

Article

Insect Abundance and Richness in Squash Agroecosystems of Georgia, United States: The Role of Cultivar Selection and Weather Conditions

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Abstract: This study investigated the abundance and richness of insect pests and beneficial insects on 20 squash cultivars across three seasons in middle Georgia, U.S. Insects were sampled using yellow sticky cards, pan traps and sweep nets. *Bemisia tabaci* Gennadius (sweet potato whitefly) was prevalent in all seasons, while other key pests showed distinct seasonal peaks. *Diaphania hyalinata* Linnaeus (melonworm) peaked mid-July in summer 2021 (21 June–1 August), while Thysanoptera species, *Acalymma vittatum* Fabricius (striped cucumber beetle), and *Diabrotica balteata* LeConte (banded cucumber beetle) peaked late July–early August. In fall 2021 (4 October–14 November), *Epilachna borealis* (squash beetle), *D. hyalinata*, and *D. nitidalis* Stoll (pickleworm) were more active in early to mid-October, whereas *D. undecimpunctata howardi* Barber (spotted cucumber beetle) peaked in late November. In fall 2022 (17 October–20 November), *D. balteata* and *D. undecimpunctata howardi* peaked mid October to early November, while *Anasa tristis* DeGeer (squash bug) peaked in mid–late November. *Orius insidiosus* Say (minute pirate bug) peaked in late summer 2021 and remained stable in fall 2021. Pollinators were most active in mid-fall. Cultivars influenced insect abundance. ‘Saffron’ and ‘Amberpic 8455’ harbored the most *O. insidiosus* and fewer *D. balteata* and Thysanoptera species. ‘Golden Goose Hybrid’ had the highest moth numbers. These patterns suggest that cultivar traits influenced pest susceptibility and beneficial arthropods’ activity. Temperature and relative humidity were positively correlated with *A. vittatum* and *E. borealis* numbers, but rainfall negatively affected bees. These findings underscore the importance of cultivar selection and weather condition considerations in integrated pest management.



Academic Editor: Fajun Chen

Received: 7 April 2025

Revised: 28 April 2025

Accepted: 4 June 2025

Published: 8 June 2025

Citation: Warsi, S.; Li, Y.; Mbata, G.N.; Simmons, A.M. Insect Abundance and Richness in Squash Agroecosystems of Georgia, United States: The Role of Cultivar Selection and Weather Conditions. *Agronomy* **2025**, *15*, 1411. <https://doi.org/10.3390/agronomy15061411>

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Keywords: squash cultivar; insect pests; pollinators; natural enemies; weather; arthropod abundance

1. Introduction

Cucurbits (including squash and pumpkins) are cultivated as high-value crops throughout the southern U.S., particularly in Georgia, Alabama, and Florida [1]. Over the past eight years, cucurbit production has significantly expanded to meet increasing market demand, with Florida leading all the states in the nation in squash production [1]. In 2022, Georgia ranked squash as the 35th agricultural commodity, with a farm gate value of approximately USD 52.79 million, representing about 0.29% of the state’s total agricultural output [2]. In the same year, yellow squash and zucchini were prominent

among Georgia's top vegetable crops, showcasing the capacity of the state to diversify its agricultural outputs [2]. Yellow squash generated USD 50.48 million, contributing 3.86% to the total vegetable segment, while zucchini followed closely with a production value of USD 42.07 million, representing 3.22% of the sector [2]. In 2024, the total economic value of squash produced in the U.S. was approximately USD 204 million [3].

However, the profitability of cucurbit production faces significant threats from outbreaks of seasonal insect pests such as *Diabrotica balteata* LeConte (banded cucumber beetles) (Coleoptera: Chrysomelidae), *Anasa tristis* De Geer (squash bug) (Hemiptera: Coreidae), and *Melittia cucurbitae* Harris (squash vine borer) (Lepidoptera: Sesiidae). These pests cause direct feeding damages but also make plants more susceptible to biotic stressors, such as viral diseases, which can limit plant growth and potentially cause total yield loss [4]. *Acalymma vittatum* Fabricius (striped cucumber beetle) and *D. undecimpunctata howardi* Barber (spotted cucumber beetle) (Coleoptera: Chrysomelidae) are also key pests [5] active throughout the growing season and damaging the plant at various stages, including feeding on the fruits near harvest [4]. *Bemisia tabaci* Gennadius (sweet potato or silverleaf whitefly) (Hemiptera: Aleyrodidae) is widely considered the most challenging pest in cucurbits [6,7]. *Diaphania nitidalis* Stoll (pickleworm) and *D. hyalinata* Linnaeus (melonworm) (Lepidoptera: Crambidae) are also other well-documented pests of cucurbit crops, with larvae that feed on leaves, flowers, and fruits, often causing significant yield losses [8]. In addition to direct damage to plants through feeding, these pests secrete honeydew, which promotes sooty mold growth, that compromises plant health and fruit quality [6,9]. More problematic is the ability of the pests to transmit viruses that can lead to yield losses of 30–50% [10,11].

The use of conventional pesticides has been the primary method employed by many growers to combat these pests [12–14]. However, this strategy is inadequate as many cucurbit pests can still transmit viruses even when exposed to sublethal doses of particular pesticides [15]. Moreover, the repetitive use of these pesticides leads to the development of resistance among pest populations [13,16]. Apart from the risk of insecticide resistance, the evolutionary behavior of pests like *B. tabaci* feeding on the lower surfaces of the leaf can effectively shelter them from the lethal dosages of many insecticides, especially those without synthetic activity [17]. This situation has driven a significant shift towards environmentally sound and effective alternatives to chemical insecticides.

One such approach is host-plant resistance (HPR), where crops are bred or genetically engineered to be less susceptible to pest damage [18]. The HPR can manifest through antibiosis or tolerance [19,20]. Antibiosis is characterized by the production of substances or morphological changes in plants that adversely affect pests' survival or development [21]; antixenosis refers to traits that deter pests from feeding or ovipositing on plants, such as changes in leaf texture, color, or secondary metabolites [22–24]; tolerance allows the plant to maintain yield despite pest pressure, through mechanisms like compensatory growth; or physiological adaptation [25,26]. Several squash cultivars have demonstrated certain levels of resistance to pests, including the *D. undecimpunctata howardi* [27], *A. tristis* [28], *Aphis gossypii* Glover (aphid) (Hemiptera: Aphididae) [29], and *B. tabaci* [7]. The value of a cultivar also depends on its ability to support broader ecological dynamics, including beneficial arthropods [30]. As cucurbits heavily rely on pollination for fruit production, the choice of cultivars can affect the health of pollinators and plant–pollinator interactions through variations in nectar quality, pollen protein content, and plant chemical profile [31–33]. Defensive chemicals may deter pollinators or shift energy allocation away from pollinator-attracting traits [34]. In addition, cultivar characteristics can impact the effectiveness of natural enemies [35]. For example, allelochemicals and physical leaf traits such as trichome density can impact the behavior of predators and parasitoids [35,36].

Given the complex challenges cucurbit growers face, one primary objective of this study was to assess the susceptibility or tolerance of twenty local and commercially avail-

able squash cultivars to infestations by multiple insect pests. We also evaluated the ability of different cultivars to sustain pollinators and natural enemies. In addition, we examined how weather factors influenced these arthropods.

2. Materials and Methods

2.1. Experimental Site Description

The field experiments were conducted during 2021 and 2022. The experimental site conditions for this study were consistent with those reported in our previous report [7]. The field experiments were carried out at the Fort Valley State University Research Farm in Fort Valley, GA, USA (32°31′11″ N, 83°52′2″ W). The study site is in a humid subtropical zone, with hot summers and cool to mild winters. The soil at the farm is predominantly red clay ultisol [37], slightly acidic (pH = 6.1–6.5) (USDA-NRCS, 2019), and offers moderate drainage, suitable for cucurbit cultivation.

2.2. Squash Cultivars

The population dynamics of insect pests and beneficial insects (pollinators and natural enemies) were determined in 20 commercially available squash cultivars commonly grown by Georgia farmers. The names of the cultivars, key characteristics, and vendor information, are presented in Table 1. Based on our observations, these cultivars show variation in development stages, with bud visibility occurring during week 4 to 5 (31–35 days), flower opening during week 5 to 6 (34–39 days), and reach relative maturity between week 6 to 8 (39–55 days) (Table 1).

2.3. Field Management Practices

Throughout the three seasons (summer 2021, fall 2021, and fall 2022), the squash plants in the fields predominantly relied on natural rainfall for irrigation. However, supplemental overhead watering was provided once during the fourth week of sampling in each season to compensate for insufficient rainfall. Each year, before sowing, the soil was prepared with N-P-K (19-19-19) fertilizer at 224 kg/ha, ensuring optimal nutrient availability for plant growth. No insecticides were applied during any of the seasons to allow natural pest dynamics to manifest. Additionally, no fungicides, biological insecticides, or fertilizers containing algae or algae combined with organic acids were applied in any of the seasons. For weed control, Command 3 ME herbicide (active ingredient: clomazone; FMC Corporation, Philadelphia, PA, USA) was applied at rates that ranged between 467.33 and 781.33 mL/ha, effectively managing weed populations without harming the squash plants [7].

2.4. Experimental Design

The experiment was conducted using a randomized complete block design (Figure 1) over three seasons: summer 2021 (21 June–1 August), fall 2021 (4 October–14 November), and fall 2022 (17 October–20 November). For spatial arrangement, each season included four blocks, each measuring 44.8 m (length) and 23.8 m (width). Each block contained all twenty cultivars, randomized within the block. Each block was divided into two planting sections, separated by approximately 2.4 m spacing. However, these sections were not independent experimental units used only for systematic planting and spacing. Each cultivar was allocated four rows. Each row was 10.6 m in length and 0.91 m in width, with a seed spacing of 0.30 m within each row. Each row accommodated 36 seeds, with seeds sown approximately 2.5 cm deep. Each block was situated 4.6 m away from adjacent fields. The inter-block spacing was maintained at 4.9 m. The total area covered by the experimental field was approximately 0.53 hectares. Squash seeds were directly sown into the fields on specific dates: 20 May 2021 (summer 2021), 3 September 2021, (fall 2021), and 16 September 2022, (fall 2022) [7].

Table 1. Key characteristics and sources of squash cultivars used in the field experiments conducted in summer 2021 (21 June–1 August), fall 2021 (4 October–14 November), and fall 2022 (17 October–20 November).

No.	Squash Cultivar	Key Characteristics	First Bud Visible Days After Sowing (DAS)	First Flower Open Days After Sowing (DAS)	Relative Maturity (Days)	References	Seed Vendor
1	Early Summer	Early maturity and productivity	34–37	38–41	53	[38]	Burpee
2	PIC-N-PIC	High productivity	38–40	44–49	50	[38]	Burpee
3	Saffron	Very high yielding, sunburn resistant	38–41	44–47	50–55	[38]	Burpee
4	Early Prolific	High yield, early harvest	38–40	44–46	50	[38]	Burpee
5	Lioness	Tolerant to ZYMV, WMV, PRSV, CMV	34–38	44–45	52	[38]	Seedway
6	Fortune	High yield	33–35	38–41	49	[39]	Seedway
7	Amberpic 8455	High germination rates	30–32	36–39	42	[40]	Amazon
8	Golden Goose Hybrid	Disease resistance	28–31	34–37	40–50	[41]	Burpee
9	Gourmet Gold Hybrid	Disease resistance	43–45	49–51	55	[41]	Burpee
10	Black Beauty	Open-pollinated heirloom cultivar	38–41	44–48	50	[38]	Burpee
11	Caserta	Open-pollinated heirloom cultivar	NA	NA	NA	[38]	Amazon
12	Grey	Heat-resistant, good general disease resistance	32–35	40–43	45–50	[38]	Amazon
13	Cocozelle	Resistance to powdery mildew and ZYMV	43–45	49–52	55	[42]	Amazon
14	Cube of Butter	Resistant to ZYMV, downy mildew, PODIV	38–41	44–45	50	[38]	Amazon
15	Respect	Resistant to powdery mildew, PRSV, WMV, ZYMV	31–33	35–36	44	[41]	Seedway
16	Golden Glory	Powdery Mildew, WMV, ZYMV	33–35	38–40	50	[41]	Seedway
17	Fordhook Zucchini	Resistant to <i>Meloidogyne incognita</i>	45–47	51–53	57	[43]	Burpee
18	Sure Thing Hybrid	Cold resistant	36–37	42–45	48	[41]	Burpee
19	Green Eclipse Zucchini	Earliest and most productive <i>zucchini</i>	32–34	38–40	44	[39]	Seedway
20	Gentry	Stress resistant, resistant to disorders	32–33	44–46	50	[41]	Seedway

ZYMV: Zucchini Yellow Mosaic Virus, WMV: Watermelon Mosaic Virus, PRSV: Papaya Ringspot Virus, CMV: Cucumber Mosaic Virus, PODIV: Podi Virus; Note: Summer 2021 did not have ‘Gourmet Gold Hybrid’ and ‘Caserta’ cultivars. Fall 2021 and 2022 did not have ‘Caserta’ cultivar. These cultivars did not grow. NA: Information not available due to crop failure.

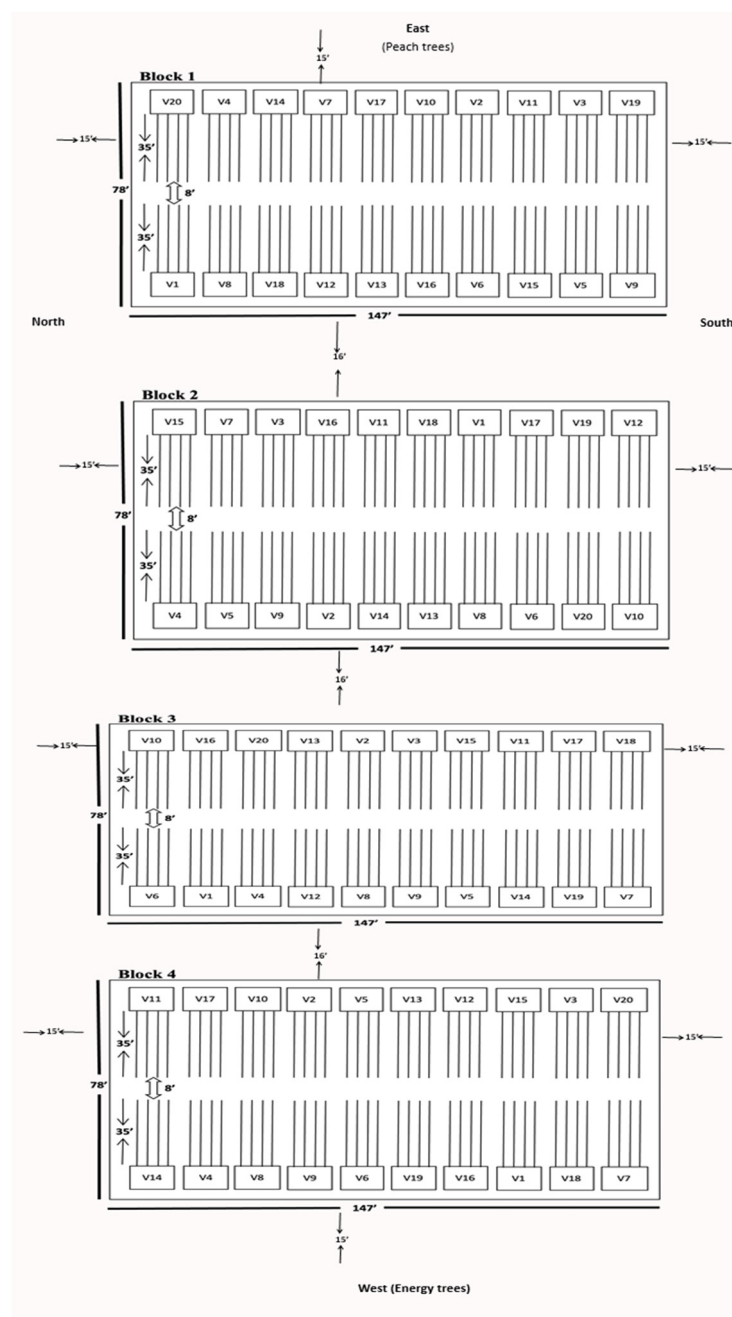


Figure 1. Field layout for the squash experiment. Cultivars were randomly assigned and labeled V1–V20 as follows: V1 = Early Summer, V2 = PIC-N-PIC, V3 = Saffron, V4 = Early Prolific, V5 = Lioness, V6 = Fortune, V7 = Amberpic 8455, V8 = Golden Goose Hybrid, V9 = Gourmet Gold Hybrid, V10 = Black Beauty, V11 = Caserta, V12 = Grey, V13 = Cocozelle, V14 = Cube of Butter, V15 = Respect, V16 = Golden Glory, V17 = Fordhook Zucchini, V18 = Sure Thing Hybrid, V19 = Green Eclipse Zucchini, and V20 = Gentry. Field measurements are in feet (e.g., 15' = 4.57 m).

2.5. Insect Sampling

Three insect sampling methods (pan traps, yellow sticky cards, and sweep nets) were used to monitor insect pests, pollinators, and natural enemies. Insect sampling was conducted once a week for six weeks 25 days after the seedling. Sampling sessions were conducted early in the morning (from 09:00 hrs to 11:00 hrs) because insect activity is often higher during this time [44]. To minimize the influence of adjacent plots, samples were collected from the middle two rows of each plot.

Three colors of pan traps, blue, yellow, and white, were used to capture pollinators [45–47]. Each pan trap (top diameter: 15 cm; bottom diameter: 8.8 cm; and height: 4.0 cm) was glued on the ring hoop of a metal stake that supported the plant (92 cm high) and placed between the rows. For each cultivar, pan traps of different colors were randomly placed between the first and second rows, the second and third rows, and the third and fourth rows. Each cultivar had all three colors of pan traps per experimental plot. Since there were 20 cultivars per block, this resulted in 60 pan traps per block (20 cultivars $\times$ 3 traps per cultivar). A soapy water solution, prepared weekly at a concentration of 0.66 mL per liter of water, was added to the traps, with approximately 200 mL (3/4 of the cup capacity) poured into each pan trap. The cups were emptied before adding soapy water, and additional soapy water was added when the weather was sunny and dry to ensure effective trapping. The pan traps remained in the field for 24 h, after which the soapy water and insects from the three traps within the same cultivar were collected into a small plastic container (6.9 cm diameter and 8.4 cm height) labeled with the corresponding cultivar and block. Each container was sealed carefully to prevent leakage. A total of 20 small containers per block were collected, with four blocks included in the study. The contents of the containers were double-checked before leaving the field to ensure all trapped insects were collected. Once in the laboratory, insects were extracted from soapy water using forceps and preserved in glass vials containing 15 mL of 70% ethanol within 24 h of collection. The specimens were stored at 4 °C in an incubator for subsequent identification.

The yellow sticky card sampling method was used to trap insect pests and natural enemies [47,48]. One sticky card measuring 7.2 cm $\times$ 12.2 cm was placed in each experimental plot's second and third rows (cultivar) to capture insects. A total of 20 cards were placed per block. Each card was secured to a cup pole using a cloth pin, with the card positioned parallel to the ground and just above the squash leaves. The sticky cards stayed in the field for 24 h, after which they were retrieved, covered with protective sheets, and labeled with block and cultivar details. All samples were thoroughly checked before leaving the field. Insects from sticky cards were also preserved in ethanol.

The sweep net method was also used for sampling insect pests and natural enemies [45,47]. Each experimental plot (cultivar) was sampled using four sweeping motions with an insect sweeping net (38 cm hoop diameter and a 91 cm handle). Sweeping was conducted between the second and third rows, with two sweeping motions performed per row. The insects collected from each plot were placed in labeled interlocking plastic bags which were transported to the laboratory and stored at 4 °C in an incubator for subsequent identification. The insects were examined under a stereo microscope (Leica EZ4W; Leica Microsystems Inc., Buffalo Grove, IL, USA) with a 10 $\times$ eyepiece.

2.6. Weather Information

The weather data, including temperature, relative humidity (RH), and rainfall, for all three seasons (summer 2021, fall 2021, and fall 2022) were retrieved from a Georgia weather station at Fort Valley State University (Fort Valley, GA, USA). Daily weather variables, including mean temperature (°C), mean RH (%), and rainfall (mm), were averaged for each sampling week [7].

2.7. Data Analysis

In the analysis of insect populations, count data from yellow sticky cards and sweep nets were pooled for each insect taxon. The descriptions for the analysis were defined as pan traps, YSC (insects captured on one yellow sticky card), and sweep net (insects collected from four sweep net sessions). A combined analysis using pooled data from both trap methods (YSC and sweep nets) was also conducted and is included as Supplementary

Materials. For each season, the data were subjected to a generalized linear mixed model (GLIMMIX). The linear predictor in the model included both fixed and random effects. Fixed effects included the sampling weeks (weeks 1–6), squash cultivars, and their two-way interactions, to investigate the influence of time and cultivar type on insect abundance. The block was considered for the random effect to account for variability between different experiment blocks. The response variable of insect numbers was modeled using a Poisson distribution, and the link function was logarithmic. Model parameters were estimated using the Dual Quasi-Newton optimization technique. Over-dispersion was evaluated using the maximum-likelihood-based fit statistic Pearson Chi-Square/DF. No evidence of over-dispersion was identified. The final statistical model used for inferences was fitted using residual pseudo-likelihood. The statistical model was fitted by the PROC GLIMMIX procedure in SAS software ver. 9.4 (SAS Institute, Cary, NC, USA). Degrees of freedom were estimated using the Kenward–Roger approximation method. To avoid inflation of type I errors, comparisons were conducted using Tukey adjustments. All graphs were generated using GraphPad Prism 10.2.3. Additionally, correlation analyses were conducted between each insect taxon and weather factors including mean temperature, mean RH, and rainfall. This was carried out using Pearson’s correlation coefficient analysis in SAS software. To better interpret the results and reveal underlying patterns in the data, we applied dimensionality reduction and machine learning techniques. These included Principal Component Analysis (PCA), Canonical Correlation Analysis (CCA), and Random Forest-based approaches for evaluating feature importance and ranking variables. For all analyses, SAS software and Google Colab were used.

3. Results

3.1. Insect Pests

During the summer of 2021 (21 June–1 August), key insect pests found affecting squash cultivars were *B. tabaci*, *D. undecimpunctata howardi*, *A. vittatum*, *D. nitidalis*, *D. hyalinata*, Thysanoptera species including *Frankliniella occidentalis* Pergande (western flower thrips) and *Thrips tabaci* Lindeman (onion thrips), *M. cucurbitae*, *A. tristis*, *Epilachna borealis* Fabricius (squash beetle) (Coleoptera: Coccinellidae), and *D. balteata*. The most abundant and dominant insect pest was *B. tabaci* in all three seasons. The population dynamics of *B. tabaci* eggs, nymphs, and adults on different squash cultivars were documented in a previous study [7].

For the other pests, no significant interactions were found between sampling weeks and squash cultivars for the mean number of insect pests captured on yellow sticky card (YSC) and collected from four sweeps. The mean number of Thysanoptera species, *D. balteata*, sampled by YSC and sweep samplings differed significantly among sampling weeks (Table 2). In addition, the mean number of *D. hyalinata* from YSC and *A. vittatum* from sweeps also varied significantly among weeks (Table 2). Other insect pests showed no significant differences among sampling weeks. No significant effect of cultivar was found on the mean number of any insect pest.

Thysanoptera species peaked in week 5 (19–25 July), with mean numbers of 27.31 on YSC and 1.85 in sweeps (Figure 2). This week corresponded with a mean temperature of 25.26 °C, high RH (87.94%), and light rainfall (0.24 mm). *Diaphania hyalinata* adults peaked earlier in week 3 (5–11 July; 2.87) with secondary activity in week 5 (19–25 July; 1.98) and week 6 (26 July–1 August; 1.72). *Acalymma vittatum*, collected by sweeps, peaked in week 5 (19–25 July; 1.28) (Figure 2), which matched the weather peak in Thysanoptera species activity. *Diabrotica balteata* activity peaked during the later part of the season. The mean number of *D. balteata* peaked in week 4 (12–18 July; 1.30), week 5 (19–25 July; 1.22), and week 6 captured on one YSC (26 July–1 August; 1.26) (Figure 2). Sweep net collections

peaked in week 6 (26 July–1 August; 1.44) (Figure 2). This week also recorded the highest mean temperature of the season (27.26 °C) and a slight decline in mean RH (81.29%). In the pooled data (YSC + sweep nets), the same insect species—such as Thysanoptera species, *A. vittatum*, *D. hyalinata*, and *D. balteata*—continued to peak during the same sampling weeks as observed in the separate method analyses (Table S1 and Figure S1). However, the mean numbers of *D. balteata* varied significantly among the cultivars in the pooled analysis (Table S1 and Figure S2); notably, Fordhook Zucchini exhibited the highest mean *D. balteata* numbers at 1.44, while Fortune, Green Eclipse Zucchini, Grey, Saffron, Respect, and PIC-N-PIC cultivars had the lower mean numbers of *D. balteata*, ranging from 1.02 to 1.16 (Figure S2).

Table 2. Type III tests of fixed effects (sampling week (Week), cultivar (Cultivar), Week, and Cultivar) for populations of adult insect pests collected from four sweeps (S) and captured on one yellow sticky card (YSC) in a squash field in summer 2021 (21 June–1 August). This analysis includes *Diabrotica balteata* LeConte (banded cucumber beetle), *Acalymma vittatum* Fabricius (striped cucumber beetle) (Coleoptera: Chrysomelidae), *Diaphania hyalinata* Linnaeus (melonworm) (Lepidoptera: Crambidae), and Thysanoptera species [*Frankliniella occidentalis* Pergande (western flower thrips) and *Thrips tabaci* Lindeman (onion thrips)].

Insect Pests	Sampling Method	Sampling Week
		F-Value, <i>p</i> -Value
<i>Diabrotica balteata</i>	S	4.09, 0.0014
	YSC	3.75, 0.0028
<i>Diaphania hyalinata</i>	YSC	5.51, <0.0001
<i>Acalymma vittatum</i>	S	5.88, <0.0001
	YSC	2.24, 0.0515
Thysanoptera species	S	3.92, 0.0020
	YSC	80.60, <0.0001

Note: degrees of freedom (df): week = 5, cultivar = 17, and week × cultivar = 85 with residual df = 214 (or 208 for Thysanoptera from YSC).

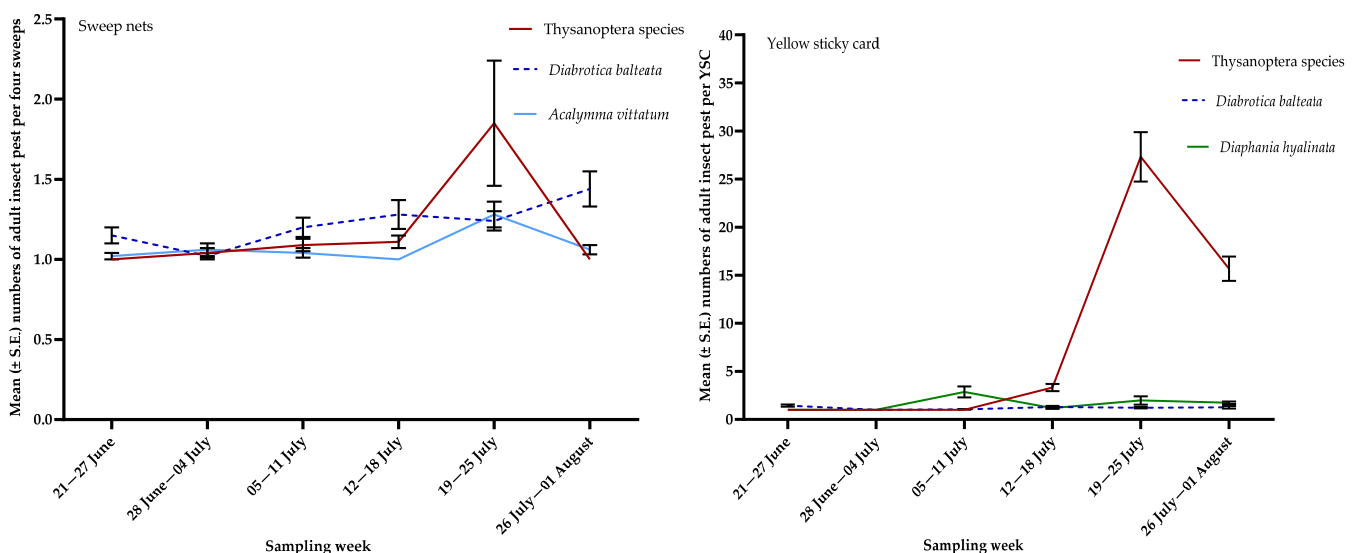


Figure 2. Mean (± S.E.) numbers of adult insect pests [Thysanoptera species: *Frankliniella occidentalis* Pergande (western flower thrips) and *Thrips tabaci* Lindeman (onion thrips), *Diabrotica balteata* LeConte (banded cucumber beetle), *Acalymma vittatum* Fabricius (striped cucumber beetle) (Coleoptera: Chrysomelidae), and *Diaphania hyalinata* Linnaeus (melonworm) (Lepidoptera: Crambidae)] collected from four sweeps or captured on one yellow sticky card (YSC) in six sampling weeks in the summer 2021 (21 June–1 August).

The mean number of *M. cucurbitae*, *A. tristis*, *E. borealis*, *D. undecimpunctata howardi*, and *D. nitidalis* sampled by either method did not differ significantly among sampling weeks. There were no significant differences in the mean number of insect pests among squash cultivars or in the interaction between cultivar and sampling week (Table S1).

During the fall of 2021 (4 October–14 November), significant interactions were found between sampling weeks and squash cultivars for adult Thysanoptera species in sweep net sampling only ($F = 2.37$; $p < 0.0001$). Thysanoptera adults also varied significantly across sampling weeks in sweep net sampling (Table 3). Most adults were found early and mid-fall (Table 4 and Figure 3). In sweep net sampling, in week 1 (4–10 October), when the mean temperature was 21.67 °C, the RH was 91.80%, and the rainfall was 7.98 mm. The highest mean numbers of Thysanoptera were recorded on the cultivars ‘Early Summer’ (8.33), ‘Black Beauty’ (6.33), ‘Cube of Butter’ (6.00), ‘Fordhook Zucchini’ (6.00), and ‘Fortune’ (6.33) (Table 4). In week 3 (18–24 October), which had a mean temperature of 16.91 °C, RH of 75.63%, and minimal rainfall (0.07 mm), adult Thysanoptera showed significantly elevated mean numbers on ‘Cube of Butter’ (5.33) and ‘Gentry’ (6.00). Their pressure peaked again in week 4 (25–31 October), when the mean temperature was 15.26 °C, the RH was 79.78%, and the rainfall was 4.68 mm. High numbers of adult Thysanoptera were found on ‘Black Beauty’ (7.67), ‘Cocozelle’ (5.00), ‘Fordhook Zucchini’ (8.33), ‘Fortune’ (4.33), ‘Golden Glory’ (8.67), ‘Golden Goose Hybrid’ (7.00), and ‘Grey’ (8.33) (Table 4). Similarly, in YSC sampling, adult Thysanoptera species numbers peaked in week 2 (11–17 October; 14.46) (Figure 3), when the mean temperature was 19.81 °C, the RH was 79.65%, and the rainfall was just 0.04 mm. Elevated levels of Thysanoptera continued in week 4 (25–31 October; 9.84) and remained high in week 6 (4–14 November; 7.42) (Figure 3), when conditions had cooled to 12.72 °C, with 71.58% RH and 1.67 mm rainfall. The mean numbers of adult *D. hyalinata*, *D. nitidalis*, and *E. borealis* also varied significantly across sampling weeks in YSC sampling (Figure 3). *Diaphania hyalinata* adults showed peak abundance in week 2 (11–17 October; 1.84), followed by a significant decline per YSC (Figure 3). *Diaphania nitidalis* adults demonstrated a singularly significant presence in week 4 (25–31 October; 1.72) compared to baseline levels (1.00) in other weeks (Figure 3). *Epilanchna borealis* numbers remained relatively stable with minor fluctuations, showing the highest numbers in week 1 (4–10 October; 1.19) (Figure 3). Sampling week had no significant effect on any insect pests in sweep net sampling, except for Thysanoptera species. Likewise, YSC sampling had no significant week effects for *D. balteata*, *D. undecimpunctata howardi*, *A. vittatum*, *A. tristis*, or *M. cucurbitae* adults. Additionally, no significant differences were observed among squash cultivars for any pest in either sampling method. These findings were further supported by the pooled data (YSC + sweeps), where Thysanoptera species again showed significant differences across sampling weeks and a consistent week and cultivar interaction (Tables S1 and S2). The pooled analysis also revealed significant differences in the mean numbers of *D. hyalinata*, *D. nitidalis*, and *E. borealis* consistent with YSC results. Notably, *D. undecimpunctata howardi* also showed significant differences among sampling weeks in pooled data. *Diabrotica undecimpunctata howardi* showed their highest abundance in week 6 (8–14 November; 1.06) (Figure S3).

Table 3. Type III tests of fixed effects (sampling week (Week), cultivar (Cultivar), Week, and Cultivar) for populations of adult insect pests collected from four sweeps (S) and captured on one yellow sticky card (YSC) in a squash field in fall 2021 (4 October–14 November). This analysis includes *Diabrotica balteata* LeConte (banded cucumber beetle) (Coleoptera: Chrysomelidae), *Epilachna borealis* Fabricius (squash beetle) (Coleoptera: Coccinellidae), *Diaphania hyalinata* Linnaeus (melonworm) and *D. nitidalis* Stoll (pickleworm) (Lepidoptera: Crambidae), and Thysanoptera species [*Frankliniella occidentalis* Pergande (western flower thrips) and *Thrips tabaci* Lindeman (onion thrips)].

Insect Pests	Sampling Method	Sampling Week
		F-Value, <i>p</i> -Value
<i>Diaphania hyalinata</i>	YSC	10.19, <0.0001
<i>Diaphania nitidalis</i>	YSC	34.70, <0.0001
<i>Epilachna borealis</i>	YSC	5.99, <0.0001
Thysanoptera species	YSC	40.39, <0.0001
	S	12.24, <0.0001

Note: degrees of freedom (df): week = 5, cultivar = 18, and week $\times$ cultivar = 90 with residual df = 214.

Table 4. Mean ($\pm$ S.E.) number of adult Thysanoptera species [*Frankliniella occidentalis* Pergande (western flower thrips) and *Thrips tabaci* Lindeman (onion thrips)] collected from four sweeps in six sampling weeks in fall 2021 (4 October–14 November).

Cultivar	Week 1 (4–10 October)	Week 2 (11–17 October)	Week 3 (18–24 October)	Week 4 (25–31 October)	Week 5 (1–7 November)	Week 6 (8–14 November)
Amberpic8455	1.00 $\pm$ 0.00 cA	1.00 $\pm$ 0.00 aA	3.67 $\pm$ 2.67 bA	1.00 $\pm$ 0.00 cA	1.00 $\pm$ 0.00 aA	1.00 $\pm$ 0.00 aA
Black beauty	6.33 $\pm$ 2.91 abA	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 cB	7.67 $\pm$ 4.41 aA	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 aB
Cocozelle	2.33 $\pm$ 1.33 bcAB	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 cB	5.00 $\pm$ 4.00 abA	4.00 $\pm$ 3.00 aA	1.00 $\pm$ 0.00 aB
Cube of Butter	6.00 $\pm$ 2.52 abA	1.00 $\pm$ 0.00 aB	5.33 $\pm$ 4.33 abA	1.00 $\pm$ 0.00 cB	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 aB
Early Prolific	1.00 $\pm$ 0.00 cA	1.00 $\pm$ 0.00 aA	1.00 $\pm$ 0.00 cA	1.00 $\pm$ 0.00 cA	1.00 $\pm$ 0.00 aA	1.00 $\pm$ 0.00 aA
Early summer	8.33 $\pm$ 2.40 aA	1.00 $\pm$ 0.00 aB	4.33 $\pm$ 3.33 bAB	4.33 $\pm$ 3.33 abAB	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 aB
Fordhook Zucchini	6.00 $\pm$ 5.00 abAB	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 cB	8.33 $\pm$ 4.33 aA	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 aB
Fortune	6.33 $\pm$ 3.53 abA	1.00 $\pm$ 0.00 aC	4.00 $\pm$ 3.00 bAB	4.33 $\pm$ 3.33 abAB	1.00 $\pm$ 0.00 aC	1.00 $\pm$ 0.00 aC
Gentry	1.00 $\pm$ 0.00 cB	1.00 $\pm$ 0.00 aB	6.00 $\pm$ 5.00 aA	1.00 $\pm$ 0.00 cB	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 aB
Golden Glory	1.00 $\pm$ 0.00 cB	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 cB	8.67 $\pm$ 4.98 aA	1.00 $\pm$ 0.00 aB	1.33 $\pm$ 0.33 aB
Golden Goose Hybrid	4.00 $\pm$ 3.00 bAB	1.00 $\pm$ 0.00 aC	2.33 $\pm$ 1.33 bB	7.00 $\pm$ 6.00 aA	1.00 $\pm$ 0.00 aC	1.00 $\pm$ 0.00 aC
Gourmet Gold Hybrid	1.00 $\pm$ 0.00 cA	1.00 $\pm$ 0.00 aA	1.00 $\pm$ 0.00 cA	1.00 $\pm$ 0.00 cA	1.00 $\pm$ 0.00 aA	1.00 $\pm$ 0.00 aA
Green Eclipse Zucchini	1.00 $\pm$ 0.00 cB	1.00 $\pm$ 0.00 aB	3.33 $\pm$ 2.33 bA	1.00 $\pm$ 0.00 cB	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 aB
Grey	2.33 $\pm$ 1.33 bcAB	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 cB	8.33 $\pm$ 5.46 aA	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 aB
Lioness	1.00 $\pm$ 0.00 cA	1.00 $\pm$ 0.00 aA	1.00 $\pm$ 0.00 cA	1.67 $\pm$ 0.67 cA	1.00 $\pm$ 0.00 aA	1.33 $\pm$ 0.33 aB
PIC-N-PIC	1.00 $\pm$ 0.00 cB	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 cB	3.00 $\pm$ 2.00 bA	3.33 $\pm$ 2.33 aA	1.00 $\pm$ 0.00 aB
Respect	1.00 $\pm$ 0.00 cB	1.00 $\pm$ 0.00 aB	6.33 $\pm$ 5.33 aA	1.00 $\pm$ 0.00 cB	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 aB
Saffron	3.00 $\pm$ 2.00 bA	1.00 $\pm$ 0.00 aA	4.00 $\pm$ 3.00 bA	1.00 $\pm$ 0.00 cA	1.00 $\pm$ 0.00 aA	1.00 $\pm$ 0.00 aA
Sure Thing Hybrid	4.33 $\pm$ 3.33 bA	1.00 $\pm$ 0.00 aB	2.33 $\pm$ 1.33 bAB	1.00 $\pm$ 0.00 cB	1.00 $\pm$ 0.00 aB	1.00 $\pm$ 0.00 aB

Means followed by different lowercase letters in each column are significantly different (Tukey's test, $p < 0.05$) among squash cultivars within each sampling week. Means followed by different uppercase letters in each row are significantly different (Tukey's test, $p < 0.05$) among sampling weeks within each squash cultivar.

During the fall of 2022 (17 October–20 November), no significant interactions were found between squash cultivar and sampling week for the numbers of Thysanoptera species (western flower thrips and onion thrips), *A. vittatum*, *M. cucurbitae*, *E. borealis*, *D. nitidalis*, *D. hyalinata*, *D. balteata*, *D. undecimpunctata howardi*, or *A. tristis* captured on one YSC or from four sweeps or in the pooled datasets (Table S1). None of these pests exhibited significant differences among squash cultivars (Table S1). However, sampling week had a significant effect on *A. tristis* and *D. undecimpunctata howardi* in sweep net sampling (Table 5), and on *D. balteata* and *A. tristis* in YSC sampling (Table 5). *Anasa tristis* adult peaked in week 5 (7–13 November; 1.07) in sweep net sampling and in weeks 4 (7–13 November; 1.09) and 5 (14–20 November; 1.07) in YSC sampling (Figure 4). These peaks coincided with declining temperatures (17.28 °C to 7.54 °C), decreasing RH (72.99% to 62.85%), and the highest mean rainfall (6.50 mm) observed in week 5. The highest mean

numbers of *D. undecimpunctata howardi* in sweep net sampling (1.21) (Figure 4) were found in week 3 (31 October–6 November) when the mean temperature was 19.12 °C, and the mean RH was 77.90%. In YSC sampling, *D. balteata* mean numbers significantly peaked (Table 5) in week 1 (17 October–23 October), and the mean temperature of this week was 12.09 °C, RH was 57.80%, and no rainfall. The same insect pests: *A. tristis*, *D. balteata*, and *D. undecimpunctata howardi* showed significant differences among sampling weeks in the pooled dataset (Table S1 and Figure S4), consistent with the results from the separate analyses regardless of sampling method.

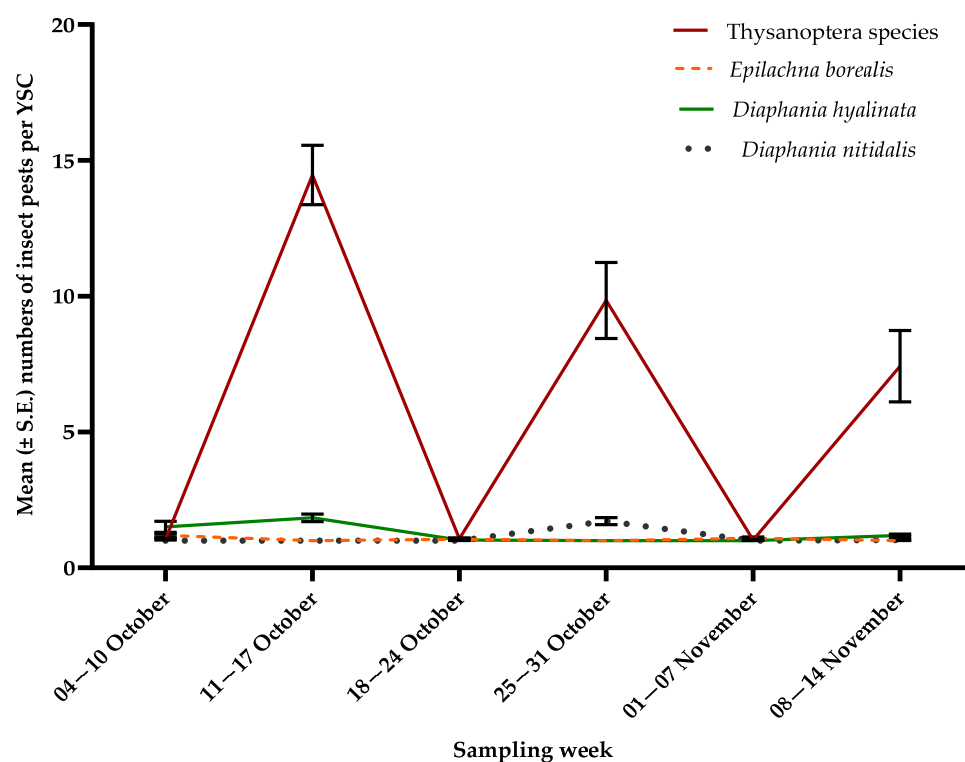


Figure 3. Mean ($\pm$ S.E.) number of adult insect pests. [Thysanoptera species: *Frankliniella occidentalis* Pergande (western flower thrips) and *Thrips tabaci* Lindeman (onion thrips), *Epilachna borealis* Fabricius (squash beetle) (Coleoptera: Coccinellidae), *Diaphania hyalinata* Linnaeus (melonworm), and *D. nitidalis* Stoll (pickleworm) (Lepidoptera: Crambidae)] captured on one yellow sticky card (YSC) in six sampling weeks in the fall 2021 (4 October–14 November).

Table 5. Type III tests of fixed effects (sampling week (Week), cultivar (Cultivar), Week, and Cultivar) for populations of adult insect pests collected from four sweeps (S) and captured on one yellow sticky card (YSC) in a squash field in fall 2022 (17 October–20 November). This analysis includes *Diabrotica balteata* LeConte (banded cucumber beetle) (Coleoptera: Chrysomelidae), and *Anasa tristis* De Geer (squash bug) (Hemiptera: Coreidae).

Insect Pests	Sampling Method	Sampling Week
		F-Value, <i>p</i> -Value
<i>Diabrotica balteata</i>	YSC	11.57, <0.0001
<i>Diabrotica undecimpunctatahowardi</i>	S	12.53, <0.0001
<i>Anasa tristis</i>	S	4.00, 0.0039
	YSC	2.82, 0.0265

Note: degrees of freedom (df): week = 4, cultivar = 18, and week $\times$ cultivar = 72 with residual df = 188.

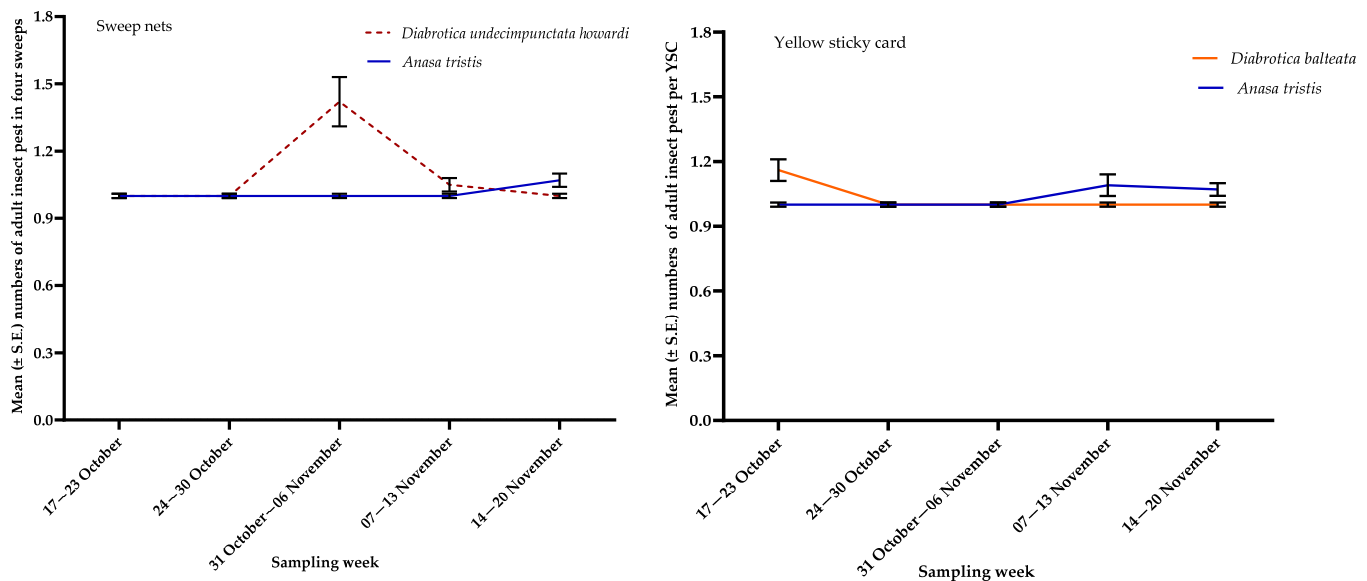


Figure 4. Mean ($\pm$ S.E.) numbers of adult insect pests [*Diabrotica balteata* LeConte (banded cucumber beetle), *D. undecimpunctata howardi* Barber (spotted cucumber beetle), *Acalymma vittatum* Fabricius (striped cucumber beetle) (Coleoptera: Chrysomelidae), and *Diaphania hyalinata* Linnaeus (melonworm) (Lepidoptera: Crambidae)] collected from four sweeps or captured on one yellow sticky card (YSC) in six sampling weeks in the fall 2022 (17 October–20 November).

3.2. Natural Enemies

Results from this study revealed that adult *Orius insidiosus* Say (minute pirate bug) (Hemiptera: Anthocoridae) was the only natural enemy collected across all seasons. No significant interactions were observed between sampling weeks and squash cultivars in the mean numbers of adult *O. insidiosus* in any season. However, in pooled data of sweeps and YSC samplings, significant interactions were observed between sampling weeks and squash cultivars in the mean numbers of adult *O. insidiosus* in summer 2021 (21 June–1 August) (Table S3). ‘Amberpic 8455’ (3.66), ‘Saffron’ (3.33), ‘Early Prolific’ (3.16), and ‘Early Summer’ (3.33) showed higher incidences of predatory bugs in the later weeks, while ‘Golden Glory’ and ‘Respect’ maintained steady populations of *O. insidiosus* throughout the season (Table S4).

In summer 2021, the number of adult *O. insidiosus* varied significantly across weeks in both sweeps, YSC samplings (Table 6), and the pooled data sets (Table S3). In fall 2021, only YSC sampling showed significant variation across weeks (Table 6). In fall 2022, the week had no significant effect on natural enemy numbers in sweep net or YSC sampling (Table 6). Also, no significant effects were detected for cultivars in any season. In summer 2021, sweep net sampling recorded significantly higher numbers of predatory bugs in week 2 (28 June–4 July; 1.79), week 5 (26 July–1 August; 1.98), and week 6 (26 July–1 August; 1.87) (Figure 5), when mean temperatures ranged from 25.26 °C to 27.26 °C, RH remained high (81.29–87.94%), and rainfall was minimal (≤ 0.24 mm). Weeks 1 (21 June–27 June), 3 (5–11 July), and 4 (19–25 July) showed consistently lower mean numbers (1.00–1.05), under similar warm and humid conditions. In fall 2021, the highest mean numbers of predatory bugs were observed in week 2 (11–17 October; 2.02) and week 4 (25–31 October; 2.05) (Figure 6), with mean temperatures of 19.81 °C and 15.26 °C, RH of 79.65% and 79.78%, and rainfall of 0.04 mm and 4.68 mm, respectively. A moderate increase occurred in week 6 (8–14 November; 1.70) (Figure 6), when the temperature dropped to 12.72 °C, RH was 71.58%, and rainfall was 1.67 mm. Lower mean numbers were recorded in weeks 1 (4–10 October; 1.09), week 5 (1–7 November; 1.19), and week 3 (18–24 October; 1.02) (Figure 6). The lowest rainfall (0.04 mm) and highest mean RH (91.80%) were recorded in

week 1 when predatory bug numbers were relatively low. *Orius insidiosus* populations also peaked in week 1 in the combined sweep net and YSC data as observed in the YSC-only data (Figure S5).

Table 6. Type III tests of fixed effects (sampling week (Week) $\times$ squash cultivar (Cultivar), Week, and Cultivar) for the number of *Orius insidiosus* Say (minute pirate bug) (Hemiptera: Anthocoridae) collected from four sweeps (S) and captured on one yellow sticky card (YSC) in the summer 2021 (21 June–1 August), and fall 2021 (4 October–14 November).

Season	Sampling Method	Sampling Week
		F-Value, <i>p</i> -Value
Summer 2021 (21 June–1 August)	S	13.30, < 0.0001
	YSC	26.24, < 0.0001
Fall 2021 (4 October–14 November)	YSC	9.66, < 0.0001

Note: degrees of freedom (df): week = 5, cultivar = 18, and week $\times$ cultivar = 90 with residual df = 188.

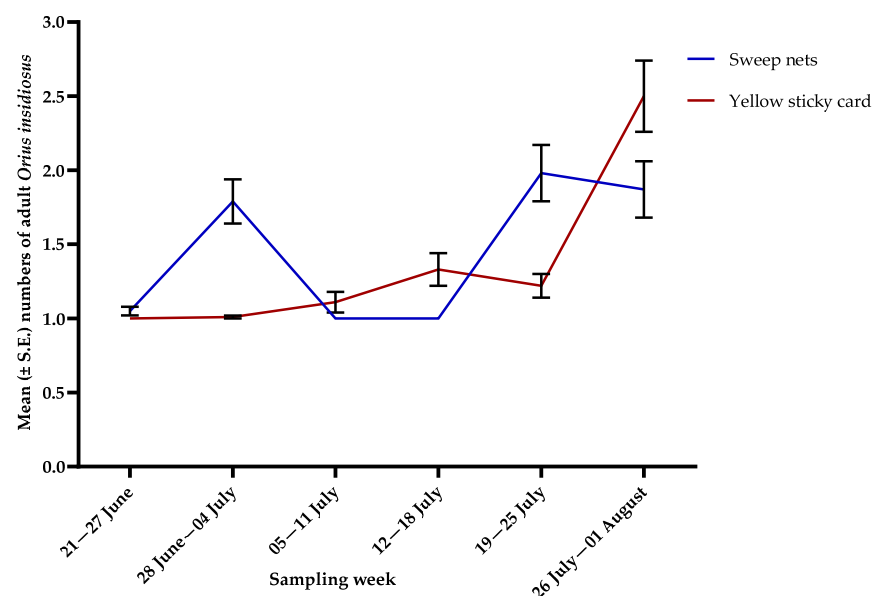


Figure 5. Mean ($\pm$ S.E.) numbers of adult *Orius insidiosus* Say (minute pirate bug) (Hemiptera: Anthocoridae) collected from four sweeps or captured on one yellow sticky card (YSC) in six sampling weeks in the summer 2021 (21 June–1 August).

3.3. Pollinators

The pollinators recorded from the squash field consisted of wasps including *Dolichovespula maculata* L. (baldfaced hornet) (Hymenoptera: Vespidae), *Vespula germanica* F. (yellowjacket wasp), and *Ammophila* species (Hymenoptera: Sphecidae); moths like *Atteva aurea* Cramer (the ailanthus webworm moth) (Lepidoptera: Yponomeutidae); assorted butterflies; and several bee species, including *Apis mellifera* L. (honeybees), *Bombus* species (bumblebees), *Xylocopa* species (carpenter bees) (Hymenoptera: Apidae), and *Halictus* species (sweat bees) (Hymenoptera: Halictidae). There were significant differences across sampling weeks for the mean numbers of bees and wasps during the summer of 2021 (21 June–1 August) (Table 7). This trend continued in fall 2021 (4 October–14 November) as both bees and wasps showed significant differences across the sampling weeks (Table 4). However, while bees continued to have significant differences across weeks, in fall 2022 (17 October–20 November), wasps did not exhibit such significant differences across the sampling weeks (Table 7).

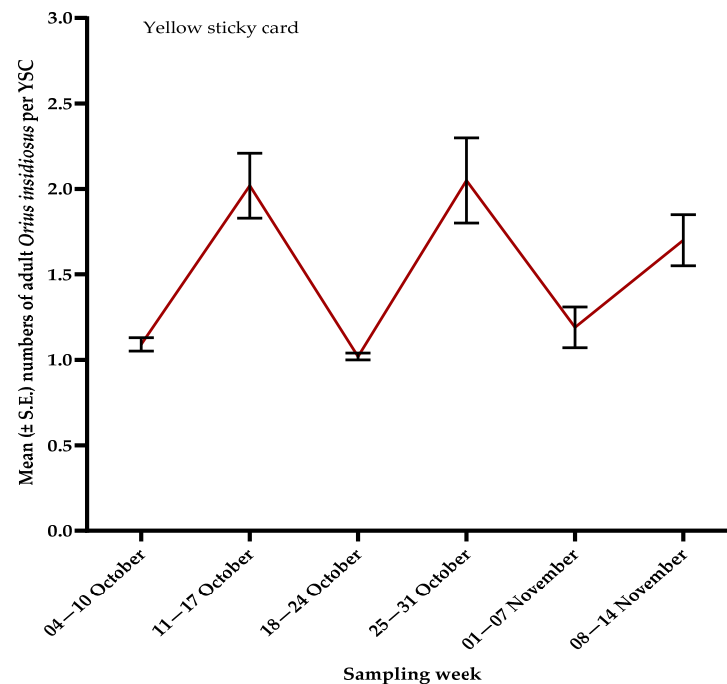


Figure 6. Mean ($\pm$ S.E.) numbers of adult *Orius insidiosus* Say (minute pirate bug) (Hemiptera: Anthocoridae) captured on one yellow sticky card (YSC) in six sampling weeks in the fall 2021 (4 October–14 November).

Table 7. Type III tests of fixed effects (sampling week (Week) $\times$ squash cultivar (Cultivar), Week, and Cultivar) for the number of insect pollinators [(*Dolichovespula maculata* Linnaeus (baldfaced hornet) and *Vespula germanica* Fabricius (yellowjacket wasp) (Hymenoptera: Vespidae), *Ammophila* species (thread-waisted wasps) (Hymenoptera: Sphecidae), *Apis mellifera* Linnaeus (honey bee), *Bombus* species (bumblebees), and *Xylocopa* species (carpenter bees) (Hymenoptera: Apidae), *Halictus* species (sweat bees) (Hymenoptera: Halictidae), and *Atteva aurea* Cramer (ailanthus webworm moth) (Lepidoptera: Attevidae) per pan trap in the summer (21 June–1 August), fall 2021 (4 October–14 November), and fall 2022 (17 October–20 November).

Season	Pollinators	Sampling Week F-Value, p-Value
Summer 2021 (21 June–1 August)	<i>Apis mellifera</i> , <i>Bombus</i> species, <i>Xylocopa</i> species, <i>Halictus</i> species	5.00, < 0.0002
	<i>Dolichovespula maculata</i> , <i>Vespula germanica</i> , and <i>Ammophila</i> species	3.71, 0.003
Fall 2021 (4 October–14 November)	<i>Atteva aurea</i>	5.17, 0.0001
	<i>Apis mellifera</i> , <i>Bombus</i> species, <i>Xylocopa</i> species, <i>Halictus</i> species	6.09, < 0.0001
	<i>Dolichovespula maculata</i> , <i>Vespula germanica</i> , and <i>Ammophila</i> species	20.81, < 0.0001
Fall 2022 (17 October–20 November)	<i>Atteva aurea</i>	7.90, 0.0001
	<i>Apis mellifera</i> , <i>Bombus</i> species, <i>Xylocopa</i> species, <i>Halictus</i> species	6.09, < 0.0001

Note: degree of freedom (df): week = 5; cultivar = 17 (Summer 2021), 18 (Fall 2021 & 2022); interaction = 85 (Summer), 90 (Fall); residual df = 214 (Summer), 226 (Fall). For *Apis mellifera*, *Bombus*, *Xylocopa*, and *Halictus* species: residual df = 1180 (Summer), 568 (Fall); for assorted butterflies: residual df = 70 (Summer 2021).

During the summer of 2021 (21 June–1 August), the mean number of bees per pan trap declined as sampling progressed, starting with the initial weeks (Figure 7). There was a slight recovery in bee numbers toward the end of the sampling period (Figure 7). Wasp abundance showed a slight decrease initially, followed by an increase towards the end of the sampling, peaking in the final week, when the temperature increased to 27.26 °C, the mean RH was 81.29%, and rainfall was low at 0.17 mm (Figure 7). No significant differences were found among squash cultivars or in the interaction between cultivar and sampling week for the numbers of moths, bees, and wasps per pan trap.

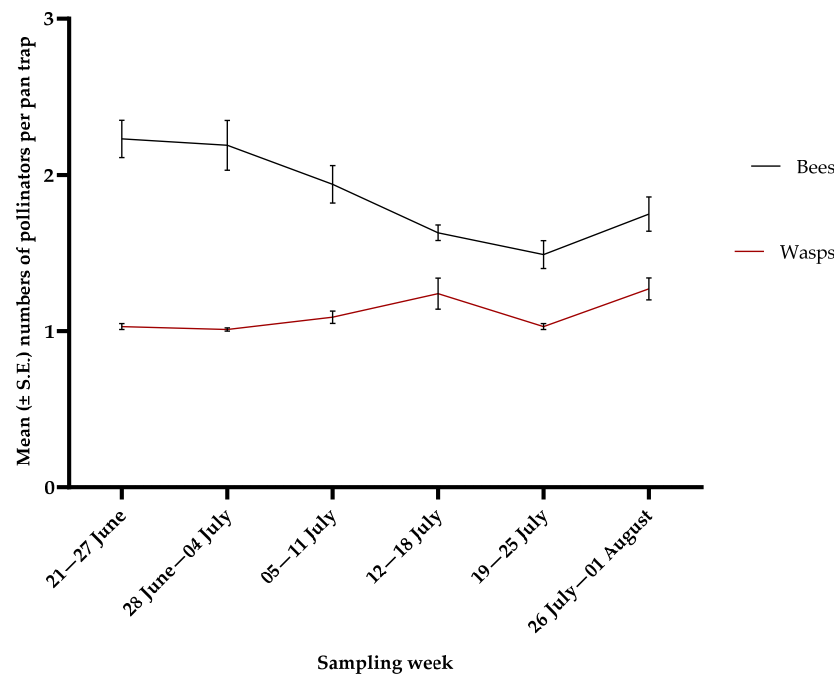


Figure 7. Mean ($\pm$ S.E.) numbers of pollinators including wasps [*Dolichovespula maculata* Linnaeus (baldfaced hornet) and *Vespula germanica* Fabricius (yellowjacket wasp) (Hymenoptera: Vespidae), *Ammophila* species (thread-waisted wasps) (Hymenoptera: Sphecidae)] and bees [*Apis mellifera* Linnaeus (honey bee), *Bombus* species (bumblebees), *Xylocopa* species (carpenter bees) (Hymenoptera: Apidae), and *Halictus* species (sweat bees) (Hymenoptera: Halictidae)] over six-week samplings in the summer 2021 (21 June–1 August). These insects were sampled using pan traps.

During the fall of 2021 (4 October–14 November), moth abundance fluctuated over the six weeks of sampling, with the highest numbers observed in week 3 (18–24 October; 1.86) and the lowest in week 5 (1–7 November; 1.22) (Figure 8). Bee numbers peaked in week 5 (1–7 November; 1.97) and were at their lowest in week 1 (4–10 October; 1.23) (Figure 8). Wasps showed a significant difference in numbers, with peaks in weeks 3 (18–24 October; 2.36) and 5 (1–7 November; 2.66) and the lowest numbers during week 4 (25–31 October; 1.01) (Figure 8).

The number of moths per pan trap significantly differed among squash cultivars ($F = 1.33$; $p = 0.05$). Among the squash cultivars, ‘Golden Goose Hybrid’ (2.22) had the highest moth numbers, significantly differing from ‘Cocozelle’ (1.11), which had the lowest (Figure 9). However, bee and wasp numbers did not significantly differ among the squash cultivars or in the interaction between cultivar and sampling week.

During the fall of 2022 (17 October–20 November), the moth numbers exhibited stability. The moth numbers showed minor fluctuations over the first two weeks (17–30 October), maintaining similar levels (1.03) (Figure 10), with temperature ranging between 12.09 and 16.79 °C and RH varying between 57.80 and 75.16%. A slight increase was observed in week 3 (31 October–6 November; 1.22), marking the highest moth number, which then decreased slightly in subsequent weeks (7–20 November) from 1.02 to 1.00 (Figure 10). There were significant differences in moth abundance, with the highest number recorded in week 3 (31 October–6 November), compared to other sampling weeks (Figure 10). Bees displayed more pronounced variability in their numbers, with the highest count recorded in week 3 (31 October–6 November; 2.42), significantly lower numbers in week 1 (17–23 October; 1.66), and a further decrease by week 5 (14–20 November; 1.05) (Figure 10). The mean temperature, RH, and rainfall of weeks 1, 3, and 5 were 12.09 °C, 57.80%, and 0.00 mm, 19.12 °C, 77.90%, and 0.40 mm, and 7.54 °C, 62.85%, and 0.33 mm, respectively. The other pollina-

tor numbers did not significantly differ among the squash cultivars, and no significant interaction was found between cultivar and sampling week for any pollinator group.

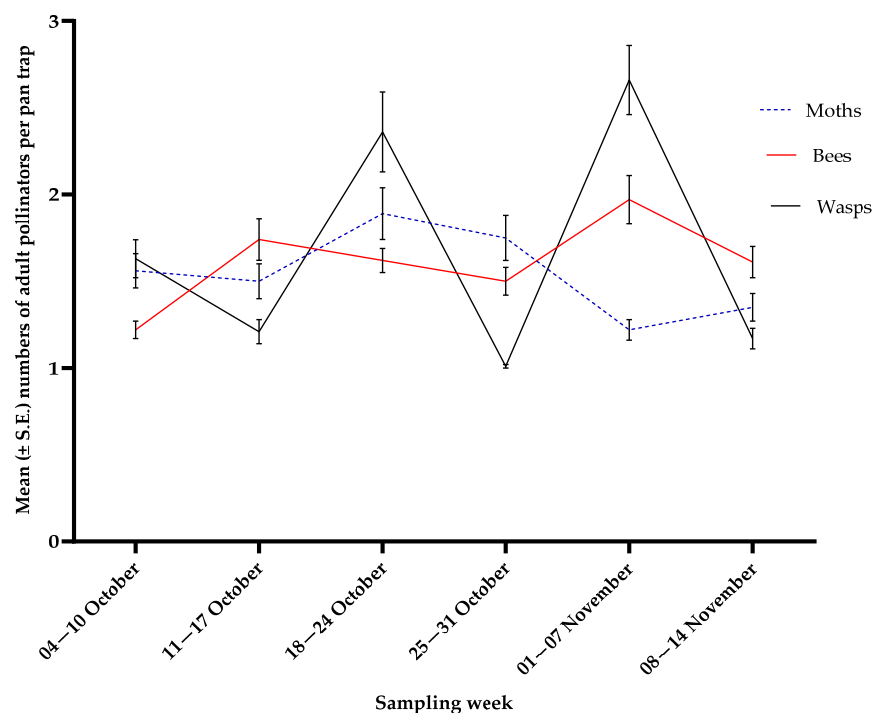


Figure 8. Mean ($\pm$ S.E.) numbers of pollinators including wasps [*Dolichovespula maculata* Linnaeus (bald-faced hornet) and *Vespula germanica* Fabricius (yellowjacket wasp) (Hymenoptera: Vespidae), *Ammophila* species (thread-waisted wasps) (Hymenoptera: Sphecidae)], bees [*Apis mellifera* Linnaeus (honey bee), *Bombus* species (bumblebees), *Xylocopa* species (carpenter bees) (Hymenoptera: Apidae), *Halictus* species (sweat bees) (Hymenoptera: Halictidae)], and moth [*Atteva aurea*, Cramer (ailanthus webworm moth) (Lepidoptera: Attetidae)] over six sampling weeks in the fall 2021 (4 October–14 November). These insects were sampled using pan traps.

3.4. Correlations Between Insect Counts and Weather Factors

For summer 2021 (21 June–1 August), we observed strong positive correlations for the *D. undecimpunctata howardi* ($r = 0.86$, $p = 0.02$) and *D. nitidalis* ($r = 0.91$, $p = 0.009$) with mean temperature, and for the *E. borealis* with mean RH ($r = 0.91$, $p = 0.009$). *Orius insidiosus* also showed a strong positive correlation with mean temperature ($r = 0.88$, $p = 0.01$). There was no significant correlation between other insects and weather factors. During the fall of 2021 (4 October–14 November), bees had strong negative correlations with RH mean ($r = -0.84$, $p = 0.03$) and rainfall ($r = -0.88$, $p = 0.01$). During the fall of 2022 (17 October–20 November), a notable strong correlation was found between *E. borealis* and rainfall ($r = 0.99$, $p < 0.0001$), with non-significant correlations for other insects with weather factors.

Correlations were also performed using actual weather conditions on the specific sampling days. *Diabrotica undecimpunctata howardi* remained positively correlated with the same-day mean temperature ($r = 0.94$, $p = 0.005$). In contrast, *D. nitidalis* showed a strong negative correlation ($r = -0.92$, $p = 0.027$) with mean temperature, differing from the weekly average results in fall 2022. None of the other insects significantly correlated with the same-day weather conditions in fall 2021.

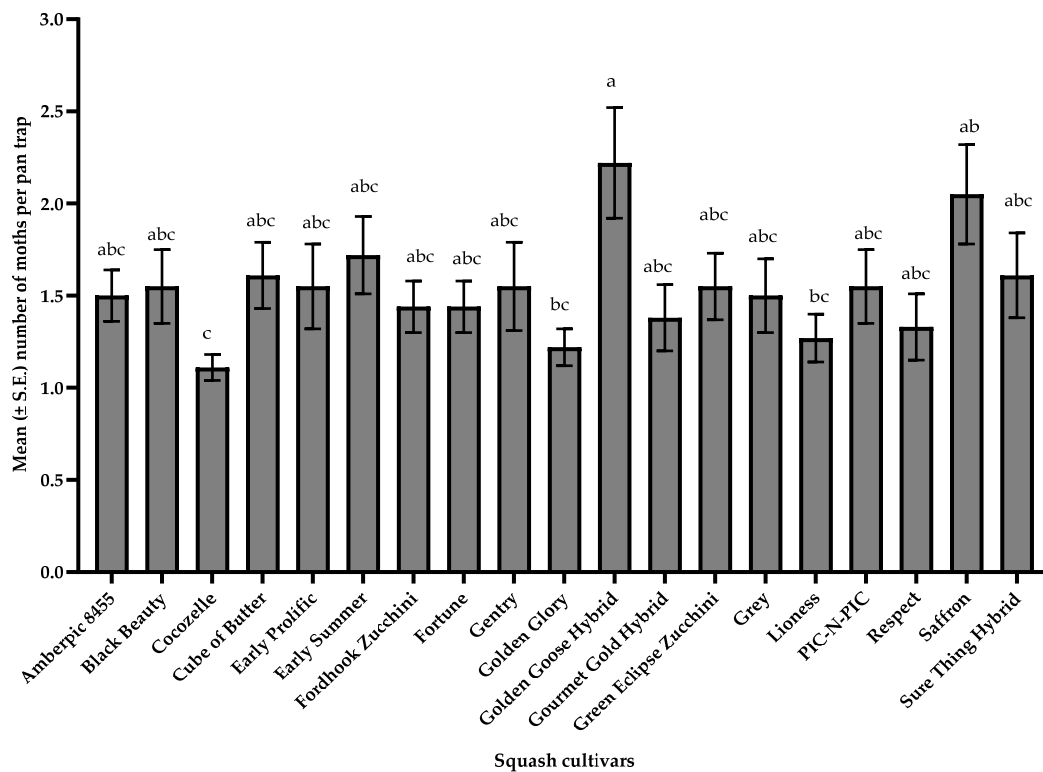


Figure 9. Mean ($\pm$ S.E.) numbers of moth [*Atteva aurea* Cramer (ailanthus webworm moth) (Lepidoptera: Attevidae)] on squash cultivars in the fall 2021 (4 October–14 November). Moths were sampled with pan traps. Different letters above the error bars indicate significant differences (Tukey's test, $p < 0.05$) among squash cultivars.

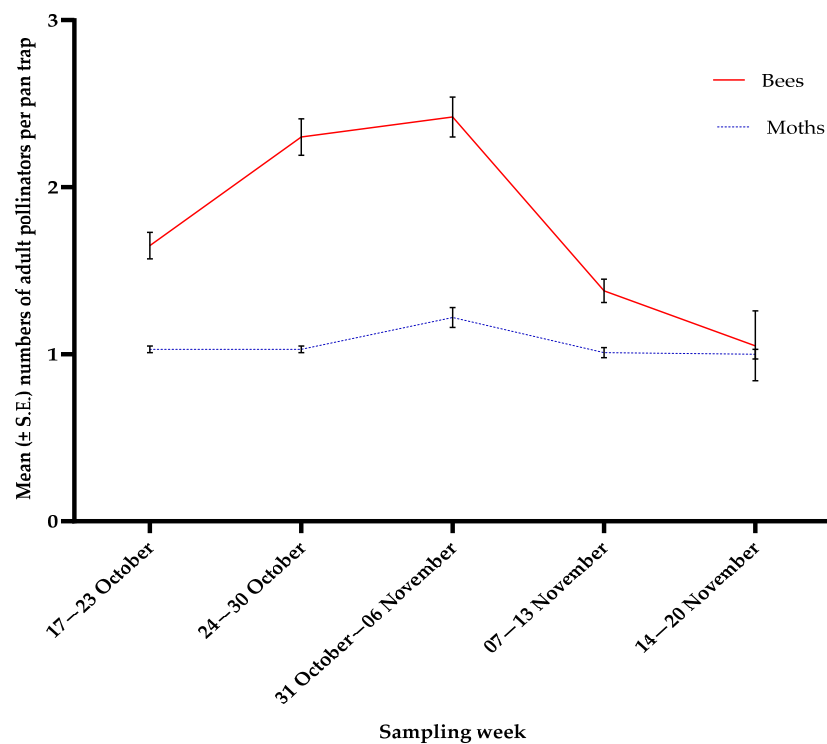


Figure 10. Mean ($\pm$ S.E.) numbers of pollinators (moth [*Atteva aurea* Cramer (ailanthus webworm moth) (Lepidoptera: Attevidae)] and bees [*Apis mellifera* Linnaeus (honey bee), *Bombus* species (bumblebees), and *Xylocopa* species (carpenter bees) (Hymenoptera: Apidae), and *Halictus* species (sweat bees) (Hymenoptera: Halictidae)] over six-week samplings in the fall 2022 (17 October–20 November). These insects were sampled using pan traps.

Principal Component Analysis (PCA) was also conducted on the only collected weekly weather variables dataset to reduce dimensionality and identify the dominant weather gradients shaping seasonal variation in weather conditions relevant to insect population dynamics. The PCA extracted five principal components that explained 78.66% of the total variance in the weather and insect dataset (Figure 11A). PC1, with the highest eigenvalue (4.65), accounted for 29.09% of the variance and predominantly represented a temperature-humidity gradient. PC2 explained 17.47% of the variance and was associated with precipitation-related variables (rainfall). PC3 (12.23%) captured seasonal transitions, while PC4 (10.79%) and PC5 (9.07%) reflected localized ecological variations such as microhabitat heterogeneity and host plant interactions. The scree plot (Figure 11) showed a steep decline in explained variance after PC1 and PC2, justifying the focus on the first five components for weather-based ecological interpretation.

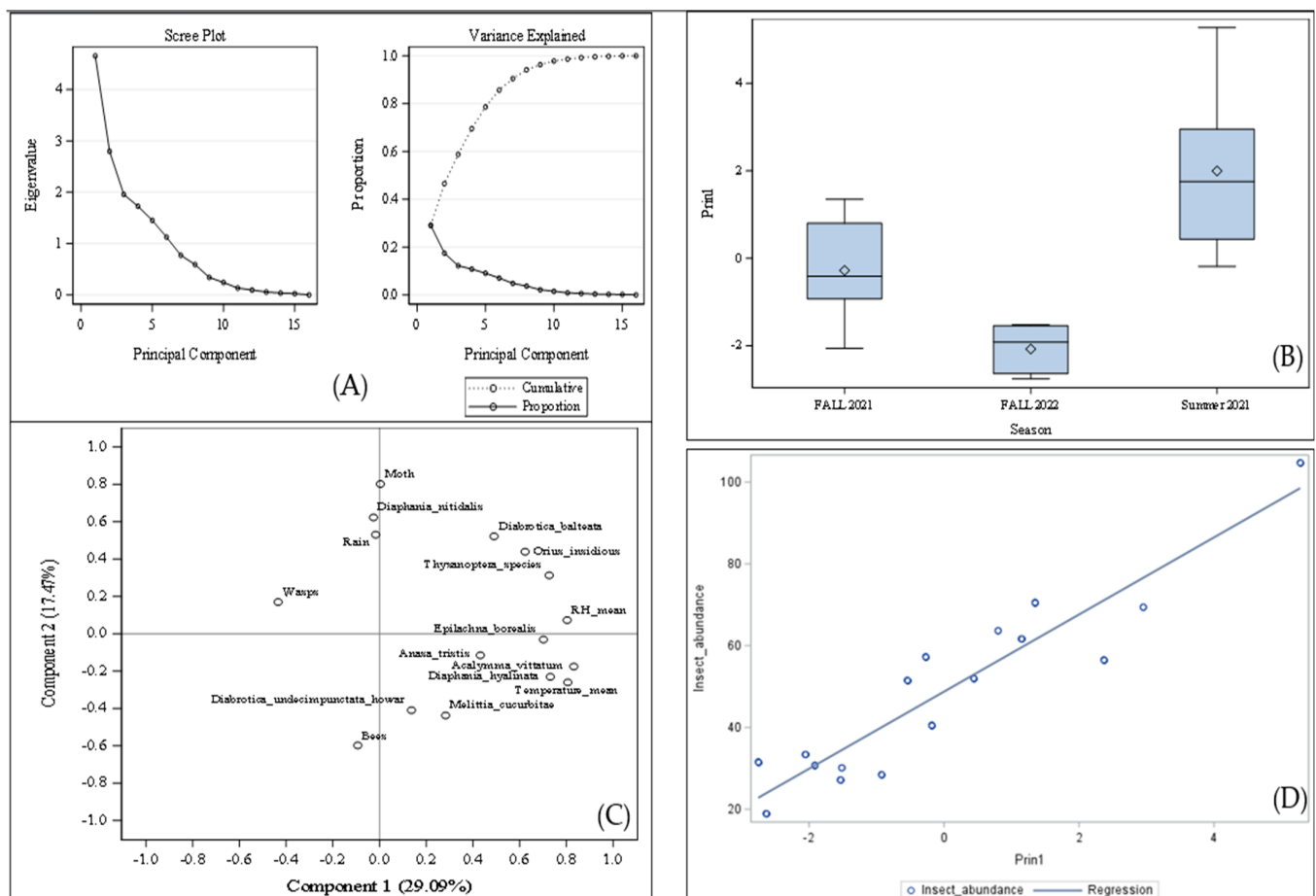


Figure 11. Principal Component Analysis (PCA): (A) Scree plot showing eigenvalues (left) and cumulative proportion of variance explained (right), (B) seasonal distribution of PC1 scores across three sampling periods, circles represents insect abundance, and line represents regression (C) PCA biplot for weather variables and insects (insect pests and beneficial arthropods on squash crops) along component 1 (PC1) and component 2 (PC2), and (D) linear regression ($R^2 = 0.96$) between Prin1 (PC1) scores and simulated insect abundance.

The PCA biplot (Figure 11B) showed the distribution of weather variables and insects along the first two principal components. *Anasa tristis*, *A. vittatum*, and *D. hyalinata* exhibited strong alignment with PC1 and clustered closely with mean temperature and mean RH, suggesting their preference for warmer and humid conditions. In contrast, *D. undecimpunctata howardi* and bees were positioned on the negative end of PC1, indicating associations with cooler weather. PC2 loaded positively with *D. nitidalis* and moths supporting its inter-

pretation as a precipitation (rain) gradient. Seasonal analysis of PC1 scores (Figure 11C) revealed the highest values in Summer 2021 (median ≈ 2.0), intermediate values in Fall 2021, and the lowest in Fall 2022 (median ≈ -2.0), corresponding to expected seasonal thermal variation. A strong positive correlation between PC1 and insect abundance ($R^2 = 0.96$; Figure 11D) confirmed that warmer and humid conditions were associated with elevated pest activity. The heatmap loadings (Figure 12), PC1 was strongly influenced by mean temperature, mean RH, and insect pests including *A. tristis*, *A. vittatum*, and *D. hyalinata*. At the same time, PC2 was dominated by rainfall and insect species such as *D. nitidalis*, *D. balteata*, *O. insidiosus*, and moths. PCs 3 through 5 captured nuanced variation in specific responses, e.g., *A. tristis* and Thysanoptera species contributed heavily to PC3, while PC5 showed positive loading patterns between wasps and *D. balteata*. Supporting analyses aligned with PCA results: K-means clustering (Figure 13A) identified three consistent insect–weather variable groupings. The data revealed distinct partitions with Cluster 0, 1, and 2 containing 6, 2, and 9 samples, respectively. The separation observed in the cluster plot confirms that specific insect assemblages consistently co-occur under shared weather conditions. This stratification supports tailoring management or forecasting strategies based on cluster characteristics. Canonical Correlation Analysis (CCA) (Figure 13B) also demonstrated a tight coupling between weather variables and insect groups. The first canonical correlation revealed a coherent alignment of scores, with weather variable (X) canonical scores ranging from -1.90 to 1.53 , and corresponding (Y) insect abundance variable scores ranging from -0.48 to 0.40 . This narrow and structured range indicates that variability in weather conditions translates consistently into insect population changes, even across different insect groups. The symmetry between the two sets of canonical variables suggests a strong multivariate association, affirming that insect groups are not responding independently to each abiotic factor but are influenced by synergistic weather gradients. Random Forest regression (Figure 13C) also identified mean temperature (42.4%) and mean RH (40.6%) as the most influential predictors of insect abundance, with rainfall contributing only 16.9%.

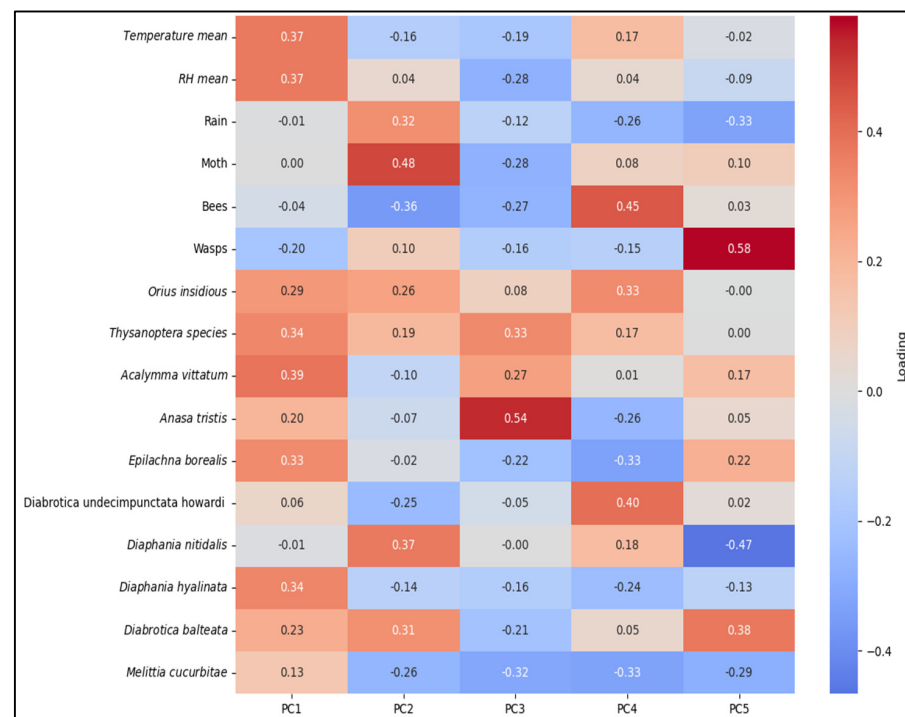


Figure 12. The heatmap of variable loadings across the first five components reveals that temperature, and relative humidity (RH) thresholds load strongly on PC1, while rainfall variables load on PC2.

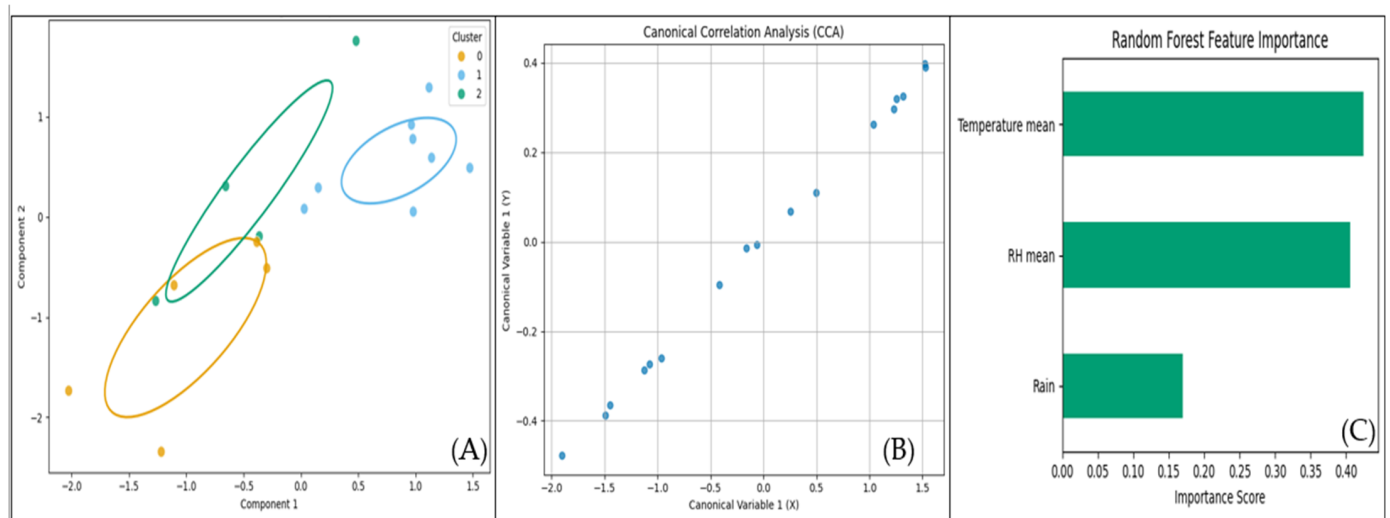


Figure 13. Multivariate analyses of insect-weather variable relationships. (A) K-means clustering of weather variables-insect interactions, (B) Canonical Correlation Analysis (CCA) between canonical variants, (C) Random Forest feature importance ranks.

4. Discussion

The results of this study are anticipated to help researchers better understand population variation in the insect pests, pollinators, and natural enemies on 20 squash cultivars in Georgia, USA, an important agricultural region. Previous studies focused on determining the susceptibility of different squash cultivars to *B. tabaci* [7,49], *A. tristis* [50], and *D. nitidalis* [51]. Therefore, this study complements previous studies by examining the abundance and richness of insect pests excluding *B. tabaci*, and beneficial insects in response to the cultivation of squash cultivars. This broader approach provides a more holistic understanding of how cultivar selection influences overall arthropod community composition, informing integrated pest and pollinator management strategies in squash production systems.

The influence of crop cultivars on insects host preference is well documented [52–59]. The main pests on squash cultivars in our study were *B. tabaci*, Thysanoptera species, *A. tristis*, *D. undecimpunctata howardi*, *A. vittatum*, *D. nitidalis*, *D. hyalinata*, and *M. cucurbitae*. The susceptibility of the 20 local and commercially available squash cultivars to *B. tabaci* has been discussed in our previous study [7]. The current study observed significant differences in adult Thysanoptera numbers across squash cultivars and sampling weeks. ‘Black Beauty’, ‘Cube of Butter’, ‘Fortune’, and ‘Fordhook Zucchini’ consistently supported higher adult Thysanoptera numbers across multiple weeks. In contrast, ‘Early Prolific’, ‘Gourmet Gold Hybrid’, ‘Lioness’, and ‘Amberpic 8455’ consistently had lower numbers of Thysanoptera throughout the season. Host plant resistance by some cucumber cultivars against Thysanoptera species was recently documented in Ghallab et al. [60]. For instance, cucumber cultivars ‘Nemsse’, ‘Sweet Crunch’, and ‘Xena squash’ showed significant differences in susceptibility to Thysanoptera species. The current study also found distinct variations in susceptibility to *D. balteata* among squash cultivars. Specifically, the cultivars ‘Green Eclipse Zucchini’, ‘Grey’, ‘Saffron’, ‘Respect’, and ‘PIC-N-PIC’ exhibited reduced susceptibility. Differential resistance levels to the *D. balteata* among squash cultivars have also been reported [61]. The observed differences in pest susceptibility across squash cultivars suggest that certain cultivars may possess resistance mechanisms that influence insect abundance. While this study did not directly examine the specific mechanisms involved, previous research has highlighted several potential factors contributing to HPR in cucurbits [61]. These may include morphological traits such as thicker leaf cuticles, increased trichome density, or variations in plant architecture that deter

herbivory [35]. Additionally, biochemical defenses, such as secondary metabolites (e.g., cucurbitacin, flavonoids, or alkaloids), could influence pest-feeding behavior or act as natural deterrents [35,36]. The cultivars identified in this study, including ‘Green Eclipse Zucchini’, ‘Grey’, ‘Saffron’, ‘Respect’, and ‘PIC-N-PIC’, likely possess one or more of these traits associated with susceptibility to *D. balteata*. Cultivar-based pest management has succeeded in other systems [62,63]. For instance, integrating partially thrips-resistant onion cultivars reduced insecticide applications by 36% without compromising yield [62]. In cucurbit crops, the field trials have shown that yellow squash cultivars such as ‘Lioness’, ‘Gold Prize’, and ‘Grand Prize’, and the zucchini cultivars ‘SV6009YG’ and ‘SV0914YG’ maintained the highest yields under high *B. tabaci* and virus pressure [63]. These examples highlight the practical relevance of selecting pest-suppressive squash cultivars to reduce insecticide reliance and support sustainable production. Future studies should investigate the specific morphological and biochemical traits responsible for their reduced susceptibility to *D. balteata*.

Pest population dynamics information, when studied over multiple seasons, can provide insight into periods when the populations of specific pests peak or dip. Our study, conducted over three seasons, revealed distinct temporal patterns that can help optimize planting dates to reduce crop vulnerability to pests [54]. For instance, the early peak of *D. hyalinata* in summer 2021 (21 June–1 August) suggests the need for early-season monitoring and intervention. For example, delaying planting by 1–2 weeks in regions with predictable *D. hyalinata* pressure could reduce exposure during vulnerable seedling stages. Thysanoptera species and *A. vittatum* that peaked in week 5 (19–25 July) of summer 2021 suggest that either adjusting planting schedules to avoid this period or enhancing protective measures during this time, such as using trap crops or targeted insecticides could mitigate their impact and reduce crop damage. *Diabrotica balteata* also peaked in the middle and later parts of the sampling week of the summer, extending the period during which vigilant pest management is necessary. During the fall of 2021 (4 October–14 November), the peak of Thysanoptera species, *E. borealis*, and *D. hyalinata* in early sampling week highlights the importance of timely control measures right after planting. The middle season peak of *D. nitidalis* adults suggests that management efforts should focus on the middle to later stages of the growing season when their populations increase, rather than earlier when numbers are low. In fall 2022 (17 October–20 November), the noticeable increase in *A. tristis* and *D. undecimpunctata howardi* populations in later sampling weeks suggests that the mid to late season is a critical period for management efforts. The early high population of *D. balteata* in week 1 (17–23 October), followed by stability. These findings demonstrate that the specific timing of pest activity is integral to developing targeted IPM strategies. By aligning planting dates, pest control measures, and specific cultivar selection with the observed pest abundance and diversity, farmers may reduce the synchrony between pest peaks and the most vulnerable stages of squash, potentially decreasing reliance on chemical controls and enhancing sustainability. The varying number of insect pests captured in the different seasons may be influenced by many factors beyond weather, including trap attractiveness relative to surrounding vegetation, host plant composition, insect pest population density, proportion of the population dispersing, and agricultural practices. However, long-term weather variables can explain most of the season-to-season variation despite the collective impact of any other factors [64–67].

In this study, we observed a predominance of the arthropod predator *O. insidiosus* among squash cultivars in six sampling weeks in summer 2021 (21 June–1 August) in pooled data. Several cultivars including ‘Amberpic 8455’, ‘Saffron’, ‘Early Prolific’, and ‘Early Summer’ support late-season peaks of *O. insidiosus*. Others, like ‘Golden Glory’ and ‘Respect’, maintained consistent predator levels throughout the season. The pronounced

activity of *O. insidiosus* on specific cultivars suggests that certain squash varieties may enhance biological control via indirect defenses. These findings align with previous study demonstrated that squash cultivars exhibit varying degrees of attractiveness to *O. insidiosus*, with the ‘Zaeim’ and ‘Xena’ cultivars receiving the highest numbers of this predator [60]. *Orius insidiosus* population peaked in weeks 5 (19–25 July) and 6 (26 July–1 August) on the ‘Zaeim’ cultivar. The differences in the attraction of predators to various accessions can be associated with differences in the individual chemical profiles of these accessions [60]. In the summer of 2021 (21 June–1 August), the activity of *O. insidiosus* became more pronounced as the season progressed. This increase coincided with a suppression of Thysanoptera species populations, which, after peaking in week 5, declined by week 6. In the fall of 2021 (4 October–20 November), peaks occurred in weeks 1 (4–10 October), 4 (11–17 October) and 6 (8–14 November). During these periods, there was a noticeable decline in many pest populations, such as Thysanoptera species in week 2 (11–17 October), *E. borealis* in weeks 2–4 (11–31 October) and 6 (8–14 November), and a decline in *D. hyalinata* adults from week 2 (11–17 October) onward. The temporal correlation between *O. insidiosus* population peaks and declines in pest populations implies a density-dependent regulatory effect, though further research is needed to confirm predation rates. Notably, cultivars that sustain consistent predator populations (e.g., ‘Golden Glory’ and ‘Respect’) may offer more stable pest suppression over time compared to those with late-season predator surges. This has critical implications for IPM: cultivars that support early-season predator establishment could pre-empt pest outbreaks, reducing reliance on reactive interventions. However, the trade-offs between predator attraction and pest susceptibility require careful evaluation. For example, a cultivar with lower *D. balteata* abundance but poor support for *O. insidiosus* may still necessitate supplemental biocontrol.

The arthropod pollinator complex recorded in squash fields was diverse. Among all pollinators, European honeybees, bumblebees, sweat bees, and carpenter bees were the most abundant. Bee populations vary across the seasons, which can be attributed to factors such as flowering phenology, resource availability, and environmental conditions [68–71]. The timing and abundance of floral resources are important in influencing bee activity patterns [72]. Bees are highly responsive to the availability of nectar and pollen; when squash plants are in peak bloom, bee visitation increases due to the plentiful resources [73]. Conversely, as flowering declines, bee populations decrease correspondingly. This was evident in our study, where flowering time varied among cultivars. For instance, early-flowering cultivars such as Amberpic 8455, ‘Respect’, and ‘Green Eclipse’ began flowering around week 5 after sowing seeds (30–32 days after sowing seeds, DAS), which corresponded to week 4 of sampling (21–27 June) and aligned with the first peak in bee abundance. In contrast, cultivars like ‘Fordhook Zucchini’ flowered later, around week 8 after sowing seeds (49–51 DAS), aligning with a secondary increase in bee numbers. These cultivar-level differences in flowering time help explain the observed seasonal trends in bee activity. Weather factors like temperature and rainfall also affect bee foraging behavior and population dynamics [74]. Variations in these conditions across different seasons can lead to fluctuations in bee abundance. Wasp populations also varied, peaking in the later weeks of summer 2021 (21 June–1 August) and during the mid to late sampling weeks of fall 2021 (4 October–14 November). These seasonal peaks suggest that wasp dynamics are closely linked to the availability of floral resources, which shift with cultivar flowering schedules. Wasp peaks in the summer aligned with the flowering of later-maturing cultivars such as ‘Cocozelle’ and ‘Fordhook Zucchini’, which flowered between week 7 and 8 after seed sowing (49–51 DAS). Similarly, in the fall, peak wasp activity coincided with the flowering of several cultivars including ‘Lioness’, ‘Gentry’, ‘Cube of Butter’, ‘Gourmet Gold Hybrid’, ‘Early Prolific’, ‘Saffron’, ‘Black Beauty’, and ‘PIC-N-PIC’, which also flowered within a

similar range (44–51 DAS). The inter-seasonal differences in peak times for wasps may also be driven by their different ecological roles and responses to environmental changes compared to bees. Wasp populations may peak later in the season due to their dependence on floral resources for energy [75]. Moth activity, which was consistent across the fall 2022 (17 October–20 November) season with a peak in week 3 (31 October–6 November). This pattern suggests that their life cycle and foraging behavior may be more closely aligned with predictable seasonal changes, such as the availability of specific host plants or the timing of flowering. The consistency in moth activity across seasons could be related to their life cycle synchronization with host plant phenology [76]. Notably, cultivar-level differences were observed, with ‘Golden Goose Hybrid’ supporting the highest moth numbers and ‘Cocozele’ the lowest, suggesting possible variation in cultivar attractiveness or suitability for moths. However, the current study focuses on abundance rather than pollination efficacy (e.g., fruit set), which limits conclusions about functional resilience. Future studies should quantify how cultivar-specific floral traits (nectar volume, flower size) interact with climate to modulate pollinator efficiency.

The relationship between weather factors and the dynamics of pests, pollinators, and natural enemies within agricultural systems is well documented [77–81]. The correlation of *B. tabaci* infestations with weather factors has been discussed previously [7]. In terms of the relationship between environmental conditions and the other insects, we found that the population of bees was negatively correlated with RH and rainfall. Most previous studies observed a correlation between weather factors and bee activity. For instance, Puškadija et al. [80] reported that RH and rainfall greatly reduced bees’ visits to flowers [82]. Similarly, rain had a strong negative impact on bee activity and pollination [83]. Furthermore, the population dynamics of *E. borealis*, a predominant pest during the fall of 2021, showed a strong positive correlation with rainfall, which aligns with the previous findings reporting that rainfall contributed significantly (44.4%) to the abundance of *E. borealis* [84].

The PCA and other supporting analyses provided additional insight into how weather gradients shaped insect population dynamics across seasons. The PC1 and PC2 together captured the majority of seasonal environmental variation, with PC1 primarily driven by temperature and RH (a temperature-humidity gradient), and PC2 dominated by rainfall (precipitation gradient). Insect pests such as *A. tristis*, *A. vittatum*, and *D. hyalinata* are the most abundant during high-PC1 periods, associated with elevated temperature and RH [85,86]. Such thermal acceleration can lead to increased feeding activity, shorter development time, and more generations per season [87–89]. This response is especially important for multivoltine species, which may expand their geographic range to higher latitudes and altitudes as temperatures rise [90]. Additionally, reduced winter mortality under warmer conditions can allow pests to persist and build populations earlier in the season [67]. In contrast, insect activity during high-PC2 conditions, reflecting increased precipitation or rainfall, was more variable. Some insects like *D. nitidalis* thrived, while others declined, potentially due to sensitivities to moisture conditions [91]. This variability is consistent with previous [91] findings that heavy rainfall can benefit some pests while directly harming others, such as *B. tabaci*, by dislodging them from host plants [89]. Meanwhile, increased soil moisture can promote the development of pests like *Agriotes lineatus* L. (wireworm) (Coleoptera: Elateridae), whereas drought-sensitive species like *Acyrtosiphon pisum* Harris (pea aphid) (Hemiptera: Aphididae) decline under dry conditions [91]. These results demonstrate the value of PCA in identifying weather-driven insect dynamics and informing seasonal, weather-based pest forecasting strategies.

Overall, this study highlights the ecological relevance of cultivar selection, seasonal timing, and weather interactions in shaping insect communities. These findings contribute valuable knowledge for improving agroecosystem sustainability and resilience. This study

advances the concept of ‘ecological cultivar design’, where squash cultivars are selected for yield and their capacity to modulate arthropod communities in ways that enhance ecosystem services. For example, cultivars like ‘Saffron’ and ‘Amberpic 8455’, which combine moderate pest suppression with strong predator support, could serve as a foundation for conservation biological control. Pairing such cultivars with staggered plantings to desynchronize pest life cycles and floral resource provisioning for pollinators could create a resilient agroecosystem. However, adoption barriers persist, including seed availability, farmer awareness, and trade-offs with market preferences (e.g., fruit appearance). Participatory breeding programs that engage growers in selecting multifunctional cultivars may bridge this gap.

5. Conclusions

In conclusion, the study highlights the potential of selecting specific squash cultivars for enhancing pest management. Cultivars such ‘Saffron’ and ‘Amberpic 8455’ demonstrated dual benefits by supporting lower pest populations (*D. balteata*, and Thysanoptera, respectively) while maintaining higher natural, predator abundance. These findings suggest that selecting such cultivars can help squash growers naturally suppress pests, reduce reliance on chemical insecticides, lower pest management costs, and improve crop productivity and profitability. The combined use of PCA, K-means clustering, CCA, and Random Forest regression offered a solid framework for exploring weather-insect dynamics. The PCA identified key environmental gradients shaping insect communities, while clustering highlighted repeatable patterns useful for spatial and seasonal IPM planning. Canonical correlations confirmed that weather variables strongly predict community responses, and Random Forest models validated temperature and RH as top predictors of insect abundance. These results show the power of multivariate weather data for pest forecasting and reinforce the importance of weather-based strategies in adaptive IPM programs.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/agronomy15061411/s1>, Table S1. Type III tests of fixed effects (sampling week (Week) $\times$ squash cultivar (Cultivar), Week, and Cultivar) for the numbers of adult *Diabrotica balteata* LeConte (banded cucumber beetle), *D. undecimpunctata howardi* Barber (spotted cucumber beetle), *Acalymma vittatum* F. (striped cucumber beetle) (Coleoptera: Chrysomelidae), *Diaphania hyalinata* L. (melonworm) and *D. nitidalis* Stoll (pickleworm), *Melittia cucurbitae* Harris (squash vine borer) (Lepidoptera: Sesiidae), *Epilachna borealis* F. (squash beetle) (Coleoptera: Coccinellidae), *Anasa tristis* De Geer (squash bug) (Hemiptera: Coreidae), and Thysanoptera species [*Frankliniella occidentalis* Pergande (western flower thrips) and *Thrips tabaci* Lindeman (onion thrips)]. These insects were sampled using one yellow sticky card (YSC) with four sweeps (S) in the summer 2021 (21 June–1 August), fall 2021 (4 October–14 November), and fall 2022 (17 October–20 November); Table S2. Mean ($\pm$ S.E.) numbers of adult Thysanoptera species including (*Frankliniella occidentalis* Pergande (western flower thrips) and *Thrips tabaci* Lindeman (onion thrips) over six sampling weeks in the 2021 fall season (4 October–14 November). Thrips were sampled using yellow sticky cards (YSC) with four sweeps (S); Table S3. Type III tests of fixed effects (sampling week (Week) $\times$ squash cultivar (Cultivar), Week, and Cultivar) for the number of *Orius insidiosus* Say (minute pirate bug) (Hemiptera: Anthocoridae) collected from four sweeps and captured on one yellow sticky card in the summer 2021 (21 June–1 August), fall 2021 (4 October–14 November), and fall 2022 (17 October–20 November); Table S4. Mean ($\pm$ S.E.) of adult *Orius insidiosus* Say (minute pirate bug) (Hemiptera: Anthocoridae) numbers on 20 squash cultivars over six sampling weeks in the 2021 summer (21 June–1 August). This bug was sampled using one yellow sticky card (YSC) with four sweeps (S); Figure S1. Mean ($\pm$ S.E.) numbers of adult insect pests [*Frankliniella occidentalis* Pergande (western flower thrips) and *Thrips tabaci* Lindeman (onion thrips)], *Diabrotica balteata* LeConte (banded cucumber beetle), *Acalymma vittatum* F. (striped cucumber beetle) (Coleoptera: Chrysomelidae), and *Diaphania hyalinata* L.

(melonworm)] in the summer 2021 (21 June–1 August). These insects were sampled using one yellow sticky card (YSC) with four sweeps (S), referred to as (YSCS); Figure S2. Mean ($\pm$ S.E.) numbers of adult *Diabrotica balteata* LeConte (banded cucumber beetle) (Coleoptera: Chrysomelidae), on twenty squash cultivars in the summer 2021 (21 June–1 August). This beetle species was captured on one yellow sticky card (YSC) with four sweeps (S), referred to as (YSCS). Different letters above the error bars indicate significant differences (Tukey's test, $p < 0.05$) among cultivars; Figure S3. Mean ($\pm$ S.E.) numbers of adult insect pests [*Epilachna borealis* F. (squash beetle) (Coleoptera: Coccinellidae), *Diabrotica undecimpunctata* Howardi Barber (spotted cucumber beetle) (Coleoptera: Chrysomelidae), *Diaphania hyalinata* L. (melonworm) and *D. nitidalis* Stoll (pickleworm) (Lepidoptera: Sesiidae)] over six weeks in the fall 2021 (4 October–14 November). These insects were sampled using yellow sticky cards (YSC) with four sweeps (S), referred to as (YSCS); Figure S4. Mean ($\pm$ S.E.) numbers of adult insect pests [*Diabrotica balteata* LeConte (banded cucumber beetle), *D. undecimpunctata* Howardi Barber (spotted cucumber beetle) (Coleoptera: Chrysomelidae), and *Anasa tristis* De Geer (squash bug) (Hemiptera: Coreidae)] in fall 2022 (17 October–20 November). These insects were sampled using yellow sticky cards (YSC) with four sweeps (S), referred to as (YSCS); Figure S5. Mean ($\pm$ S.E.) numbers of adult *Orius insidiosus* Say (minute pirate bug) (Hemiptera: Anthocoridae) over six weeks in the fall 2021 (4 October–14 November). This bug was sampled using yellow sticky cards (YSC) with four sweeps (S), referred to as (YSCS).

Author Contributions: S.W.: Writing—original draft, Data curation, Formal analyses. Y.L.: Experimental design, Writing—review & editing, Visualization, Investigation, Validation. G.N.M.: Conceptualization, Experimental design, Writing—review & editing, Visualization, Validation, Supervision, Funding acquisition. A.M.S.: Experimental design, Writing—review & editing, Validation, Funding acquisition. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the United State Department of Agriculture—Agricultural Research Service Non-Assistance Cooperative Agreement #58-6080-9-006. This article reports on the results of the research only. Mention of a proprietary product does not constitute an endorsement or recommendation for its use by USDA.

Data Availability Statement: Data can be provided upon reasonable request by the corresponding author.

Acknowledgments: The authors thank Jared Fluellen, Anurag Singh, and Kaitlyn Garland for their technical support.

Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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