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Crop-Specific Effects on Pan-Trap Sampling of Potential Pollinators as Influenced by Trap Color and Location

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Abstract: Characterizing insect communities in pollinator-dependent crops helps determine the potential pollinator effectiveness and their effects on crop yield. Few studies have examined pollinator communities and their services to crops in South America. Furthermore, optimal sampling methods for these communities in the crop habitat have received little attention. Pan traps are one of the simplest and most widely used sampling methods to assess insect diversity. We compared different pan trap arrangements to describe potential pollinator communities in two commercial crops (blueberry and canola) in Southern Chile. We compared communities in the crops and assessed how sampling position (border or center) and pan trap color (blue, white, or yellow) affected sample composition. Species composition was significantly different between crops. Furthermore, trap color affected sample composition in blueberry, but trap position did not, whereas color had no significant effect on canola, but trap position did. In all cases, yellow pans captured the largest number of species. Hymenoptera explained most of the differences in sampling efficiency because of the differential responses across species. We suggest that pan trap assessments of the diversity in potential pollinator insects depend on crop characteristics, including planting configuration and floral morphology. Therefore, comparative studies should include pans of different colors positioned at various locations within the crop.

Keywords: blueberry; biodiversity; canola; Central Chile; pan traps

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Citation: Jaques, S.A.; Jofré-Pérez, C.; Murúa, M.M.; Vieli, L.; Fontúrbel, F.E. Crop-Specific Effects on Pan-Trap Sampling of Potential Pollinators as Influenced by Trap Color and Location. *Agronomy* **2023**, *13*, 552. https://doi.org/10.3390/agronomy13020552

Academic Editors: Finbarr Horgan and Paul-andré Calatayud

Received: 12 January 2023
Revised: 10 February 2023
Accepted: 13 February 2023
Published: 15 February 2023

1. Introduction

Pollinators are important for many plant species and provide an essential ecosystem service for humanity [1,2]. Studies on pollination and pollinators have become more common in recent years due to the considerable decline in some species and because this 'pollination crisis' affects natural ecosystems and food production systems [3]. For this reason, monitoring pollinator communities is an important task to evaluate the impact of conservation strategies, habitat degradation, crop management practices, or invasive species. Monitoring pollinators and their services in croplands is particularly important given the potential links between pesticide use and pollinator declines [3,4]. However, whereas several studies have focused on pollinator communities in cropland, certain geographical regions remain understudied, including, for example, the western nations of South America and much of Africa [5].

Several sampling methods have been used to characterize pollinator communities, each of which has advantages and disadvantages depending on the aims of the study and the effectiveness of the method for sampling different species assemblages; methods are further influenced by external factors [6]. In particular, study site location, vegetation type, resource availability (i.e., flowers), and the pollinator community composition can influence the outcome of pollinator sampling methods [7]. Many sampling approaches are commonly used to sample potential pollinator species within the communities. These include direct observations (transects and observation plots), entomological nets, pan traps, and other approaches based on devices such as camera traps, e.g., [8,9].

Colored pan traps make up a passive sampling method that does not require specialized equipment [10] and, thus, is considered an effective method for assessing insect diversity [11,12]. Pan traps are shallow containers (commonly 20 cm diameter and 10 cm deep), usually made of plastic, filled with soapy water, salt, propylene glycol, or any combination of these [13]. Pan traps usually have different colors, mainly white, blue, and yellow. Those different colors capture different insect groups due to their visual perceptions and flower color preferences [6,14]. Although pan traps are not influenced by the investigator, other important factors should be considered, such as trap size, odor, location, weather conditions, habitat, floral morphology, pollinator vision range, and surrounding vegetation, as these might influence the results [10,15,16]. Therefore, it is important to consider these variables during the sampling study to obtain more accurate estimates of species richness and relative abundance.

Plants depend on their flowers to attract pollinators. Flowers have different shapes, sizes, odors, and colors. Some pollinator groups are specifically associated with particular floral traits (i.e., floral syndromes), where flower color is emphasized as a key property in plant–pollinator interactions [17]. This is due to each pollinator's specific and distinctive color vision. Considering this, pan traps can be used to study and assess the diversity in potential pollinator insects [18], providing complementary information to active sampling approaches (e.g., netting). Insects can be attracted to a particular color, which depends on the ability to discriminate certain light wavelengths. Thus, most insects respond to a wavelength range from near-ultraviolet light (300–400 nm) to orange (600–650 nm). Matthews and Matthews [19] mentioned that most insects have two types of pigments, one that absorbs green and yellow light (~550 nm) and the other that absorbs blue and ultraviolet light (<480 nm). Some insect species perceive a wider color spectrum (e.g., bees [20]), which different flower colors can attract.

In this methodological study, we aimed to (1) provide a preliminary description of the potential pollinators (including non-hymenopterans) of blueberry and canola in an understudied region of Southern Chile, (2) compare the performance of different pan trap arrangements (pans laced at the center or the border of the crop) in blueberry and canola crops for detecting potential pollinator insects in the two crops, and (3) to test whether insect species composition varies among three pan trap colors. We hypothesized that pan traps will capture different species of potential pollinator insects at each crop type, irrespective of their placement within the crop.

2. Materials and Methods

2.1. Study Area

The study was carried out in Southern Chile, in the Araucanía Region (38.2–39.3° S; Figure S1). Pan traps were placed during flowering in eight blueberry (*Vaccinium corymbosum*) orchards (=crop fields) between September and October 2019 and in eight canola (*Brassica napus*) fields between October and November 2019. In both cases, the same crop species cultivar was sampled to reduce the confounding effects of different cultivars on the results [21]. Blueberry orchards had a mean size of 35.38 ± 12.66 ha (mean ± SE), while canola orchards had a mean size of 130.50 ± 54.36 ha. Sampled blueberry orchards were at least 8 km apart, while canola fields were at least 4.7 km apart from each other. Blueberry and canola fields were spatially interspersed.

2.2. Study Crops

We sampled two widely used commercial crops in Chile: highbush blueberry (*Vaccinium corymbosum* cv. Legacy; Figure 1a,b) and canola (*Brassica napus* cv. 'Implement CL'; Figure 1c,d). These crops are pollinator-dependent, quite common in South-Central Chile, but have very different morphologies. Blueberry flowers are inconspicuous with white or pink colors and a mild fragrance [21]. This species requires its flowers to be pollinated by insects to obtain larger and heavier fruits; it also has hermaphrodite flowers with characteristics that determine low self-pollination, such as hanging clusters and circular stamens. On the other hand, canola is planted for oil production, but other products, such as mash, honey, and fodder, can be obtained [22]. Canola flowers are protandrous with a pale-yellow color; when the flower opens, the stigma is already receptive, but the anthers are not ripe until a later stage. Therefore, canola flowers depend on pollinators for pollen transport while the anthers remain closed, further favoring cross-pollination.

Figure 1. Study crops: (**a**) blueberry flower, (**b**) blueberry crop field, (**c**) canola flower, (**d**) canola crop field (photograph credits: Lorena Vieli).

2.3. Sampling Design

We used three pan trap colors: blue (430–500 nm), white (400–700 nm), and yellow (565–580 nm). In each orchard, we placed three sets of pan traps at the crop border (0–10 m) and three sets within the crop (50–70 m from the border; in some smaller blueberry orchards, it was not possible to place them 50 m from the field border; in such locations, we maximized the distance to the border as much as possible; Figure S2). Each pan trap set consisted of three traps of different colors (i.e., white, yellow, and blue), separated ~3 m from each other (following FAO recommendations [23]). Pan traps were placed 50 cm above the ground and secured using a wooden stake to fix them and avoid mechanical effects from the wind. Thus, we placed 18 pan traps at each orchard, 9 (i.e., three sets of yellow, white, and blue plates) in the edge of the crop and 9 in the center, making a total of 144 pan traps per crop type, and 288 pan traps overall.

Pan traps (18 cm in diameter and 10 cm in depth, Forfest, Brazil) were placed twice during flowering in blueberry (sampling bouts were separated by at least five days) orchards and once during flowering in the canola fields on days with good weather (i.e., no rain). We placed pan traps in the morning, filled them with water and a few drops of odorless soap, and left them for 24 h in the field. After that, we collected the insects captured by the pan traps and preserved them in recipients with 70% ethanol, separating them according to trap color and position (center or border). In our study area, blueberries bloomed early in spring, and canola started to bloom a few weeks after blueberry flowering was over. We conducted pan trap sampling in blueberry crops between 16 September and 5 October 2019, and between 30 October and 8 November 2019 in the canola crops.

2.4. Data Processing

Collected specimens were examined by an expert entomologist (CJP) and identified at the lowest taxonomic level possible, based on the Catalogue of Life (https://www.catalogueoflife.org/ accessed on 24 March 2021) database. Then, we filtered the database, leaving only potential pollinators using the criteria from the Chilean Pollination Network (details in Appendix A), excluding those species that were not previously reported as pollinators in Chile (e.g., some coccinellids). This filter allowed us to leave some families and genera belonging to the orders Diptera, Hymenoptera, Coleoptera, and Lepidoptera, as no ant and hemipteran species were found in our pan trap samples.

2.5. Data Analysis

To determine the effectiveness of our sampling, we conducted rarefaction analyses based on Hill numbers, estimating the 95% confidence intervals using 999 permutations. We also calculated the expected species richness using the average of three widely used estimators (Chao1, Jackknife1, and Bootstrap). Thus, sampling effectiveness was estimated as the ratio between the observed and expected species richness [24]. We conducted separate sampling effectiveness for each study crop.

Then, to determine if insect species composition differs between blueberry and canola crops, we performed an ANOSIM (an acronym for Analysis of Similarities) test [25]. ANOSIM is a non-parametric multivariate test that allows us to determine if species composition differs between two or more groups. This test is based on the rankings of a similarity matrix, and its statistical significance is obtained using permutations. In this case, we used a Bray Curtis similarity index and 999 permutations to compare composition. Then, we conducted another ANOSIM test to compare species composition between crop center and border. Further, as trap color has been documented to be an important factor for insect sampling, we also conducted an ANOSIM test using trap colors as a comparison factor. We repeated this procedure for each crop.

To visualize the ANOSIM results, we used an nMDS (non-metric Multidimensional Scaling) approach to represent our data in a two-dimensional geometric space. The nMDS performance is measured by the stress value, which varies between 0 and 1 (lower stress values represent better performance). Further, when ANOSIM gave significant results, we conducted a SIMPER (an acronym for Similarity Percentage) test, which evaluates the average percentage contribution of individual species to the difference.

Then, we used rank–abundance curves to describe insect communities (steeper curves represent a less-even community). We used the Shannon index (H′) to estimate species diversity and the Pielou index (J) to estimate evenness. Statistical analyses were conducted in R 4.0.5 [26] using the packages vegan [27] and BiodiversityR [28].

3. Results

We obtained a total of 3375 insect specimens, belonging to 127 insect species grouped in 58 families. After filtering for potential pollinator species, we found a total of 27 potential pollinator insect species, corresponding to the orders Coleoptera (7 species from two families, all native), Diptera (4 species from the Syrphidae family, all native), Lepidoptera

(3 morphospecies from the Gelechiidae family, all native), and Hymenoptera (11 native and 2 exotic species from two families). From those species, 13 were found in the blueberry crops and 22 in the canola crops (8 species were shared between crops; details are presented in Table S1). The most frequently recorded species were the native bees *Corynura chloris* (Spinola, 1851), *Alloscirtetica tristrigata* (Spinola, 1851), *Lasioglossum* sp. (Curtis, 1833), the exotic bee *Apis mellifera* (Linnaeus, 1758), and the coleopteran *Astylus trifasciatus* (Guérin-Méneville, 1844). Contrarily, butterflies and hoverflies were found at very low frequencies. Sampling effectiveness at the blueberry crops was 83% (the rarefaction curve is presented in Figure S3), while the sampling effectiveness at the canola crop was 76% (the rarefaction curve is presented in Figure S4).

Overall, insect species composition was significantly different between crops (ANOSIM R = 0.541, p = 0.001). While both crops share some species, there are several exclusive species to a single crop (Figure 2a, details in Table S2), explaining such composition differences. The species that explain the differences between crops are detailed in Table 1. While dominant species are particular to a given crop, such as the native bee *C. chloris*, others, such as *A. mellifera* and *A. trifasciatus*, were highly abundant in both crops.

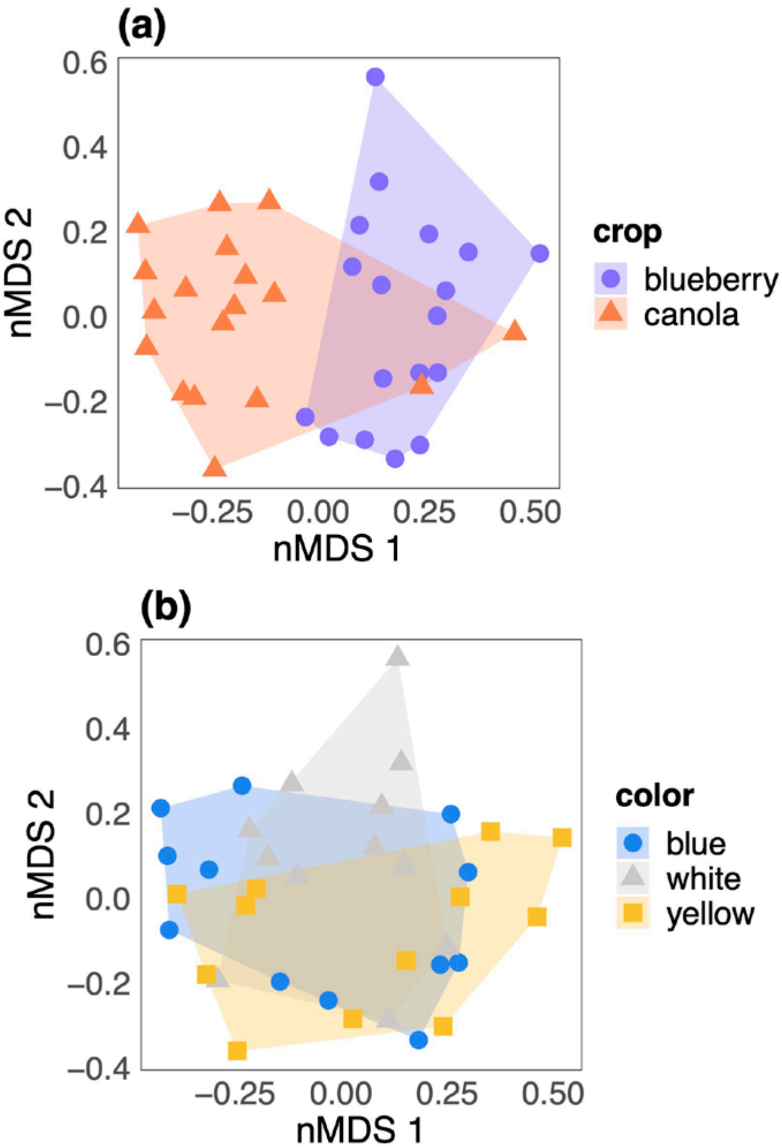

Figure 2. Insect species composition (**a**) between crops and (**b**) among pan trap colors (ordination stress = 0.197).

Table 1. Results of the SIMPER analysis showing the species that explain 80% of the differences between blueberry and canola crops. The individual contribution (average and standard deviation in parentheses), relative abundances per crop, and cumulative dissimilarity are shown. Probability of difference between crops was estimated upon permutations: ns: $p \geq 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Species	Ind. Contrib	AbundB	AbundC	Cum Dissim
Corynura chloris	0.197 (0.169)	0.667	6.500	0.232 ***
Alloscirtetica tristrigata	0.171 (0.211)	0.000	7.111	0.433 ***
Apis mellifera	0.117 (0.146)	3.722	1.722	0.571 ns
Lasioglossum sp.	0.088 (0.102)	0.389	3.611	0.674 **
Astylus trifasciatus	0.069 (0.075)	1.778	1.444	0.755 ns
Ruizantheda proxima	0.062 (0.069)	0.167	2.222	0.828 **

Overall, when comparing the pan trap position, there were no significant differences in species composition between traps placed at the center or the border of the crops (ANOSIM R = 0.034, $p = 0.182$). Conversely, we found a significant difference among pan trap colors (ANOSIM R = 0.107, $p = 0.016$; Figure 2b), with yellow plates capturing a larger number of insect species.

3.1. Blueberry Crop Insect Diversity

The honeybee *A. mellifera* dominated the insect community in blueberry crops, followed by two native species as the most abundant species: *A. trifasciatus* and *C. chloris* (Figure 3a). Examining community data by pan trap position, insect species at the crop border (Figure 3b) show a more even abundance than those at the crop center (Figure 3c), while the most abundant species are the same. Whereas, when we examine community distribution among pan trap colors, we found that white plates are largely dominated by *A. mellifera* (Figure 3d), while in yellow (Figure 3e) and blue (Figure 3f) plates, *A. trifasciatus* was the most abundant species, followed by A. mellifera and some native bees. In the case of blue plates, *A. trifasciatus* was much more abundant than other species, contrary to what was observed in the yellow plates, which shows a more even distribution.

From a total of 13 insect species found at the blueberry orchards, 10 species were found at the crop center and 6 at the crop border. Regarding plate color, yellow plates presented the 11 species found in this crop, while white plates presented 8 species, and blue plates presented 6 species (Table 2). Thus, the highest diversity and evenness were reached at the crop border and yellow plates (Table 2).

Table 2. Insect species richness (S), species diversity (H′), and evenness (J) in blueberry crops.

Comparison	Level	S	H′	J
Overall		13	1.362	0.716
Position	Center	10	1.243	0.708
	Border	6	1.481	0.795
Color	White	8	1.055	0.451
	Yellow	11	1.910	0.902
	Blue	6	1.121	0.795

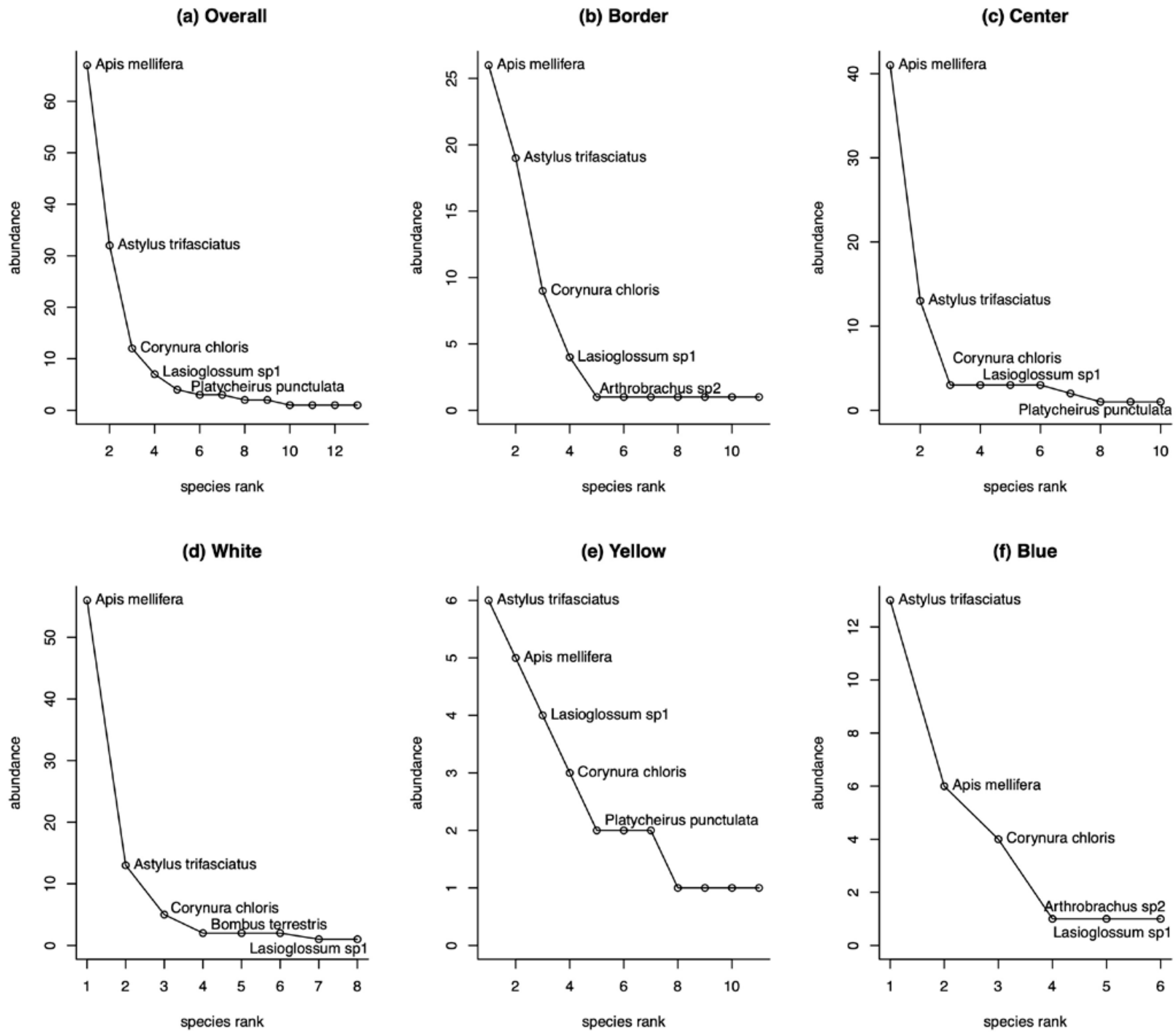

Figure 3. Rank–abundance curves of potential pollinator insects in the blueberry crops by: overall (**a**); position (**b**,**c**); and pan trap color (**d**–**f**).

Regarding species composition, when comparing pan trap position, we found no significant differences between traps placed in the center and those situated at the border of the crop (ANOSIM R = −0.005, p = 0.436; Figure 4a). However, we found a significant difference in species composition among pan trap colors (ANOSIM; R= 0.262, p = 0.009; Figure 4b), with yellow plates being the most effective in capturing insect species.

3.2. Canola Crop Insect Diversity

The insect community in canola crops was dominated by the native bees *A. tristrigata* and *C. chloris*, followed by *Lasioglossum* sp. and *Ruizantheda proxima* (Spinola, 1851) as the most abundant species (Figure 5a). Examining community data by pan trap position, insect species at the crop border (Figure 5b) and the crop center (Figure 5c) show similar trends, but with different dominant species, as *A. tristrigata* was the most abundant species at the crop border while *C. chloris* was the most abundant species at the crop center. When examining community distribution among pan trap colors, we found that white and yellow plates are largely dominated by *C. chloris* (Figure 5d,e), while blue (Figure 5f) plates were largely dominated by *A. tristrigata*.

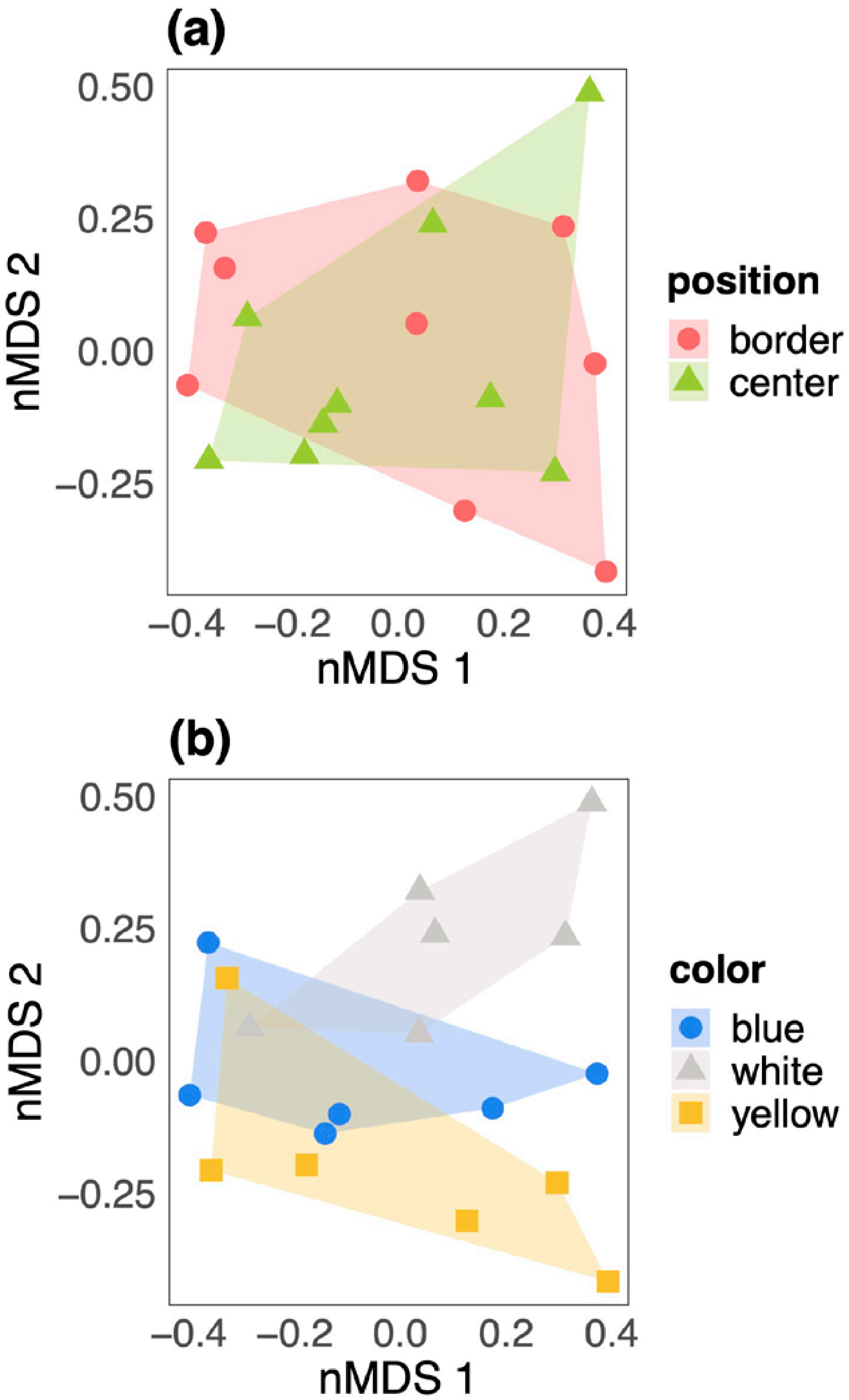

Figure 4. Insect species composition (**a**) between center and border placement and (**b**) among pan trap colors for blueberry crops (ordination stress = 0.121).

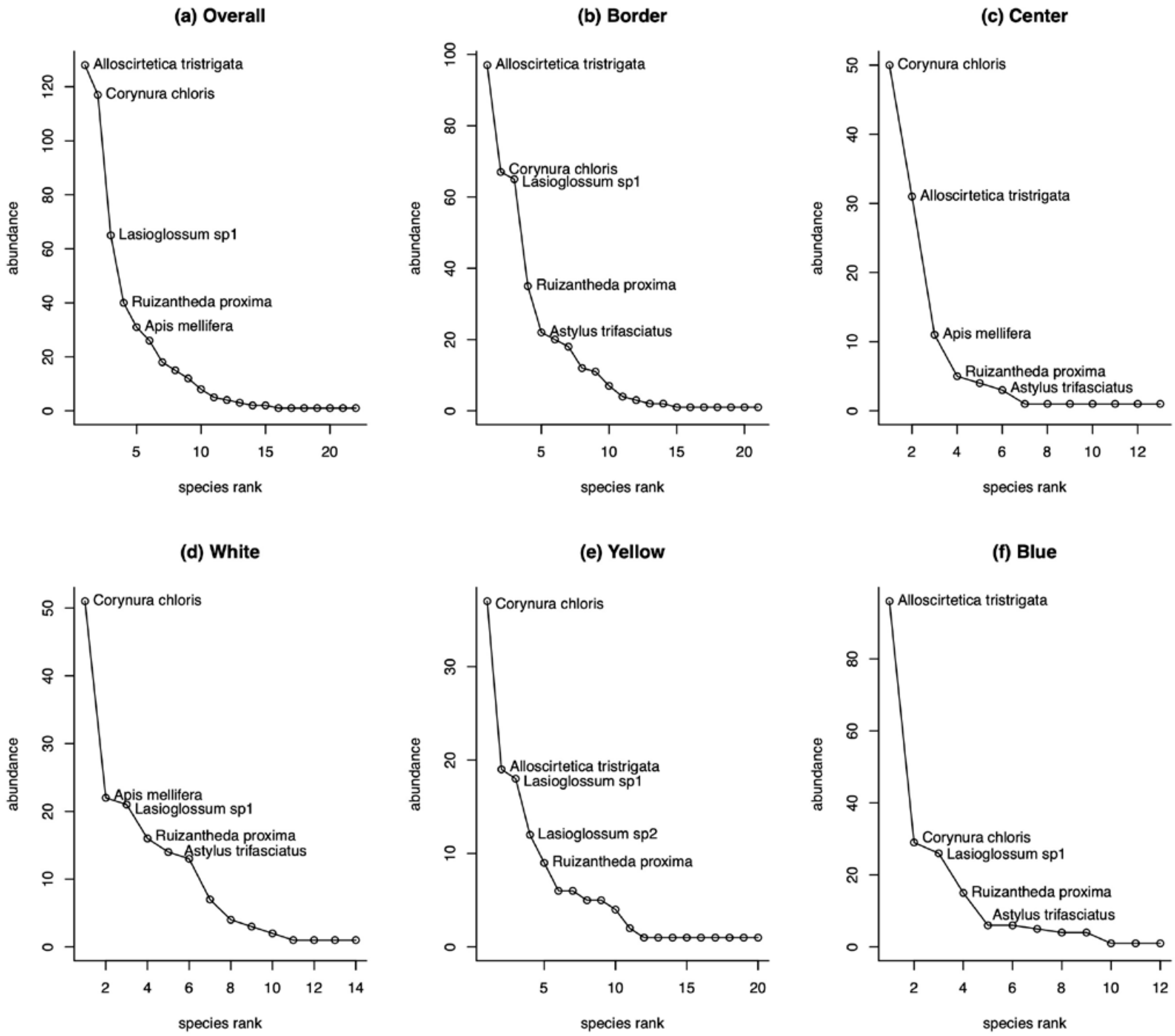

Figure 5. Rank–abundance curves of potential pollinator insects in the canola crops by: overall (**a**); position (**b**,**c**); and pan trap color: (**d**–**f**).

From a total of 22 insect species found at the canola crop, 13 species were found at the crop center and 12 at the crop border; regarding plate color, yellow plates presented 20 species, while white plates presented 14 species, and blue plates presented 12 species (Table 3). Thus, the highest diversity and evenness were reached at the crop center and yellow plates (Table 3).

Table 3. Insect species richness (S), species diversity (H′), and evenness (J) in canola crops.

Comparison	Level	S	H′	J
Overall		22	1.711	0.553
Position	Center	13	1.384	0.534
	Border	12	2.037	0.490
Color	White	14	1.624	0.546
	Yellow	20	2.030	0.622
	Blue	12	1.478	0.490

Regarding species composition, we found a significant difference between pan traps placed at the center from those at the border of the crop (ANOSIM R= 0.318, p = 0.001; Figure 6a). Conversely, we found no significant differences in species composition among pan trap colors (ANOSIM R = 0.042, p = 0.262; Figure 6b).

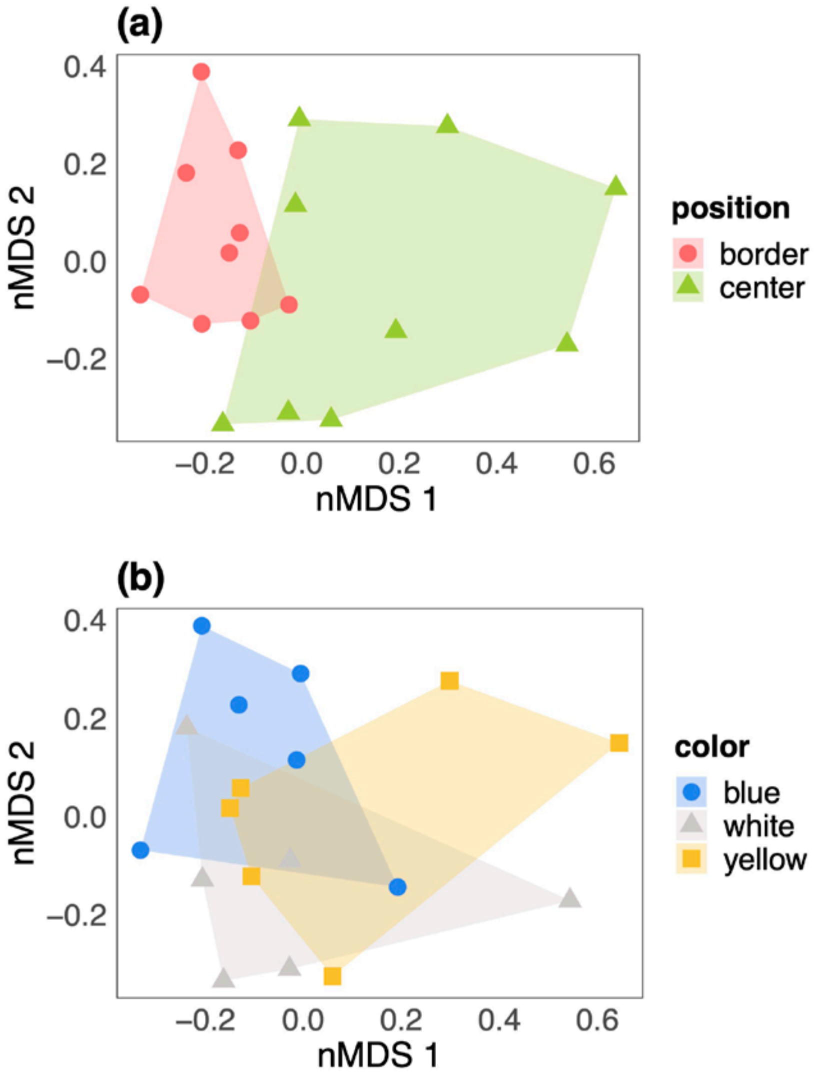

Figure 6. Insect species composition (**a**) between center and border placement and (**b**) among pan trap colors for canola crops (ordination stress = 0.168).

4. Discussion

Most insect species found in blueberry and canola crops were native, despite being under intensive agricultural management. Bees were the most represented group, accounting for 48% of the overall species richness. In addition to the exotic species *A. mellifera* and *B. terrestris*, eleven native bee species were frequently found in the crop fields. Such native bees are endemic to South-Central Chile, with communal or semi-social species nesting in the soil, and they are polylectic (i.e., can use a wide diversity of floral resources) [29], which may explain their presence in crop fields. Some authors have reported that native bees are more effective crop pollinators than *A. mellifera* or *B. terrestris* [4,30,31], but the specific contribution of these bee species to crop pollination remains largely unknown. South-Central Chile is considered a biodiversity hotspot [30]; particularly, bees show a high proportion of endemic species [29]. Consequently, optimizing sampling protocols is of paramount importance to improve our knowledge of insect species diversity present in crop fields and, therefore, to expand our understanding of the pollination services that such native insect species provide.

We found that blueberry and canola crops differed in the diversity of potential pollinator insects. Furthermore, these insects showed contrasting responses to pan trap placement and color. Overall, placing pan traps at the border or the center of the crop had little effect on sampling, but plate color had a significant effect. However, these effects were crop-dependent, with blueberry and canola showing opposite patterns. Thus, in order to obtain representative samples, we should place a battery of pan traps of different colors in various locations within the crops to optimize sampling and capture as many functional groups as possible [16]. Moreover, the different insect sampling approaches have advantages and limitations [15,18]. For instance, active sampling approaches, such as netting, can capture species that pan traps cannot, but imply a certain bias, as researchers tend to capture some species (due to their movement behavior and detectability) more often than others, resulting in over- or under-representing some insect groups (e.g., bees and hoverflies, respectively). Contrarily, pan traps do not depend on researcher capturing ability and can be operated for wider time periods. However, the color preference of the different insect groups may be over- or under-representing some groups as well. Thus, different sampling methods provide complementary information [11], as well as different pan trap arrangements (including colors and locations within the crop), where habitat effects should be considered as well [16].

Other studies of pollinator insects in agroecosystems found that yellow plates were the most effective [12,16,32]. However, other ones in which pan traps were used to sample insects in natural habitats found that blue plates were the most effective [16,33,34]. While many studies using pan traps use three standard colors (yellow, white, and blue), other studies (e.g., refs. [32,35]) have used alternative plate colors (e.g., green, purple, pink), which can be effective in sampling insects in other kinds of habitats, such as livestock pastures [35]. Those articles showed that pan traps are an effective method for studying entomofauna in different systems but also showed that this is not only determined by the plate color used, but also by the context in which the traps are installed. In addition, there are many studies assessing pan trap effectiveness to sample pollinator insects in crop fields e.g., [6,11,12,36], but most of those studies were conducted in Europe, where bees are, by far, the most abundant and diverse pollinator group, and, therefore, the European pollinator monitoring schemes are targeted to bees [37]. In the case of Chilean crop fields, whereas bees are abundant and effective pollinators, we highlighted other insect groups that also perform pollination services, which we try to highlight in this study. The Chilean biota is characterized by a depauperate fauna with a large proportion of endemic species and monotypic families, given its biogeographical context (a continental island). Therefore, in this case, in addition to many endemic bee species [29], hoverflies and some coleopterans are major crop pollinators [4], but their role as crop pollinators remains largely unknown. In our study crops, the coleopteran *Astylus trifasciatus* was one of the most abundant species. This coleopteran presents different functional traits than other common pollinators, such as large body size and hairiness, which could make it an effective native pollinator in these crops. In this regard, it is important to properly identify crop pollinator species in order to target management and conservation actions aimed at maximizing ecosystem services [36].

Blueberry grows as a bush, spatially arranged in rows, with a separation between rows of ~3m, and its flowers are white with a pendulous shape, while canola is an annual crop, with minimal separation among individual plants and has an easily accessible yellow flower. As described in previous studies, canola is a mass flowering crop (e.g., [38]) that offers a pulse of super-abundant flower resources during bloom. As a result, this crop species is highly attractive to pollinators, especially bees [39]. These differences may partially explain the contrasting effects of pan trap position and color.

The species that generate a significant difference between crops belong to the Halictidae family (*C. chloris* and *Lasioglossum* sp.) and the Apidae family (*A. tristrigata* and *A. mellifera*), all belonging to the Hymenoptera order, and one from the Melyridae family

(Coleoptera). This outcome is expected since several studies have documented that the bee species most captured by pan traps in various habitats are from the Halictidae family (reviewed in Portman et al. [40]). It is also important to consider that the honeybee (*A. mellifera*) alone acts as the main pollinator of approximately 15% of the world's crops, being the most efficient pollinator for many crop species [41]. The absence of bumblebees in pan traps is noteworthy, as, despite their high abundance in the crop fields (L.V. unpublished data), we only captured two *Bombus terrestris* individuals in white plates at the blueberry crops. This confirms previous studies, suggesting that pan traps are unsuitable for large-bodied insect species that can easily escape from the trap [11,42]. Furthermore, the relatively low number of native insects that may perform pollination services found in these commercial crops could be related to the fact that they are managed under an intensive regime (i.e., large monoculture crop fields), as the amount of neighboring natural or semi-natural vegetation is known to increase the abundance and richness of native insects [43].

Given the significant difference in both study crops, it is important to notice that pan trap position and color are advantageous in insect sampling. As our results suggest, in blueberry, the position of the pan trap does not influence sampling. By growing upwards and not having leafy foliage, the visual of the pan trap plates for insects is complete, and access is easy. On the other hand, color differences are noticeable. White and yellow plates have a conspicuous color contrast against blueberry flowers and the surrounding vegetation context, in which brown-greenish colors predominate. Meanwhile, pan trap color does not make a significant difference in canola crops, probably due to the contrast between the pan traps and the flowers. Considering the characteristics of this crop species, insect color perception may be compromised by the confusion between the flower and pan traps. Plates do not stand out as they do in blueberry because a strong yellow flower color visually predominates within this crop (Figure 1d), affecting the color contrast between flowers and traps. In addition, in sites with high flower density, it is possible that the color of surrounding flowers can influence captures [15]. Despite this, white and yellow plates are preferred by many insect species as both colors represent highly visited flowers with high reflectance [44].

Pan trap position within the canola fields does generate a significant difference in insect diversity. By observing Figure 1d, it is possible to see that the canola crop has dense foliage; therefore, locating the pan traps in the center might decrease sampling effectiveness. To optimize the method, it is advisable to place the plates on the border, thus allowing the colors (mainly yellow and white) to have a higher reflectance and contrast with the field around the crop [45,46]. On the other hand, borders might also attract other insects from the surrounding vegetation that are not attracted by the crop species itself or are less prone to forage larger distances from their reproductive (nesting) habitat [47]. Additionally, the sampling effort is higher at the crop center, as it is difficult to access the inside of the crop due to the high crop density (plant height can reach 2 m). Conversely, in the blueberry crop, the significant difference between crop center and border is explained by *A. mellifera*, which, despite being the most abundant species, has twice the number of individuals in the center than in the border. This might be caused by the contrast between the plates and the crop flowers as well. Therefore, by placing the plates in the center of the crop, the blueberry aroma may attract more insect species [21], competing for attraction with the pan traps. By placing the pan traps at the border of the crop, we can capture a greater diversity of species; even though there is a lower abundance, the number of individuals is more even. Therefore, we suggest placing pan traps of different colors in various locations within the crop field to maximize the chance of the chance of capturing different insect species/functional groups. This is particularly relevant in the absence of prior information about the entomofauna associated with a given crop.

When analyzing the results of the comparison of the abundance range curves for the 11 species present in the sample based on trap colors, captures from the yellow-color pans had the greatest diversity and included specimens of all species. Due to the reflectance of the color and its relationship to its surroundings, in the center or at the border, yellow will stand out over the white color of the blueberry flowers. However, it is important to consider, at the border, the field surrounding the crop. In this case, the dominant species in quantity is *A. mellifera*, but the difference between its number of individuals and the next species, *A. trifasciatus* is much less abundant, suggesting a pan trap position effect. Our results indicate that yellow and white pan traps would capture more insect species.

The rank–abundance curves obtained in the canola crop indicate that, out of a total of 22 species, when comparing the position between center and border, the greatest diversity is found in the center (13 out of the 22 species are found). In the case of color, the rank–abundance curves indicate that yellow is the preferred color, as 20 of the 22 species were found in yellow plates. As most crop flower visitation events are attributed to a small proportion of bee species, it has been proposed that species-rich communities positively influence crop yields and the stability of pollination service [48,49]. Thus, optimizing the sampling method would allow us to characterize better and monitor pollinator diversity, which largely influenced yield in pollinator-dependent commercial crops.

We acknowledge that the pan trap approach has some limitations in this case. First, this approach allows for sampling insects visiting the crop fields, but it does not allow us to determine if those insects visit the flowers or perform pollinator services. For that reason, we refer to those insects as potential pollinators. Second, pan trap sampling was conducted during the bloom period, which is known to influence insect capturing [38]. Thus, studies aiming to obtain a full description of the pollinator insect community should repeat pan trapping before, during, and after crop bloom. Third, pan traps may over- or under-represent some insect groups. Thus, using complementary sampling methods is encouraged if sampling is targeted to fully characterize the insect community [18,34], representing a tradeoff between generality and detail that depend on the research question to be answered. However, addressing those limitations is beyond the scope of this methodological paper.

5. Conclusions

A diverse community of potential pollinators is associated with blueberry and canola crops in Southern Chile. Moreover, many non-hymenopteran species may be potential pollinators, which are active within the crops during bloom. Optimizing pan trap sampling would provide a significant benefit for future research on potential pollinator insects in crop fields, which is why determining the relationship between the characteristics of the plates and the use of these is of the utmost relevance. Crop type generates a context-dependent sampling effect that results in important differences in the estimated insect diversity. In the case of the blueberry and canola crops assessed here, flower color and plant density seem to influence position and pan trap color effects, affecting insect species diversity. Thus, no single method can obtain optimal results across crop species.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy13020552/s1, Figure S1: Map of the study area; Figure S2: Diagram of the pan trap arrangement used; Table S1: List of the insect species found; Figures S3 and S4: Rarefaction curves; Table S2: Insect species per crop.

Author Contributions: Conceptualization, L.V., M.M.M. and F.E.F.; methodology, L.V.; software, F.E.F.; validation, S.A.J., F.E.F., M.M.M. and L.V.; formal analysis, S.A.J. and F.E.F.; investigation, L.V., F.E.F., C.J.-P., M.M.M. and S.A.J.; resources, L.V., C.J.-P. and F.E.F.; data curation, L.V., C.J.-P. and F.E.F.; writing—original draft preparation, S.A.J. and F.E.F.; writing—review and editing, F.E.F., M.M.M. and L.V..; visualization, S.A.J. and F.E.F.; supervision, L.V. and F.E.F.; project administration, F.E.F. and L.V.; funding acquisition, F.E.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the SURPASS2 project under the Newton Fund Latin America Biodiversity Programme, with funding from the Chilean Agency of Research and Development (ANID, grant NE/S011870/1) and support from the UKRI Natural Environment Research Council (NERC, grant NE/S011870/2) in the United Kingdom, Consejo Nacional de Investigaciones

Científicas y Técnicas (CONICET, grant RD 1984/19) in Argentina, and São Paulo Research Foundation (FAPESP, grant 2018/14994-1) in Brazil.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Original data are available from the figshare digital repository: https://doi.org/10.6084/m9.figshare.21641378.

Acknowledgments: We thank Luis Flores-Prado for outlining the criteria to determine which insect species are potential pollinators. We also thank Gastón Carvallo, Finbarr Horgan, and four anonymous reviewers for their comments on earlier versions of the manuscript. We are grateful to F. Spirito, E. Fonseca, L. Morante, L. Vallejos, J.M. Garcés, H. Moreno, A. Jara, and G. Salas, who assisted in the field, and the farmers that gave us access to sample their crops. CJP acknowledges the support of a doctoral fellowship from ANID (21150472). FEF acknowledges the support of ANID—Millennium Science Initiative Program—NCN2021-050, the ANID/PIA/ACT192027 associative research project, and Fundación San Ignacio del Huinay. L.V. acknowledges support of ANID PIA/BASAL FB0002 (Chile).

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

This appendix contains the details of the insect groups (orders, families, and genera) that we considered as potential pollinators in this study. We found several insect species in the pan traps placed in blueberry and canola crops, but not all of them perform pollination services. Thus, we filtered the list of insect species found following the criteria outlined by the Chilean Pollination Network (http://www.polinizacionchile.org, accessed on 7 June 2021), which are detailed in Table A1.

Table A1. Insect groups considered as potential pollinators.

Order	Family	Genus
Lepidoptera	All	All
Hemiptera	Lygaeidae	All
Coleoptera	Buprestidae	All
	Melyridae	All
	Nitidulidae	All
	Chrysomelidae	All
	Cleridae	All
	Cantharidae	All
Diptera	Syrphidae	All
Hymenoptera	Apidae	All
	Colletidae	All
	Andrenidae	All
	Megachilidae	All
	Halictidae	All
	Formicidae	*Camponotus*
	Formicidae	*Formica*
	Formicidae	*Iridomyrmex*
	Formicidae	*Leptothorax*

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