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Effects of *Artemisia dracunculus* L. Water Extracts on Selected Pests and Aphid Predator *Coccinella septempunctata* L.

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Abstract: The aim of this study was to determine the effects of water extracts of tarragon (*Artemisia dracunculus* L.) on the feeding intensity, mortality, and weight gain of selected pests, i.e., adult pea leaf weevils (*Sitona lineatus* L.), nymphs, wingless females of black bean aphids (*Aphis fabae* Scop.), and L2 and L4 larvae of Colorado potato beetle (*Leptinotarsa decemlineata* Say). In addition, the effect of the tarragon extracts on the voracity of the non-target organism *Coccinella septempunctata* L. L3 larvae was examined. To reduce *S. lineatus* feeding, at least 10% dry matter (DM) extract and 20% fresh matter (FM) should be used. Tarragon water extract has strong aphicidal potential against *A. fabae*, with 84% mortality of nymphs at 30% FM and 78% mortality of wingless females at 10% DM after 108 h of exposure. Aphid nymphs turned out to be more sensitive to the extracts prepared from fresh tarragon than from its dry matter. They were also more sensitive than wingless females. The body weight gain of L2 and L4 larvae of Colorado potato beetle was significantly reduced through the application of 10% and 5% extracts prepared from dry matters, respectively, while extracts prepared from fresh matter turned out to be ineffective. L2 larvae were more susceptible to extracts than L4 larvae, which suggests that they should be used as early as possible in the pest season. No negative influence of the extracts used on the voraciousness of *C. septempunctata* L3 larvae was found.

Keywords: plant extracts; tarragon; biological control; pests; ladybirds

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1. Introduction

In the current agricultural system, pest control is often implemented through the excessive use of agrochemicals, which can pollute the environment and promote the development of resistant pests. In these situations, bio pesticides may represent a better option than synthetic pesticides, enabling the safe control of pest populations. Recently, increased attention has been paid to botanical insecticides as a promising option for replacing agrochemicals in agricultural pest control techniques [1–3]. The use of unrefined plant extracts to combat pests has the advantage of preventing the development of resistance to insecticides due to the presence of several bioactive compounds as well as their low persistence in the environment; since they generally have a low cost of use, they can be implemented by small farms with limited income as well as in organic farming [4–7]. According to the Regulation (EU) 2018/848 of the European Parliament and of the Council [8], it is permissible to use edible parts of plants as well as plant-based traditional herbal preparations (Annex I) in organic farming. Moreover, according to Tavares et al. [9], who reviewed the results of 95 plants that have been shown to have insecticidal properties, ethanol and/or water extracts of these plants are environmentally friendly and the solvents are easily available; therefore, these botanical insecticides can constitute a bridge between raw scientific data and practical reality.

Tarragon (*Artemisia dracunculus* L.) is a perennial, herbaceous plant that is native to a wide area of the Northern Hemisphere, from Eastern Europe across central and eastern

Asia to India, western North America, and south to northern Mexico [10]. In Europe, it is grown mainly as a spice, but it is also used in medicine [11,12]. Tarragon can be eaten fresh or dried. The plant reaches a significant size (up to 150 cm) and grows quickly during the growing season, which is potentially important for enabling the easy acquisition of a significant amount of plant material for self-preparation of the extract. The material can be harvested with an ordinary lawn mower. As the research conducted so far has shown, extracts and essential oils from this plant are used in the control of some pests. Research by Metspalu et al. [13] showed that the extract of this plant prepared with the use of hot water caused 50% mortality of young Colorado potato beetle (*Leptinotarsa decemlineata* Say) larvae. The essential oils of tarragon have been shown to be effective in combating storage pests (*Sitophilus granarius* L. [14], *Callosobrochus maculatus* F. [15,16]), aphids (*Aphis gossypii* Glover), thrips (*Thrips tabaci* L.) [17,18], greenhouse whitefly *(Trialeurodes vaporariorum* Westwood) [19], and the Colorado potato beetle [20]) as well as sanitary pests such as *Calliphora vomitoria* L. [21], *Blatella germanica* L. [22], and *Anopheles stephensi* Liston [23]. The effectiveness of plant extracts depends on, among other things, the method of their preparation, and particularly the solvent used. Typically, alcohol extracts, as well as essential oils, show higher insecticidal effectiveness; however, their preparation is more complicated and more expensive than water extracts. Water extracts, especially those based on cold water, are the simplest and cheapest preparation that farmers are able to prepare themselves. The research carried out so far with the use of aqueous extracts of tarragon showed that they were effective against pea aphid (*Acyrthosiphon pisum* Harris), adult Colorado beetle, and cereal leaf beetles (*Oulema melanopa* L.) [24], which justifies the need to also test them against other economically important pests.

Pea leaf weevil (*Sitona lineatus* L.) is one of the major pests of Fabaceae plants [25]. The semicircular areas of pest feeding on leaves constitute the signs of beetle presence. Moreover, pea leaf weevil larvae cause damage and necrobiosis of root nodules. Black bean aphid (*Aphis fabae* Scop.) is the main polyphagous pest of many agricultural crops. This pest can lead to the death of plants and its occurrence always results in reduced yield quantity and quality [26]. The Colorado potato beetle is the main pest of *Solanum tuberosum* plants in most potato-growing regions of the world. In the absence of control practices, *L. decemlineata* populations can completely defoliate potato plants. Applying insecticides is one of the main methods of controlling this pest. In addition to the negative side-effects of chemical pesticides, such as environmental contamination and the threat to human health, there are several studies indicating resistance of *L. decemlineata* to most classes of insecticides [27]. As such, there is an urgent need to introduce an eco-friendly and effective method to control this pest.

Before introducing a biocide for use, it is necessary to assess its potential impact on non-target organisms, many of which are natural enemies of the pests. So far, very little research has been done on the effects of plant extracts on beneficial organisms and the results are ambiguous [28–30]. Negative effects of some plant extracts were noted in relation to lady beetles [31,32]. Importantly, the toxicity to lady beetles could be higher than for its prey [32]. However, research by Tomescu et al. [29] showed no negative impact of mugworm (*Artemisia absinthium* L.) extract on the presence of larvae of two ladybug species, *Coccinella septempunctata* L. and *Scymnus subvillosus* Goeze, in the colonies of plum-reed aphid (*Hyalopterus pruni* Geoffroi) under field conditions. The effect of extracts on non-target organisms is not necessarily to cause death. The effect may also manifest itself in changes in their voracity [33].

The goals of the investigation were: (a) to determine of the effect of water extracts prepared from dried and fresh tarragon on the feeding intensity, mortality, and weight gain of selected pests, i.e., adult pea leaf weevils, nymphs, wingless females of black bean aphid, and L2 and L4 larvae of Colorado potato beetle; (b) and examination of the effect of tarragon extracts on the voracity of the non-target organism *Coccinella septempunctata* L. L3 larvae.

2. Materials and Methods

2.1. Experimental Design

The experiments were conducted at the University of Agriculture in Krakow in the Department of Microbiology and Biomonitoring under laboratory conditions (at room temperature (24 °C) in day light). Included in the experiment were seven treatments in six replications. The treatments used were as follows:

C—control—redistilled water;
2% DM—2% concentration of dry mater extract;
5% DM—5% concentration of dry mater extract;
10% DM—10% concentration of dry matter extract;
10% FM—10% concentration of fresh matter extract;
20% FM—20% concentration of fresh matter extract;
30% FM—30% concentration of fresh matter extract.

2.2. Extract Preparation

A. dracunculus plants, harvested in June 2020 (cultivated at the University of Agriculture in Krakow, southeastern Poland), were used to prepare the extracts. In the case of dry matter extracts, the collected aerial plant parts were first air-dried and then crushed. In turn, for the fresh matter extracts, plants collected on the same day were used and also crushed before pouring with redistilled water.

Extracts were prepared in concentrations assumed conventionally as 2%, 5%, and 10% for dry matter (DM) (dried above-ground parts of plants [g] + cold redistilled water [mL] in proportions of 2:100, 5:100, and 10:100) and 10%, 20%, and 30% for fresh matter (FM) (fresh above-ground parts of plants [g] + cold redistilled water [mL] in proportions of 10:100, 20:100, and 30:100). The doses were established on the basis of previous experiments (Ref. [23] and preliminary trials), which showed a higher efficiency of extracts prepared on the basis of dry matter than from fresh plant material. For a period of 24 h, the extracts were kept in the dark, and were then filtered through filter paper and immediately used for the experiment.

2.3. Insect Treatment

Insects were taken from cultures maintained in the Department of Microbiology and Biomonitoring, University of Agriculture in Krakow. They were starved for 24 h prior the experiments.

In the case of *S. lineatus*, broad bean leaves (*Vicia faba* L., Bartek cultivar) were soaked for 3 s in the individual extracts or in redistilled water (control) and then dried at room temperature. The test was conducted on Petri dishes (diameter of 9 cm) and the substrate consisted of moist filter paper. For a given treatment, one leaf was placed per each dish, and then the pests were introduced—one specimen of adult *S. lineatus* beetle per each Petri dish. The experiments were conducted separately for males and females. The area of the semicircle-shaped losses in leaves due to feeding of pea leaf weevil beetles was measured initially at 8 h intervals and then once a day nine times; that is, after 8-, 16-, 24-, 32-, 40-, 48-, 56-, 80-, and 104 h from the start of the experiment. The surface area of leaves that were eaten was measured with the use of graph paper. On conclusion of the observations, the values of absolute deterrence index (ADI) were calculated, which included the relationship between the area of leaf consumed by *S. lineatus* in the analyzed treatments and the area of leaf consumed in the control.

$$\mathrm{ADI} = [(\mathrm{K} - \mathrm{T}):(\mathrm{K} + \mathrm{T})] \cdot 100,$$

where K is the average area of leaf consumed by the pest in the control [mm^2] and T is the average area of leaf consumed by the pest in the analyzed treatment [mm^2].

In the case of black bean aphids, the initial procedure (soaking, drying) was the same as for *S. lineatus*. For a given treatment, one broad bean leaf was placed per each dish, and then 10 individuals were placed in each Petri dish. The experiment was conducted separately for wingless females and 6-days old nymphs. Nine observations were performed. Mortality of the insects was investigated every 12 h.

One larvae of Colorado potato beetle together with one potato leaf (*Solanum tuberosum* L., Bella rosa cultivar, prepared in the same way as broad bean leaves) were placed in each Petri dish. The experiment was conducted separately for the L2 and L4 larvae growth stages. The stages (L2 and L4) were determined on the basis of tracking the development of the pest in deliberately managed experimental culture. The weight gain of *L. decemlineata* was measured 6 times at 24 h intervals.

In the case of *C. septempunctata* L. larvae (L3 growth stages—stage determined as in the case of *L. decmlineata* larvae), mock-orange (*Philadelphus coronarius* L.) leaves were used (one leaf per one Petri dish). Along with the leaf, one lady beetle larva and 15 black bean aphid nymphs of identical size (7-day-old) were placed in each dish. The gastric effect of the extracts on the voracity of lady beetle larvae was assessed over a period of 120 h. At the start of the experiment, and at each subsequent 12-h interval, fresh aphids were added to each Petri dish after determining the number of aphids eaten by noting the number of living and dead aphids. Dead aphids were not included as eaten aphids. Aphids were added in numbers to restore the number in each Petri dish at the start of each 12-h period. For example, an observation of seven living aphids and three dead aphids was taken to correspond to five aphids eaten. The number of aphids restored at each segment of the experiment time was initially 15; however, when larvae became more voracious and consumed 14 or 15 aphids in a 12-h period, the number of aphids was increased to 20. If 20 or 25 aphids were consumed, this number was increased further to 25 or 30 aphids in the later 12-h periods in the experiment. The protocol for each control of the Petri dishes was as follows: after determining the number of aphids eaten, aphids were replaced using a fine moistened brush to transfer them to the dish. In general, the transfer of all aphids to the mock leaf was attempted followed by spraying of the leaf on both sides to achieve the best possible coverage of the aphids with the extract or redistilled water. Care was taken to relay the mock leaf on the Petri dish with as large a gap as possible between the leaf surface and the petri dish, to avoid the drowning or suffocation of the aphids.

The filter paper in Petri dishes in all experiments was moistened if necessary to prevent drying the leaves.

2.4. Statistical Analysis

Collected data were subjected to statistical analysis by using the SPSS software (Ver. 20, IBM Corporation, New York, NY, USA). The significance of the differences between means was tested via one-way ANOVA (the study factor was extract type—prepared from fresh matter or dry matter and at different concentrations) and the means were differentiated using the Tukey test at the significance level of $\alpha = 0.05$.

3. Results

3.1. Effect of Extracts on Sitona lineatus L. Feeding

The feeding of *S. lineatus* on broad bean leaves was influenced by the application of various concentrations of tarragon extracts (Tables S1 and S2). However, the intensity of this effect depended on the concentration of the extract, the sex of the pest, and the time from the start of experiment. The 20% and 30% fresh matter extracts and the 10% dried matter extract of tarragon significantly limited the feeding intensity of male pea leaf weevils throughout almost the whole duration of the experiment (Table 1). The treatment that received 5% dry matter extract also significantly reduced the surface area of the leaf eaten by males; however, the effect was weaker and not always statistically significant. The 2% dried and 10% fresh extracts of the plant did not cause any significant reduction in the feeding by males, except for the first few hours of the experiment (8–16 h and 8–24 h, respectively). Female pea leaf weevils generally consumed more leaf area than males. After 104 h, the surface area of the host leaf eaten by one female of the control treatment was by

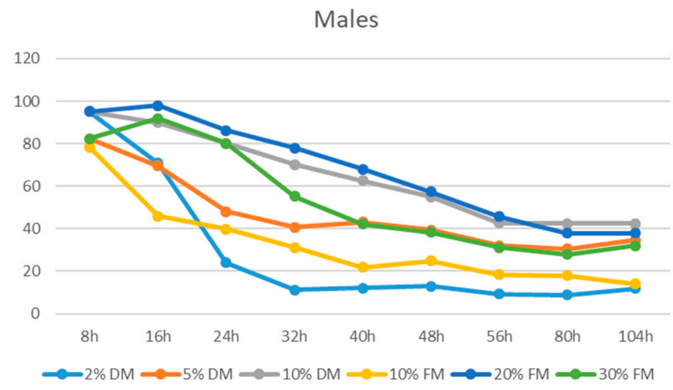
36 mm^2 higher than that eaten by one male. The first significant effect of the tested extracts on female feeding was identified after 16 h from the start of the experiment. The 20% and 30% fresh extracts of *A. dracunculus* significantly reduced the surface area eaten by females on most of the observation dates (Table 1). A significant effect of the 10% dry matter extract was observed only after 40 h from the start of the experiment. The 2% and, in most cases, the 5% dried matter extracts of the plant did not cause any significant reduction in the feeding intensity of females. The significant (negative) effect of the 10% fresh matter extract was observed only at particular times in the experiment (at the beginning and after 40, 48, and 80 h).

Table 1. The surface area of places eaten in broad bean leaves by males and females of *Sitona lineatus* L. [mm^2] after the application of the water extracts made from fresh (FM) and dried (DM) matter of tarragon.

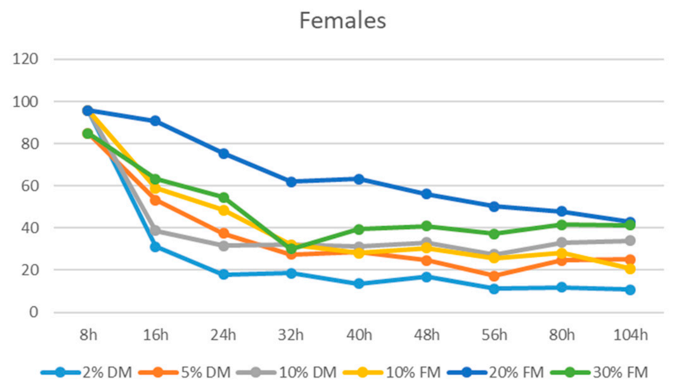
Treatments		Surface Area (mm^2) Eaten by One Male after								
		8 h	**16 h**	**24 h**	**32 h**	**40 h**	**48 h**	**56 h**	**80 h**	**104 h**
	Control	3.21 (±1.4) b*	7.37 (±1.6) b	10.75 (±1.8) c	16.54 (±3.2) c	21.49 (±2.8) c	27.6 (±2.7) b	31.29 (±2.8) b	37.40 (±1.7) c	45.80 (±1.1) c
DM	2%	0.08 (±0.1) a	1.26 (±0.4) a	6.59 (±1.0) bc	13.18 (±3.8) bc	16.87 (±3.7) bc	21.25 (±3.6) ab	26.02 (±2.5) ab	31.38 (±2.5) bc	36.08 (±2.7) bc
	5%	0.31 (±0.3) a	1.33 (±0.8) a	3.76 (±1.5) ab	6.98 (±2.4) abc	8.55 (±2.5) ab	12.00 (±3.6) a	16.08 (±4.1) ab	19.93 (±3.9) ab	22.28 (±4.5) ab
	10%	0.08 (±0.1) a	0.39 (±0.3) a	1.18 (±0.9) ab	2.90 (±1.2) ab	4.94 (±1.5) ab	8.00 (±1.7) a	12.56 (±2.4) a	15.15 (±2.7) a	18.52 (±2.2) a
FM	10%	0.39 (±0.3) a	2.74 (±1.8) a	4.62 (±1.9) ab	8.70 (±1.1) abc	13.79 (±2.4) abc	16.62 (±2.5) ab	21.56 (±2.9) ab	26.00 (±2.8) abc	34.49 (±3.4) bc
	20%	0.08 (±0.1) a	0.08 (±0.1) a	0.79 (±0.4) a	2.04 (±1.1) a	4.08 (±1.7) a	7.45 (±1.0) a	11.69 (±1.8) a	16.87 (±2.3) ab	20.64 (±2.8) ab
	30%	0.31 (±0.3) a	0.31 (±0.3) a	1.18 (±0.6) ab	4.78 (±2.2) ab	8.71 (±3.8) ab	12.32 (±5.0) a	16.39 (±6.5) ab	21.10 (±5.7) ab	23.62 (±5.8) ab
		Surface Area (mm^2) Eaten by One Female after								
	Control	3.21 (±2.3) a	9.62 (±2.6) b	15.83 (±3.5) c	22.51 (±3.1) b	30.60 (±3.5) c	39.94 (±5.9) b	45.81 (±3.5) c	69.61 (±9.7) c	81.89 (±11.7) b
DM	2%	0.07 (±0.1) a	5.04 (±1.6) ab	11.01 (±1.2) bc	15.44 (±2.1) ab	23.24 (±3.5) bc	28.46 (±4.3) ab	36.55 (±4.0) bc	54.88 (±8.5) bc	65.87 (±10.4) ab
	5%	0.26 (±0.3) a	2.94 (±1.0) a	7.20 (±2.0) abc	12.82 (±2.8) ab	17.01 (±2.4) ab	24.14 (±3.6) ab	32.25 (±5.7) abc	42.00 (±6.5) abc	48.97 (±6.4) ab
	10%	0.07 (±0.1) a	4.25 (±0.6) ab	8.24 (±1.6) abc	11.58 (±1.9) ab	16.03 (±2.1) ab	20.08 (±2.7) a	26.04 (±2.9) ab	35.06 (±3.8) ab	40.43 (±4.3) a
FM	10%	0.07 (±0.1) a	2.49 (±1.0) a	5.50 (±2.0) ab	11.58 (±4.4) ab	17.14 (±3.2) ab	21.26 (±4.2) a	27.08 (±5.5) abc	39.12 (±5.9) ab	53.84 (±8.8) ab
	20%	0.07 (±0.1) a	0.46 (±0.3) a	2.22 (±1.3) a	5.30 (±2.2) a	6.87 (±2.2) a	11.25 (±2.9) a	15.18 (±3.9) a	24.60 (±6.2) a	32.71 (±5.6) a
	30%	0.26 (±0.3) a	2.16 (±0.8) a	4.64 (±1.0) ab	12.10 (±2.6) ab	13.28 (±3.1) ab	16.75 (±3.7) a	21.00 (±4.4) ab	28.72 (±4.4) ab	34.02 (±4.5) a

* Values for individual dates of observations and sexes marked by different letters are statistically different (α = 0.05).

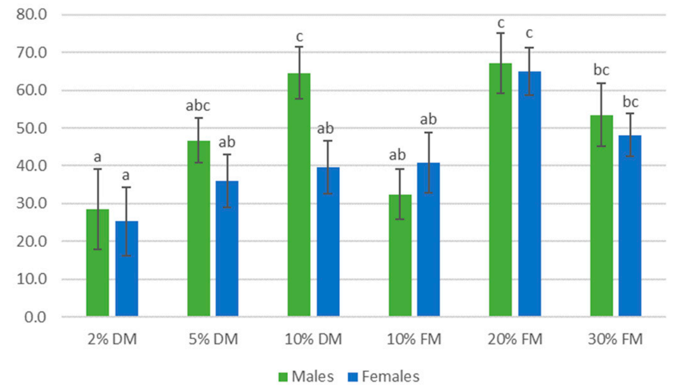
In all extract treatments, the ADI for both male and female pea leaf weevils was a positive value. This indicates the inhibitory effect of the applied extracts on the feeding intensity of the examined insect pests (Figure 1). The strongest deterrent effect was observed for the 10% dry and 20% fresh matter extracts for males (Figure 1a) and the 20% fresh matter extract for females (Figure 1b). With the passage of time from the beginning of the experiment, the deterrent properties of the extracts gradually decreased (Figure 1a,b). In the case of extracts prepared from dry matter, it was seen that the higher the concentration of the extract, the stronger its deterrent effect (Figure 1c, Table S3). The effect was also stronger for males than for females. In the case of extracts prepared from fresh matter, the trends were not so clear; for example, the extract with the highest concentration (30%) had slightly weaker (not statistically significant) deterrent properties than the one with the average concentration (20%). Moreover, the weakest fresh matter extract (10%) was characterized by slightly higher deterrent properties for females than for males.



(**a**)



(**b**)



(**c**)

Figure 1. Absolute deterrence index (ADI) of fresh and dry matter extracts of tarragon at various concentrations for males (**a**) and females (**b**) of *Sitona lineatus* L. at respective hours of the experiment and the mean for all dates of observations (**c**). Means ± SE for individual sexes that are marked by different letters are statistically different (α = 0.05). DM, dry matter; FM, fresh matter.

3.2. Effect of Extracts on Aphis fabae Scop. Mortality

The analysis of variance revealed that the mortality of black bean aphid was significantly ($p \leq 0.05$) influenced by tarragon extracts (Tables S4 and S5). The first significant effects on the mortality of black bean aphid nymphs were identified after 24 h from the start of the experiment (in the case of 20% and 30% fresh matter extracts). The extract prepared from the fresh matter of tarragon at a concentration of 30% had the strongest effect and significantly increased the mortality of this pest throughout the entire experiment (Table 2), followed by the dry matter extract at a concentration of 10%. In the final hours of the experiment, i.e., after 108 h, the mortality in those treatments was around three times higher than in the control. A statistically significant effect of the 10% and 20% fresh matter concentrations on the mortality of nymphs was observed only after 60 h. The 2% and 5% dry matter extracts had a non-significant impact on the mortality of this insect. The application of aqueous extracts of dried and fresh tarragon also led to the increased mortality of wingless females of black bean aphid (Table 2). Results of the statistical analysis indicated that the 10% dry matter extract caused the greatest increase in mortality, followed by the 5% dry matter extract, and the 20% and 30% fresh matter extracts. A non-significant effect on the mortality of adult black bean aphids was observed for the 10% fresh matter extract, while the 2% dry matter extract increased mortality of wingless females only after 96 h of the experiment. The results also indicated that the influence of extracts on the mortality of nymphs was stronger than on wingless females. At the end of the experiment, the mortality for the treatments with strongest activity was around three and two times higher than in the control for nymphs and adults, respectively.

Table 2. Mortality of the *Aphis fabae* Scop. nymphs and wingless females [mean number of dead individuals out of ten at the beginning of the experiment] feeding on broad bean leaves after the application of water extracts made from fresh (FM) and dried (DM) parts of tarragon.

Treatments		Mortality of Nymphs after								
		12 h	**24 h**	**36 h**	**48 h**	**60 h**	**72 h**	**84 h**	**96 h**	**108 h**
	Control	0.20 (±0.20) a*	0.40 (±0.24) a	0.80 (±0.37) a	1.20 (±0.20) a	1.20 (±0.20) a	1.60 (±0.24) a	2.00 (±0.32) a	2.60 (±0.60) a	2.60 (±0.60) a
DM	2%	0.60 (±0.24) a	1.60 (±0.51) ab	2.40 (±0.40) ab	3.00 (±0.6) abc	3.40 (±0.7) ab	3.40 (±0.7) ab	4.00 (±0.71) ab	4.20 (±0.66) ab	4.40 (±0.8) ab
	5%	0.80 (±0.37) a	1.40 (±0.51) ab	2.40 (±0.51) ab	2.60 (±0.51) ab	3.20 (±0.49) ab	4.20 (±0.58) abc	4.60 (±0.40) ab	5.00 (±0.45) abc	5.40 (±0.51) abc
	10%	0.80 (±0.20) a	2.40 (±0.24) b	3.00 (±0.45) ab	4.80 (±0.86) bc	5.80 (±0.86) b	6.20 (±0.73) bc	6.60 (±0.75) bc	6.80 (±0.80) bc	7.80 (±0.66) c
FM	10%	0.60 (±0.24) a	1.40 (±0.40) ab	2.80 (±0.58) ab	4.40 (±0.87) abc	5.80 (±1.02) b	6.00 (±1.14) bc	6.40 (±1.03) bc	6.80 (±0.97) bc	6.80 (±0.97) bc
	20%	0.80 (±0.37) a	2.40 (±0.24) b	3.40 (±0.40) ab	4.00 (±0.71) abc	5.20 (±0.73) b	5.40 (±0.68) bc	6.20 (±0.58) bc	6.40 (±0.51) bc	6.60 (±0.68) bc
	30%	1.40 (±0.24) a	2.40 (±0.40) b	5.00 (±1.14) b	6.20 (±1.32) c	6.60 (±1.12) b	7.20 (±0.86) c	7.80 (±0.58) c	7.80 (±0.58) c	8.40 (±0.51) c
		Mortality of Wingless Females after								
	Control	0.00 (±0.00) a	0.33 (±0.21) a	0.83 (±0.17) a	1.33 (±0.21) a	2.50 (±0.22) a	2.83 (±0.17) a	3.17 (±0.17) a	3.33 (±0.21) a	3.33 (±0.21) a
DM	2%	0.00 (±0.00) a	0.83 (±0.17) a	1.67 (±0.21) ab	2.33 (±0.42) ab	3.50 (±0.34) a	4.33 (±0.21) ab	5.33 (±0.21) ab	6.00 (±0.26) bc	6.17 (±0.31) bc
	5%	0.33 (±0.21) a	1.00 (±0.26) a	1.83 (±0.48) ab	3.33 (±0.56) ab	4.17 (±0.48) a	5.00 (±0.73) ab	5.83 (±0.70) b	6.83 (±0.48) c	6.83 (±0.48) c
	10%	0.17 (±0.17) a	0.83 (±0.17) a	2.17 (±0.42) b	4.00 (±0.26) b	5.17 (±0.48) a	6.00 (±0.45) b	6.83 (±0.31) b	7.17 (±0.17) c	7.83 (±0.31) c
FM	10%	0.33 (±0.21) a	0.83 (±0.17) a	1.83 (±0.48) ab	2.50 (±0.34) ab	3.83 (±0.31) a	4.50 (±0.34) ab	4.50 (±) 0.34ab	4.67 (±0.33) ab	4.83 (±0.31) ab
	20%	0.33 (±0.21) a	0.50 (±0.22) a	1.67 (±0.49) ab	3.00 (±0.82) ab	4.50 (±0.96) a	5.00 (±0.93) ab	5.33 (±) 0.99ab	6.67 (±0.49) c	6.83 (±0.54) c
	30%	0.00 (±0.00) a	0.83 (±0.17) a	2.17 (±0.54) ab	2.67 (±0.49) ab	4.17 (±0.83) a	5.00 (±0.93) ab	5.50 (±0.81) ab	6.17 (±0.70) bc	6.83 (±0.54) c

* Means ± SE for individual dates of observations marked by different letters are statistically different (α = 0.05).

3.3. Effect of Extracts on Colorado Potato Beetle Larvae Body Weight Gain

The body weight gain of Colorado potato beetle larvae was also significantly ($p \leq 0.05$) influenced by the application of tarragon extracts (Table 3, Tables S6 and S7). The treatment with the highest concentration of dry matter extract (10%) had the strongest effect and significantly reduced the body weight gain of the L2 growth stage throughout the entire experiment (except for the first observation), even reaching negative values after 120 and 144 h (which means that the body weight at those hours were lower than at the beginning of the experiment). The 5% dry matter extract limited the body weight gain of L2 larvae after 96 h, while the 2% dry matter extract did not affect this parameter. With the exception of the 30% fresh matter extract at 48, 72, and 120 h, the extracts prepared from fresh matter had a statistically insignificant impact on the body weight gain of L2 larvae. In the case of L4 larvae, the results were not so unambiguous. The limiting effect was not clearly correlated with the increasing concentration of the extract and it was much weaker than in the case of L2 larvae. The 5% dry matter extract adversely influenced L4 body weight gain, giving a reduction of almost 50% after 144 h compared to the control. Similarly, the 20% fresh matter extract reduced the body weight gain of L4 larvae after 144 h of the experiment by a factor of 1.5. The non-significant impact was observed for the 10% and 30% fresh matter extracts, as well as the 2% and 10% dry matter extracts.

Table 3. Body weight gain of *Leptinptarsa decemlineata* (Say) larvae [mg] after the application of the water extracts made from the fresh (FM) and dried (DM) parts of tarragon.

	Treatments	L2 Body Weight Gain (mg) after					
		24 h	**48 h**	**72 h**	**96 h**	**120 h**	**144 h**
	Control	8.6 (±3.67) a*	17.8 (±5.95) b	21.4 (±6.09) b	25.0 (±6.52) c	27.4 (±6.93) c	29.4 (±7.35) c
DM	2%	5.0 (±1.67) a	8.4 (±1.40) ab	15.6 (±3.30) ab	18.4 (±3.56) bc	20.8 (±3.43) bc	24.0 (±3.36) bc
	5%	3.4 (±2.56) a	4.4 (±4.41) ab	6.6 (±4.63) ab	5.6 (±5.82) ab	4.8 (±7.26) ab	−0.4 (±9.33) a
	10%	2.4 (±0.75) a	2.0 (±2.39) a	2.4 (±2.09) a	−2.0 (±3.11) a	−5.8 (±3.07) a	−7.8 (±2.85) a
FM	10%	6.4 (±0.81) a	10.0 (±1.58) ab	12.2 (±1.46) ab	14.4 (±1.96) abc	15.6 (±2.16) bc	18.0 (±2.30) bc
	20%	6.2 (±1.11) a	9.6 (±1.69) ab	12.6 (±1.83) ab	14.0 (±3.78) abc	11.8 (±5.12) abc	8.2 (±7.33) abc
	30%	0.6 (±1.57) a	3.0 (±2.30) a	5.6 (±2.38) a	6.4 (±2.44) abc	6.2 (±1.83) ab	5.6 (±0.93) abc
		L4 Body Weight Gain (mg) after					
	Control	11.0 (±1.81) a	20.2 (±2.91) a	26.2 (±2.68) b	32.7 (±3.03) b	37.3 (±3.03) c	42.0 (±3.18) c
DM	2%	8.7 (±1.48) a	16.3 (±3.19) a	21.2 (±2.98) ab	26.3 (±3.00) ab	30.7(±3.13) abc	35.2 (±3.09) abc
	5%	5.7 (±1.15) a	11.0 (±1.46) a	13.7 (±1.74) a	17.3 (±2.09) a	19.7 (±2.22) a	22.3 (±2.50) a
	10%	7.3 (±2.11) a	14.2 (±2.94) a	19.7 (±2.86) ab	24.8 (±2.64) ab	29.5(±2.64) abc	32.2 (±2.83) abc
FM	10%	9.7 (±1.38) a	19.0 (±2.48) a	25.2 (±3.38) ab	31.7 (±3.41) b	36.2 (±2.89) bc	41.0 (±2.78) bc
	20%	6.2 (±1.11) a	12.3 (±1.94) a	17.2 (±2.32) ab	22.5 (±3.31) ab	24.3 (±3.12) ab	28.5 (±3.16) ab
	30%	7.2 (±1.01) a	15.3 (±2.78) a	20.8 (±2.71) ab	26.2 (±3.42) ab	29.8(±3.25) abc	34.0 (±3.27) abc

* Means ± SE for individual dates of observations marked by different letters are statistically different (α = 0.05).

3.4. Effect of Extracts on the Voracity of Coccinella septempunctata L. Larvae

The number of aphids eaten by one L3 larvae of *C. septempunctata* after the application of tarragon extracts did not differ significantly from the control for any treatment or time interval in the experiment (Tables 4 and S8). The number of aphids eaten in a 12-h interval increased as the experiment progressed. Although no statistically significant differences were noted in the quantities eaten on the individual observation dates, the analysis of the means from all observation dates revealed an increase in the number of aphids eaten by ladybug larvae exposed to 5% DM and 10% FM extracts, while other extracts showed no significant effect compared to the control (Figure 2, Table S9).

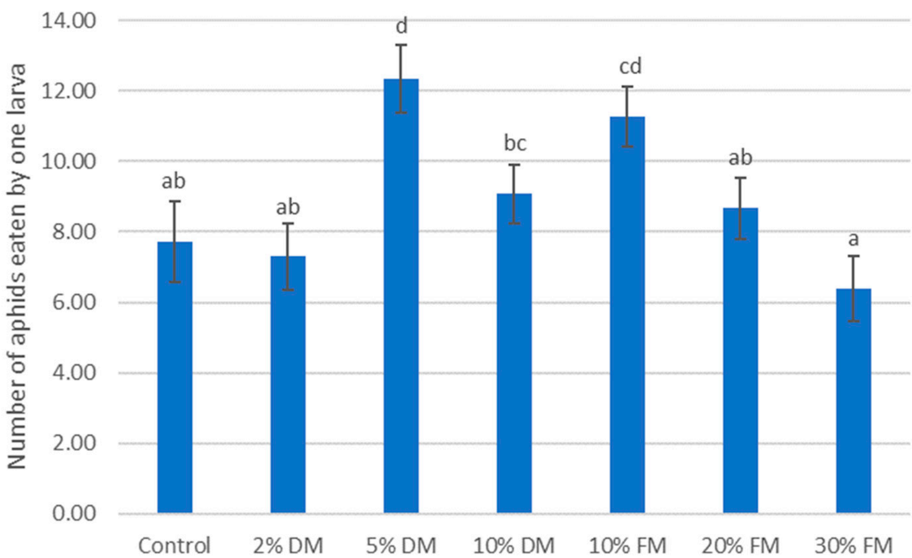


Figure 2. Mean number of aphids eaten by one L3 larvae of *C. septempunctata* during the period of observation (12 h) after the application of water extracts made from the fresh (FM) and dried (DM) parts of tarragon. Means ± SE marked by different letters are statistically different (α = 0.05).

Table 4. Number of aphids eaten by one L3 larvae of *Coccinella septempunctata* L. after the application of water extracts made from the fresh (FM) and dried (DM) parts of tarragon.

Treatments		Number of Aphids Eaten by One L3 Larvae after								
		24 h	**36 h**	**48 h**	**60 h**	**72 h**	**84 h**	**96 h**	**108 h**	**120 h**
	Control	4.17 (±0.60) a*	3.67 (±0.92) a	7.17 (±2.57) a	2.33 (±1.12) a	6.50 (±2.45) a	7.83 (±3.25) a	12.33 (±4.22) a	11.83 (±5.52) a	13.67 (±4.79) a
DM	2%	4.33 (±0.95) a	6.00 (±2.37) a	9.00 (±3.15) a	6.50 (±4.25) a	12.00 (±3.88) a	6.50 (±1.95) a	9.83 (±3.10) a	6.00 (±3.12) a	5.50 (±2.31) a
	5%	3.83 (±1.49) a	8.33 (±0.80) a	11.17 (±1.08) a	8.33 (±2.11) a	14.00 (±0.45) a	11.33 (±1.12) a	17.17 (±2.09) a	18.17 (±3.90) a	18.83 (±4.04) a
	10%	6.67 (±0.99) a	5.67 (±0.99) a	7.67 (±1.36) a	8.17 (±1.83) a	8.50 (±2.16) a	8.17 (±2.83) a	12.17 (±2.55) a	11.50 (±3.44) a	13.17 (±4.24) a
FM	10%	6.17 (±0.79) a	4.17 (±1.96) a	10.37 (±0.80) a	8.83 (±2.09) a	11.17 (±1.08) a	11.67 (±2.43) a	17.00 (±1.57) a	16.00 (±1.65) a	15.83 (±3.91) a
	20%	5.50 (±1.38) a	3.83 (±1.45) a	9.67 (±0.99) a	6.83 (±2.09) a	9.50 (±2.03) a	8.83 (±2.39) a	12.67 (±2.86) a	9.17 (±3.59) a	12.00 (±4.20) a
	30%	6.17 (±1.17) a	5.00 (±2.05) a	5.33 (±2.25) a	6.50 (±2.72) a	6.17 (±3.39) a	8.33 (±3.82) a	7.17 (±3.38) a	5.00 (±2.88) a	7.83 (±3.82) a

* Means ± SE for individual dates of observations marked by different letters are statistically different (α = 0.05).

4. Discussion

The study indicated that a statistically significant effect of water extracts of *A. dracunculus* on *S. lineatus* depends on the concentration of the extract, method of extract preparation (using fresh or dry matter), and sex of the studied insects. The foraging of males of *S. lineatus* was limited to the greatest extent under the influence of the 10% dry matter extract, while the effect on females was greatest under the influence of an extract prepared from fresh matter in concentrations of 20% and 30%. Similar differences in the response of females and males were noted when testing the effect of fennel (*Foeniculum vulgare* Mill.) seeds [34] and lemon balm (*Melissa officinalis* L.) [35] extracts. There are no scientific publications available regarding the impact of aqueous extracts of tarragon on the feeding behavior of *S. lineatus*. As a comparison, aqueous sage (*Salvia officinalis* L.) extract showed the strongest effect on both male and female *S. lineatus* at the highest concentration (30%) prepared from fresh mass, followed by a 10% extract prepared from dry matter [36]. The leaf area eaten by this pest after 108 h of the experiment in the treatment with 30% FM sage extract was nearly three times lower than in the control (for both males and females). In the case of the 30% FM tarragon extract, this value was approximately two times and 2.5 times lower than in the control for males and females, respectively, which indicates a slightly weaker insecticidal potential of this extract than that of sage. The ADI values in this experiment ranged from 28 to 68 depending on the concentration of the extract used and the sex of the pest, reaching a maximum value for males for the 10% DM and 20% FM extracts and for females with the 20% FM extract. This indicates similar deterrent properties to fennel seed extracts (maximum 70 for males under 20% dry matter extract) [34] and lemon balm (maximum 68 for females under 10% dry matter extract) [35] and slightly stronger than with the aqueous extract of *Tanacetum vulgare* L. (50 for males under 10% dry matter extract) [37].

Hence, in this study, the insecticidal properties of *A. dracunculus* extracts on the mortality of wingless females and nymphs of black bean aphid were studied. The results showed that mortality depended on exposure time, developmental stage, concentration, and method of extract preparation. According to recent findings on the insecticidal activity of *A. dracunculus* extracts against aphids, the water extracts prepared from dry (5% and 10%) and fresh (20% and 30%) matter caused a significant increase in mortality of wingless females and nymphs of pea aphid (*Acyrthosiphon pisum* Harris) after only 12 h from the start of the experiment [24]. After 96 h of exposure, these extracts caused between 86.7–100.0% mortality of *A. pisum* wingless females and 100.0% mortality of *A. pisum* nymphs. At the same point in our experiment, the same treatments caused 61.7–71.7% mortality of wingless females of *A. fabae* and 50.0–78.0% mortality of *A. fabae* nymphs, which suggests a slightly lower sensitivity of *A. fabae* to the tested extracts. Comparing with results obtained by

Mousavi and Valizadegan [18], who studied the insecticidal properties of *A. dracunculus* essential oil (used as fumigant) against adult of *Aphis gossypii* Glover under laboratory conditions, our water extracts seem to be quite effective. The results of these studies showed that the essential oil of *A. dracunculus* had a strong impact on the mortality of *A. gossypii*, with LT_{50} and LC_{50} values found to be 10.74 h and 18.63 µL/L of air, respectively. Lebbal et al. [38] investigated the insecticidal properties of water extracts (prepared with the use of cold or hot water) from *Pistacia atlantica*, *Marrubium vulgare*, and *Thymus algeriensis* against *A. fabae* nymphs, achieving the best results after 24 h (70% mortality in the treatment with the extract in relation to 20% mortality in the control) with the 25% dry matter extract of *Thymus algieriensis*, which was prepared in the same way as in our study, i.e., with cold water. In our case, the highest concentration prepared from dry matter was 10% and after 24 h, we achieved 24% mortality of aphid nymphs (with 4% mortality in the control), which puts the effectiveness of the aqueous extract of *A. dracunculus* at a similar level to *T. algieriensis*. For the comparison with *P. atlantica* and *M. vulgare*, water extracts had no significant aphicidal activity. On the other hand, the ethanol extract (prepared for 3 days) from a plant systematically similar to tarragon, *Artemisia judaica* L., showed very high effectiveness against *A. fabae* [39]. Ninety-six hours after application, 100% aphid mortality was achieved at the dose of 1.56 mg/mL.

The present research showed that the water extracts prepared from *A. dracunculus* dry matter in the concentration of 10% inhibited the body weight gain of L2 larvae of Colorado potato beetle the most. After 144 h from the beginning of the experiment, the average weight of the L2 larva in the treatment with the 10% dry extract was, on average, 7.8 mg lower than at the beginning of the experiment, while in the control after that time, the body weight of the larva was higher by 29.4 mg compared to the beginning. Weaker effects were obtained at the 5% concentration of dry matter and in the case of extracts prepared from *A. dracunculus* fresh matter. So far, some research has been carried out regarding the use of tarragon extracts on adults of Colorado potato beetles [24] showing, as in the present study, that only the dry matter extract limited the pest's feeding. There is no information in the available literature on the use of *A. dranunculus* aqueous extracts against the Colorado beetle larvae. A water extract prepared from a systematically close *Artemisia annua* used against *Mythimna separata* turned out to be one of the most effective of all tested water extracts and not much weaker than the insecticide Dichlorvos 76 EC [40]. Comparing the potential of *A. dracunculus* aqueous extracts in inhibiting weight gain of the Colorado beetle L4 larvae with the aqueous extract from wild thyme [41], the tarragon extract was significantly weaker. After 60 h from the beginning of the experiment, a 10% thyme dry matter extract reduced the body weight of L4 larvae by an average of 30 mg comparing to control, while in a similar period (i.e., after 72 h), the 10% DM *A. dranunculus* extract decreased L4 larvae body weight gain by only 6 mg.

There is little information in the available literature on the effects of plant extracts (water, acetone, or ethanol as solvents) used against pests on non-target organisms [28,29,32,41]. The results of these studies indicate the possibility of a negative effect of ethanol or acetone extracts, but not that of water extracts, on beneficial organisms. In particular, Kumral et al. [32] showed that the ethanol extract of *Datura stramonium* L. was lethal for both the harmful mite *Panonychus ulmi* (Koch.) and its predator *Stethorus gilvifrons* (Muls.) (Col.: Coccinellidae). Di Chiara et al. [28], by testing the water and acetone extracts of *Annona cherimola* Mill., *Melia azedarach* L., *Artemisia absinthium* L., and *Quassia* spp. against *Tetranyus urticae* Koch. and its predator *Cydnodromus califiornicus* (Mc Gregor), showed that acetone extracts from some plants were as toxic to the pest as it was to its predator, whereas water extracts from *Melia* and *Artemisia* were harmless to *C. californicus*, although toxic to *T. urticae*. Nettle water extract did not have a negative effect on the biological characteristics and population parameters of the aphid predator *Macrolophus pygmaeus* (Rambur), although it effectively limited the fertility of *Myzus persicae* (Sulzer) [42]. The aqueous extract of *Artemisia absinthium* used in field conditions did not significantly affect the useful entomofauna (*Scymnus subvillosus* Goeze, *Coccinella septempunctata* L., and *Aphidoletes aphidiomyza* Rond.) occurring in the colonies of

Hyalopterus pruni Geoffroi [29]. The results obtained by us confirm the above-mentioned results that there is no negative impact of water extracts prepared from *A. dranunculus* on predatory insects. The voracity of L3 *C. septempunctata* larvae against aphids exposed to water extracts of *A. dranunculus* was at a similar level as against the control and, in some cases (5% of DM and 10% of FM), even slightly higher.

5. Conclusions

- To reduce pea leaf weevils feeding by using water extract from tarragon, at least a 10% dry matter extract or a 20% fresh matter extract should be used. The reduction of the eaten leaf area after 24 h under the aforementioned extracts was 10-fold and 13-fold for males, and 2-fold and 7-fold for females, respectively. As time passes, the antifeedant properties of the extracts decrease.
- Water tarragon extract has good aphicidal potential against *A. fabae*, with 84% mortality of nymphs at 30% FM and 78% mortality of wingless females at 10% DM after 108 h of exposure. Aphid nymphs turned out to be more sensitive to extracts prepared from fresh tarragon than from its dry matter. They were also more sensitive than wingless females.
- The body weight gain of L2 and L4 larvae of the Colorado potato beetle was significantly reduced through the application of 10% and 5% extracts prepared from dry matters, respectively, while extracts prepared from fresh matter turned out to be ineffective. L2 larvae were more susceptible to extracts than L4 larvae, which suggests that they should be used as early as possible in the pest season.
- No negative influence of the extracts used was found on the voraciousness of *C. septempunctata* L3 larvae.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy12040788/s1, Table S1: ANOVA result on the surface area of broad bean leaf eaten up by male *Sitona lineatus* L.; Table S2: ANOVA result on the surface area of broad bean leaf eaten up by female *Sitona lineatus* L.; Table S3. ANOVA result on the absolute deterrence index; Table S4: ANOVA result on the mortality of *Aphis fabae* Scop nymphs.; Table S5: ANOVA result on the mortality of wingless females of *Aphis fabae* Scop.; Table S6: ANOVA result on body weight gain of L2 larvae of *Leptinotarsa decemlineata* Say.; Table S7: ANOVA result on body weight gain of L4 larvae of *Leptinotarsa decemlineata* Say.; Table S8: ANOVA result on the number of aphids eaten by one L3 larvae of *Coccinella septempunctata* L.; Table S9: ANOVA result on the mean number of aphids eaten by one L3 larvae of *Coccinella septempunctata* L.

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