Which shrubs and trees can conserve natural enemies of aphids in spring?

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Abstract: Habitats with shrubs and trees within the agricultural landscape may contribute to the maintenance of natural enemies of pests. Aphids and flowers are important resources for beneficial natural enemies such as ladybeetles, hoverflies and lacewings. Woody plants are the most likely candidates to provide these resources in spring, as they are among the first to develop aphid colonies as well as flowers. To evaluate their possible contribution, 19 species have regularly been sampled in four consecutive springs on presence of flowers and on numbers and nature of aphids and their natural enemies. The species show large differences in flowering period and in numbers of aphids. Species that develop high numbers of aphids generally show the highest numbers of ladybeetles and hoverflies, while the number of ladybeetles is also related to the presence of flowers. Aphid species are with few exceptions identified as unharmful for agriculture. The preliminary top 5 of species recommended for planting are: sycamore maple spindle, hazel, blackthorn and grey willow, as it provides a sufficient spread in floral and prey resources for natural enemies in spring.

Key words: natural pest control, conservation biological control, landscape ecology, nectar, pollen, banker plants, hedgerows, Coccinellidae, Syrphidae

Introduction

The persistence of predatory insects and their effect on natural pest control is likely affected by the spatial and temporal pattern of essential resources such as prey, flowers and (winter) cover (Tscharntke et al., 2007). Several studies have highlighted the role of woodlots, hedgerows and other woody landscape elements as a reservoir of aphid natural enemies (Langer, 2001; Burgio *et al*., 2004). Studies at the landscape level have indicated that the (potential) levels of pest control is affected by the proportion non-crop habitats in the surrounding landscape (Tscharntke et al., 2007), both herbaceous and woody habitats. The results, however, show a large variability between studies (Bianchi *et al*., 2006). One possible cause for this variability is that the category of ‘woodlot’ or ‘forest’ may actually include many different habitats, e.g. due to differences in species composition. Similarly as in field margin flower strips, the value of the habitat for natural enemies may largely depend on the presence of species providing the right resources (Wäckers & Van Rijn, 2012).

Woody plants may be important for natural enemies of pest, especially of aphids, for providing three types of resources: (1) the branches and leaf litter that may accumulate on the soil surface provide protection and overwintering sites, (2) the flowers may provide accessible nectar and pollen, which are essential resources for many adult predators and parasitoids, and (3) aphids, psyllids and other arthropods feeding on the leaves and stems may be important prey for (especially) the larval stages, whereas honeydew may be an additional sugar source for adults. While the shelter function will especially be important in winter, food and prey provision will likely be mostly important in spring. The reasons are that most insect-pollinated shrubs flower in spring, and that most aphids overwinter on woody plants and go through a period of rapid population growth after bud burst, due to the high phloem transport rates that are associated with the development of leaves, flowers and fruits (Dixon & Thieme, 2008). At the same time most herbaceous plants (including arable crops) are not yet infested with aphids and do not yet flower, thereby providing no alternative for the woody plants yet.

The aim of this study is to quantify differences among woody plants species in terms of (1) the resources they provide for natural enemies in spring, and (2) the number of natural enemies observed on the plants. In addition, identifying the aphids present on these plants should reveal which species may perform as winter hosts for pest species. Such a comparative study, which is rare in scientific literature, can help qualifying various woody habitats when studying their impact on ecosystem services. Moreover, it can be the basis for advising which shrubs and trees should be planted to support natural pest control.

Material and methods

In the research area of the Functional Agrobiodiversity (FAB) project (Van Rijn *et al.*, 2008) in the southeast of the Hoeksche Waard, Zuid-Holland, the Netherlands, all common woody plant species from 5 woodlot parcels next to arable farm land were sampled 2 to 5 times between budburst and end of June for 4 consecutive years. Leaf development was recorded in 5 stages between closed buds and full grown leaves. Flowering was quantified as the percentage of open flowers relative to the sum of flower buds, open flowers and developing fruits. At each census the insects from 2 to 4 individual plants were sampled by carefully examining 10 branches per plant with 10 leaves per branch, recording the number of aphids and other plant-feeding insects, as well as the number of predatory insects. From each plant species subsamples of aphids were collected and preserved in 70% ethanol. If needed also other species were collected and later identified in the lab.

Table 1. Temporal pattern in leaf development, flowering and aphid populations for 19 woody plant species sorted by mean flowering period. No data are available for weeks 15 and 25. Last columns indicate mean densities (numbers per 100 leaves) (n=21-48); top 5-6 values are marked bolt.

Shrub species	Latin name	March			April				May			June				Aphids	Lady-beetles	Hover-flies
	week	<11	12	13	14	15	16	17	18	19	20	21	22	23	24	26			
hazel	*Corylus avellana*				→		A	a	A	AA	AA	AA	A	A	AA	AA	**232.0**	**0.34**	0.07
grey alder	*Alnus incana*				→												0.0	0.00	0.00
black alder	*Alnus glutinosa*					→	a			A	A	A	?	AA	A	AA	49.5	0.11	0.04
hybrid black poplar	*Populus × canadensis*					→											0.0	0.00	0.00
Cornelian cherry	*Cornus mas*					→											0.0	0.14	0.00
blackthorn	*Prunus spinosa*					→			AA	AA	A	AA	?	A	A	A	**69.3**	0.17	**0.17**
grey willow	*Salix cinerea*					→	a		A	a	A		AA	AA	AA	AA	24.2	**0.66**	0.03
bird cherry	*Prunus padus*			→	A	?	AA	A	AA	AA	A	AA					**213.5**	**1.13**	**0.21**
field maple	*Acer campestre*				→A	?	A	a	A	A	a	a					19.5	**0.73**	0.09
white willow	*Salix alba*				→						A	AA	AA	AA	AA	A	15.1	0.19	0.00
common hawthorn	*Crataegus monogyna*			→					A	A	A	A			A		13.9	0.21	0.10
sycamore maple	*Acer pseudoplatanus*				→A	?	a	?	AA	AA	AA	A	AA				**159.9**	**0.33**	**0.18**
spindle	*Euonymus europaeus*			→			A	?	A	A	AA				A		**231.2**	**0.47**	**0.27**
dogwood	*Cornus sanguinea*						→			A	a						2.3	0.19	**0.25**
guelder rose	*Viburnum opulus*				→		A	?	A	A	A			AA	AA	AA	**88.1**	0.03	0.07
dog rose	*Rosa canina*			→					a	A	AA	a	AA	AA	A		46.6	0.24	0.03
alder buckthorn	*Rhamnus frangula*						→										0.1	0.25	0.13
elderberry	*Sambucus nigra*		→									AA				A	26.0	0.12	0.00
wild privet	*Ligustrum vulgare*		→											a			0.2	0.00	0.12

Legend: → = unfolding leaves; (yellow) = some flowers (>5%); (orange) = many flowers (>25%); a = some aphids (2-10); A = aphids (>10); AA = many aphids (>100)

To match the plant phenology of the different years the week numbers of 2010, 2011, 2012 and 2013 were corrected by −1,+1,0 and −1 respectively. This correction was based on the mean onset of flowering of bird cherry (*Prunus padus*) (www.natuurkalender.nl). For statistical analysis of population data the period from week 15 to 26 was divided in four 3-week periods. Average numbers of aphids and predators were calculated per period and plant species (based on 5-15 samples each) and were square-root transformed to achieve normality. These population values were analysed by a linear model (ANCOVA using 'lm()' in R) including period, plant species, percentage flowers and aphid numbers and, if significant, their interactions.

Table 2. *F*-values of main effects of plant species, period and flowers (and aphid abundance) on the abundance of aphids, ladybeetles and hoverflies, and their interactions when significant; results from ANCOVA. Population data are square-root transformed means per plant species per period.

	Aphids				Ladybeetles				Hoverflies			
	df	SS	F		df	SS	F		df	SS	F	
Species	18	1481.1	3.9	***	18	4.113	3.3	***	18	0.972	1.1	
Period	3	230.8	3.7	*	3	0.235	1.1		3	0.853	5.9	**
Flowers	1	50.8	2.4		1	0.641	9.1	**	1	0.032	0.7	
Aphids					1	1.972	28.1	***	1	0.379	7.9	**
Aphids*Flowers					1	0.867	12.3	***				
Aphids*Period									3	0.469	3.3	*
Residuals	53	1104.9			51	3.583			49	2.342		

Significance codes: '***' p<0.001, '**' p< 0.01, '*' p<0.05, '.' p<0.1.

Results & Discussion

All investigated shrub and tree species flowered before the end of spring. The succession of flowering implied that several species had open flowers any moment in time (Table 1). The morphology of most flowers suggest that their nectar is accessible for natural enemies, except privet (see Wäckers & Van Rijn, 2012 for the criteria), but further investigation is needed. The number of aphids varied strongly with plant species (Table 2, F=3.7, p<0.001). Some species never showed any aphids, whereas 6 species showed an average of more than 100 aphids per 100 leaves for more than one period in spring: hazel, blackthorn, bird cherry, sycamore maple, spindle and guelder rose (Table 1).

The natural enemies most commonly found are ladybeetles (adults, larvae and egg clusters of mainly *Coccinella septempunctata* and *Harmonia axyridis*), followed by zoophagous hoverflies (mainly larvae but also eggs and adults), green lacewings (*Chrysoperla* spp. larvae and adults), various heteropterans and spiders from various families. The species from the latter two groups were rarely found in arable crops (Van Rijn et al., 2008) and not included in the analysis. Ladybeetles were present on the shrubs and trees during the whole spring (F=1.1, p>0.1), whereas hoverflies were mainly present during the intermediate two periods (F=5.9, p<0.01). Ladybeetle numbers were strongly affected by the number of aphids (F=28.1, p<0.001), the presence of (suitable) flowers (F=9.1, p<0.01) and by plant species itself (F=3.3, p<0.001) (Table 2). Also, the interaction between the number of aphids and presence of flowers was significant. The highest ladybeetle numbers were found on bird cherry, blackthorn, field maple and grey willow. Also hoverfly numbers were affected by the number of aphids ($F=8.1$, $p<0.01$), but not by flower abundance or plant species directly. The highest hoverfly incidence was consequently found on species with many aphids, such as spindle, bird cherry, blackthorn and sycamore maple. The low number of lacewings was not significantly related to plant species or aphid number or flowers but only to period (data not shown), with the highest incidence on guelder rose.

From 15 plant species 17 species of aphids were identified, which are all (winter) host plant specific, at least at the genus level. It is known that later in spring some species switch to herbaceous summer hosts, which may include agricultural crops. Only one species that is also a pest in crops (*Rhopalosiphum padi*) is found on its winter host: bird cherry.

The study shows that shrubs and trees can indeed provide resources to natural enemies such as ladybeetles and hoverflies in spring. Considering the low abundance of aphids and flowers in and around arable fields it is likely that woody landscape elements can play a role in maintaining natural enemy populations here. At the same time, large differences exist between plant species. Very few species host aphids that are potential pests for arable crops. Based on these still preliminary results I would recommend planting sycamore maple, spindle, hazel, blackthorn and grey willow to obtain a sufficient spread in floral and prey resources for natural enemies in spring.

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