The occurrence and control of black bean aphid (*Aphis fabae* Scop.) in broad bean

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Abstract

To assess changes in the population of black bean aphid (*Aphis fabae* Scop.) in relation to the cultivar and timing of pest control using insecticides, precision field experiment was carried out in the fields of broad bean (*Vicia faba* L.). The research was conducted on three broad bean cultivars 'Tiffany', 'Fuego' and 'Vertigo' during three successive growing seasons in 2018, 2019 and 2020 at different sites with a distance between the experimental fields of 1–2 km. The experiment included five insect pest control regimes. The population of black bean aphid was monitored from the beginning of germination by using yellow traps and by counting percent of damaged plants. Assessments of black bean aphid's abundance were done at beginning of flowering to pod development stage. The infestation of black bean aphids on the plants of broad bean cultivars was affected by different spray regimes. All the tested broad bean cultivars were variably infested with *Aphis fabae*. The experimental data suggest that among the three cultivars tested the most susceptible to *A. fabae* was 'Tiffany', while 'Fuego' and 'Vertigo' supported a low population density of this pest. Insecticide application according to the local threshold resulted in a significantly lower aphid population compared to the untreated, and the efficacy was similar to that of the full control treatment.

The data from four field trials obtained during the three growing seasons suggest that *A. fabae* infestation can incur a grain yield reduction of 0.21 t ha^{-1}. Applications according to local threshold with contact and systemic insecticides increased grain yield at the same level, and it was in line with the full control treatment.

Key words: *Aphis fabae*, abundance, insecticide, local threshold, *Vicia faba*, yield.

Introduction

Black bean aphid (*Aphis fabae* Scop.) is spread almost worldwide (Esmaeili-Vardanjani et al., 2013). It occurs throughout Europe, Western Asia, Africa and South America (Meradsi, Laamari, 2018). It attacks all plant parts and prefers the newly growing plant tips to deposit nymphs (Stoddard et al., 2010) causing growth repression and distortion of leaves, which results in yield losses depending on the infestation time and colonization intensity (Goszczyński et al., 2002). Hansen et al. (2008) suggest that the *A. fabae* is generally considered to be a serious pest of spring-sown field beans in Northern Europe, and field studies have shown that yield losses can exceed 50% due to attacks from the *A. fabae*.

Thirty years ago, *A. fabae* was identified as one of the most harmful insect pests in broad bean in Lithuania (Tamošiūnas, 1993). The intense infestation can stimulate dropping or shrivelling of immature pods causing a large loss in yield (Subedi et al., 2018). *A. fabae* is the main reason for the transmission of plant viruses (Dedryver et al., 2010). It is the main vector for more than 30 plant viruses including the non-persistent viruses in faba bean, peas, beets and potato, and also the persistent viruses like potato leafroll virus (PLRV) and beet yellow net virus (BYNV) (Blackman, Eastop, 2017).

Pyrethroid insecticides are the main class used for foliar application to control the aphids (Johnson et al., 2009), besides the new class of insecticides chemically related to nicotine (neonicotinoids). Some researchers (Rondon, Thompson, 2019) reported no significant differences between insecticide-treated and untreated plots, and others found that neonicotinoids significantly reduced aphid population but not below the economic threshold (Magalhaes et al., 2009). Dotasara et al. (2017) found that neonicotinoids reduced the incidence of mustard aphid (*Lipaphis erysimi* K.) by 87.53% over the untreated. Pyrethroid and neonicotinoid insecticides were highly effective against black bean aphid under laboratory conditions (Purhematy et al., 2013). The neonicotinoid insecticide imidacloprid had a high efficacy against *A. fabae* and led to a yield increase compared to the carbamate insecticide carbofuran and to the untreated (Al-Naser, Ezz Al-dden, 2011). Another study found that neonicotinoid insecticides were highly effective against cowpea aphid (*Aphis craccivora* Koch) compared to the other groups of insecticides (Patil et al., 2017).

Reasonable application of insecticides is the basis. Therefore, the insecticides should be applied at the proper rate and at the correct time for controlling aphids successfully (Roy et al., 2014). On the other hand, genetic resistance of aphids to insecticides can be delayed by reducing application frequency and treating only when aphid population override the economic threshold (Hodgson et al., 2012).

The research aims to determine the abundance of *A. fabae* pests in the broad bean crops, estimate their harmfulness and identify the most efficient control times in the conventional farming conditions.

Materials and methods

Experimental site. The experiment was carried at the Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry (55° N lat., 23° E long., 63 m a.s.l.), Akademija, Kėdainiai distr., during the period 2018–2020.

Weather conditions. Monthly air temperatures and precipitation during the growing season months (April to July) were obtained from Dotnuva Meteorological Station, located about 0.5–1.0 km from the experimental site. The maximum and minimum temperature and the total precipitation were recorded every day. Average of temperatures was recorded for every 10 days, and then the average of the three values was calculated.

Field experiment. Field experiment a total of 6 trials was established during 2018–2020. However, the yield data were evaluated only for four trials, because the threshold was not reached and the application according to the trial design was not done in the 2019 season. Three broad bean (*Vicia faba* L.) cultivars were grown: 'Tiffany' in 2018 and 2019, 'Vertigo' and 'Fuego' in 2019 and 2020. Broad bean crops were grown according to the recommended agronomic practices, seed rate – 0.5 million seeds ha⁻¹. The experiment was laid out in a randomized complete block design. The field was divided into equal plots maintaining a size of 10×2.0 m = 20 m², 2-meter block to block distance and 0.25-meter plot to plot distance. Each treatment was allocated randomly within the block and replicated four times.

Occurrence of Aphid fabae. Monitoring of pests was started at the beginning of germination (BBCH 10)

growth stage by using water traps and by counting percent of damaged plants. Assessments of black bean aphid abundance were done four times at growth stages BBCH 60, 69, 74 and 79 in 2018 and two times at BBCH 65 and 69–70 in 2019 and 2020. The abundance of *A. fabae* was recorded for each plot by taking the black bean aphid (*Aphid fabae* Scop.) population (both nymph and adult) on the whole plant from each of randomly selected 20 plants per plot. The number of plants infested by *A. fabae* was recorded at BBCH 79. A total of 25 broad bean plants were evaluated within each plot. The infestation level was calculated by the following formula:

$$IP = P2/P1 \times 100,$$

where IP is percentage of infested plants, P1 – total number of plants checked, P2 – number of infested plants.

To determine the levels of damage to broad bean plants, the percentage of the different infestation densities was estimated at BBCH 79 by plant visual scouting using a scale from 0 to 100 for the total infested area by aphids on the plant, representing 0% healthy plant and 100% completely infested plant.

To identify the best aphid control times, field experiment of 6 trials was done during the three growing seasons. Different control regimes were used: 1) untreated (Un); 2) one spray, when the first aphid insect was caught in the yellow water traps; according to the monitoring data (MD), contact (C) insecticide was used (MDC); 3) one spray at the local recommendation, when 20% of plants are infested by aphids; according to the local threshold (TH), contact (C) insecticide was used (THC); 4) one spray at stem elongation stage (BBCH 30); according to the growth stage (GS), contact (C) insecticide was used (GSC); 5) full control (FC): three sprays at BCH 10–13, BBCH 30 and BBCH 69 growth stages; contact (C) insecticide was used (FCC); 6) one spray at the local recommendation, when 20% of plants are infested by aphids; according to the local threshold, systemic insecticide (THS) was used.

Aphid control according to the described spray regimes was done with contact and systemic insecticides. Specifications of insecticides used are provided in Table 1.

Table 1. Description of insecticides used

Commercial product	Active ingredient	Application rate	Chemical sub-group	Mode of action
Cyperkill 500 EC	cypermethrin 500 g l⁻¹	0.05 l ha⁻¹	pyrethroid	contact
Biscaya OD	thiacloprid 240 g l⁻¹	0.3 l ha⁻¹	neonicotinoid	systemic

Insecticide application date and crop growth stage for each treatment are described in Table 2.

Statistical analysis. The data were recorded and analysed statistically by the software *SAS*, version 7.15 (SAS Institute Inc., USA). The significance of differences was estimated by Duncan's multiple range test at the $P \leq 0.05$ probability level.

Results and discussion

Occurrence of aphids. The general abundance and the incidence period/time of *A. fabae* differed extremely from season to season under the field conditions in the experimental sites. The infestation level on the tested broad bean cultivars differed between the experimental years. In 2018, the winged *A. fabae* individuals were found in the traps in the first week of
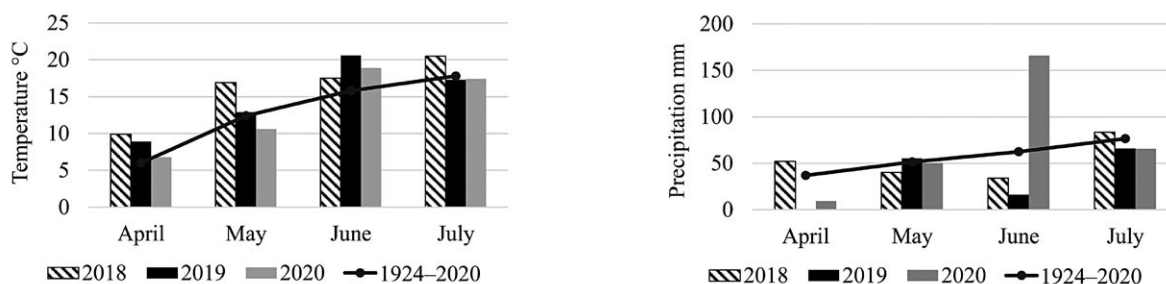
May at BBCH 10, while in 2019 and 2020 they were found in the last week of May at BBCH 15–16 growth stages. The early occurrence in 2018 corresponded with air temperature increasing in April (3.9°C warmer than the long-term means) compared with the other years (Figure 1).

The early spring in 2018 was much warmer than in 2019 and 2020 with less precipitation and lower air humidity; hence, insects during the 2018 were exposed to more favourable conditions compared to the other growing seasons. According to Narjary et al. (2013), the abundance of insect pests may differ due to the amount of heat accumulated, day degrees accumulated and humid thermal ratio, which affect the growth and development of insects. Aphid population on 'Tiffany' increased constantly in 2018 and reached the highest amount at BBCH 74 (six weeks after broad bean emergence).

Table 2. Insecticide application date and broad bean growth stage (BBCH) for *Aphis fabae* control in 2018–2020
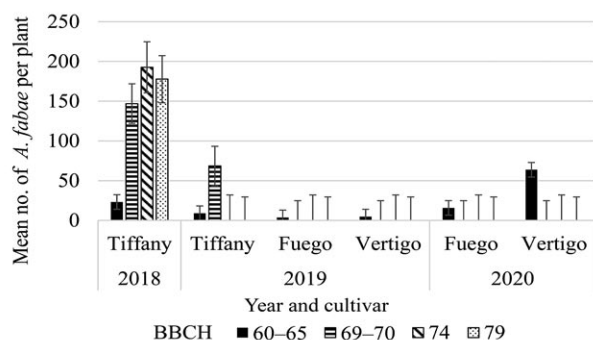
Treatment	Year	Cultivar		
		'Tiffany'	'Fuego'	'Vertigo'
Untreated (control)	2018	–	–	–
	2019	–	–	–
	2020	–	–	–
MDC	2018	04 05, BBCH 10	–	–
	2019	21 05, BBCH 15	23 05, BBCH 15	23 05, BBCH 15
	2020	–	26 05, BBCH 16	26 05, BBCH 16
THC	2018	21 06, BBCH 71	–	–
	2019	12 06, BBCH 63	no*	no*
	2020	–	04 06, BBCH 50	04 06, BBCH 33
GSC	2018	28 05, BBCH 30	–	–
	2019	30 05, BBCH 30	20 05, BBCH 30	20 05, BBCH 30
	2020	–	28 05, BBCH 30	03 06, BBCH 30
FCC	2018	07 05, BBCH 11 28 05, BBCH 30 18 06, BBCH 69	– – –	– – –
	2019	08 05, BBCH 12 30 05, BBCH 30 25 06, BBCH 69	– 	17 05, BBCH 13 24 05, BBCH 30 12 06, BBCH 69
	2020	– – –	30 04, BBCH 10 28 05, BBCH 30 19 06, BBCH 69	04 05, BBCH 10 03 06, BBCH 30 16 06, BBCH 69
THS	2018	21 06, BBCH 71	–	–
	2019	12 06, BBCH 63	no*	no*
	2020	–	04 06, BBCH 50	04 06, BBCH 33

Note. Contact (C) insecticide was used: MDC – according to monitoring data (MD), THC – according to the local threshold (TH), GSC – according to the growth stage (GS), FCC – full control (application at BBCH 10–13, BBCH 30 and BBCH 69); THS – according to the local threshold, systemic insecticide was used; no* – threshold was not reached.

Figure 1. The air temperature and total monthly precipitation during the 2018–2020 growing seasons and the long-term average (1924–2020)

Results of our experiment showed that in the first week of June (at BBCH 30) *A. fabae* population was 21.8 aphids per plant. It gradually increased to the 23ʳᵈ of June to 192.5 aphids per plant, thereafter, the population started to decline. Increasing of *A. fabae* population occurred at the pod formation stage and then started to decline slightly as shown in Figure 2.

These results agree with those of Choudhary et al. (2017), who found that the population of cowpea aphid (*Aphis craccivora* Koch) increased fast with

Figure 2. Population of *Aphis fabae* at different growth stages on broad bean cultivars during 2018–2020

crop growth and reached its peak at the pod formation stage. *A. fabae* population decreased with increasing temperature till 26–28°C for 3 days compared to 20°C, and the apterae produced more nymphs (Dixon, Wratten, 1971). The temperature rise above 15°C is inversely proportional to the abundance of aphids to some extent, as a temperature of 30°C gave the lowest longevity and duration of the immature stages for aphids, where the survival curves declined at an earlier age obviously, when temperatures increased from 20°C to 30°C (Akca et al., 2015). The results agree with those of Kumar and Kumar (2015), who also reported that the population of aphids was influenced negatively by maximum temperature.

The results of our experiment showed that *A. fabae* population differed among the cultivars and among the years for the same cultivar (Figure 2). The highest infestation of *A. fabae* at BBCH 65 was established on 'Tiffany' in 2019 and it was 100% higher than that on 'Fuego' and 'Vertigo'. In one week, at BBCH 69–70 growth stages, on 'Tiffany' the abundance of *A. fabae* increased around 7.5 times from 9 to 68 aphids per plant. While on 'Fuego' and 'Vertigo', *A. fabae* population remained at low abundance (4–5 aphids per plant) during the growing season and dropped to the zero-population density at BBCH 69–70 growth stages. In 2020, 22 days

after the beginning of infestation, at BBCH 65, *A. fabae* was more abundant on 'Vertigo' (63.6 aphids per plant) compared to 'Fuego' (15.7 aphids per plant). A rapid decrease in *A. fabae* population was recorded from mid flowering (BBCH 65) to end of flowering (BBCH 69–70) in 2020 on both the cultivars.

Alyokhin et al. (2011) reported that the population of potato aphids was influenced by the weather effects and negatively affected by predators. Therefore, natural enemies as a seven-spot ladybird (*Coccinella septempunctata* L.) and green lacewing (*Chrysoperla rufilabris* Bur.) may be a reason for the rapid reduction of *A. fabae* population in 2019 and 2020. In our experiment, during the 2019 and 2020, the aphid infestation was at different level on 'Vertigo', while the lowest aphid abundance was established on 'Fuego'. The number of aphids continued to increase on 'Tiffany' till the pod development stage (BBCH 70–74) in 2018 and 2019.

All the tested broad bean cultivars were naturally infested with aphids, and the infestation level was variable. The obtained results suggested that there was significant difference in the aphid population on 'Tiffany' only. The highest mean number of aphids in this cultivar was 146.9 and 68.3 aphids per plant during the 2018 and 2019, respectively. The lowest population was observed on 'Fuego' – 3.7 and 15.7 aphids per plant during the 2019 and 2020, respectively.
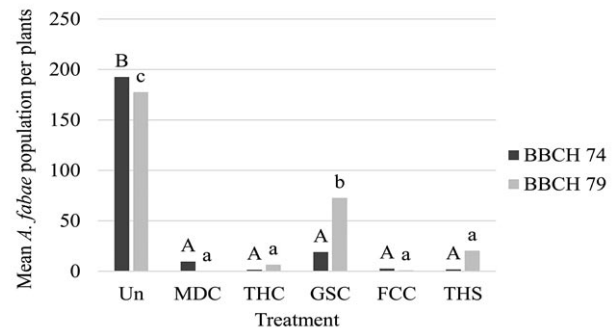
After four years of experiment, Hansen et al. (2008) have concluded that the growing of partially host plant resistant cultivars of field bean will reduce the infestation with black bean aphid. In our experiment, the tested broad bean cultivars also showed different susceptibility to this aphid. As an indicator for establishment of susceptibility to this pest, the intensity of infestation by the mean number of aphids per plant was used. The 'Tiffany' was more infested than the other two tested cultivars 'Fuego' and 'Vertigo'.

Holt and Wratten (1986) found that the concentration of nonprotein amino acids in the leaf and stem extracts was one of the factors, which affected the resistance of broad bean cultivar to *A. fabae*. Resorption of amino acids was much higher in the partially resistant cultivar, which showed little differences in amino acid content and pattern of phloem extracts compared to susceptible cultivars. All of that may depend on genotypes of broad bean cultivars (Ebadah et al., 2006). The population on each cultivar is related to two main parameters, fecundity and longevity of aphids. Meradsi and Laamari (2018) reported that the reproductive period and adult longevity of *A. fabae* on one broad bean cultivar were six times higher than on other cultivar in the same conditions and that led to differences in the number of aphids. Razmjou and Fallahi (2009) found that the population growth characteristics of *A. fabae* can be affected by sugar beet cultivar. In our experiment, 'Fuego' and 'Vertigo' supported a low population density of *A. fabae*, and these tested cultivars can be used as tool for Integrated Pest Management of aphids in the broad bean. But, on the other hand, the environmental conditions (microclimate) may influence the physiological processes of the plant as well as the insect pest, thus the same cultivar can be the most suitable host for aphids in one site and the worst one in another site (Kumar, 1984).

Aphis fabae control. The data on aphid population occurrence at growth stages BBCH 74 and 79 in 2018 and at BBCH 65 and 69–70 in 2019 and 2020 are presented in Figures 3–6.

Based on the monitoring data in the untreated (control) treatment, in 2018 and 2019 on 'Tiffany', aphid population increased regularly until BBCH 74,

then they started declining. But in 2019 and 2020 on 'Fuego' and 'Vertigo', the aphid population plummeted rapidly to zero at BBCH 69–70 growth stages. In 2018, at BBCH 79 *A. fabae* population was significantly lower for all spray regimes compared to the untreated (control) treatment. The population on the plants treated at early growth stage was significantly higher than for other spray regimes. Maiteki and Lamb (1985) found that early insecticide application did not prevent recovery of aphid population in 2–3 weeks. In our experiment, during the 2018 growing season, all insecticide spray regimes significantly affected *A. fabae* population. The application time of insecticides according to monitoring data, growth stage and local threshold showed a similar aphid control level at BBCH 74 (Figure 3).
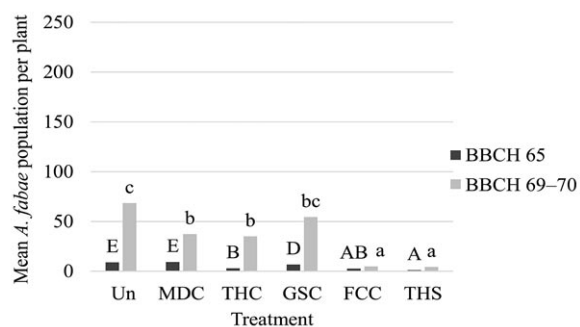
Note. Explanations of treatments under Table 2; columns with the same letter(s) are not significantly different at $P \leq 0.05$.

Figure 3. *Aphis fabae* control by using insecticide at different spay regimes on the broad bean cultivar 'Tiffany' (2018)

Significant differences among the spray regimes were not established at BBCH 74 and 79, except for the application according to growth stage. Application at stem elongation stage (BBCH 30) was done earlier than the other spray regimes; therefore, the efficacy went down more quickly than in the other treatments. Comparable difference in *Acyrthosiphon pisum* population was reported for different spray regimes on field peas (Maiteki, Lamb, 1985), where the aphid population recovery started in a short period after an insecticide spray.
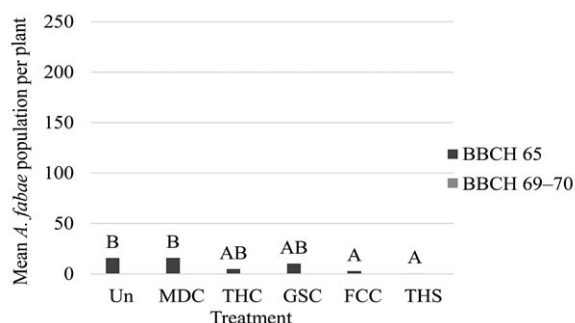
In 2019 on 'Tiffany', all insecticide spray regimes significantly affected *A. fabae* population like in 2018 (Figure 4). The aphid population at BBCH 65 and 69–70 growth stages decreased significantly on the plants treated by contact and systemic insecticide according to the local threshold (THS). On the other hand, on the plants treated by contact insecticide according to the local threshold (THC), the aphid population was significantly higher than on the plants treated by systemic insecticide according to the local threshold. In 2019, a very low *A. fabae* infestation level by was recorded on 'Fuego' and 'Vertigo'. The threshold level was not reached in this growing season. At BBCH 69–70 growth stages, there was zero-population density in all plots.

In 2020 on 'Fuego', the highest rate of aphids was recorded on the untreated (control) plants and where application was done according to the monitoring data (MD): 15.7 and 15.8 aphids per plant, respectively (Figure 5). The best control was seen when the application had been done according to the local threshold. The same control level tendencies were observed on 'Vertigo' also: the best efficacy was established, when contact and systemic insecticides had been used according to the local threshold (Figure 6).
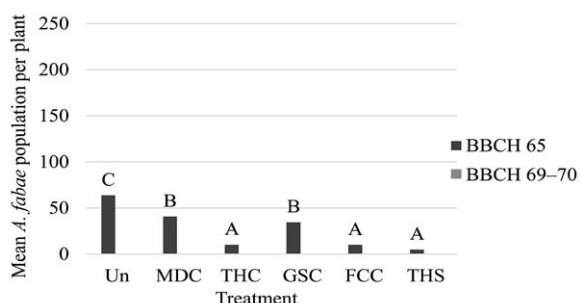
Note. Explanations of treatments under Table 2; columns with the same letter(s) are not significantly different at $P \le 0.05$.

Figure 4. *Aphis fabae* control by using insecticide at different spay regimes on the broad bean cultivar 'Tiffany' (2019)

Note. Explanations of treatments under Table 2; not significantly different at $P \le 0.05$.

Figure 5. *Aphis fabae* control by using insecticide at different spay regimes on the broad bean cultivar 'Fuego' (2020)

Note. Explanations of treatments under Table 2; not significantly different at $P \le 0.05$.

Figure 6. *Aphis fabae* control by using insecticide at different spay regimes on the broad bean cultivar 'Vertigo' (2020)

Similar results were recorded by Kusi et al. (2019), where the abundance of sucking insect pests on cowpea was affected by insecticide spraying time. They found that insecticide sprayed two times gave a lower population of pod sucking bugs compared with sprayed once. The yield loss correlated with the incidence time of the insect pest. Alghali (1992) found that insect pests attacking cowpea at the vegetative stage did less damage than those attacking at the flower bud development stages. Kusi et al. (2019) reported that insecticide applied twice or thrice, which coincided with pod borer thresholds gave effective protection for cowpea.

Results of 2018, 2019 and 2020 for cultivars 'Tiffany', 'Fuego' and 'Vertigo' may be combined, because the response of *A. fabae* to the different insecticide spray regimes was more or less the same for all experimental years, whatever the low *A. fabae* abundance in 2019 and 2020. There were no significant differences of control level at BBCH 74 among the insecticide spray regimes in 2018. However, at BBCH 79, the aphid population slightly recovered in the plots treated at the beginning of stem elongation (the spray regime according to the growth stage, GS) (Figure 5). The reduction in *A. fabae* population by spray regimes according to the local threshold indicates that it is efficient for the pests control (Figure 4).

The data of our experiment showed that at very low aphid level there were no significant differences in efficacy between the insecticides applied according to the different spray regimes. However, at the high abundance of aphids, early application, when the initial migrants of *A. fabae* are arriving at the broad bean field (spray regime according to the monitoring data, MD) may prevent an increase in aphid population. That agrees with the results of Way et al. (1954), who found that early application with insecticides markedly increases the seed yield of broad bean. Hodgson et al. (2012) reported that suitable insecticide timing is decisive for the control of soybean aphid (*Aphis glycines*), and the aphids can recover from insecticide applications in the absence of natural enemies.

In our experiment, spray regime according to the local threshold resulted in a significantly lower aphid population compared to the spray regime according to the monitoring data (when the first aphid insect was caught in the yellow water traps), which did not prevent recovery of aphid population in 2019 and 2020. That may be due to the rapid reproductive rate of aphids (Myers et al., 2005). This agrees with the findings of the study suggesting that the best time for foliar insecticide application to control *A. glycines* and to ensure the highest yield was according to the economic threshold (Ragsdale et al., 2007). Contrariwise, insecticide application late after aphid population had reached the economic threshold will not cover the cost of the insecticides because of the losses in yield (Johnson et al., 2008).

Aphid severity may vary highly from year to year due to the weather conditions that may reduce the severe attack by aphids, even if most broad bean plants were infested by the initial migrants. Other researchers (Leather et al., 2017) reported that the size of aphids' population was varied by diet quality, abiotic environment and plant growth stage. Some species such as *A. pisum* on similar plant hosts showed variability in population density. Over the experimental years, *A. fabae* population was markedly reduced by the insecticides applied once according to the local threshold. The results are comparable to those of Dewar and Denholm (2017), who has reported that the current recommendation for *A. fabae* control is economically justified, if *A. fabae* population exceeds the economic threshold. But he also reported that insecticide application more than once did not produce significant yield increases because of the tolerance of the new cultivars to aphid colonization. So, to avoid undesired negative effects of insecticides on beneficial organisms as the natural enemies, a careful timing of applications can guide to obtain better control of these sap-sucking insects.

Over the experimental years, the lowest percentages of *A. fabae* infested plants at BBCH 79 were found in the plots treated according to the local threshold using systemic insecticide. They significantly reduced the percentage of infested plants compared the other spray regimes. In 2018 on 'Tiffany', the lowest average percentage of infested plants was recorded for the insecticide spray regimes according to the monitoring

data (9.3%) and full control (9.3%), while the growth stage regime had no positive effect (22.1%) (Table 3).

In 2019, the percentages of infested plants were zero on 'Vertigo' in all treatments, even in the untreated (control), and it was very low on 'Fuego' with no significant differences between the insecticide treatments. On 'Tiffany', the lowest percentage of infested plants was given by both full control and threshold spray regimes

(4.25% and 5.25%) with significant differences compared to the other treatments. All the spray regimes significantly reduced the damage percentage on the plants. In 2020, the application according to the local threshold with systemic insecticide (THS) gave the lowest percentage of infested plants on 'Fuego' and 'Vertigo' (2.5% and 6.0%) (Table 3), and the lowest damage percentage (10% and 21%) with significant differences compared to the early

Table 3. Mean percentage of *Aphis fabae*-infested plants of broad bean cultivars in 2018, 2019 and 2020 at BBCH 79 growth stage

Treatment	Percentage of infested plants %					
	2018	2019			2020	
	'Tiffany'	'Tiffany'	'Fuego'	'Vertigo'	'Fuego'	'Vertigo'
Untreated (control)	34.9 ± 2.98 c	36.75 ± 3.52 c	6 ± 1.78 a	0 ± 0.00 a	26 ± 6.28 d	55.5 ± 4.03 c
MDC	9.3 ± 3.94 ab	35.75 ± 1.70 c	4.25 ± 0.48 a	0 ± 0.00 a	13.25 ± 1.65 bc	30 ± 8.49 b
THC	12 ± 4.76 ab	12 ± 1.68 a	–	–	7.5 ± 0.87 abc	9.5 ± 1.85 a
GSC	22.1 ± 2.16 b	25.75 ± 2.25 b	5.5 ± 0.64 a	0 ± 0.00 a	13.5 ± 0.96 bc	19 ± 2.68 ab
FCC	9.3 ± 3.89 ab	4.25 ± 1.03 a	–	0 ± 0.00 a	4.75 ± 0.85 ab	11.75 ± 0.75 a
THS	20 ± 6.87 ab	5.25 ± 0.48 a	–	–	2.5 ± 0.50 a	6 ± 1.08 a

Note. Explanations of treatments under Table 2; means within each column followed by the same letter(s) are not significantly different at $P \leq 0.05$; mean ± SE (standard error).

treatment (application according to monitoring data) (Table 4).

In 2018, all spray regimes reduced the infested area by *A. fabae* on the plant compared to the untreated (control) treatment at BBCH 79 (Table 4). The lowest infested area percentage was recorded in the early treated plants according to the monitoring data (11%) followed by treated according to threshold (18%). There were no significant differences between the application

times. In 2019, the percentages of infested area were zero on 'Vertigo' in the untreated (control) and the other treatments. On 'Fuego', there were no significant differences between the treatments. In 2019 on 'Tiffany', the lowest percentage of infested area was recorded in the plots that had been treated three times (full control, FCC) (14%) and in the plots treated according to the local threshold (16%) with significant differences compared to the other insecticide and untreated (control) treatments.

Table 4. Mean total *Aphis fabae*-infested area per plant of broad bean cultivars in 2018, 2019 and 2020 at BBCH 79 growth stage

Treatment	Aphid-infested area per plant %					
	2018	2019			2020	
	'Tiffany'	'Tiffany'	'Fuego'	'Vertigo'	'Fuego'	'Vertigo'
Untreated (control)	48 ± 3.65 c	42 ± 2.82 cd	11 ± 1.91 a	0 ± 0.00 a	55 ± 6.61 d	82 ± 2.58 d
MDC	11 ± 4.43 ab	51 ± 3.41 d	13 ± 2.51 a	0 ± 0.00 a	35 ± 3.00 c	59 ± 9.71 c
THC	18 ± 7.39 ab	26 ± 3.64 ab	–	–	27 ± 2.52 bc	25 ± 3.00 a
GSC	28 ± 2.82 b	36 ± 1.63 bc	17 ± 2.52 a	0 ± 0.00 a	32 ± 2.83 c	49 ± 5.97 bc
FCC	16 ± 5.66 ab	14 ± 2.58 a	–	0 ± 0.00 a	18 ± 2.58 ab	33 ± 2.52 ab
THS	26 ± 8.41 ab	16 ± 0.00 a	–	–	10 ± 2.00 a	21 ± 3.78 a

Note. Explanations of treatments under Table 2; means within each column followed by the same letter(s) are not significantly different at $P \leq 0.05$; mean ± SE (standard error).

The results can be explained by the fact that the systemic insecticide residues were in the plant tissues with a sufficient concentration to kill a large number of aphids feeding on the sap contaminated with the insecticide (Al-Naser, Ezz Al-dden, 2011). Similar results indicated that neonicotinoid insecticides were highly effective against aphids and reduced their population under the field conditions (Gerami et al., 2012; Abd-Ella, 2014). On the other hand, the lower efficacy of cypermethrin against aphids may be due to its toxicity to ladybirds (coccinellids), which are the main natural enemies against aphids. *A. fabae* population, where the coccinellids are absent, is developing faster than the population attacked by coccinellids (Kindlmann et al., 2015). The toxicity of cypermethrin to coccinellids has been reported by Wagh et al. (2017), while Fitzgerald (2004) reported that that neonicotinoid insecticides did not show detriment to some predators as *Chrysoperla carnea*.

The seed yield did not differ significantly among the treatments. Applications according to the

local threshold with contact and systemic insecticide gave similar grain yield, and it was in line with the full control treatment. This data suggested that the application according to the local threshold ensured sufficient control of aphids and prevented yield loss.

Way et al. (1954) reported that when the *A. fabae* attack was slight, there were no significant differences in seed yield between the insecticidal treatments and the untreated (control) one. The plots treated against aphids gave higher yield, but it did not differ significantly compared to the untreated treatment (Khan et al., 2012).

Conclusions

1. All the tested broad bean cultivars were variably infested with black bean aphid (*Aphis fabae*). The experimental data suggest that among the three cultivars tested, 'Tiffany' was the most susceptible to *A. fabae*, while 'Fuego' and 'Vertigo' supported a low population density of this pest; the latter two cultivars

can be used as a tool for Integrated Pest Management of aphids in the broad bean.

　　2. Insecticides applied according to the local threshold resulted in a significantly lower aphid population compared to that in the untreated (control) treatment, and the efficacy was at a similar level with the full control treatment.

　　3. The data from the four field trials conducted during the three growing seasons suggest that *A. fabae* infestation can result in a grain yield reduction of 0.21 t ha⁻¹. Applications of contact and systemic insecticides according to the local threshold gave a similar yield increase, and it was in line with the full control treatment.

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Pupinių amarų (*Aphis fabae* Scop.) išplitimas ir kontrolė pupose

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Santrauka

Siekiant įvertinti pupinių amarų (*Aphis fabae* Scop.) populiacijos pokyčius priklausomai nuo auginamos veislės ir kenkėjo kontrolės laiko naudojant insekticidus, paprastųjų pupų (*Vicia faba* L.) pasėliuose trejus (2018, 2019 ir 2020) metus buvo vykdytas tikslusis lauko eksperimentas. Augintos trijų veislių – 'Tiffany', 'Fuego' ir 'Vertigo' – pupos. Eksperimento laukeliai buvo išdėstyti 1–2 km atstumu vienas nuo kito. Eksperimento metu buvo taikyti penki purškimo laiko režimai. Amarų populiacija stebėta nuo žydėjimo pradžios iki ankščių vystymosi tarpsnio. Tarp purškimo režimų esminiai skirtumai buvo nustatyti pupinių amarų populiacijos, užkrėstų augalų procento ir pažeidimo procento. *Aphis fabae* išplitimas ant tirtų veislių pupų varijavo. Tyrimo duomenimis, iš trijų tirtų veislių *A. fabae* buvo jautriausios veislės 'Tiffany' pupos, o veislių 'Fuego' ir 'Vertigo' augaluose amarų populiacija buvo negausi. Purškiant pagal žalingumo ribą, amarų populiacija esmingai sumažėjo, lyginant su nepurkštu kontroliniu variantu, o insekticidų veiksmingumas buvo panašus, lyginant su visiška apsauga nuo šio kenkėjo.

Keturių laukelių eksperimento, vykdyto tris auginimo sezonus, duomenimis, pupų pasėlyje išplitus *A. fabae*, grūdų derlius gali sumažėti 0,21 t ha⁻¹. Pagal žalingumo ribą nupurškus kontaktiniu ir sisteminiu insekticidais, grūdų derliaus padidėjimas atitiko visiškos amarų kontrolės variantą.

Reikšminiai žodžiai: *Aphis fabae*, gausumas, vietinė žalingumo riba, insekticidai, *Vicia faba*, derlius.