Article

Abundance, Harmfulness, and Control of Pea Leaf Weevil in Broad Beans (Vicia faba Linn.)

Mohammad Almogdad * and Roma Semaškienė

Lithuanian Research Centre for Agriculture and Forestry, Department of Plant Pathology and Protection, Institute of Agriculture, Akademija, LT-58344 Kėdainiai, Lithuania; roma.semaskiene@lammc.lt

* Correspondence: mohammad.almogdad@lammc.lt

Abstract: A field experiment was carried out on broad beans (Vicia faba L.) to investigate the abundance of the pea leaf weevil (Sitona lineatus L.), as influenced by the timing of pest control, using insecticides. The study was conducted in broad bean var. ‘Vertigo’, during the period 2019–2020. The study included six spray regimes, as well as an untreated control. Yellow water traps were used to monitor the occurrence of the pea leaf weevil from the start of germination until harvest. Pea leaf weevil abundance was observed over the growing season. The adult density showed two peaks at two plant phenology stages, at flowering and before harvest (BBCH 89). The amount of damaged root nodules by this pest ranged from 41 to 59%. Data from two years of study suggest that S. lineatus infestation does not result in a seed yield reduction. Spray regimes did not impact larval density. Applying foliar insecticides at the local threshold can be recommended as an effective method to protect broad beans from feeding by pea leaf weevils.

Keywords: abundance; broad bean; Sitona spp.; spray time; insecticide; notches

1. Introduction

Broad bean (Vicia faba L.) is an important crop, not only as green manure, but also as feed and food with a high protein content [1]. In 2020, the total grown area of V. faba in Lithuania increased to 58.3 thousand ha, with an average yield of 3.75 t ha⁻¹, compared to 3000 ha in 2010 [2]. The pea leaf weevil (Sitona lineatus Linnaeus, 1758) (Coleoptera: Curculionidae) is a legume-destroying pest, and the severity of its damage is largely determined by the season. In the last three decades, the average air temperature in Lithuania has risen rapidly, so the day-degrees necessary for S. lineatus have changed [3]. S. lineatus causes persistent problems in V. faba, affecting both harvest quantity and seed quality [4,5]. It is a significant pest of V. faba in most temperate regions, including Europe and North America [6].

In spring, S. lineatus adults emerge, when the temperature is above 12 °C and the photoperiod is suitable for feeding upon several legume species [7]. S. lineatus prefers feeding on V. faba [8] and pea (Pisum sativum L.) as reproductive hosts [9]. S. lineatus adults feed on the leaves of V. faba plants, immediately creating U-shaped notches along the leaf margins [6]. One S. lineatus adult can feed on around 40 mm² of pea leaves per day [10]. In the early growth stages, high infestation levels decrease the stand density significantly, which can kill young seedlings [11]. Although the plants overcome this damage, yield losses can occur [12]. It is a univoltine pest; the adults start laying eggs within 7 days and continue laying eggs over 3 months, leading to the presence of all life stages [13]. S. lineatus larvae consume the root nodules, which contain Rhizobium bacteria, lowering the plant’s nitrogen supply [8]. Nodules can be completely destroyed when there is a high level of infestation [11,14]. S. lineatus attacks during early growth stages can reduce V. faba density [6]. Yield reduction happens by both S. lineatus adults feeding on leaves and larva feeding on root nodules [7,15].
Foliar insecticides can decrease adult populations of *S. lineatus* by about 56%, compared with untreated areas and, thus, protect the plant yield [16]. Insecticides have been reported to be the most effective control agents against insect pests in legumes [17]. Foliar spray must be applied when *S. lineatus* weevils appear in the field to stop adult females from depositing eggs. If this is done too late, it will not control the larval populations [18]. Other studies have reported that applying foliar insecticide after the economic threshold has been reached will not show any yield benefit [7,13]. Pyrethroid insecticides, for example, were shown to decrease larval counts by about 50% [16], but other studies documented that they were not able to preserve yields [19]. Sprays only caused the death of females, having no effect on larvae [20]. Carbofuran and related compounds in seed treatment are no longer available in most European countries and were replaced by neonicotinoids, although seed coating with systemic insecticide (thiamethoxam, neonicotinoid) provided higher efficacy against *S. lineatus* than foliar sprays [19,21].

An evaluation of different spray regimes would contribute to reducing the use of insecticides. To ensure that this is achieved, monitoring the appearance and abundance of *S. lineatus* should be conducted seasonally. The study aimed to determine the status of *S. lineatus* in broad bean in Lithuania and to estimate its occurrence and harmfulness and the most efficient control measures.

2. Materials and Methods

The research was carried out at the Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, Akademija, Kėdainiai District, Lithuania, during the period 2019–2020. Geographically, the area is situated at 55° north latitude and 23° east longitude at an altitude of 63 m above mean sea level. Broad bean var. ‘Vertigo’ was grown following the recommended agronomic practices. The crop was sown at a rate of 0.5 million seeds ha$^{-1}$. The experiments were laid out in a randomized complete block design (RCBD). The field was divided into equal plots of 25 m$^2$ (10 × 2.5 m), with a 2 m block-to-block distance and 0.25 m plot-to-plot distance. Each treatment was allocated randomly within the block and replicated 4 times.

In each year, 6 yellow water traps were distributed (6 m apart from each other) in the untreated large plot (10 × 34 m) of the field to detect the appearance time and abundance of *S. lineatus*. Some drops of clear, unscented liquid soap were added to the traps to break the surface tension of the water and make the insects sink. The traps were checked weekly from the BBCH 00 to BBCH 89 growth stages. The water was poured through a fine aquarium mesh net, then the contents were rinsed with water into a jar of 70% ethanol. *S. lineatus* was distinguished from other Sitona species using the morphological descriptors provided in [22,23]. The species was also identified using a published guide [24]. Plant growth stages were identified according to a phenological growth stage key (BBCH) [25,26].

Different application regimes were applied as follows:

1. Untreated control (UN)
2. At growth stage BBCH 08 (GS08C)
3. When the first pea leaf weevil adult was caught in the yellow water trap (MDC)
4. When the daily air temperature for 3 days exceeded the threshold (12.5 °C) for adult activity (DDC)
5. At the local threshold (5–10 weevils m$^{-2}$) (THC)
6. At growth stage BBCH 10–11 (GSC)
7. Full control spray at BBCH 10, 30, and 70 growth stages (FCC)

For pea leaf weevil control according to the trial scheme, Cyperkill 500 EC insecticide was used, as described in Table 1, and spray times are given in Table 2.
Table 1. Description of insecticide used against Sitona lineatus.

<table>
<thead>
<tr>
<th>Commercial Product</th>
<th>Active Ingredient</th>
<th>Spray Rate</th>
<th>Chemical Sub-Group</th>
<th>Mode of Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyperkill 500 EC</td>
<td>cypermethrin, 500 g L$^{-1}$</td>
<td>0.05 L ha$^{-1}$</td>
<td>pyrethroid</td>
<td>contact</td>
</tr>
</tbody>
</table>

Application was done with a wheelbarrow sprayer (one spraying path with five nozzles; spraying span 2.5 m; flat fan nozzle; application pressure 2.5 bar).

Table 2. Broad bean growth stages (BBCH) and dates of insecticide application for Sitona lineatus control in 2019–2020.

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>Growth Stage and Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>UN</td>
<td>BBCH 08 (3 May)</td>
</tr>
<tr>
<td></td>
<td>GS08C</td>
<td>BBCH 13 (17 May)</td>
</tr>
<tr>
<td></td>
<td>MDC</td>
<td>BBCH 18 (4 June)</td>
</tr>
<tr>
<td></td>
<td>DDC</td>
<td>BBCH 15 (24 May)</td>
</tr>
<tr>
<td></td>
<td>THC</td>
<td>BBCH 10 (10 May)</td>
</tr>
<tr>
<td></td>
<td>FCC *</td>
<td>BBCH 13 (17 May)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BBCH 15 (24 May)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BBCH 70 (12 July)</td>
</tr>
<tr>
<td>2020</td>
<td>UN</td>
<td>BBCH 08 (30 April)</td>
</tr>
<tr>
<td></td>
<td>GS08C</td>
<td>BBCH 10 (4 May)</td>
</tr>
<tr>
<td></td>
<td>MDC</td>
<td>BBCH 15 (28 May)</td>
</tr>
<tr>
<td></td>
<td>DDC</td>
<td>BBCH 14 (19 May)</td>
</tr>
<tr>
<td></td>
<td>THC</td>
<td>BBCH 10 (4 May)</td>
</tr>
<tr>
<td></td>
<td>FCC *</td>
<td>BBCH 16 (3 June)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BBCH 71 (24 June)</td>
</tr>
</tbody>
</table>

Note: UN, untreated control; GS08C, at BBCH 08 growth stage; MDC, when first pea leaf weevil adult was caught in yellow water trap; DDC, when daily air temperature for three days exceeded threshold for adult activity; THC, at local threshold (5–10 weevils m$^{-2}$); GSC, at BBCH 10–11 growth stage; FCC, full control spray at BBCH 10, 30, and 69 growth stages (*: full control was applied to eliminate impact of other insect pests during growing season).

Pea leaf weevils were counted at roughly weekly intervals from BBCH 12 to BBCH 16 growth stages during the 2019–2020 seasons. Adults were counted using a 0.25 m$^2$ frame placed on the soil surface, then sitting quietly and waiting for a short time until weevils started moving on the soil surface. Monitoring was done in 2 randomly selected places in each plot. Damage by S. lineatus adults on broad bean foliage was assessed at the BBCH 18 growth stage. U-shaped notches on leaf margins of 10 randomly selected plants in each plot were evaluated. A damage rating at the BBCH 18 growth stage was performed for each leaf according to a modified scale [15] of 5 levels (0 = no notches; 1 = 1–10% of leaf margin with damage; 2 = 11–50%; 3 = 51–75%; 4 = 76–100%) (Figure 1).

Figure 1. Images of cotyledon broad bean leaves showing damage from Sitona lineatus adults across rating scale. Rating scales of leaf damage: (1 = 1–10% of leaf margin with damage; 2 = 11–50%; 3 = 51–75%; 4 = 76–100%).

During the flowering period, most S. lineatus larvae are usually completely developed [27]. In our field experiments, plant roots were sampled from 10 randomly selected plants at the full flowering stage (BBCH 65). The larvae were collected and morphologically
identified as the genus Sitona according to [10]. Soil surrounding the roots (surface of 0.0625 m² and depth of 25 cm) was soaked in salty water (10% sodium chloride), then passed through a 250 µm sieve to count the larvae. The roots were rinsed with water and kept at +4 °C to prevent unwanted damage until the nodules could be evaluated at the laboratory. The total number of damaged nodules was counted. Active nodules were distinguished by their pink color [28] and counted under a magnifier.

The plots were harvested using a small plot combine. Plot size for harvesting was 20 m². For each plot, moisture percentage and weight fresh grain (kg plot⁻¹) were recorded. The yield from each plot was adjusted to moisture content using this formula: 

\[ W_d = W_w \times \left[ 100 - \left( \frac{\text{Moisture at harvest time}}{0.85} \right) \right] \]  

where \( W_d \) is the adjusted weight at standard moisture (15%) and \( W_w \) is the weight at harvest time. Then the value was converted to tons per hectare (t ha⁻¹).

SAS version 7.15 (SAS Institute Inc., Cary, NC, USA) was used to record and statistically analyze the data. Prior to analysis, the data were examined for homogeneity using the Kolmogorov–Smirnov Test. Analysis of variance (ANOVA) of the data was carried out to determine whether there were differences between spray regimes. Duncan’s multiple range test was used to separate means when \( p < 0.05 \) in the original ANOVA.

3. Results

3.1. Temporal Abundance of Sitona lineatus Adults and Its Control

The seasonal abundance, total \( S. \ lineatus \) weevils in traps, and average air temperature during the 2019–2020 growing seasons are given in Figure 2. In 2019, before 10 May, no \( S. \ lineatus \) weevils were recorded in traps, although the mean daily temperature reached 18.2 °C on 26 April and 18.7 °C on 28 April. The highest mean daily temperature in the 7 days prior to 10 May in 2019 was 10.5 °C. \( S. \ lineatus \) adults were first recorded in the monitoring traps placed on 10 May 2019. On this date, two adults were recorded, and the mean daily temperature was 13.0 °C. Between 10 May and 12 June, 267 \( S. \ lineatus \) weevils were recorded during trap observations, and during this period, the highest daily average temperature was on 12 June, at 26.4 °C. Despite the high average maximum daily temperature between 15 June and 15 July of 31.6 °C, mean daily temperature was 23.8 °C and only five weevils were recorded on 15 July.

In 2020, the first \( S. \ lineatus \) weevil was recorded in the monitoring traps on 30 April, and the mean daily temperature on this date was 7.3 °C. During the prior 7-day period, the average daily temperature ranged from 5.9 to 11.9 °C. Pairs of scale leaves of broad bean plants were visible on 4 May, and 10 \( S. \ lineatus \) weevils were recorded in traps on this day. On 3 June, six leaves of broad bean plants were unfolded (BBCH 16 growth stage), and the largest numbers of \( S. \ lineatus \) weevils were recorded in traps (130 weevils). The highest mean daily temperature in the prior 7 days was 16.9 °C.

In 2019, \( S. \ lineatus \), captured in yellow water traps, showed two peaks, the first at the flowering stage and the second at the full ripening stage. The trend of abundance of \( S. \ lineatus \), in 2020, at almost all growth stages of broad bean, was in line with that in 2019. \( S. \ lineatus \) density declined from the end of the flowering growth stage (BBCH 69) to the beginning of the ripening growth stage (BBCH 80). From the beginning of pod development, the density tended to level off and settle down, and then increased until harvest. These fast-density increases coincided with the emergence of adults from pupae.

In 2019, the dispersal of \( S. \ lineatus \) adults into broad bean fields coincided with unfolding the first leaf (BBCH 11), whereas in 2020, it coincided with the emergence of shoots through the soil surface (BBCH 09). The abundance of \( S. \ lineatus \) was substantially higher in 2020 than in 2019.
Figure 2. Numbers of *Sitona lineatus* adults captured in yellow water traps across growth stages of broad bean during 2019 and 2020 and mean daily temperatures. Note: Arrow on the left denotes flowering stage and the one on the right denotes full ripe stage.

In study years, the adult density at early growth stages (BBCH 12–13) in the untreated plots was quite low (2.5 weevils m$^{-2}$). At later growth stages (BBCH 15), the density of adults in the untreated plots reached the local threshold (5–10 weevils m$^{-2}$). By counting *S. lineatus* weevils on the soil surface, using a metal frame in each plot, in 2019 and 2020, a clearer response to various spray regimes could be established (Table 3). In 2019, at BBCH 16, the abundance of *S. lineatus* in untreated plots was 11.5 weevils m$^{-2}$, which is markedly higher than the local threshold. The spray regimes, according to the local threshold (THC), when the first pea leaf weevil adult was caught in the yellow water trap (MDC) and at BBCH 08 (GS08C), decreased the density of *S. lineatus* adults. In 2020, *S. lineatus* density in the untreated plots was 17.2 weevils m$^{-2}$ (72% higher than the local threshold). At this high density, THC, GS08C, and MDC spray regimes had a significant effect on decreasing the density of *S. lineatus* adults to 5–7.5 weevils m$^{-2}$. There were no significant differences between spray regimes when plots were treated, according to THC, GS08C, and MDC. The spray regime at BBCH 10–11 (GSC) did not decrease *S. lineatus* adults compared to the untreated control (UN) in our experiment.
Table 3. Density of *Sitona lineatus* (weevil m$^{-2}$) at BBCH 16 in broad bean treated at different times with insecticide.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Year</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>UN</td>
<td></td>
<td>11.5 ± 2.2 b</td>
<td>17.2 ± 1.9 c</td>
</tr>
<tr>
<td>GS08C</td>
<td></td>
<td>5 ± 1.2 a</td>
<td>5.5 ± 2.8 a</td>
</tr>
<tr>
<td>MDC</td>
<td></td>
<td>6.5 ± 1.8 ab</td>
<td>7 ± 0.9 ab</td>
</tr>
<tr>
<td>THC</td>
<td></td>
<td>7 ± 1.2 ab</td>
<td>5 ± 1.6 a</td>
</tr>
<tr>
<td>GSC</td>
<td></td>
<td>9.5 ± 1.5 ab</td>
<td>12.7 ± 2.0 bc</td>
</tr>
<tr>
<td>FCC *</td>
<td></td>
<td>9.5 ± 1.2 ab</td>
<td>5.5 ± 0.9 a</td>
</tr>
</tbody>
</table>

Note: Values are arithmetic means ± SE (standard error); different letters in same column indicate significant difference between treatments ($p < 0.05$). UN, untreated control; GS08C, at BBCH 08 growth stage; MDC, when first pea leaf weevil adult was caught in yellow water trap; DDC, when daily air temperature for three days exceeded threshold for adult activity (DDC treatment occurred after BBCH 16); THC, at local threshold (5–10 weevils m$^{-2}$); GSC, at BBCH 10–11 growth stage; FCC, full control spray at BBCH 10, 30, and 69 growth stages (*: full control was applied to eliminate impact of other insect pests during growing season).

3.2. Foliage Damage

The foliar damage score, at BBCH 18 in untreated control plots (UN), ranged between 2.5 and 2.8 in 2019 and 2020. Meanwhile, the foliar damage score in plots treated, according to the local threshold (THC), was 1.2 in both years (Figure 3). Application, according to THC, was the most effective regime compared to other spray regimes. In 2019, when the *S. lineatus* adult density was 11.5 weevils m$^{-2}$ in the untreated plots, only the spray regime according to THC resulted in a significantly lower severity of foliar damage. In 2020, at high adult density (17.2 weevils m$^{-2}$ in the untreated plots), the foliar damage by *S. lineatus* adults was significantly less in plants treated once, according to THC, day degree (DDC), or monitoring data (MDC) compared to UN. Insecticide application, according to THC, reduced foliar damage, showing significant differences compared to UN and early spray at BBCH 08 growth stage (GS08C). In the study years, the GS08C early spray regime did not prevent foliar damage, showing no significant differences compared to UN.

Figure 3. Effect of spray regime on *Sitona lineatus* feeding (mean damage rating) on broad bean at BBCH18 in 2019 and 2020. Note: Different letters in column indicate significant difference between treatments ($p < 0.05$); ($p$-value ≤ 0.0001 for 2019, $p$-value = 0.0231 for 2020). UN, untreated control; GS08, at BBCH 08 growth stage; MDC, when first pea leaf weevil adult was caught in yellow water trap; DDC, when daily air temperature for three days exceeded that of threshold for adult activity; THC, at local threshold (5–10 weevils m$^{-2}$); GSC, at BBCH 10–11 growth stage; FCC, full control spray at BBCH 10, 30, and 69 growth stages. Rating scales of leaf damage: (0 = no notches; 1 = 1–10% of leaf margin with damage; 2 = 11–50%; 3 = 51–75%; 4 = 76–100%).
3.3. Damaged Root Nodules by Sitona lineatus Larvae

In 2019 and 2020, different insecticide regimes did not significantly reduce the number of damaged nodules compared to the untreated control. In 2020, at high S. lineatus adult density, insecticide application at the local threshold (THC) more effectively decreased the percentage of damaged nodules compared to other spray regimes (Table 4). Furthermore, full control, applied to eliminate the impact of all insect pests during the growing season, did not decrease the damaged nodules caused by S. lineatus larvae.

Table 4. Mean (± SE) percentage of damaged nodules in broad bean at BBCH 65 (flowering growth stage) when treated at different times with insecticide in 2019 and 2020.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Year</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>UN</td>
<td></td>
<td>57.76 ± 3.91 a</td>
<td>51.89 ± 5.10 ab</td>
</tr>
<tr>
<td>GS08C</td>
<td></td>
<td>59.44 ± 1.58 a</td>
<td>59.03 ± 2.95 b</td>
</tr>
<tr>
<td>MDC</td>
<td></td>
<td>62.67 ± 4.12 a</td>
<td>53.18 ± 3.42 ab</td>
</tr>
<tr>
<td>DDC</td>
<td></td>
<td>59.27 ± 1.96 a</td>
<td>50.29 ± 3.04 ab</td>
</tr>
<tr>
<td>THC</td>
<td></td>
<td>54.28 ± 5.76 a</td>
<td>41.28 ± 3.20 a</td>
</tr>
<tr>
<td>GSC</td>
<td></td>
<td>51.93 ± 0.82 a</td>
<td>54.95 ± 5.80 b</td>
</tr>
<tr>
<td>FCC</td>
<td></td>
<td>54.67 ± 4.20 a</td>
<td>53.49 ± 4.40 ab</td>
</tr>
</tbody>
</table>

Note: Values are arithmetic means ± SE (standard error); different letters in same column indicate significant difference between treatments (p < 0.05). UN, untreated control; GS08C, at BBCH 08 growth stage; MDC, when first pea leaf weevil adult was caught in yellow water trap; DDC, when daily air temperature for three days exceeded that of threshold for adult activity; THC, at local threshold (5–10 weevils m⁻²); GSC, at BBCH 10–11 growth stage; FCC, full control spray at BBCH 10, 30, and 69 growth stages.

3.4. Yield

The grain yields, in tons per hectare, obtained in 2019 and 2020, are given in Table 5. The grain yield did not differ significantly among spray regimes for the S. lineatus control. No significant treatment regarding yield was observed in 2019 or 2020. Compared to the untreated control (UN), the full control spray (FCC) regime did not have a significant positive effect on yield compared to single spray in other regimes. It gave a slight yield increase in 2019 and 2020 (8 and 3.3%, respectively).

Table 5. Mean (± SE) grain yield (t ha⁻¹) of broad bean treated with insecticide at various times to control Sitona lineatus in Lithuania in 2019 and 2020.

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>UN</th>
<th>GS08C</th>
<th>MDC</th>
<th>DDC</th>
<th>THC</th>
<th>GSC</th>
<th>FCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td></td>
<td>6.0 ± 0.2 a</td>
<td>6.0 ± 0.1 a</td>
<td>6.1 ± 0.2 a</td>
<td>6.2 ± 0.1 a</td>
<td>6.2 ± 0.2 a</td>
<td>5.8 ± 0.1 a</td>
<td>6.2 ± 0.2 a</td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td>2.5 ± 0.2 a</td>
<td>2.5 ± 0.2 a</td>
<td>2.3 ± 0.1 a</td>
<td>2.6 ± 0.1 a</td>
<td>2.6 ± 0.2 a</td>
<td>2.6 ± 0.1 a</td>
<td>2.7 ± 0.1 a</td>
</tr>
</tbody>
</table>

Note: Values are arithmetic means ± SE (standard error); different letters in same row indicate significant difference between treatments (p < 0.05). UN, untreated control; GS08C, at BBCH 08 growth stage; MDC, when first pea leaf weevil adult was caught in yellow water trap; DDC, when daily air temperature for three days exceeded that of threshold for adult activity; THC, at local threshold (5–10 weevils m⁻²); GSC, at BBCH 10–11 growth stage; FCC, full control spray at BBCH 10, 30, and 69 growth stages.

4. Discussion

The capture of S. lineatus adults in yellow water traps did not correlate with germination of broad beans in the field. The first weevil arriving in the broad bean field was recorded in the early stages of broad bean development. The temperature was about 13.0 and 7.3 °C, when the first weevils were recorded in traps in the fields, in 2019 and 2020, respectively. The appearance of insects in the traps was not correlated with the emergence of broad bean seedlings in the field, which may be due to the rise in temperature, to the extent necessary to end their overwintering. With the increased temperature at the early growth stage of broad bean, the abundance of S. lineatus adults increased. This is in line with [30],
which indicated that *S. lineatus* adults start moving from overwintering sites at a minimum temperature of 12.5 °C. In our results, the lower threshold for *S. lineatus* flight activity was at 7.3 °C. This can be explained by the interaction between the daily temperature and the form of the light intensity periodicity. According to [31], if the temperature is unusually low, relative to the temperature at which insects can fly, this might be explained by the temperature tolerance being adapted to fit the light sensitivity. On the other hand, insect flight activity is not only a result of temperature, but also a result of an interaction between temperature, light and wind speed, as [32] reported. In the current study, the temperature stimulated insect activity, and *S. lineatus* adults appeared in the broad bean field at the early growth stage (BBCH 09), when the cotyledons emerged.

In this study, weevil density increased until flowering, then declined until ripening, but then showed an increase. This is in line with the results of [33], which reported that *S. hispidulus* had a period of relative inactivity through the high-temperature period of the summer. The temperature at broad bean flowering in our experiment was 22.3 to 22.7 °C. The changes in abundance occurred quickly after the new adults emerged from pupae, as found in previous studies [33]. The peak of emergence from pupae occurred at the same growth stage (BBCH 82) in both study years. It was reported in [34] that the autumn flight timing of *S. lineatus* adults was correlated with the timing of the host plant senescence stage. The plant odor is important to *S. lineatus* for mating and host finding [35]. *S. lineatus* adults were present during the entire growing season, from germination to harvest. In the experimental years, the new generation of *S. lineatus* adults emerged from the soil and started migrating from the broad bean field at the same time as the beginning of the ripening stage (BBCH 80), i.e., at the end of the summer season, which agrees with the findings of [7,11].

At the early growth stages, the plant still does not have enough leaves and needs protection from *S. lineatus* adults to overcome the critical period (before the 6th node) [6,36]. In 2019, applying insecticide early, at BBCH 08, significantly reduced adult density. Application, according to the local threshold, did not show significant differences in adult density, which may be due to the high activity of *S. lineatus* adults and their movement from the high-density part of the field to areas where their abundance was decreased by insecticide spray [37]. However, at a higher abundance of adults (17.2 weevils m⁻² in the untreated plots) in 2020, the insecticide spray regime, according to the local threshold, had significant efficacy against *S. lineatus*. A single spray, applied when the local threshold is reached, or at BBCH 08, reduced adult abundance. It was reported in [19] that foliar insecticide spray decreased the density of *S. lineatus* adults. In 2019 and 2020, our results showed that insecticide spray at the local threshold reduced the abundance of adult weevils by 39.1 and 71%, respectively, at BBCH 16 growth stage. In 2020, the reduction in *S. lineatus* weevils at BBCH 16, resulting from spraying insecticides early at BBCH 08, or according to the monitoring data (when the first pea leaf weevil adult was caught in the traps), reached 68 and 59.3%, respectively. Other studies reported that foliar insecticides applied at the correct time reduced beetle density by 56% [20] and increased the mortality rate of *S. lineatus* females [6] by around 30% [36].

It was reported in [27] that weevil density can be estimated by the number of notches in the leaves. Using the spray regime, applied when the local threshold is met, decreased the number of leaf notches significantly, compared to the other treatments in 2020. Monitoring of weevils was used to determine the appropriate time to apply the insecticide; however, efficacy of these applications is probably affected by weevil density, as that changes over time [21]. At the highest weevil density in our experiments, seedlings had passed the critical growth stage (BBCH 09–10) and formed rich vegetative growth. A greater number of leaf notches were recorded on plants treated at the early growth stages (BBCH 08–10) in our study years. This agrees with [21], which found that later waves of *S. lineatus* cannot be controlled if spraying is done too early. Soil moisture and precipitation may be among the most important edaphic elements impacting the survival of *S. lineatus* larvae. It was reported in [38] that the number of flea beetles, *Longitarsus bethae* (Coleoptera:
Chrysomelidae), was greater in soil with a moderate moisture content (16%) than in soil with either low-moisture (11%) or high-moisture (20%) contents. This also agrees with [39], which found a high mortality rate for the larval stage of southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber (Coleoptera: Chrysomelidae). It was found to be more abundant in areas with high-moisture content (16%) than in areas with low-moisture content (2%) [39]. To decrease the foliar damage, the timing of insecticide application is important to effectively manage *S. lineatus*. When applied once at the local threshold, the insecticide significantly decreased foliar damage compared to the other spray regimes. However, this decrease was not significantly different from the damage level recorded in plants treated twice (full control spray) in 2020.

Generally, there were no significant differences in damaged nodules among insecticide spray regimes. Similar results were reported in [21], in which damaged nodules were not significantly affected by seed treatment with insecticides. This agrees with [18], in which treatment with insecticides did not show any significant differences in the amount of damaged nodules on a *P. sativum* crop. Similarly, in another study on seed treatment with insecticides [40], there was no significant effect of treatment timing on the number of damaged nodules. In our study, early spraying at the BBCH 08 growth stage had lower efficacy than the spray regime at the local threshold, which agrees with the results of [21], in which insecticides applied early did not increase the amount of healthy nodules. Our results showed fewer damaged nodules in the untreated control compared with other treatments. This agrees with [21], in which seed treatment with insecticides resulted in higher numbers of damaged nodules compared to the untreated control. The differences in damaged nodules and larval numbers may be affected by the death rate, due to their competition on nodules [41], or by plant tolerance, as reported in [42]. The positive impact of different spray regimes on the number of nodules damaged by *S. lineatus* larvae was not confirmed in the study years, which agrees with [20]. In other studies, foliar spray using pyrethroid insecticides reduced the number of larvae by about 50% [16]. Regrettably, published studies evaluating the effect of insecticide timing against *S. lineatus* larvae are scarce.

Our results show that the insecticide did not increase yields when applied three times (at BBCH 10–11, BBCH 15–16, and BBCH 70 growth stages). Therefore, economically, full control spray does not seem to be a viable option for *S. lineatus* management, which does not agree with [43], in which it was reported that full control sprays were effective for seed yield. A density of >20 *S. lineatus* adults m\(^{-2}\) was found to have a negative impact on broad bean yields (total yield in grams or number of pods and seeds) [41]. This may be because there were no differences in the number of larvae between treatments, as previous studies have shown that reduction by one larva can increase yield by about 0.06 t ha\(^{-1}\) [16]. Previous studies showed that foliar insecticides did not significantly increase yield compared to soil treatments, although the number of larvae was decreased by up to 70% [36]. In other studies, seed treatment with insecticides against *S. lineatus* did not prevent yield losses. In our study, there were significant differences in damaged nodules across treatments in 2020, but this did not transfer into higher yields. It may because younger nodules, created during the blooming phases, may not be injured by *S. lineatus* larvae that have already completed their feeding and are ready to pupate. Broad bean plants with more damaged nodules may be able to overcome the unfavorable effects of larvae [8]. Intact root nodules are thought to have a carrying capacity influence on Sitona weevil larval populations [44]. Our findings are consistent with those of [44], in which yield was unaffected by *S. lineatus* density, in the range of 13–40 weevils per m\(^2\). An increase in healthy nodules, according to [36], may not always translate to increased yield. This might be due to ineffective control of weevils, or to the lack of a severe impact by weevils on plant yield [45]. At later developmental stages, larvae were no longer actively feeding and destroying root nodules and, therefore, younger nodules continued to fix nitrogen, thus, compensating for the loss of damaged nodules [8]. On the other hand, the variation in yield, between years for the same variety, may be due to fungal diseases or the severity of *S. lineatus* attacks [46], or to broad bean weevil (*Bruchus rufimanus* Boh.), which can affect the crop yield [47]. The damage caused
by *B. rufimanus* was visually noticed in the field experiments during our study but no data on the number of beetles were collected. Therefore, the yield data were at the same level and no differences were established in the early spray regimes.

5. Conclusions

The dispersal of *S. lineatus* weevils in the field coincided with the stages of broad bean shoots growing toward the soil surface (BBCH 08), and shoots emerging through the soil surface (BBCH 09). In 2019 and 2020, the temperatures at the beginning of leaf weevil occurrence were 13.0 and 7.3 °C, respectively. The peaks of weevil abundance were reached at the stages when nearly all the pods had reached the final length (BBCH 79) and at full ripening (BBCH 89). Application, according to the local threshold, resulted in a significantly lower number of notches on leaves and a significantly decreased percentage of damaged root nodules, compared to early spraying at BBCH 08. The results of two seasons of field experiments show that *S. lineatus* damage is not destructive to the host plant and there is no evidence of a substantial effect on grain yield.

Author Contributions: Idea, implementation, analysis, and writing: M.A.; correction and recommendations for improvement: R.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. This study was supported by the long-term research program “Harmful Organisms in Agro and Forest Ecosystems”, implemented by the Lithuanian Research Centre for Agriculture and Forestry.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

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

References
1. Merga, B.; Egigu, M.C.; Wakgari, M. Reconsidering the Economic and Nutritional Importance of Faba Bean in Ethiopian Context. *Cogent Food Agric*. 2019, 5, 1683938. [CrossRef]

41. Nielsen, B.S. Yield Responses of *Vicia Faba* in Relation to Infestation Levels of *Sitona lineatus* L. (Col., Curculionidae). *J. Appl. Entomol.* 1990, 110, 398–407. [CrossRef]

42. El-Dessouki, S.A.; Stein, W. Intraspecific Competition between Larvae of *Sitona* spp. (Col., Curculionidae). *Oecologia* 1970, 6, 106–108. [CrossRef]


47. Segers, A.; Caparros Megido, R.; Lognay, G.; Francis, F. Overview of *Bruchus Rufimanus* Boheman 1833 (Coleoptera: Chrysomelidae): Biology, Chemical Ecology and Semiochemical Opportunities in Integrated Pest Management Programs. *Crop Prot.* 2021, 140, 105411. [CrossRef]