Effect of aqueous extracts of black alder (*Alnus glutinosa* (LINNAEUS, 1753) GAERTNER, 1791) and elder (*Sambucus nigra* LINNAEUS, 1753) on the occurrence of *Brevicoryne brassicae* LINNAEUS, 1758 (Hemiptera, Aphidoidea), its parasitoid *Diaeretiella rapae* (M'INTOSH, 1855) (Hymenoptera, Ichneumonoidea) and predatory Syrphidae on white cabbage

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ABSTRACT. The insecticidal and antifeedant effects of aqueous extracts from two common plants (black alder *Alnus glutinosa* and elder *Sambucus nigra*) on the occurrence of *Brevicoryne brassicae*, its parasitoid *Diaeretiella rapae* and predatory Syrphidae on white cabbage were investigated in 2008-2009. Both extracts reduced the number of cabbage aphids, although the *Sambucus nigra* extract proved to have a better effect. Differences were seen both in the numbers of winged aphids settling on plants and in the overall numbers of aphids on plants during the entire season. There were no significant differences in the degree of parasitization by *Diaeretiella rapae* in the three experimental combinations. Eight species of Syrphidae were found in the *Brevicoryne brassicae* colonies: *Episyrphus balteatus*, *Sphaerophoria scripta*, *S. rueppelli*, *S. menthastri*, *Eupeodes corollae*, *Scaeva pyrastris*, *Scaeva selenitica* and *Syrphus vitripennis*. The dominant species was *Episyrphus balteatus*. The largest numbers of syrphid larvae and pupae were collected from cabbage aphid colonies on the control plants. Smaller numbers were recorded on the plot where the cabbages were sprayed with the *Sambucus nigra* extract. The results of this study indicate that botanical insecticides based on *S. nigra* have the potential to be incorporated into control programmes for the cabbage aphid.

KEY WORDS: cabbage aphid, natural enemies, botanical insecticides.

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INTRODUCTION

Commercially, white cabbage is one of the most important vegetables in Poland. Several pests attack cabbage and can cause serious financial losses. The most important pest affecting white cabbage every year is the cabbage aphid *Brevicoryne brassicae* LINNAEUS, 1753 (JANKOWSKA & WIECH 2004, SZWEJDA 2004). The parasitoid *Diaeretiella rapae* (M'INTOSH, 1855) (GABRYŚ & SOBOTA 1994, JANKOWSKA & WIECH 2003, DUCHOVSKIENĖ & RAUDONIS 2008, DUCHOVSKIENĖ et al. 2010) and aphidophagous Syrphidae (WNUK 1971, WNUK & WOJCIECHOWICZ 1993, JANKOWSKA 2005, 2012) are of the greatest importance in limiting the numbers of this aphid.

The misuse and excessive use of chemical pesticides cause irrevocable harm to natural communities and adversely affect the quality of agricultural products. That is why interest in the possibilities of applying natural substances to protect plants against pests has been growing in recent years. The pesticidal properties of many plants have been known for a long time, and natural pesticides based on plant extracts such as rotenone, nicotine and pyrethrum are commonly used in pest control. Plants may be an alternative to the currently used insect control agents because they are an abundant source of bioactive organic chemicals. Plants contain a number of chemical substances that are not directly beneficial to their growth and development. These secondary compounds act on insects as repellents, antifeedants, toxins; they also have an antibacterial and fungistatic impact (NAWROT 1984, BURGIEL 2005). Many authors have made reference to the antifeedant activity of plant extracts in relation to phytophagous insects associated with cabbage (ENDERSBY & MORGAN 1991). Although biologically active substances such as botanical pesticides impact the target organism, they also have side effects on non-targets, such as natural enemies. These effects are relatively minor, however, and are therefore tolerable.

The aim of this work was to determine the impact of aqueous extracts of two wild plants – black alder (*Alnus glutinosa* (LINNAEUS, 1753) GAERTNER, 1791) and elder (*Sambucus nigra* LINNAEUS, 1753) – on the presence of *Brevicoryne brassicae*, its parasitoid *Diaeretiella rapae* and predatory Syrphidae.

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MATERIAL AND METHODS

The research was carried out at an organic farm in Roczyny near Andrychów (2008) and at the Experimental Station of the Plant Protection Department of the University of Agriculture in Mydlniki near Kraków (2009). The white cabbage cultivars Kamienna Głowa (2008) and Amager (2009) were used in the experiments. In late-May 75 seedlings were transplanted to 12 m² plots (6 m long by 2 m wide) at a spacing of 40 x 50 cm. No chemical treatment was applied and weeds were removed mechanically. Three experimental combinations were studied: A – unsprayed cabbage (control), B – cabbage sprayed with *Alnus glutinosa* extract, C – cabbage sprayed with *Sambucus nigra* extract.

Black alder and elder are both locally common and are cheap and easy to obtain. To prepare the extracts, young healthy leaves were harvested from trees growing in their natural habitats and then dried in a ventilated room without access to sunlight. The extracts were made by allowing 50 g of ground dried leaves to stand in 100 ml water for 24 hours (WAWRZYŃIAK 1996), after which the extracts were filtered through muslin. Cabbage plants were sprayed once weekly, in the evenings. Fifteen plants situated in the central part of each plot (3 replicates of 5 plants each) were selected and marked. The analyses were carried out once a week, 1-2 days after spraying. Each time the winged and non-winged forms of the cabbage aphid, both living in colonies and solitary, were counted. In order to assess the degree of parasitization mummies in the aphid colonies were counted by direct observation. The number of mummies provides feedback on the activity of parasitoids and their so-called field effectiveness (BARCZAK 1992). In 2009 larvae and pupae of Syrphidae from the aphid colonies from all the plants on the plots were collected and reared. The emerged adults were identified to species level based on the keys by BAŃKOWSKA (1963) and VAN VEEN (2004). Duncan's multiple range test ($\alpha = 0.05$) was used for the statistical analysis of the results.

RESULTS

Both aqueous extracts affected the occurrence of *Brevicoryne brassicae* in that fewer cabbage aphids were counted on the extract-treated plants. There were differences both in the numbers of winged aphids settling on plants and in the numbers of aphids on the plants throughout the season (Table 1). The *Sambucus nigra* extracts proved to be superior in this respect, the deterrent effect of the aqueous extract from *Alnus glutinosa* being far weaker. During the peak occurrence of aphids, their numbers were twice (2008) and eleven times as high (2009) on the control plants as on the plants sprayed with the *Sambucus nigra* extract (Table 1).

Table 1. Occurrence of the cabbage aphid *Brevicoryne brassicae* (2008-2009); A – unsprayed cabbage (control), B – cabbage sprayed with *Alnus glutinosa* extract, C – cabbage sprayed with *Sambucus nigra* extract.

Information	Combination		
	A	B	C
2008			
Mean number of winged aphids per plant	0.96 b	0.85 b	0.53 a
Time of aphid maximum occurrence	11 VII	18 VIII	18 VIII
Mean number of aphids/plant during the maximum occurrence	28 c	19.7 b	14 a
Mean number of aphids per plant	1.9 b	1.22 a	1.1 a
Reduction in numbers of aphids depending on the aqueous extract applied [%]	–	35.8	42.1
Parasitization by <i>Diaeretiella rapae</i> [%]	26 a	25 a	27.8 a
2009			
Mean number of winged aphids per plant	0.7 c	0.3 b	0.1 a
Time of aphid maximum occurrence	28 VIII	10 VII	10 VII
Mean number of aphids/plant during the maximum occurrence	35 b	6 a	3 a
Mean number of aphids per plant	13.7 b	2.3 a	1.6 a
Reduction in numbers of aphids depending on the aqueous extract applied [%]	–	83.2	88.2
Parasitization by <i>Diaeretiella rapae</i> [%]	36.6 a	34.2 a	30.2 a

The mean numbers identified in the rows with the same letters do not differ significantly ($\alpha = 0.05$).

In both years the numbers of aphids on the plants were substantially reduced by the parasitoid *Diaeretiella rapae*. The percentage of parasitization varied between combinations from 2.5% to 27.8% in 2008, and from 30.2 % to 36.6% in 2009 (Table 1). There were no significant differences in the degree of parasitization in any of the experimental combinations.

Syrphidae whose predatory larvae fed in cabbage aphid colonies were another important factor in reducing the aphid population. A total of 68 syrphid larvae and pupae were collected during the observation period in 2009. The presence of eight hoverfly species was confirmed: *Episyrphus balteatus* (DE GEER, 1776), *Syrphus vitripennis* MEIGEN, 1822, *Sphaerophoria scripta* (LINNAEUS, 1758), *S. rueppelli* (WIEDEMANN, 1830), *S. menthastris* (LINNAEUS, 1758), *Eupeodes corollae* (FABRICIUS, 1794), *Scaeva pyrastris* (LINNAEUS, 1758) and *S. selenitica* (MEIGEN, 1822).

The species composition and numbers of Syrphidae are listed in Table 2. *Episyrphus balteatus* was the most abundant syrphid species (eudominant) in all three experimental combinations. The second most numerous species was *Eupeodes corollae*, but it was absent in the *Brevicoryne brassicae* colonies on the plot where the cabbages were sprayed with the *Sambucus nigra* extract. The largest numbers of syrphid larvae and pupae were collected

from the control plants (Table 2). Smaller numbers were found on the plot where the cabbages were sprayed with the *S. nigra* extract. These differences were significant in relation both to the control and to the plot where the cabbage plants were sprayed with the *Alnus glutinosa* extract (Table 2).

Aphidophagous Syrphidae are attacked by a wide range of parasitic Hymenoptera (WOJCIECHOWICZ-ŻYTKO 2000, JANKOWSKA 2004). They reduce the number of syrphids and negatively affect their function of controlling aphid populations. Parasitized syrphid larvae were collected only from cabbage aphid colonies feeding on the control plants and on the cabbages sprayed with the *Alnus glutinosa* extract (Table 2).

Table 2. Species composition and numbers of syrphids in cabbage aphid colonies on white cabbage according to the experimental combination used (2009); A – unsprayed cabbage (control), B – cabbage sprayed with *Alnus glutinosa* extract, C – cabbage sprayed with *Sambucus nigra* extract.

Species of Syrphidae	Combination						Total	
	A		B		C			
	No.	%	No.	%	No.	%	No.	%
<i>Episyrphus balteatus</i>	19	46.4	4	25	10	83.34	33	47.8
<i>Sphaerophoria scripta</i>	4	9.8	2	12.5	1	8.33	7	10.1
<i>S. rueppelli</i>	3	7.3	1	6.25	-	-	4	5.8
<i>S. menthastri</i>	1	2.4	1	6.25	-	-	2	2.9
<i>Eupeodes corollae</i>	6	14.6	2	12.5	-	-	8	11.6
<i>Scaeva pyrastris</i>	3	7.3	2	12.5	-	-	5	7.3
<i>S. selenitica</i>	-	-	1	6.25	-	-	1	1.4
<i>Syrphus vitripennis</i>	2	4.9	1	6.25	1	8.33	4	5.8
Parasitized larvae	3	7.3	2	12.5	-	-	5	7.3
Total	41 c	100	16 b	100	12 a	100	69	100

The mean numbers identified in the rows with the same letters do not differ significantly ($\alpha = 0.05$).

DISCUSSION

Characteristic plant odours (volatile chemicals) are credited with the major role of guiding phytophagous insects to their host plants (HARBORNE 1997). In the process of host plant finding, glucosinolanes (GS) and some of their breakdown products, e.g. the isothiocyanates (ITC) present in all brassicae plants, are important phagostimulants for the cabbage aphid (ZABŹA 1989, HARBORNE 1997, GABRYŚ 1999). Foraging aphids are attracted by host-plant volatiles and supposedly repelled by volatiles from non-host plants (VISSER et al. 1996). The spraying of cabbage with extracts of plants that are not host plants may mask their proper scent; in relation to the cabbage aphid it may also indicate

antifeedant activity (ENDERSBY & MORGAN 1991). Moreover, plant extracts can lead to the mortality of aphids which are already on the plants (ACHREMOWICZ 1995, ACHREMOWICZ & CIEŻ 1998). Most *Sambucus nigra* parts, but particularly the leaves, are thought to contain various cyanogenic glycosides and to be somewhat toxic (ATKINSON & ATKINSON 2002). In Poland research on the usefulness of substances obtained from plants in limiting the number of aphids was carried out by PUSZKAR et al. (1994), ACHREMOWICZ (1995), ACHREMOWICZ & CIEŻ (1998), BARCZAK (1994), BARCZAK & GULEWICZ (1998), DANCEWICZ & GABRYŚ (2008), KSIEŻAK et al. (2008) and WOJCIECHOWICZ-ŻYTKO et al. (2013). Antifeedant activity in relation to the cabbage aphid was achieved by spraying cabbage with extracts of French marigold (*Tagetes patula* LINNAEUS, 1753) extract (JANKOWSKA 2008), *Calendula officinalis* LINNAEUS, 1753. and *Euphorbia cyparissias* LINNAEUS, 1753 (JANKOWSKA & WILK 2009), and *Calendula* sp., *Chrysanthemum carinatum* SCHOUSBOE, 1800 and *Coriandrum sativum* LINNAEUS, 1753 (JANKOWSKA 2012).

The parasite *Diaeretiella rapae* is one of the most important factors reducing numbers of the cabbage aphid (GABRYŚ & SOBOTA 1994, JANKOWSKA & WIECH 2003, DUCHOVSKIENĖ & RAUDONIS 2008, DUCHOVSKIENĖ et al. 2010). According to NEMEC & STARY (1984) and ELLIOT et al. (1994), *Diaeretiella rapae* prefers *Brevicoryne brassicae* to other aphids. The degree of parasitization of aphids on white cabbage was found to be 14.2-17.6% in Poland (JANKOWSKA & WIECH 2003), 23.9-26.2% in Lithuania (DUCHOVSKIENĖ & RAUDONIS 2008) and 22.7-26.6% in England (CHUA 1977).

The same signals that attract herbivorous insects are also attractive to predators and parasitoids (HARAMATHA & NAWROT 1985). According to many authors *Diaeretiella rapae* is attracted by allyl isothiocyanate (READ et al. 1970, ZABŻA 1989, TITAYAVAN & ALTIERI 1990), which is released when cabbage plants are damaged. The coverage of plants with extracts may confuse not only aphids but also parasitoids. Some authors found that the application of plant extracts did not affect the performance of the natural enemies of insect pests (JANKOWSKA 2012); others reported a negative impact of plant extracts on parasitoids (BARCZAK 1994, WYROSTKIEWICZ et al. 1996, JANKOWSKA & WILK 2009).

The most effective agents controlling the cabbage aphid are hover flies, whose predatory larvae feed in cabbage aphid colonies. All the species found during this research are common, and their significance in limiting numbers of cabbage aphids was confirmed by other authors from Poland (WNUK 1971, WNUK & WOJCIECHOWICZ 1993, JANKOWSKA 2005, 2012).

KINDLMANN & RŮŽIČKA (1992) found that syrphid larvae did not feed on parasitized aphids, so their feeding did not limit the effectiveness of the parasite *Diaeretiella rapae*.

Botanical insecticides are among the best alternatives to synthetic pesticides. Oviposition and feeding deterrent properties are important factors in pest control, and the

results of this study indicate that botanical insecticides based on *Sambucus nigra* have the potential to be incorporated into control programmes for the cabbage aphid. Another important aspect regarding the application of botanical insecticide formulations should be their compatibility with other integrated pest management strategies.

CONCLUSIONS

1. Aqueous extracts of *Alnus glutinosa* and *Sambucus nigra* both reduced the number of cabbage aphids, but the effect of the latter extract proved to be superior
2. There were no significant differences in the degree of parasitization by *Diaeretiella rapae* in the three experimental combinations.
3. Eight species of Syrphidae were found in the *Brevicoryne brassicae* colonies: *Episyrphus balteatus*, *Sphaerophoria scripta*, *S. rueppelli*, *S. menthastri*, *Eupeodes corollae*, *Scaeva pyrastris*, *Scaeva selenitica* and *Syrphus vitripennis*. *Episyrphus balteatus* was the most abundant syrphid species in all three experimental combinations
4. The largest numbers of syrphid larvae and pupae were collected from cabbage aphid colonies on the unsprayed plants. Smaller numbers were observed on the plot where the cabbages were sprayed with the *Sambucus nigra* extract.

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