, intercropping, cover crops, green manure), or the introduction of non-cultivated plants at the field edges, referred to as "non-crop diversification" (e.g., flower strips, grass margins, inter-row vegetation management, scattered trees, etc.) [10].

Planting flower strips on the edges of crops and using intercropping practices can improve resource use efficiency, enhance soil water retention capacity, and increase habitat diversity for beneficial insects, ultimately favouring the provision of ecosystem services such as pest regulation and pollination [10–12]. However, the effectiveness of this strategy depends on various factors, such as species composition [13], functional traits that attract pollinators and natural enemies [14], scale spectrum [15], strip-wide [16], time of establishment [17,18], and the complexity of the landscape surrounding the crops [19].

One way to determine the response of this interaction between crops is through a calculation based on the biomass generated by each species, comparing the yield between monoculture and polyculture, thus obtaining the Land Equivalent Ratio (LER) [20]. When the value is >1, it indicates that the combined yield of the associated crops is greater than in monoculture, while a value <1 suggests that the association is less favourable than monoculture production [20]. As an example, lettuce, when associated with rocket, has an LER value of 1.41 [21]. In association with carrots, this index is 1.41, and when ground cover is implemented, it is 1.31 [22], indicating that lettuce is a plant well-suited to intercropping. Broccoli shows a similar response when associated with beans, with an LER ranging from 1.13 to 1.44, depending on the proportions of plants used for the intercropping [23]. The same principle is used to measure the level of competition among the species involved in the association, for which the competitive ratio (CR) is estimated. When values are <1, they indicate a positive effect, showing limited competition among the plants involved, whereas values >1 indicate a negative level of competition in the association [20].

Although agricultural diversification has been extensively studied, there is still a need for a deeper understanding of how combining different diversification strategies affects crop productivity, especially in the Colombian Andean highlands. Therefore, the aim of our study is to evaluate how the association between broccoli–lettuce and flowering (aromatic) plant strips affect land use efficiency. Given that agroecological practices, such as diversification, are associated more frequently with positive socioeconomics outputs [24–26], we also compared the economic performance of diversified crop arrangements compared to pure stand crops. Some studies highlight that applying multiple diversification strategies creates more positive outcomes than individual management strategies [27]. We hypothesised that combining intercropping and flower strips on the edges enhances the efficiency of land use, increasing LER (land equivalent ratio), which in turn enhances the profitability of crops.

The transition towards sustainable horticultural production requires the development of new knowledge that supports the expansion of organic farming in Colombia. However, despite the implementation of regulations for organic agricultural products since 2006, only 1% of cultivated areas have been certified as organic, indicating a limited progress in this area [28,29]. The initiatives towards organic farming has been mainly led by farmers associations, with some political support for agroecological transition processes [30]. This study highlights the significance of agricultural diversification as a practice to reconfigure agroecosystems, reduce input dependence, and mitigate the risk of productivity loss for producers during the stage of input substitution. The proposed schemes are based on ecological processes [31,32]. The results of this study provide insights on how to integrate traditional practices with organic management schemes in broccoli and lettuce production.

2. Materials and Methods

2.1. Study Site

Two experimental evaluation cycles were conducted: 1. From 10 October 2022 to 3 January 12023; 2. 19 April to 14 July 2023. All experiments were held at the Obonuco Research Center-Agrosavia, located in Pasto, Nariño, Colombia (1°11′52.55″ N; 77°18′25.67″ W). The location corresponds to the Altiplano subregion of Nariño at an altitude of 2841 m.a.s.l., with an average annual temperature of 12.9 °C. Based on these two climate variables and according to the Caldas-Lang classification [33], it is categorised as a cold semi-humid climate (Fsh). The location had an average annual precipitation of 840 mm.

2.2. Edaphic Characterisation of the Soil of the Plots

The research was conducted on Andisol order, classified as Vitric haplustands subgroup with a clay loam texture [34]. The soil's chemical characteristics in the experimental trial area were as follows: pH (6.18); organic matter (3.41%); in mg.kg^{-1} for P (77.54), S (6.95), Fe (335.61), B (0.46), Mn (5.69), Cu (2.45), and Zn (3.61); in cmol(+).kg^{-1} for K (1.01), Ca (6.06), and Mg (1.16). There was no exchangeable acidity. The bulk density was 1.92 g.cm^{-3}.

2.3. Plant Species and Agronomic Management

The plant species evaluated were lettuce (*Lactuca sativa*) variety Coolguard, and broccoli (*Brassica oleracea* var. italica) hybrid Legacy. The flower strip was established with the species *Chamaemelum nobile* (Chamomile), *Calendula officinalis* (Marigold), *Mentha* sp. (Mint), *Thymus vulgaris* (Thyme), and *Artemisia absinthium* (Wormwood). These species were selected because they are widely used by agroecological producers in the region to enhance natural biological pest control in their gardens.

2.3.1. Sanitary Management

The first evaluation cycle was carried out organically, using plant extracts of *Allium sativum* and *Capsicum annuum* (garlic and chilli), *Azadirachtin indica* (neem), wormwood hydrosol (*Artemisia absinthium*), tea tree extract (*Melaleuca alternifolia*), elicitors, biocontrol agents (*Bacillus amyloliquefaciens, Agrobacterium radiobacter, Bacillus pumilus*, and *Trichoderma koningiopsis*), entomopathogens (*Beauveria bassiana, Metharhizium anisopliae, Lecanicillium lecanii, Bacillus thuringiensis*), and mineral products based on sulphur and calcium.

In the second cycle, for the organically managed plots, the same products as described for the first cycle were used. While for conventional management, fungicides with active ingredients such as azoxystrobin, captan, flutriafol, carbendazim, metalaxil + propamocarb; insecticides based on cyromazine, acephate, permethrin, emamectin benzoate, diflubenzuron + lambda-cyhalothrin, and metaldehyde were applied in rotation to control slugs.

2.3.2. Plant Nutrition

Nutrition was provided using mineral fertilisers with an application equivalent to 88, 50, and 50 kg.ha^{-1} of N, P_2O_5, and K_2O, respectively, for lettuce and 120, 150, and 210 kg.ha^{-1} of N, P_2O_5, and K_2O for broccoli. Minor edaphic elements were supplemented at a rate of 96 kg.ha^{-1} of commercial product, and nutrition was further complemented with foliar fertilisation based on phosphorus, boron, and calcium. Soil fertilisation was performed with 5 t.ha^{-1} of rock phosphate and 15 t.ha^{-1} of vermicompost, with supplementary foliar fertilisation based on boron, organic carbon, nitrogen, and calcium [35]. We utilised the following foliar fertilisers for our crops:

- Wuxal Tapa Verde: A concentrated suspension (SC) of grade 16 + 0 + 0 + 24 Ca + microelements. It contains the following nutrients in grams per litre: Total Nitrogen (160), Calcium (CaO) (240), Magnesium (MgO) (32), Total sulphur (S) (1.6), Boron (0.32), Copper (0.24), Iron (0.49), Manganese (0.41), Molybdenum (0.08), and Zinc (0.32).
- Globafol: An organic-mineral fertiliser for foliar application based on vegetable extracts. It is formulated as a soluble concentrate and contains the following nutrients in grams per litre: Total Nitrogen (35), Phosphorus (98.3), and Organic Carbon (63.5).

- Klip Boron: A simple fertiliser for foliar and soil application. It is formulated as a soluble powder and contains the following nutrient in grams per kilogram: Boron (205).

2.4. Experimental Design and Evaluated Variables

The experiment was conducted using a randomised complete block design with four replications in a factorial arrangement. We selected a homogeneous field (2500 m^2) with a slight slope (10%). To account for the impact of variable changes due to this condition, we considered four blocks in the experimental design. We established pure stand and intercropped plots of lettuce and broccoli to compare variables between monoculture and diversified plots. The intercropping plots were designed to replace a given number of plants of one component crop, lettuce or broccoli, with the same number of the other component crop, using a replacement or substitutive design. As a result, the density of each crop was lower in the intercrop than in its pure stand (control). However, the total stand density was the same in the intercrop as in each pure stand [36,37]. We assessed various factors, in addition to intercropped treatments, which included:

Flower Strip: This factor was evaluated in both experimental cycles and considered two levels: plots with flower strips, and control plots without them.

Sown density: We only evaluated this factor during the first experimental cycle to determine the optimal sown density for the lettuce–broccoli intercropping. For intercropping treatments, we considered three levels: 37,800 plants.ha^{-1}, 50,000 plants.ha^{-1}, and 62,500 plants.ha^{-1}. We used the commercial reference values for pure stand crops for lettuce monocrop (62,500 plants.ha^{-1}) and broccoli monocrop (40,000 plants.ha^{-1}).

Agricultural management: This factor was evaluated only in the second experimental cycle to assess the effect of ecological management versus chemical management on the variables.

2.4.1. First Cycle

During the first cycle, which lasted 95 days (from 10 October 2022 to 13 January 2023), we set up a total of 40 plots, each with a dimension of 15 m^2. For this cycle, we evaluated five treatments that involved a combination of flower strip and sown density (as shown in Figure 1).

Factor 1: Flower Strips	
Level 1	Flower Strips
Level 2	Control

Factor 2: Sown Density	
Level 1	Intercropping 37,800 plants.ha^{-1}
Level 2	Intercropping 50,000 plants.ha^{-1}
Level 3	Intercropping 62,500 plants.ha^{-1}

Treatment	Description
T1	Lettuce monocrop 62,500 plants.ha^{-1}
T2	Broccoli monocrop 40,000 plants.ha^{-1}
T3	Intercropping 50,000 plants.ha^{-1}
T4	Intercropping 37,800 plants.ha^{-1}
T5	Intercropping 62,500 plants.ha^{-1}

Figure 1. Experimental design for Cycle 1.

2.4.2. Second Cycle

During the second cycle, which lasted 86 days from 19 April to 14 July 2023, we set up 48 plots of 12 m^2 each. Our aim was to assess the effects of combining flower strips and agricultural management on crop yield (see Figure 2). To determine planting density, we held a workshop with producers and agreed on a density of 50,000 $plants.ha^{-1}$. This decision took into account factors such as production area, land use, farming practices, productivity improvements, and marketing implications.

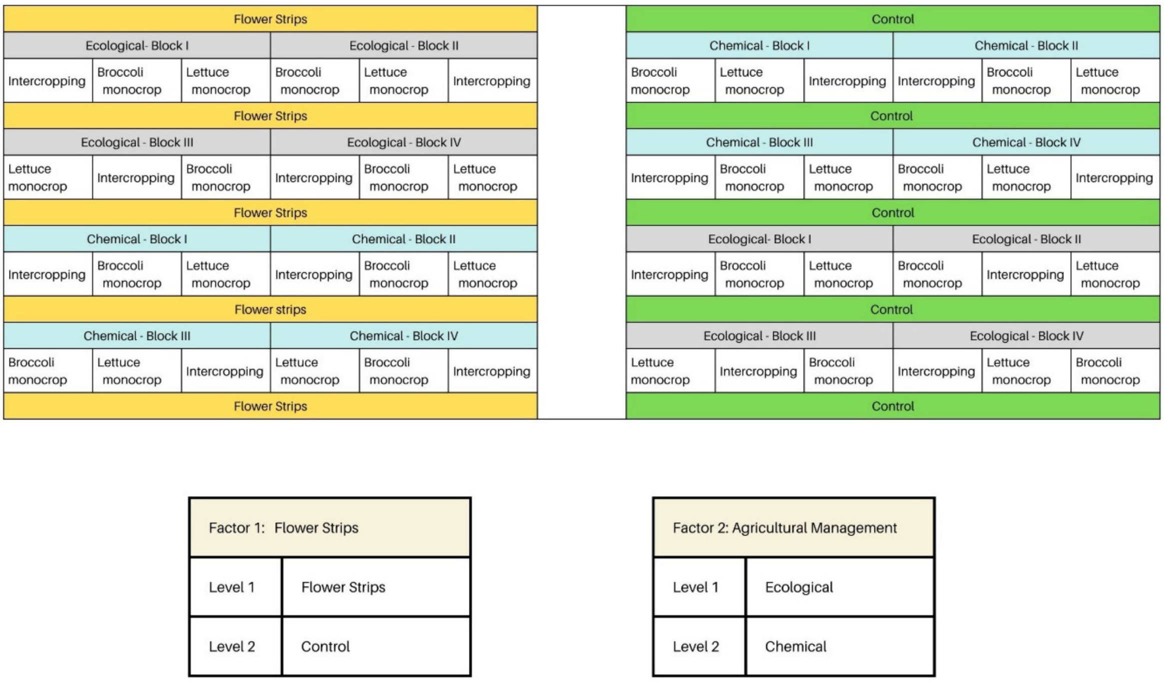


Figure 2. Experimental design for Cycle 2.

Variables

We assessed the Land Use Efficiency by utilising an index called the Land Equivalent Ratio (LER). This ratio measured the ability of broccoli and lettuce plants to utilise resources in intercropped plots [36]. To determine the LER, we measured the yields of each crop in pure stand plots as well as intercropped plots. We then used the following formula to calculate the LER:

$$ER = LER_{LETTUCE} + LER_{BROCCOLI} \tag{1}$$

$$LER_{LETTUCE} = \frac{YAL}{YML} \tag{2}$$

$$LER_{BROCCOLI} = \frac{YAB}{YMB} \tag{3}$$

where:

LER: Land Equivalent Ratio
YAL: Yield of associated lettuce
YML: Yield of monoculture lettuce
YAB: Yield of associated broccoli
YMB: Yield of monoculture broccoli

We assessed the competitiveness of broccoli and lettuce using the Competitive Ratio (CR) index, which indicates how often one crop is more competitive than the other [36]. CR was calculated as follows:

$$CR_{LETTUCE} = \frac{LER_{LETTUCE}}{LER_{BROCCOLI}} \cdot \frac{PR_{BROCCOLI}}{PR_{LETTUCE}} \tag{4}$$

$$CR_{BROCCOLI} = \frac{LER_{BROCCOLI}}{LER_{LETTUCE}} \cdot \frac{PR_{LETTUCE}}{PR_{BROCCOLI}} \quad (5)$$

where:

$PR_{LETTUCE}$: Proportion of lettuce in the crop
$PR_{BROCCOLI}$: Proportion of broccoli in the crop

Crop Yield: The yield (ton.ha^{-1}) of each experimental unit was determined by harvesting the useful plot. Then, to estimate the above-ground biomass, six plants per plot were randomly collected at harvest, and their tissues were dried at 65 °C for 72 h. The intercrop yields for each species were also estimated per hectare.

Pest and Disease Incidence: To assess the presence of diamondback moth (*Plutella xylostella*), molluscs (*Deroceras* sp. and *Milax* spp.), and incidence of lettuce rot (*Sclerotinia* spp.), ten plants per plot in monoculture (same species) and ten plants in intercropping (5 plants of each species) were evaluated. The incidence of disease was calculated by dividing the number of plants with damage by the total number of plants evaluated. A similar procedure was used to estimate the incidence of *P. xyllostella* on broccoli, where the number of plants with larvae was counted regardless of their abundance.

2.5. Economic Analysis

The net income was estimated for broccoli and lettuce crops in both planting systems (monoculture and intercropping). The average yields obtained from each treatment were used to calculate the net income (NI). In the first cycle, the selling price per kilogram of broccoli and lettuce corresponds to the average price in 2022 in two local markets in Nariño [38]. The NI in the second cycle was calculated based on the average prices in local markets for chemical management and the prices in organic stores for organic management [38,39]. For the determination of production costs (PC), plot leasing, labour, plant material, and input costs were considered. The profit (USD ha^{-1}) was calculated as the difference between NI and PC. In treatments where flower strips were implemented, an additional cost of 5% of direct costs (inputs and labour) was estimated for the establishment and maintenance of flower strips.

2.6. Statistical Analysis

A two-way ANOVA analysis was performed to evaluate the data. To compare treatment means, Tukey's test (p = 0.05) was utilised. The analysis was performed using R software v.4.3.1 [40] and the AgroR package [41]. The data underwent the Shapiro–Wilk normality test and Bartlett's homogeneity test. For variables that did not meet assumptions, equivalent non-parametric tests like the Wilcoxon Test or the Kruskal–Wallis Test were used for comparing medians.

3. Results

3.1. First Experimental Cycle

3.1.1. Land Use Efficiency and Competitive Ratio

The Land Equivalent Ratio (LER) significantly differed between crops with and without flower strips ($F_{(1,15)}$ = 5.4779 and p-value = 0.0335) and among intercrop planting densities ($F_{(2,15)}$ = 4.8076 and p-value = 0.0244). On average, the LER in plots with flower strips was 1.10 compared to 0.96 in plots without these strips (Figure 3). Regarding planting densities, the land use efficiency of the intercrop increased in direct proportion with the planting density: at a density of 37,800 plants.ha^{-1}, the LER was 0.91, at 50,000 plants.ha^{-1}, the LER was 1.04, and at 62,500 plants.ha^{-1} the LER was 1.14 (Figure 3). The interaction between the evaluated factors was not significant (p-value = 0.9223).

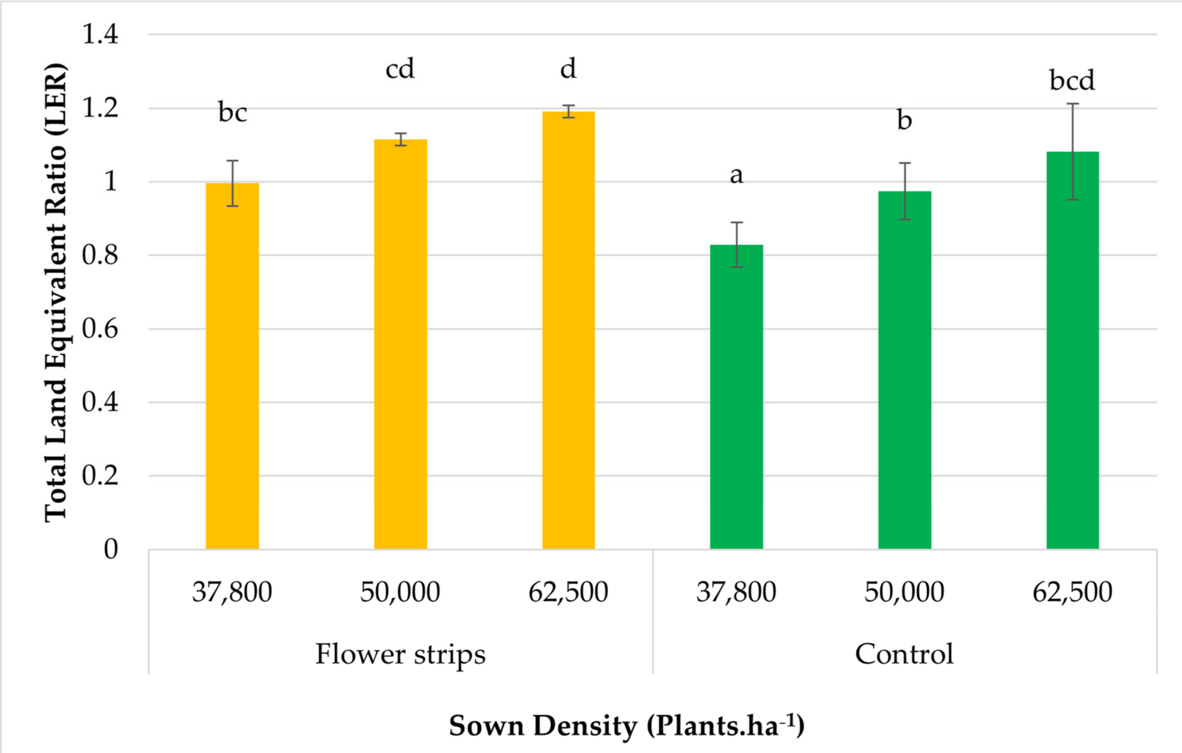


Figure 3. Effect of the establishment of flower strips and planting density on the Land Equivalent Ratio (LER) in the broccoli–lettuce intercropping (1:1). The letters in the graph denote significant differences among factors, based on the results of a 2-way ANOVA Test with a significance level $\alpha = 0.05$.

In Table 1, it can be observed that the CR (Competitive Rate) values for broccoli were >1 during the first experimental cycle, indicating that this crop was more competitive than lettuce, whose values were <1 in all cases. Planting density and the introduction of flower strips did not significantly affect the competitiveness of broccoli during the first cycle, although higher CR values were observed in plots with flower strips. In contrast, flower strips significantly affected CR values for lettuce with higher values in control plots (*p*-value = 0.0399).

Table 1. Effect of plant density and introduction of flower strips on Competitive ratio (CR) of lettuce + broccoli intercropping (1:1) systems.

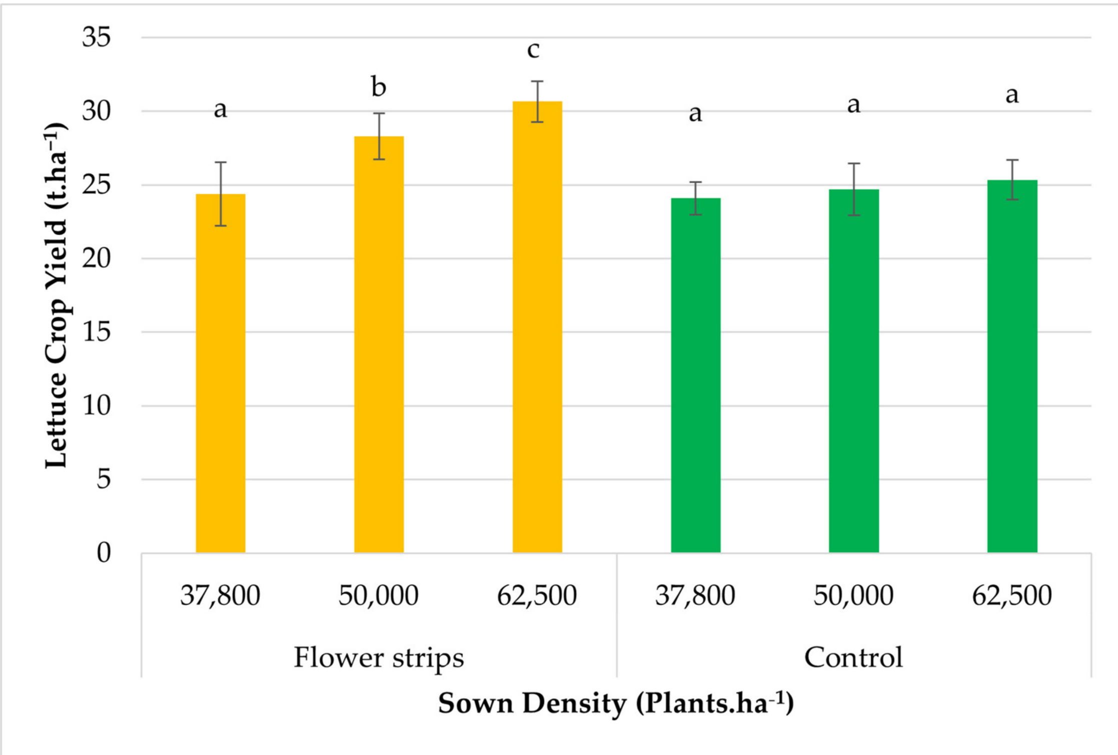
Factor 1: Sown Density	Factor 2: Flower Strips	CR Lettuce	CR Broccoli
37,800 plants.ha^{-1}	Flower strips	0.48	2.12
	Control	0.78	1.49
50,000 plants.ha^{-1}	Flower strips	0.51	2.00
	Control	0.63	1.87
62,500 plants.ha^{-1}	Flower strips	0.52	1.91
	Control	0.54	2.03
Two-factor variance analysis (F)			
Factor 1: Sown Density		0.7370 ns	0.4646 ns
Factor 2: Flower strips		5.0608 *	2.0144 ns
Sown Density × Flower strips		1.6176 ns	1.5997 ns

* = $p < 0.05$; ns = not significant.

3.1.2. Crop Yields and Pest and Disease Regulation

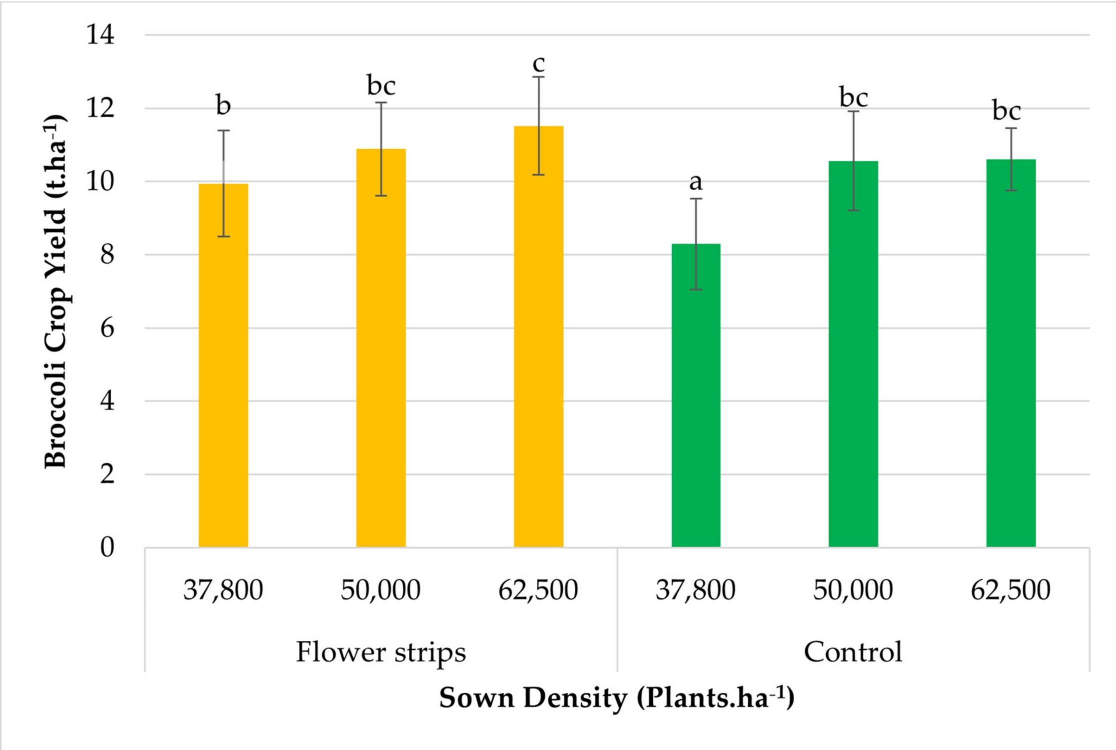
The yield of both crops in intercropping and monoculture was higher in plots with flower strips (Figure 4a,b), except for broccoli planted at high densities. Lettuce associated with broccoli showed an increase in yield with the presence of flower strips by 3.1 t.ha^{-1} ($F_{(1,15)}$ = 9.9035, *p*-value = 0.0066). Similarly, broccoli exhibited a statistically significant increase in plots with flower strips ($F_{(1,15)}$ = 3.8997, *p*-value = 0.0067). Regarding the effect of plant density in the intercrop, for lettuce, a positive effect was observed, with a difference of 3.77 t.ha^{-1} between planting in intercropping at 62,500 and 37,800 plants.ha^{-1} ($F_{(2,15)}$ = 5.0748, *p*-value = 0.0207). In contrast, for broccoli, statistical differences in yields were evident from 50,000 plants.ha^{-1} compared to 37,800 plants.ha^{-1} an average yield of 10.7 t.ha^{-1} and 9.12 t.ha^{-1}, respectively ($F_{(2,15)}$ = 3.8997, *p*-value = 0.01162). This indicates that broccoli in intercropping from 50,000 plants.ha^{-1} did not increase yields, which could be related to a suppressive effect on head weight or size as plant density increased.

An average crop yield of broccoli on pure stand plots was 14.60 t.ha^{-1} in flower strips plots compared to 17.31 t.ha^{-1} in control plots. For lettuce, crop yield was 75.94 t.ha^{-1} in flower strips plots and 71.06 t.ha^{-1} in control plots. No significant differences were found in crop yield between flower strips and control plots for pure stand crops of broccoli ($F_{(1,6)}$ = 2.17, *p*-value = 0.191) and lettuce ($F_{(1,6)}$ = 0.7210, *p*-value = 0.4280).



(a)

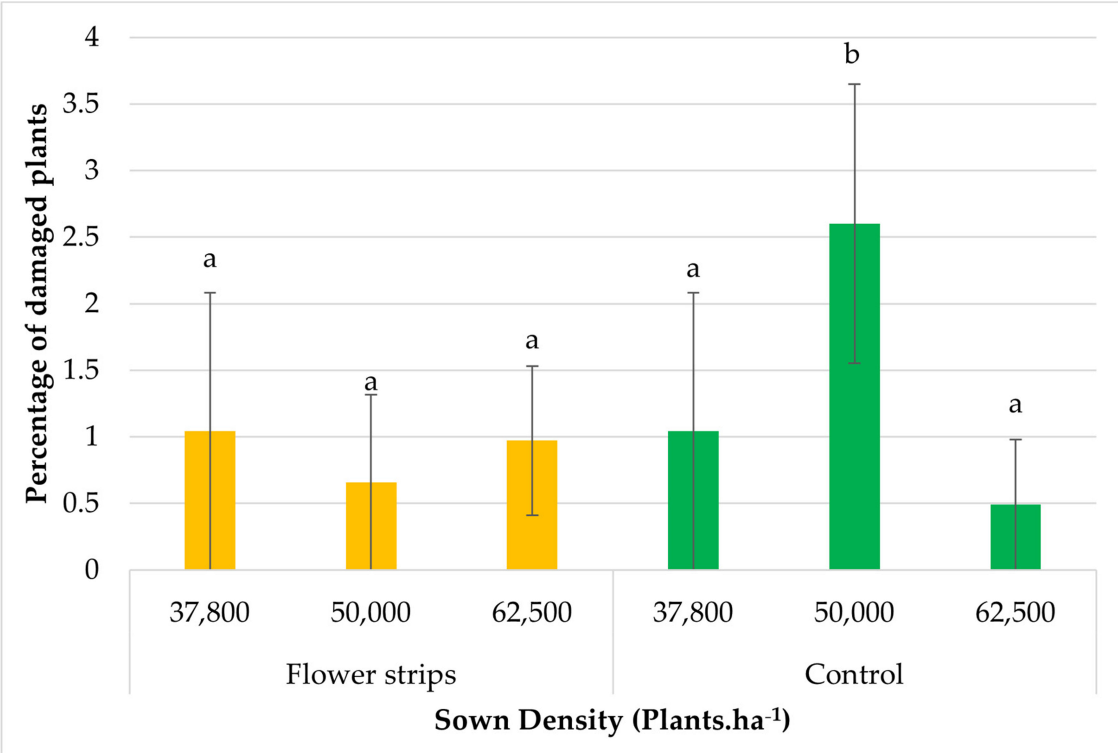
Figure 4. *Cont.*



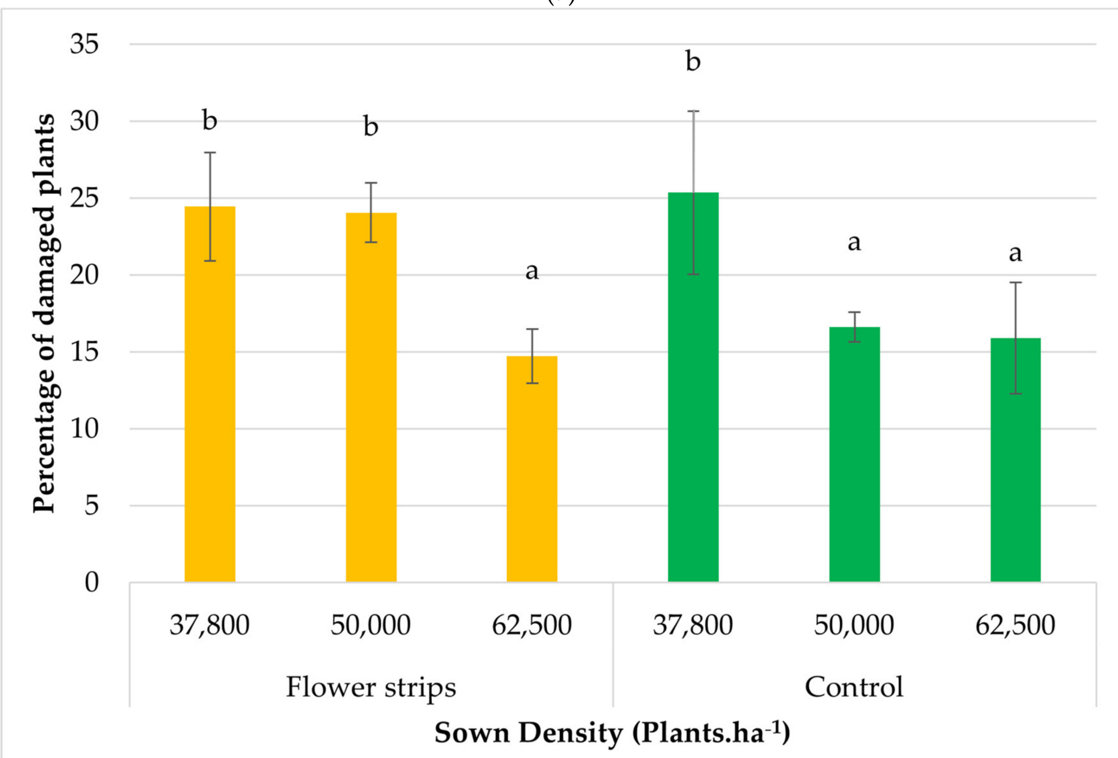
(**b**)

Figure 4. Effect of the establishment of flower strips and planting density on the yield of (**a**) lettuce; (**b**) broccoli planted in intercropping (1:1). The letters in the graph denote significant differences among factors, based on the results of a 2-way ANOVA Test with a significance level α = 0.05.

The percentage of lettuce plants with damage from *Sclerotinia* sp. varied between 0.9% in monoculture without flower strips and 5.2% in intercropped plots planted at an intermediate density of 50,000 plants.ha^{-1}, with significant differences between pure stand (3.7%) and intercropped plots (1.2%) (Kruskal–Wallis Test = 9.2904, *p*-value = 0.0230). Sown density and the inclusion of flower strips did not affect the incidence of this disease on lettuce plants (Figure 5a, Table 2). In contrast, the presence of molluscs was affected by sown density, but not for the inclusion of flowering plants or their interaction (Figure 5b, Table 2). The lowest infestation of molluscs was observed in associated plots planted at low densities and without flower strips (2.07%), while the highest values were found in associated plots planted at low density with the presence of flowering plants (47.92%). Slug infestation in lettuce was lower in monocultures (12%) compared to that observed in associated crops (20%), although this difference was not statistically significant ($F_{(1, 30)}$ = 1.497, *p*-value = 0.231). In broccoli, none of the factors influenced the incidence of *Plutella xyllostela* larvae, but the interaction between both did have an effect (Figure 5c, Table 2). We observed more larvae of *P. xylostella* in monocrops (median = 89%) compared to intercropped plots (median = 20%) (Kruskal–Wallis Test = 17.516, $p < 0.0001$).

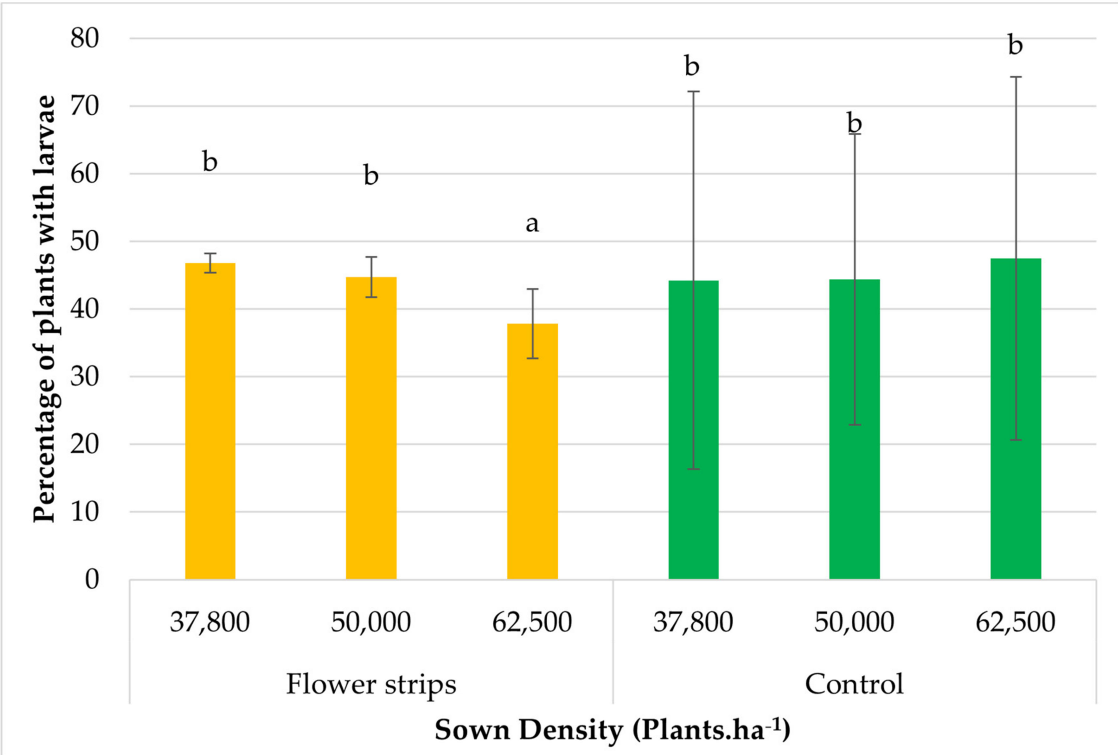


(**a**)



(**b**)

Figure 5. *Cont.*



(**c**)

Figure 5. Pest incidence: (**a**) Damage by *Sclerotinia* sp. in lettuce. (**b**) Percentage of lettuce plants with damage by molluscs. (**c**) Percentage of broccoli plants with the presence of *Plutella xylostella* larvae. The letters in the graph denote significant differences among factors, based on the results of a 2-way ANOVA Test with a significance level α = 0.05.

Table 2. Results of two-factor variance analysis (F) for Incidence of Pest and Disease in the first cycle of broccoli: lettuce intercropping.

Variable	Factor	F-Statistic
Incidence of *Sclerotinia* sp. in lettuce (% of damaged plants)	Factor 1: Sown Density	0.8381 ns
	Factor 2: Flower strips	0.7165 ns
	F1 × F2: Sown Density × Flower strips	1.6573 ns
Incidence of mollusc in lettuce (% of damaged plants)	Factor 1: Sown Density	5.1618 *
	Factor 2: Flower strips	0.5414 ns
	F1 × F2: Sown Density × Flower strips	1.3483 ns
Incidence of *P. xylostella* sp. in broccoli (% of damaged plants)	Factor 1: Sown Density	0.8318 ns
	Factor 2: Flower strips	1.4771 ns
	F1 × F2: Sown Density × Flower strips	4.0883 *

* = $p < 0.05$; ns = not significant.

3.1.3. Production and Economic Aspects

In Table 3, the results of the profit generated by different treatments are shown. Profitability reaches up to 46.9% in lettuce crops. In intercropping, the implementation of flower strips generated higher profit compared to control plots. The increase in planting density between 37,800 plants.ha^{-1} and 50.000 plants.ha^{-1} was USD 755, while changing from 62,500 plants.ha^{-1} to 50,000 plants.ha^{-1} was USD 264, contrasting with control intercrops, where increasing density also increases profit (USD 643 and USD 838). With regard to broccoli monoculture, it incurs economic losses of USD 2858 and USD 1330 with and without flower strips, respectively; the lowest losses occur in the absence of the flower strip. The depressing effect may be related to crop management, which was organic for this cycle.

Table 3. Net income, production cost, and profit (USD ha^{-1}) of broccoli and lettuce in monoculture and intercropped cultivation at different planting densities *.

Crop System	Net Income (USD ha^{-1})		Production Cost (USD ha^{-1})		Overall Profit (USD ha^{-1})		Profitability (%)	
	Flower Strip	Control	Flower Strip	Control	Flower Strip	Control	Flower Strip	Control
Broccoli Pure stand	5984	7092	8843	8422	−2858	−1330	−47.8	−18.8
Lettuce Pure Stand	15,302	14,333	8122	7735	7180	6598	46.9	46.0
Intercropping 37,800 plants.ha^{-1}	8977	8262	8167	7778	810	484	9.0	5.9
Intercropping 50,000 plants.ha^{-1}	10,173	9324	8608	8197	1565	1127	15.4	12.1
Intercropping 62,500 plants.ha^{-1}	10,883	10,587	9054	8623	1829	1965	16.8	18.6

* Note: This production was carried out under an organic management scheme.

3.2. Second Experimental Cycle

3.2.1. Land Use Efficiency and Competitive Ratio

The broccoli–lettuce intercropping increased land use efficiency in all cases (LER > 1). However, no significant differences were observed between the agricultural management type ($F_{(1,9)}$ = 0.3248, p-value = 0.5826) or between plots with and without flower strips ($F_{(1,9)}$ = 0.5898, p-value = 0.4635). In plots under ecological management with aromatic borders, the LER was 1.58, while in plots without flowers, it was 1.18. Conversely, in the management with chemical input, the LER was 1.21 when flower strips were introduced and 1.36 without them (Figure 6). The interaction between the evaluated factors was not significant (p-value = 0.1203).

During the second experimental cycle, it was found that broccoli was more competitive than lettuce. The CR values for broccoli ranged between 3.2 and 4.7, while for lettuce, they varied between 0.3 and 0.5. This indicates that broccoli plants are better at utilising resources than lettuce plants, and it suggests that a series replacement is not a suitable method for this intercropping system. The flower strips and agricultural management did not have any impact on CR values for either crop (Table 4).

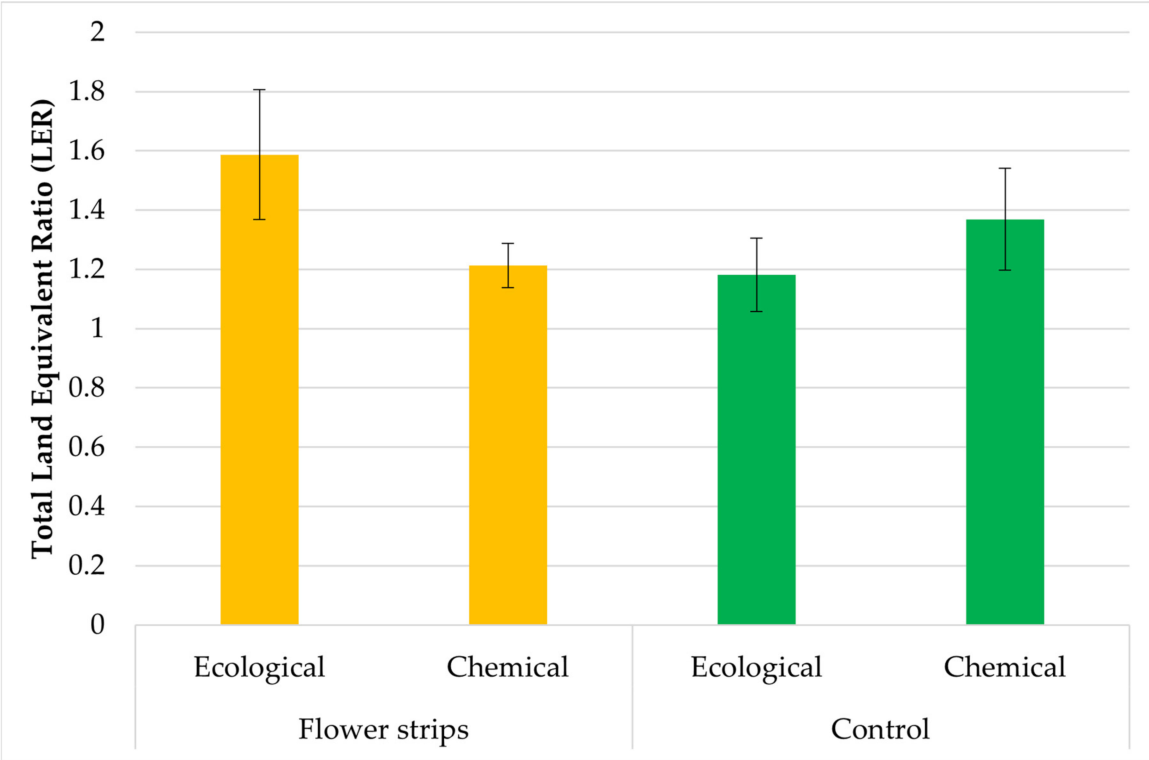


Figure 6. Effect of the establishment of flower strips and agricultural management type on the Land Equivalent Ratio (LER) in the broccoli–lettuce intercropping (1:1).

Table 4. Effect of agricultural management and introduction of flower strips on Competitive ratio (CR) of lettuce + broccoli intercropping (1:1) systems.

Factor 1: Agricultural Management	Factor 2: Flower Strips	CR Lettuce	CR Broccoli
Ecological inputs	Flower strips	0.5	3.2
	Control	0.6	3.5
Chemical inputs	Flower strips	0.3	4.4
	Control	0.5	4.7
Two-factor variance analysis (F)			
F1: Agricultural management		2.8308 ns	2.0021 ns
F2: Flower strips		2.6852 ns	4.2257 ns
F1 × F2: Agricultural management × Flower strips		0.1717 ns	0.5644 ns

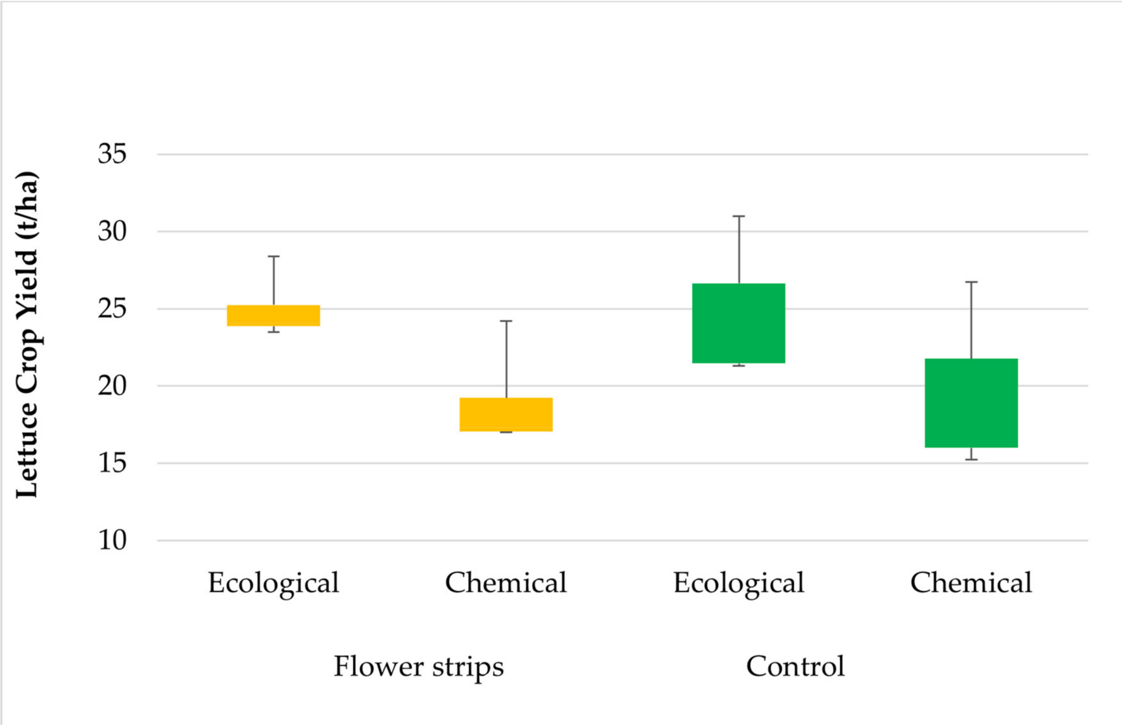
ns = not statistically significant.

3.2.2. Crop Yields and Pest and Disease Regulation

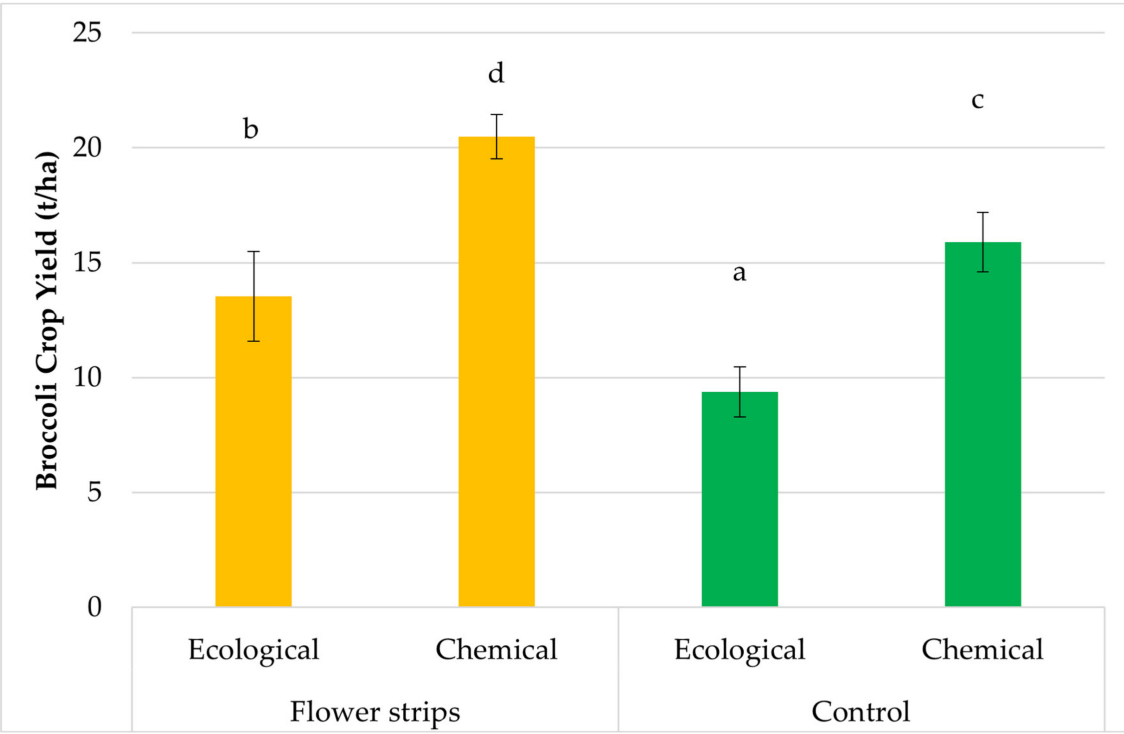
In monoculture, the average lettuce crop yield was 72.9 t.ha^{-1} in plots with flower strips, compared to 58.2 t.ha^{-1} in control plots. The difference was statistically significant ($F_{(1,9)}$ = 7.9796, p-value = 0.0199). Agricultural management did not have any significant effect on yield in lettuce monocultures ($F_{(1,9)}$ = 3.0826, p-value = 0.1130), on average, the yield was 70.1 t.ha^{-1} with chemical inputs compared to 60.9 t.ha^{-1} with ecological inputs. The interaction between agricultural management and flower strips was also not statistically significant ($F_{(1,9)}$ = 2.8962, p-value = 0.1229).

For lettuce in intercropping, the yield was higher in control plots (median = 23.7 t.ha^{-1}) compared to those with flowering plants (median = 21.4 t.ha^{-1}), but the difference was not statistically significant (Wilcoxon Test: W = 16, p = 0.10). Similarly, the type of agricultural management did not have any significant effect on lettuce yield in intercropped plots.

The median yield was 24.1 t.ha^{-1} in ecological management compared to 17.3 t.ha^{-1} in chemical management (Wilcoxon Test: W = 47, p = 0.13, Figure 7a). Lettuce yield decreased by 25 to 40% when intercropped compared to the monoculture.



(**a**)



(**b**)

Figure 7. Effect of agronomic management and the introduction of flowering plants on the yield of (**a**) lettuce; (**b**) broccoli planted in intercropping (1:1), and established under two agronomic management schemes (organic vs, chemical). The letters in the graph denote significant differences among factors, based on the results of a 2-way ANOVA Test with a significance level α = 0.05.

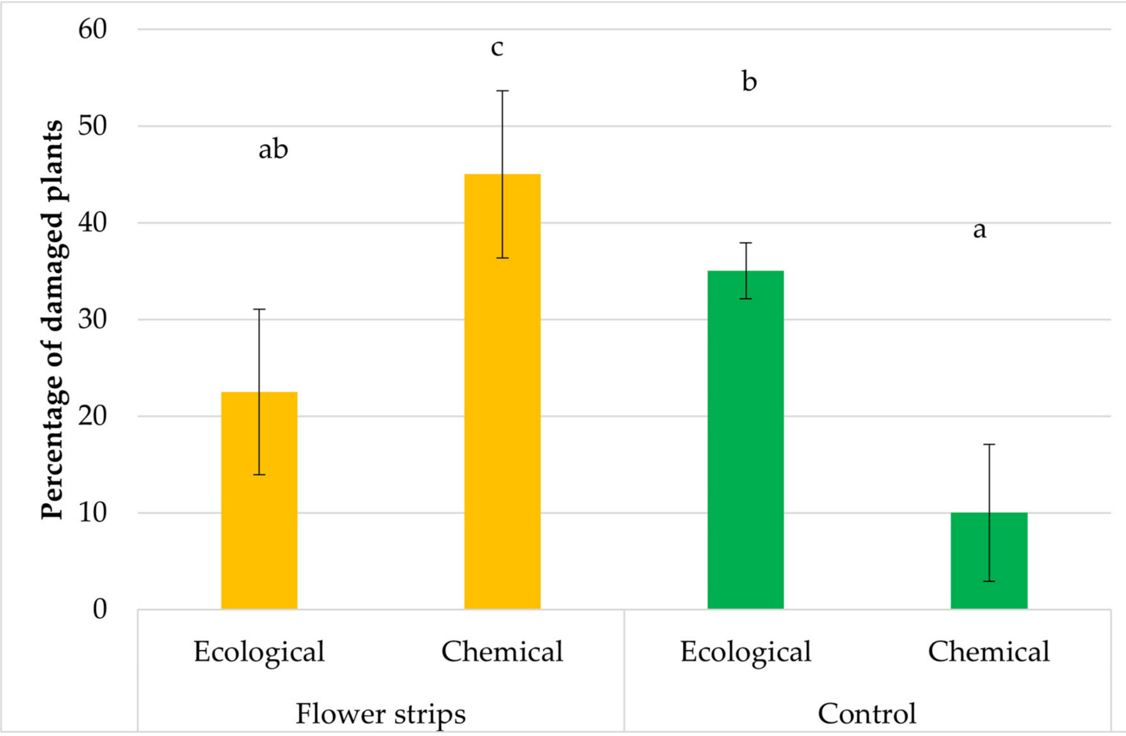
In the case of broccoli in monoculture, significant differences were observed between plots managed with chemicals and those managed ecologically in terms of crop yield ($F_{(1,9)}$ = 91.1893, *p*-value < 0.0001), the mean yield was 21.3 t.ha^{-1} for chemical management and 13.3 t.ha^{-1} for ecological management. The presence of flower strips also affected crop yield, with an average of 19.0 t.ha^{-1} in plots with flower strips compared to 15.6 t.ha^{-1} in control plots ($F_{(1,9)}$ = 16.6858, *p*-value = 0.0027). There was a significant interaction between these factors ($F_{(1,9)}$ = 5.8255, *p*-value = 0.0390).

In intercropped plots, differences were observed in broccoli yield between chemical (mean = 18.19 t.ha^{-1}) and ecological management (mean = 11.45 t.ha^{-1}), ($F_{(1,9)}$ = 91.1893, *p*-value < 0.0001). The addition of flower strips had a positive and significant effect on broccoli yield, with a mean of 17.01 t.ha^{-1} in the presence of flower strips compared to 12.63 t.ha^{-1} in control plots ($F_{(1,9)}$ = 5.8255, *p* = 0.0390), (Figure 7b). However, the interaction between factors was not significant ($F_{(1,9)}$ = 0.0482, *p*-value = 0.831). Broccoli yield crop was similar between monoculture (mean yield = 17.3 t.ha^{-1}) and intercropping plots (mean yield = 17.2 t.ha^{-1}).

During the second experimental cycle, it was observed that the damage caused by *Sclerotinia*, a disease affecting lettuce plants, was higher compared to the first cycle. We found that diversification practices, such as intercropping, had a positive effect on reducing the incidence of this disease (W = 73.5, *p*-value = 0.0383). In fact, monocultures had a higher incidence of Sclerotinia damage (46.9%) than intercropped plots (28.1%). Contrary to expected, we found that plots with flower strips showed even higher values of damaged plants (50.6%) compared to control plots (24.4%) with statistically significant differences (W = 207, *p*-value = 0.0026). In terms of agricultural management, there was no significant difference between ecological (38.1%) and chemical (36.9%) practices on the damage caused by Sclerotinia (W = 140.5, *p*-value = 0.6453). In intercropped plots, the interaction between agricultural management and the introduction of flower strips was significant (Figure 8a).

The incidence of molluscs was higher in pure stand crops (26.9%) compared to intercropped plots (19.4%), although this difference was not statistically significant (W = 94, *p*-value = 0.1702). Similar to *Sclerotinia* incidence, plots with flower strips showed a higher presence of molluscs (25.0%) compared to control plots (21.3%) with no statistically significant differences (W = 139.5, *p*-value = 0.6524). Agricultural management type did not affect the incidence of molluscs in lettuce plants (W = 139, *p*-value = 0.6613). In intercropped plots, none of the evaluated factors affected the incidence of molluscs in lettuce (Figure 8b).

We recorded the number of larvae found on harvested broccoli plants, but did not observe any economic damage caused by this pest. The percentage of broccoli plants with *P. xylostella* larvae was higher in pure stand crops (87.5%) compared to intercropped plots (53.8%), with statistically significant differences (W = 25.5, *p*-value < 0.0001). In plots with flower strips, *P. xyllostella* larvae had a higher incidence (78.8%) compared to control plots (62.5%), although the differences were not statistically significant (W = 168.5, *p*-value = 0.1217). Agricultural management type did not significantly affect *P. xyllostella* incidence in broccoli plants (W = 178.5, *p*-value = 0.0530); plots with chemical inputs had 61.3% compared to 80% using ecological inputs. In intercropped plots, only agricultural management affected *P. xyllostella* incidence, with more larvae found in plants managed ecologically (Figure 8c).



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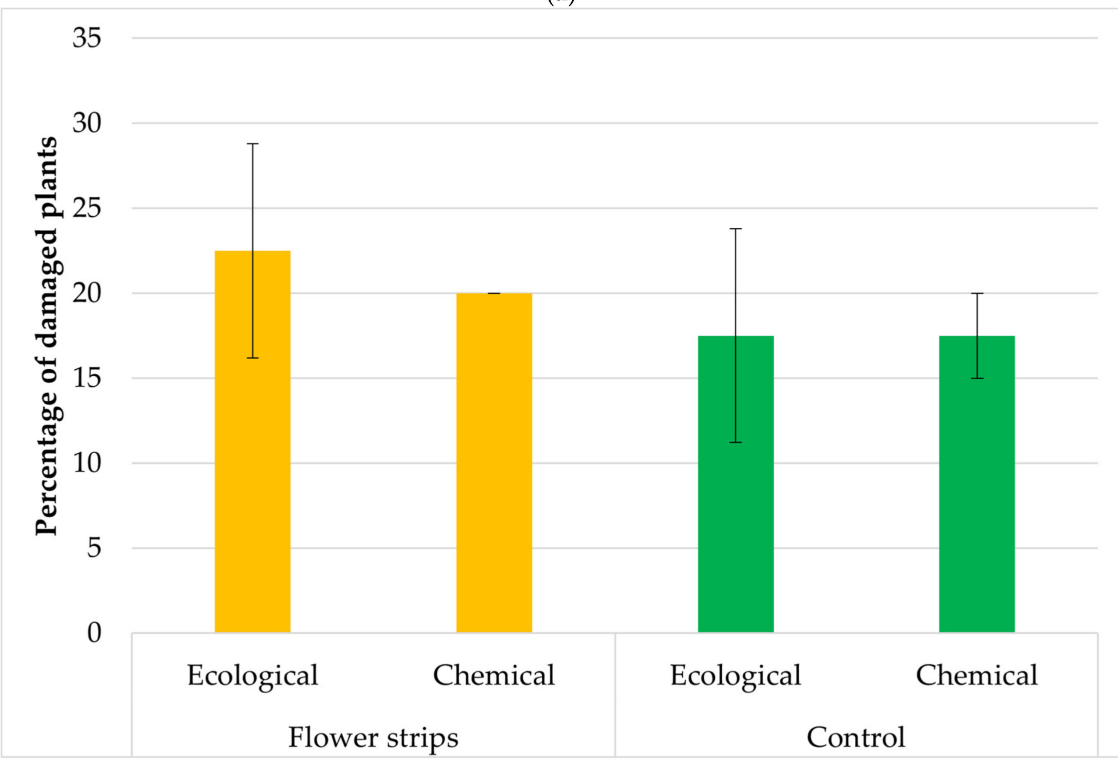
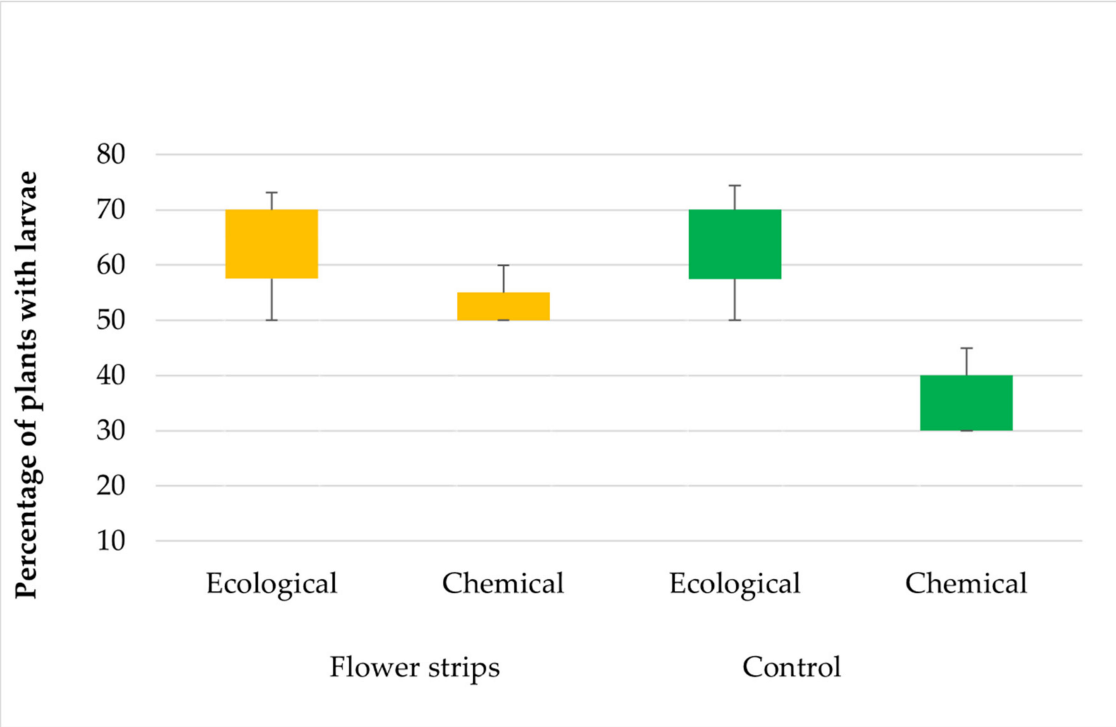


(**b**)

Figure 8. *Cont.*



(**c**)

Figure 8. Effects of intercropping and the inclusion of flowering plants on the incidence of pests and diseases in the Broccoli + Lettuce system (1:1). (**a**) Incidence of *Sclerotinia* sp. in lettuce. (**b**) Incidence of molluscs in lettuce. (**c**) Incidence of *P. xylostella* in broccoli. The letters in the graph denote significant differences among factors, based on the results of a 2-way ANOVA Test with a significance level $\alpha = 0.05$.

3.2.3. Production and Economic Aspects

In the second production cycle, a positive economic effect of the aromatic strips was evident under both crop management systems (Table 5). The highest profits were obtained in the organic market with monoculture of lettuce and intercropping, whereas the opposite occurred in broccoli, which recorded economic losses in organic monoculture, with a loss of USD 1437 ha^{-1} with flower strips and USD 2805 ha^{-1} in the control. In chemical management, profits of USD 3567 and USD 2120 ha^{-1} were reported with flower strips and control, respectively.

Table 5. Net income, production cost and profit (USD ha^{-1}) of broccoli and lettuce in monoculture and intercropped cultivation with different management practices.

Crop System	Net Income (USD ha^{-1})		Production Cost (USD ha^{-1})		Overall Profit (USD ha^{-1})		Profitability (%)	
	Flower Strip	Control	Flower Strip	Control	Flower Strip	Control	Flower Strip	Control
Ecological								
Broccoli Pure Stand	8590	6747	10,027	9550	−1437	−2803	−16.7	−41.5
Lettuce Pure Stand	44,901	41,035	9209	8771	35,692	32,264	79.5	78.6
Intercropping	25,351	22,845	9760	9295	15,591	13,550	61.5	59.3
Chemical								
Broccoli Pure Stand	11,248	9437	7682	7317	3567	2120	31.7	22.5
Lettuce Pure Stand	18,744	13,417	6864	6536	11,880	6881	63.4	51.3
Intercropping	13,873	11,870	7415	7060	6458	4810	46.6	40.5

4. Discussion

This study provides an assessment of how agricultural diversification strategies in broccoli and lettuce production affect land use efficiency and other agronomic variables when comparing intercropped plots against pure stand crops. As expected, the combination of flowering plants and intercropping improve land use efficiency. This information is valuable in the context of horticulture in countries such as Colombia, where organic farming only constitutes around 1% [28], and small family farmers require more validated technological recommendations to facilitate the adoption of practices like intercropping or flower strips.

4.1. Land Use Efficiency and Competitive Ratio

4.1.1. First Experimental Cycle

The introduction of flower strips and increased sown density positively affected land use efficiency in intercropping lettuce and broccoli. As planting density increased, intercropping efficiency improved, with LER (Land Equivalent Ratio) values ranging between 1.08 and 1.19. The highest LER value of 1.19 was observed in the presence of flowering plants. Previous studies have shown that intercropping lettuce and broccoli leads to a higher Land Equivalent Ratio (LER) greater than 1 [42,43]. Similar results indicate that improved land use efficiency is due to plant species' greater root length density and the higher nutrient uptake per area than in sole cropping. The root growth of component species with different root properties explores a larger soil mass [42]. In addition, intercropping can create a soothing microclimate with less evaporation [44,45] or a cooler microclimate by providing more ground coverage that minimises the soil temperature [46]. Future research for this system should evaluate biotic and abiotic factors directly to understand the subjacent mechanisms in which polyculture and flower strips increase land use efficiency.

Broccoli has been found to be more competitive than lettuce, as demonstrated by the higher Competitive Ratio of broccoli compared to lettuce. One possible reason for this is the larger size and more horizontal leaves of broccoli, which allows it to develop a taller canopy earlier, as reported by a previous study [47]. The arrangement of leaves, or phyllotaxis, can also play a role, given that lettuce has its leaves concentrated at a point, which puts it at a disadvantage compared to broccoli, whose leaf arrangement allows it to capture more direct sunlight. As a result, lettuce receives less radiation due to interference from broccoli, even more so in the presence of flower strips.

Studies by Ohse [48] and Brennan have also reported a higher competitive ability of broccoli over lettuce and inhibition of lettuce growth when planted with larger plants [47]. In the tomato–lettuce intercropping, the photosynthetically active radiation (PAR) intercepted by lettuce decreases as the tomato grows [49]. Although nutrient uptake was not directly assessed, previous findings have reported that intercropping broccoli with lettuce decreased the concentration of N, K, Mg, Ca, and Zn in broccoli plants [42]. Therefore, we recommend using a row intercropping method, such as alternating rows of broccoli and lettuce, or spacing the plants properly to minimise nutrient competition.

Intercropping broccoli with potato [50] or onion [51] is suitable. However, intercropping the same species, such as cauliflower, can lead to negative interference due to their similar use of nutrients [50]. Negative interference has been observed in intercropping broccoli with cabbage and oats, where broccoli dominated cabbage in the former case and oats dominated the intercropping in the latter [50].

To reduce nutrient competition in intercropping systems, Yildirim and Turam [42] recommend selecting plant species with varying rooting patterns, nutrient requirements, and peak nutrient demand timing. Based on this recommendation, farmers should consider intercropping lettuce with other crops such as legumes [52], cucumber [53,54], beet [55,56], radish [57], tomato [58], carrots [59], and rocket [60], as it has resulted in better outcomes in the past.

4.1.2. Second Experimental Cycle

The efficiency of land use was higher in intercropped plots than in monocultures, with all intercropped plots having LER values greater than 1. However, neither agricultural management nor the introduction of flowering (aromatic) plant strips had any effect on land use efficiency. In the first cycle, intercropping was found to be more efficient than pure stand crops by up to 19%, whereas in the second cycle, LER values showed that land use efficiency was 18% to 58% higher in intercropped plots compared to monocultures. In terms of the agronomic management type, intercropping was more efficient in plots with ecological inputs (average LER = 1.38) compared to conventional chemical management (average LER = 1.29).

The inclusion of flower strips improved this efficiency by up to 40%, compared to the 27% observed in control plots under conventional management. The combination of aromatic flower strips with the intercropping of broccoli and lettuce ecological management scheme enhanced land use efficiency by up to 58%. These positive effects of flower strips may be due to higher insect pollination and biological pest control [19,61]. Thus, we recommend assessing natural enemies population and direct measurements of biological pest control to confirm these hypothesis.

Regarding competition ratio, conventional chemical management combined with the inclusion of flowering plants exacerbates the competitive ability of broccoli, shifting from a competition ratio (CR) of 4.7 in conventional production to 3.2 in organic management. This result reinforces the idea that a replacement series is unsuitable for lettuce–broccoli intercropping due to the strong negative interference of broccoli over lettuce.

4.2. Crop Yields and Pest and Disease Regulation

4.2.1. First Experimental Cycle

Flower strips enhance the yield of lettuce in both intercropped and pure stand plots. However, for broccoli, a significant increase in crop yield was observed only in intercropped, not in pure stand plots. Increasing the sowing density beyond 50,000 plants.ha^{-1} for broccoli did not significantly increase crop yield. One possible reason for this last result could be a suppressive effect on head weight or size as plant density increased. Therefore, the functional sowing density for lettuce–broccoli intercropping should be 50,000 plants.ha^{-1}, where both crops have an optimum yield. Farmers with experience in horticultural crops also selected this density based on feasibility of labour.

Previous research has shown that diversification practices, such as intercropping and flower strips, can result in mutually beneficial outcomes, such as increased crop yields, and support services related with biodiversity conservation [62,63]. However, the effectiveness of these practices can vary depending on the specific context, and there may be trade-offs to consider [12]. For instance, we observed that flower strips did not affect the incidence of *Sclerotinia* in intercropped plots. In contrast, intercropping reduced the incidence of *Sclerotinia* with a median of 0% compared to 4% in pure stand crops. Low values of *Sclerotinia* incidence observed during the first experimental cycle may be related to the history of the plot prior to the experimental trial, where the disease inoculum in the soil was low.

In the case of molluscs, none of the diversification strategies evaluated reduced their incidence. On the contrary, the presence of flowering strips in associated plots planted at low densities resulted in the highest infestation of molluscs (47.92%). This finding may indicate that the presence of flowering strips and intercropping can increase the risk of mollusc infestation in lettuce. Previous studies have shown that slugs can cause significant economic damage to a wide range of crops [64,65], including oilseed rape, vegetables, legumes, cereals, and fruits [66]. However, we could not find much published research on the effects of intercropping or flower strips on slugs to compare with our results. The only existing study on this subject was conducted by Emery [67], which found that intercropping treatments resulted in pest damage that was either equivalent or lower than the pest damage in oilseed rape alone (*Brassica napus* L.).

For broccoli, the presence of flower strips did not have an impact on the incidence of *P. xyllostela* larvae. However, the interaction between flower strips and sown density did have an effect. Meanwhile, intercropping decreased the incidence of this pest, with a higher percentage of plants with larvae in monocrops (median = 89%) compared to the intercropped plots (median = 20%). These findings are consistent with the research conducted by Qasim Mohammed and Adnan Alyousuf [68], which also found a higher incidence of *P. xyllostela* in monocrops than intercropped plots.

The inconsistent outcomes observed in the first experimental cycle regarding pest and disease might indicate that multiple factors, such as field size, structure and composition of the surrounding landscape [69], history of field crops, and tolerance or resistance to herbivores, among other variables, were affecting the spillover and colonisation of crops by these organisms masking the effects of intercropping. Therefore, we could not conclude with certainty that intercropping and flowering strips are associated with better regulation of pests and diseases in the context of the broccoli–lettuce intercropping.

4.2.2. Second Experimental Cycle

Flower strips have been found to improve lettuce yield in pure stand plots, but not in intercropped plots. Meanwhile, for broccoli, a significant increase in crop yield was observed in both pure stand and intercropped plots when flower strips were included in field margins.

The coherence of outcomes between the first and second experimental cycle reinforces the idea that farmers can enhance the yield crops and the net income by using intercropping with flower strips, while also reducing pressure on natural areas surrounding the cultivated field [62,70]. Although we have observed that intercropping strategy produces different outcomes for each species. In the case of lettuce, yield crops decreased by 25–40% compared to pure stand plots. However, the yield crops for broccoli were similar in terms of intercropped and pure stand plots.

Farmers can also adjust the time of sowing lettuce by using a "relay intercropping design". This means raising two crops at a time during a portion of the growing period of each [36]. By allowing the lettuce plants to develop before, it will avoid the intense competition from broccoli [16,54].

Agricultural management has a significant impact on crop yield in broccoli, but not in lettuce. When chemical inputs are replaced by ecological alternatives, crop yields in broccoli were reduced by 38%, while in lettuce, the yield only drops by 13%. The interaction between flower strips and agricultural management was significant only in pure stand plots of broccoli, reinforcing the positive effect of flower strips on crop yield. Previous studies have reported higher yield crops when using mineral fertilisers instead of organic sources such as green manure [71]. The availability of nutrients in the soil could differ between conventional management and organic fertilised plots since the latter requires mineralization before plants can uptake the nutrients [71]. For instance, fertigation increases broccoli yields by 83% compared to conventional methods [72]. In further studies aimed at ecologically producing broccoli, we recommend considering local materials that are adapted to poor nutrient environments and assessing the concentration and time of the availability of nutrients in organic fertilisation sources. Our new empirical evidence shows that adding flower strips and implementing better ecological management practices in field borders complements intercropping strategies, resulting in increased productivity.

During the second experimental cycle, we noticed a higher damage caused by *Sclerotinia* sp. than in the first cycle. We also observed that the flower strips increased the incidence of *Sclerotinia* by 52% compared to the control plots, which was contrary to our expectations. However, intercropping has proven to be effective in reducing the incidence of *Sclerotinia* by 40% compared to pure stand crops. We found no significant difference in the damage caused by *Sclerotinia* between ecological and chemical agricultural management. The interaction between flower strips and agricultural management was significant. We did not find any evidence of synergistic effects when combining diversification strategies, which suggests that other factors not measured in this research, such as microclimatic conditions, vectors, and labour field might significantly influence the inoculum concentration of *Sclerotinia* inside the field. It has been suggested to be a major predictor of the incidence of this disease [73,74].

Furthermore, intercrops have several benefits [74,75] such as diversifying soil microbe communities that can limit pathogen growth [76], reducing exposed soil, which in turn reduces the likelihood of splash-dispersed and soilborne [77], suppressing virus vectors [78,79], and diluting the pool of viable host plants for pathogens [80]. However, our findings did not indicate any significant effects of the evaluated variables on pest and disease incidence. We hypothesise that the scale of the experiment was insufficient to identify other factors that could have a substantial role in determining the size of the pest population.

Intercropping was found to be effective in reducing the incidence of *P. xyllostella* in broccoli plants by 38.5%, while flower strips did not have a significant impact. Agricultural management practices did not affect the incidence of this pest, either. This finding supports the disruptive crop hypothesis, which suggests that herbivores in polycultures will have a harder time locating crop plants associated with one or more taxonomically or genetically different plants compared to those in [81,82]. Given that we did not measure the natural enemy population in this experiment to validate the natural enemy hypothesis [83], we recommend further research to evaluate the relationships between the richness and abundance of natural enemies and natural biological pest control in these agricultural systems.

Pest and disease regulation in crops depends on the life traits of each herbivorous species and landscape characteristics surrounding the crop. Therefore, as suggested in a previous meta-analysis, different herbivores respond differently to plant diversification [69]. While one species may respond positively to diversification (as observed in *Plutella* in this study), another species may increase its population in diversified habitats (as seen with slugs in this study). In such cases, it is recommended to focus on controlling pests that have a higher economic impact on the crop yield of component crops in a polyculture.

4.3. Production and Economic Aspects

4.3.1. First Experimental Cycle

Among the main findings of this study, it is highlighted, firstly, that organic lettuce production is the most profitable activity for producers. Secondly, organic broccoli production is economically viable only when cultivated in intercropping. According to the results, all intercropping treatments are financially viable, and their profitability significantly increases when flower strips are incorporated into the system. These findings are consistent with the idea that organic agriculture provides higher benefits due to lower production costs and higher market prices when compared to conventional production [84]. Similarly, the outcomes support the idea that diversified systems in developing countries results in significantly higher gross and net financial returns relative to simplified systems [85].

It is worth noting that the economic analysis has not considered the potential utilisation of flower species included in the strips, which can typically be used for direct sale, home consumption of herbs, or in the crafting of natural cosmetic products. Therefore, the combination of productive diversification strategies in vegetable production emerges as an alternative for small-scale producers to address the price volatility of main crops or losses incurred due to the progression of diseases that limit crop production, such as *P. brassicae* in the study area—a disease exclusive to cruciferous crops with no technologies available to control its progression. Diversification not only helps mitigate risks, but also enhances socioecological resilience. Our findings add to the research on crop diversification and its role in building resilience in agriculture, as analysed by Lin [86].

4.3.2. Second Experimental Cycle

Another key finding of this study is that beyond production parameters, market conditions must be considered when evaluating the feasibility of diversification strategies in transitions to more sustainable agriculture. In the evaluated case, the reductions in lettuce yield in intercropping and organic production systems are offset by greater recognition of value in a specialised agroecological market (La Tulpa). Agroecological markets tend to operate on a local scale and cater to a specialised audience that values producers' efforts to reconfigure their plots and produce healthy food [87]. In relation to the producers, these markets aim to build networks of trust between producers and consumers, ensuring fair payment to the producer and favourable prices for the consumer. Therefore, the development of more sustainable agriculture should be driven by consumers, through raising awareness about food production practices that translate into fair prices for the producer. In this way, the producer should not bear the sole risk of economic losses when transitioning to a more sustainable agriculture model.

5. Conclusions

The inclusion of flower strips enhances the land use efficiency of the broccoli–lettuce intercropping, especially in organic production schemes and at planting densities of 50,000 plants.ha^{-1}. However, the selected intercropping arrangement (replacement series) reveals strong competition among the involved species. Therefore, future research suggests modifying the plant arrangement to reduce the effects of competition for light between broccoli and lettuce. Regarding agronomic management, organic lettuce production is economically viable in the analysed context. However, organic broccoli production results in financial losses, highlighting the need for research focused on improving nutrient uptake efficiency for this species and identifying varieties well-adapted to nutrient-poor environments. In conclusion, intercropping and the introduction of flower strips enhance resource use efficiency in broccoli and lettuce production, making them technologies that should be promoted in the transition towards more sustainable agriculture. However, this strategy should be accompanied by the creation of market niches that recognise the added value of low-input production, generating healthier foods and protecting the environment.

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References

1. MADR (Ministerio de Agricultura y Desarrollo Rural). Cadena de Hortalizas. Dirección de Cadenas Agrícolas y Forestales. 2021. Available online: https://Sioc.Minagricultura.Gov.Co/Hortalizas/Documentos/2021-03-30%20cifras%20sectoriales (accessed on 16 March 2024).
2. MADR (Ministerio de Agricultura y Desarrollo Rural). Evaluaciones Agropecuarias Municipales EVA: Base Histórica de Los Años 2007 a 2018. Available online: https://www.Datos.Gov.Co/Agricultura-y-Desarrollo-Rural/Evaluaciones-Agropecuarias-Municipales-EVA/2pnw-Mmge/About_data (accessed on 26 March 2024).
3. Agronet. Área, Producción y Rendimiento Nacional Por Cultivo. Available online: http://www.Agronet.Gov.Co/Estadistica/Paginas/Home.Aspx?Cod=1 (accessed on 8 August 2023).
4. Patiño, M.; Valencia-Guerrero, M.F.; Barbosa-Ángel, E.S.; Martínez-Cordón, M.J.; Donado-Godoy, P. Evaluation of Chemical and Microbiological Contaminants in Fresh Fruits and Vegetables from Peasant Markets in Cundinamarca, Colombia. *J. Food. Prot.* **2020**, *83*, 1726–1737. [CrossRef] [PubMed]
5. Moreno-Velandia, C.A.; Garcia-Arias, F.L.; Dávila-Mora, L.; Rodríguez, E.; Villabona-Gélvez, A.; Revelo-Gómez, E.G.; Marcillo-Paguay, C.A.; Riascos-Ortiz, D.H.; Zuluaga, A.P. The Potential of PGPR and Trichoderma-Based Bioproducts and Resistant Cultivars as Tools to Manage Clubroot Disease in Cruciferous Crops. *Front. Plant Sci.* **2024**, *14*, 1323530. [CrossRef] [PubMed]
6. Rempel, C.B.; Hutton, S.N.; Jurke, C.J. Clubroot and the Importance of Canola in Canada. *Can. J. Plant Pathol.* **2014**, *36*, 19–26. [CrossRef]
7. Van Der Putten, W.H.; Bardgett, R.D.; Bever, J.D.; Bezemer, T.M.; Casper, B.B.; Fukami, T.; Kardol, P.; Klironomos, J.N.; Kulmatiski, A.; Schweitzer, J.A.; et al. Plant–Soil Feedbacks: The Past, the Present and Future Challenges. *J. Ecol.* **2013**, *101*, 265–276. [CrossRef]
8. Albrecht, M.; Kleijn, D.; Williams, N.M.; Tschumi, M.; Blaauw, B.R.; Bommarco, R.; Campbell, A.J.; Dainese, M.; Drummond, F.A.; Entling, M.H.; et al. The Effectiveness of Flower Strips and Hedgerows on Pest Control, Pollination Services and Crop Yield: A Quantitative Synthesis. *Ecol. Lett.* **2020**, *23*, 1488–1498. [CrossRef] [PubMed]
9. Kremen, C.; Iles, A.; Bacon, C. Diversified Farming Systems: An Agroecological, Systems-Based Alternative to Modern Industrial Agriculture. *Ecol. Soc.* **2012**, *17*, art44. [CrossRef]
10. Balzan, M.V.; Bocci, G.; Moonen, A. Utilisation of Plant Functional Diversity in Wildflower Strips for the Delivery of Multiple Agroecosystem Services. *Entomol. Exp. Appl.* **2016**, *158*, 304–319. [CrossRef]
11. Brooker, R.W.; Karley, A.J.; Newton, A.C.; Pakeman, R.J.; Schöb, C. Facilitation and Sustainable Agriculture: A Mechanistic Approach to Reconciling Crop Production and Conservation. *Funct. Ecol.* **2016**, *30*, 98–107. [CrossRef]
12. Tamburini, G.; Bommarco, R.; Wanger, T.C.; Kremen, C.; Van Der Heijden, M.G.A.; Liebman, M.; Hallin, S. Agricultural Diversification Promotes Multiple Ecosystem Services without Compromising Yield. *Sci. Adv.* **2020**, *6*, eaba1715. [CrossRef]
13. Kowalska, J.; Antkowiak, M.; Sienkiewicz, P. Flower Strips and Their Ecological Multifunctionality in Agricultural Fields. *Agriculture* **2022**, *12*, 1470. [CrossRef]
14. Szitár, K.; Deák, B.; Halassy, M.; Steffen, C.; Batáry, P. Combination of Organic Farming and Flower Strips in Agricultural Landscapes—A Feasible Method to Maximise Functional Diversity of Plant Traits Related to Pollination. *Glob. Ecol. Conserv.* **2022**, *38*, e02229. [CrossRef]
15. Donkersley, P.; Witchalls, S.; Bloom, E.H.; Crowder, D.W. A Little Does a Lot: Can Small-Scale Planting for Pollinators Make a Difference? *Agric. Ecosyst. Environ.* **2023**, *343*, 108254. [CrossRef]
16. Raza, M.A.; Feng, L.Y.; Van Der Werf, W.; Iqbal, N.; Khan, I.; Khan, A.; Din, A.M.U.; Naeem, M.; Meraj, T.A.; Hassan, M.J.; et al. Optimum Strip Width Increases Dry Matter, Nutrient Accumulation, and Seed Yield of Intercrops under the Relay Intercropping System. *Food Energy Secur.* **2020**, *9*, e199. [CrossRef]
17. Killewald, M.F.; Costamagna, A.C.; Lawley, Y.; Gulden, R.H.; Gibbs, J. Floral Strips Adjacent to Manitoba Crop Fields Attract Beneficial Insects Shortly after Establishment Regardless of Management Type or Landscape Context. *Agric. For. Entomol.* **2024**, *26*, 18–37. [CrossRef]
18. Schmied, H.; Getrost, L.; Hamm, A.; Dünzkofer, T. The Flower Strip Dilemma (FSD): An Overlooked Challenge in Nature Conservation and a Possible First Step towards a Solution by Combining Different Aged Flower Strips. *Agric. Ecosyst. Environ.* **2023**, *347*, 108375. [CrossRef]
19. Schoch, K.; Tschumi, M.; Lutter, S.; Ramseier, H.; Zingg, S. Competition and Facilitation Effects of Semi-Natural Habitats Drive Total Insect and Pollinator Abundance in Flower Strips. *Front. Ecol. Evol.* **2022**, *10*, 854058. [CrossRef]
20. Willey, R.W. Intercropping–Its Importance and Research Needs. I. Competition and Yield Advantages. Part II. Agronomy and Research Approaches. *Field Crops Abstr.* **1979**, *32*, 73–85.
21. Hailu, G. A Review on the Comparative Advantage of Intercropping Systems. *J. Biol. Agric. Healthc.* **2015**, *5*, 28–38.
22. Gomes, D.P.; Carvalho, D.D.; Almeida, W.D.; Medici, L.O.; Guerra, J.G.M. Organic Carrot-Lettuce Intercropping Using Mulch and Different Irrigation Levels. *J. Food Agric. Environ.* **2014**, *12*, 323–328.
23. Marcos-Pérez, M.; Sánchez-Navarro, V.; Martinez-Martinez, S.; Martínez-Mena, M.; García, E.; Zornoza, R. Intercropping Organic Melon and Cowpea Combined with Return of Crop Residues Increases Yields and Soil Fertility. *Agron. Sustain. Dev.* **2023**, *43*, 53. [CrossRef]
24. Mouratiadou, I.; Wezel, A.; Kamilia, K.; Marchetti, A.; Paracchini, M.L.; Bàrberi, P. The Socio-Economic Performance of Agroecology. A Review. *Agron. Sustain. Dev.* **2024**, *44*, 19. [CrossRef]

25. Ewert, F.; Baatz, R.; Finger, R. Agroecology for a Sustainable Agriculture and Food System: From Local Solutions to Large-Scale Adoption. *Annu. Rev. Resour. Econ.* **2023**, *15*, 351–381. [CrossRef]
26. Dushyant; Sharma, K.; Roy, S.; Rooma, K.; Mahan, N.; Kumar, P.; Kumar, M.; Singh, S.K.; Kumar, B.; Hussain, A.; et al. Principles and Applications of Agroecology: A Review. *J. Sci. Res. Rep.* **2024**, *30*, 843–853. [CrossRef]
27. Rasmussen, L.V.; Grass, I.; Mehrabi, Z.; Smith, O.M.; Bezner-Kerr, R.; Blesh, J.; Garibaldi, L.A.; Isaac, M.E.; Kennedy, C.M.; Wittman, H.; et al. Joint Environmental and Social Benefits from Diversified Agriculture. *Science* **2024**, *384*, 87–93. [CrossRef] [PubMed]
28. Velez, R.J. La Agricultura Orgánica Solo Tiene 1% de Hectáreas Del Total Del Mercado de Alimentos. Agronegocios. 2021. Available online: https://www.Agronegocios.Co/Agricultura/La-Agricultura-Organica-Solo-Tiene-1-de-Hectareas-Del-Total-Delmercado-de-Alimentos-3140358 (accessed on 4 August 2023).
29. Resolución 187 de 2006 "Por La Cual Se Adopta El Reglamento Para La Producción Primaria, Procesamiento, Empacado, Etiquetado, Almacenamiento, Certificación, Importación, Comercialización y Se Establece El Sistema de Control de Productos Agropecuarios Ecológicos". Available online: https://www.Ica.Gov.Co/Getattachment/Efc964b6-2ad3-4428-Aad5-A9f2de5629d3/187.Aspx (accessed on 10 November 2023).
30. Resolución 464 de 2017 "Lineamientos Estratégicos Para La Agricultura Campesina, Familiar y Comunitaria". Available online: https://www.Minagricultura.Gov.Co/Normatividad/Resoluciones/Resoluci%C3%B3n%20No%20%20464%20de%202017%20Anexos.Pdf (accessed on 1 October 2023).
31. Bommarco, R.; Kleijn, D.; Potts, S.G. Ecological Intensification: Harnessing Ecosystem Services for Food Security. *Trends Ecol. Evol.* **2013**, *28*, 230–238. [CrossRef] [PubMed]
32. Tittonell, P. Ecological Intensification of Agriculture—Sustainable by Nature. *Curr. Opin. Environ. Sustain.* **2014**, *8*, 53–61. [CrossRef]
33. Gutierrez, H.J. *Clasificaciones Climáticas*; HIMAT (Instituto Colombiano de Hidrología y Meteorología y Adecuación de Tierras): Bogotá, Columbia, 1991.
34. IUSS Working Group WRB. *World Reference Base for Soil Resources 2014, Update 2015 International Soil Classification System for Naming Soils and Creating Legends for Soil Maps*; World Soil Resources Reports No. 106; FAO: Rome, Italy, 2015; Available online: https://www.Fao.Org/3/I3794en/I3794en.Pdf (accessed on 4 August 2023).
35. FAO (Food and Agriculture Organization of the United Nations). *Utilización de las Rocas Fosfóricas para una Agricultura Sostenible*; Zapata, F., Roy, R.N., Eds.; FAO: Rome, Italy, 2007; ISBN 978-92-5-305030-7.
36. Maitra, S.; Hossain, A.; Brestic, M.; Skalicky, M.; Ondrisik, P.; Gitari, H.; Brahmachari, K.; Shankar, T.; Bhadra, P.; Palai, J.B.; et al. Intercropping—A Low Input Agricultural Strategy for Food and Environmental Security. *Agronomy* **2021**, *11*, 343. [CrossRef]
37. Paut, R.; Garreau, L.; Ollivier, G.; Sabatier, R.; Tchamitchian, M. A Global Dataset of Experimental Intercropping and Agroforestry Studies in Horticulture. *Sci. Data* **2024**, *11*, 5. [CrossRef] [PubMed]
38. Departamento Administrativo Nacional de Estadística (DANE). Sistema de Información de Precios y Abastecimiento Del Sector Agropecuario—SIPSA. Available online: https://www.Dane.Gov.Co/Index.Php/Estadisticas-Portema/Agropecuario/Sistema-de-Informacion-de-Precios-Sipsa (accessed on 8 November 2023).
39. La Tulpa. Productos. Available online: https://www.familiatulpa.com/Tienda/ (accessed on 8 November 2023).
40. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2023.
41. Shimizu, G.; Marubayashi, R.; Goncalves, L. AgroR: Experimental Statistics and Graphics for Agricultural Sciences. R Package Version 1.3.3. 2023. Available online: https://agronomiar.github.io/AgroR_package/index.html (accessed on 4 August 2023).
42. Yildirim, E.; Turan, M. Growth, Yield and Mineral Content of Broccoli Intercropped with Lettuce. *J. Anim. Plant. Sci.* **2013**, *23*, 919–922.
43. Demir, H.; Polat, E. Effects of Broccoli-Crispy Salad Intercropping on Yield and Quality under Greenhouse Conditions. *Afr. J. Agric. Res.* **2011**, *6*, 4116–4121.
44. Gitari, H.I.; Gachene, C.K.K.; Karanja, N.N.; Kamau, S.; Nyawade, S.; Sharma, K.; Schulte-Geldermann, E. Optimizing Yield and Economic Returns of Rain-Fed Potato (*Solanum tuberosum* L.) through Water Conservation under Potato-Legume Intercropping Systems. *Agric. Water Manag.* **2018**, *208*, 59–66. [CrossRef]
45. Nyawade, S.O.; Karanja, N.N.; Gachene, C.K.K.; Gitari, H.I.; Schulte-Geldermann, E.; Parker, M.L. Intercropping Optimizes Soil Temperature and Increases Crop Water Productivity and Radiation Use Efficiency of Rainfed Potato. *Am. J. Potato Res.* **2019**, *96*, 457–471. [CrossRef]
46. Miao, Q.; Rosa, R.D.; Shi, H.; Paredes, P.; Zhu, L.; Dai, J.; Gonçalves, J.M.; Pereira, L.S. Modeling Water Use, Transpiration and Soil Evaporation of Spring Wheat–Maize and Spring Wheat–Sunflower Relay Intercropping Using the Dual Crop Coefficient Approach. *Agric. Water Manag.* **2016**, *165*, 211–229. [CrossRef]
47. Brennan, E.B. Agronomy of Strip Intercropping Broccoli with Alyssum for Biological Control of Aphids. *Biol. Control.* **2016**, *97*, 109–119. [CrossRef]
48. Ohse, S.; Rezende, B.L.A.; Silveira, L.S.; Otto, R.F.; Cortez, M.G. Agronomic Feasibility of Broccoli and Lettuce Intercropping Established in Different Growing Periods. *Idesia Arica* **2012**, *30*, 29–37. [CrossRef]

49. Cunha-Chiamolera, T.P.; Cecílio Filho, A.B.; Santos, D.M.; Chiamolera, F.M.; Guevara-González, R.G.; Nicola, S.; Urrestarazu, M. Lettuce in Monoculture or in Intercropping with Tomato Changes the Antioxidant Enzyme Activities, Nutrients and Growth of Lettuce. *Horticulturae* **2023**, *9*, 783. [CrossRef]
50. Santos, R.; Gliessman, S.R.; Cecon, P.R. Crop Interactions in Broccoli Intercropping. *Biol. Agric. Hortic.* **2002**, *20*, 51–75. [CrossRef]
51. Yildirim, E.; Cil, B.; Ekinci, M.; Turan, M.; Dursun, A.; Gunes, A.; Kul, R.; Kitir, N. Effects of Intercropping System and Nitrogen Fertilization on Land Equivalent Ratio, Yield and Mineral Content of Broccoli. *Acta Sci. Pol. Hortorum Cultus* **2020**, *19*, 101–109. [CrossRef]
52. Sharaiha, R.; Gliessman, S. The Effects of Crop Combination and Row Arrangement in the Intercropping of Lettuce, Favabean and Pea on Weed Biomass and Diversity and on Crop Yields. *Biol. Agric. Hortic.* **1992**, *9*, 1–13. [CrossRef]
53. Ribas, R.G.T.; Cecílio Filho, A.B.; Dutra, A.F.; Barbosa, J.C.; Rolim, G.D.S. Land Equivalent Ratio in the Intercropping of Cucumber with Lettuce as a Function of Cucumber Population Density. *Agriculture* **2020**, *10*, 88. [CrossRef]
54. Cecílio Filho, A.B.; Rezende, B.L.A.; Dutra, A.F. Yield of Intercropped Lettuce and Cucumber as a Function of Population Density and Cropping Season. *Rev. Caatinga* **2019**, *32*, 943–951. [CrossRef]
55. Silva, Í.N.; Bezerra Neto, F.; Barros Júnior, A.P.; Lima, J.S.S.D.; Batista, T.M.D.V.; Lins, H.A. Green Manure and Spatial Arrangement in the Sustainability Improvement of Lettuce-Beet Intercrops. *Rev. Bras. Eng. Agríc. Ambient.* **2018**, *22*, 451–457. [CrossRef]
56. Guerra, N.M.; Bezerra Neto, F.; Lima, J.S.; Santos, E.C.; Nunes, R.L.; Porto, V.C.; Queiroga, R.C.; Lino, V.A.; Sá, J.M. Agro-Economic Viability of Lettuce-Beet Intercropping under Green Manuring in the Semi-Arid Region. *Hortic. Bras.* **2022**, *40*, 82–91. [CrossRef]
57. Cecílio Filho, A.; Rezende, B.L.A.; Canato, G.H.D. Lettuce and Radish Productivity in Intercropping Systems as Influenced by Starting Time and Row Spacings. *Hortic. Bras.* **2007**, *25*, 15–19. [CrossRef]
58. Cecílio Filho, A.B.; Rezende, B.L.A.; Barbosa, J.C.; Grangeiro, L.C. Agronomic Efficiency of Intercropping Tomato and Lettuce. *An. Acad. Bras. Ciênc.* **2011**, *83*, 1109–1119. [CrossRef]
59. Bezerra Neto, F.; Gomes, E.G.; De Araújo, R.R.; De Oliveira, E.Q.; Nunes, G.D.S.; Grangeiro, L.C.; Azevedo, C.D.S. Evaluation of Yield Advantage Indexes in Carrot-Lettuce Intercropping Systems. *Interciencia* **2010**, *35*, 59–64.
60. Nascimento, C.S.; Cecílio Filho, A.B.; Mendoza-Cortez, J.W.; Nascimento, C.S.; Bezerra Neto, F.; Grangeiro, L.C. Effect of Population Density of Lettuce Intercropped with Rocket on Productivity and Land-Use Efficiency. *PLoS ONE* **2018**, *13*, e0194756. [CrossRef]
61. Yousefi, M.; Marja, R.; Barmettler, E.; Six, J.; Dray, A.; Ghazoul, J. The Effectiveness of Intercropping and Agri-Environmental Schemes on Ecosystem Service of Biological Pest Control: A Meta-Analysis. *Agron. Sustain. Dev.* **2024**, *44*, 15. [CrossRef]
62. Tschumi, M.; Albrecht, M.; Bärtschi, C.; Collatz, J.; Entling, M.H.; Jacot, K. Perennial, Species-Rich Wildflower Strips Enhance Pest Control and Crop Yield. *Agric. Ecosyst. Environ.* **2016**, *220*, 97–103. [CrossRef]
63. Mei, Z.; De Groot, G.A.; Kleijn, D.; Dimmers, W.; Van Gils, S.; Lammertsma, D.; Van Kats, R.; Scheper, J. Flower Availability Drives Effects of Wildflower Strips on Ground-Dwelling Natural Enemies and Crop Yield. *Agric. Ecosyst. Environ.* **2021**, *319*, 107570. [CrossRef]
64. Derbyshire, M.C.; Denton-Giles, M. The Control of Sclerotinia Stem Rot on Oilseed Rape (*Brassica napus*): Current Practices and Future Opportunities. *Plant Pathol.* **2016**, *65*, 859–877. [CrossRef]
65. Mazumdar, P. Sclerotinia Stem Rot in Tomato: A Review on Biology, Pathogenicity, Disease Management and Future Research Priorities. *J. Plant Dis. Prot.* **2021**, *128*, 1403–1431. [CrossRef]
66. AHDB Integrated Slug Control. Available online: https://Ahdb.Org.Uk/Knowledge-Library/Integrated-Slug-Control (accessed on 8 March 2024).
67. Emery, S.E.; Anderson, P.; Carlsson, G.; Friberg, H.; Larsson, M.C.; Wallenhammar, A.-C.; Lundin, O. The Potential of Intercropping for Multifunctional Crop Protection in Oilseed Rape (*Brassica napus* L.). *Front. Agron.* **2021**, *3*, 782686. [CrossRef]
68. Qasim Mohammed, I.; Adnan Alyousuf, A. Effect Of Intercropping Systems on Diamondback Moth (*Plutella xylostell* L.) and Turnip Aphid (Lipaphis Erysimi Ka) Infesting Cabbage, Brassica Oleracea Var. Capitate. *Nat. Vol. Essent. Oil* **2021**, *8*, 2245–2262.
69. Karp, D.S.; Chaplin-Kramer, R.; Meehan, T.D.; Martin, E.A.; DeClerck, F.; Grab, H.; Gratton, C.; Hunt, L.; Larsen, A.E.; Martínez-Salinas, A.; et al. Crop Pests and Predators Exhibit Inconsistent Responses to Surrounding Landscape Composition. *Proc. Natl. Acad. Sci. USA* **2018**, *115*, E7863–E7870. [CrossRef]
70. Klimek-Kopyra, A.; Neugschwandtner, R.W.; Dłużniewska, J.; Bernas, J.; Kulig, B. Chapter Three—Flowers strips and herbal living mulch as an innovative approach to the design of farming systems for sustainable crop production. In *Advances in Agronomy*; Sparks, D.L., Ed.; Academic Press: Cambridge, MA, USA, 2024; Volume 185, pp. 119–151. ISBN 9780443295263. [CrossRef]
71. Peralta-Antonio, N.; Watthier, M.; Santos, R.H.S.; Martinez, H.E.P.; Vergütz, L. Broccoli Nutrition and Changes of Soil Solution with Green Manure and Mineral Fertilization. *J. Soil Sci. Plant Nutr.* **2019**, *19*, 816–829. [CrossRef]
72. Vidal-Martínez, J.L.; Núñez-Escobar, R.; Lazcano-Ferrat, I.; Etchevers-Barra, J.D.; Carrillo-González, R. Nutrición Potásica Del Brócoli (*Brassica olearacea*) Con Manejo Convencional y Fertirrigación En Un Vertisol En Invernadero. *Agrociencia* **2006**, *40*, 1–11.
73. Hao, J.; Subbarao, K.V.; Koike, S.T. Effects of Broccoli Rotation on Lettuce Drop Caused by *Sclerotinia minor* and on the Population Density of Sclerotia in Soil. *Plant Dis.* **2003**, *87*, 159–166. [CrossRef]
74. Huss, C.P.; Holmes, K.D.; Blubaugh, C.K. Benefits and Risks of Intercropping for Crop Resilience and Pest Management. *J. Econ. Entomol.* **2022**, *115*, 1350–1362. [CrossRef]
75. Hatt, S.; Döring, T.F. Designing Pest Suppressive Agroecosystems: Principles for an Integrative Diversification Science. *J. Clean. Prod.* **2023**, *432*, 139701. [CrossRef]

76. Wang, G.; Bei, S.; Li, J.; Bao, X.; Zhang, J.; Schultz, P.A.; Li, H.; Li, L.; Zhang, F.; Bever, J.D.; et al. Soil Microbial Legacy Drives Crop Diversity Advantage: Linking Ecological Plant–Soil Feedback with Agricultural Intercropping. *J. Appl. Ecol.* **2021**, *58*, 496–506. [CrossRef]
77. Hiddink, G.A.; Termorshuizen, A.J.; Van Bruggen, A.H.C. Mixed Cropping and Suppression of Soilborne Diseases. In *Genetic Engineering, Biofertilisation, Soil Quality and Organic Farming*; Lichtfouse, E., Ed.; Sustainable Agriculture Reviews; Springer: Dordrecht, The Netherlands, 2010; Volume 4, pp. 119–146. ISBN 978-90-481-8740-9.
78. Trenbath, B.R. Intercropping for the Management of Pests and Diseases. *Field Crops Res.* **1993**, *34*, 381–405. [CrossRef]
79. Boudreau, M.A. Diseases in Intercropping Systems. *Annu. Rev. Phytopathol.* **2013**, *51*, 499–519. [CrossRef]
80. Zhang, C.; Dong, Y.; Tang, L.; Zheng, Y.; Makowski, D.; Yu, Y.; Zhang, F.; Van Der Werf, W. Intercropping Cereals with Faba Bean Reduces Plant Disease Incidence Regardless of Fertilizer Input: A Meta-Analysis. *Eur. J. Plant Pathol.* **2019**, *154*, 931–942. [CrossRef]
81. Vandermeer, J. *The Ecology of Intercropping*; Cambridge University Press: Cambridge, UK, 1989; ISBN 978-0-511-62352-3.
82. Poveda, K.; Martínez, E.; Kersch-Becker, M.F.; Bonilla, M.A.; Tscharntke, T. Landscape Simplification and Altitude Affect Biodiversity, Herbivory and Andean Potato Yield. *J. Appl. Ecol.* **2012**, *49*, 513–522. [CrossRef]
83. Root, R.B. Organization of a Plant-Arthropod Association in Simple and Diverse Habitats: The Fauna of Collards (*Brassica oleracea*). *Ecol. Monogr.* **1973**, *43*, 95–124. [CrossRef]
84. Durham, T.C.; Mizik, T. Comparative Economics of Conventional, Organic, and Alternative Agricultural Production Systems. *Economies* **2021**, *9*, 64. [CrossRef]
85. Sánchez, A.C.; Kamau, H.N.; Grazioli, F.; Jones, S.K. Financial Profitability of Diversified Farming Systems: A Global Meta-Analysis. *Ecol. Econ.* **2022**, *201*, 107595. [CrossRef]
86. Lin, B.B. Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change. *BioScience* **2011**, *61*, 183–193. [CrossRef]
87. Loconto, A.; Jimenez, A.; Vandecandelaere, E. *Constructing Markets for Agroecology: An Analysis of Diverse Options for Marketing Products from Agroecology*; FAO (Food and Agriculture Organization of the United Nations): Rome, Italy; INRA (Institut National de la Researche Agronomique): Paris, France, 2018; ISBN 978-92-5-130339-9.