Attractiveness of alfalfa (*Medicago sativa* L.) to wild pollinators in relation to wildflowers

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Brookes, B., Small, E., Lefkovitch, L. P., Damman, H. and Fairey, D. T. 1994. **Attractiveness of alfalfa (*Medicago sativa* L.) to wild pollinators in relation to wildflowers.** Can. J. Plant Sci. **74**: 779–783. This study attempted to assess the effects of proximity to wildflowers on the relative number of pollinators foraging on alfalfa flowers, as this information may bear on alfalfa seed production, an important industry in Canada. Five hundred and forty-five collections were made of wild pollinating bees attracted to 20 alfalfa plantations in Canada. Of the 13 genera of bees collected, almost half belonged to *Megachile*, followed by *Bombus* with 20% of the collections. Analysis indicated that increased visitation to alfalfa was significantly related to distance of the alfalfa from wildflowers, but not to the size of the alfalfa plantation. Alfalfa growing less than 10 m from wildflowers seemed to benefit by spill-over ("facilitation") of pollinators from the wildflowers. Alfalfa isolated from wildflowers by other alfalfa plants for a distance of at least 200 m attracted very few pollinators, the wildflowers apparently providing more attractive sources of pollen and nectar. A single plantation highly isolated (by about 600 m) from wildflowers proved to be very attractive to pollinators, apparently because wild nesting bees in the vicinity had little alternative but the alfalfa. These observations may be useful in exploring crop layouts to maximize attraction of wild pollinators for seed production.

Key words: *Medicago sativa*, alfalfa, pollinators, competition, facilitation, seed production

Brookes, B., Small, E., Lefkovitch, L. P., Damman, H. et Fairey, D. T. 1994. **Effet de la proximité de fleurs sauvages sur l'attrait de la luzerne (*Medicago sativa* L.) pour les pollinisateurs sauvages.** Can. J. Plant Sci. **74**: 779–783. La production des semences de luzerne est une importante activité économique au Canada. L'objet de nos travaux était d'évaluer les effets de la proximité de fleurs sauvages sur le nombre relatif d'insectes pollinisateurs butinant les fleurs de luzerne. Cinq cent quarante-cinq prélèvements ont été faits sur les apoïdes pollinisateurs fréquentant les luzernières au Canada. Des 13 genres d'apoïdes capturés, près de la moitié appartenait au genre *Megachile* et 20% au genre *Bombus*. L'analyse a révélé que la fréquence des visites de ces insectes dans les luzernières était significativement reliée à la distance entre le champ de luzerne et les fleurs sauvages, mais qu'elle n'était pas reliée à la surface de la luzernière. Les champs de luzerne installés à moins de 10 m de fleurs sauvages semblaient profiter du "débordement" des pollinisateurs de ces espèces. Les luzernières distantes des fleurs sauvages de 200 m ou davantage attiraient très peu de pollinisateurs sauvages, les fleurs sauvages leur offrant apparemment des sources de pollen et de nectar plus attrayantes. Un seul champ de luzerne très éloigné (d'au moins 600 m) des fleurs sauvages s'est révélé très attrayant pour les pollinisateurs, vraisemblablement parce que les apoïdes nichant dans le voisinage n'avaient quère d'autres choix que la luzerne. Ces observations peuvent aider à rechercher les dispositions des champs favorisant le plus possible l'intervention des pollinisateurs dans les luzernières porte-graines.

Mots clés: *Medicago sativa*, luzerne, pollinisateur, concurrence

Alfalfa, pollinated by native North American bees, was considered to produce acceptable yields of seed until 1955 (Pankiw et al. 1978). However, as the prairies were cleared and nesting sites of the native bees were eliminated, yields declined dramatically (Peck and Bolton 1946; Parker et al. 1976). For Ontario, Smith (1960) stated "intensive farming practices have, in recent years, been largely responsible for a decline in the wild bee population." The conviction is now widespread in North America that "most species that trip alfalfa flowers are either too scarce in alfalfa seed areas or too uncommon as alfalfa visitors to be important" (Pedersen et al. 1972). As a result, seed production in Canada has become dependent on the managed alfalfa leafcutting bee, *Megachile rotundata* (F.) (Hobbs 1973; Pankiw and Siemens 1974; Pankiw et al. 1978; Fairey et al. 1984). Nevertheless, the use of wild bees as pollinators epitomizes environmentally friendly, sustainable, low-input agriculture, and there is interest in the evaluation of native bees for alfalfa pollination in Canada.

Relatively little attention has been given to the problem of attracting wild pollinators to targeted economic crops, such as forage legumes, particularly in instances where there is competition from flowers of non-target species. The attractiveness of plant species to bees depends, among other

factors, on the abundance of the floral display (Baker 1983) and, consequently, flowering monocultures of economic crops could have an advantage. On the other hand, flowers of some competing non-target species are known to be more attractive to pollinators than many target species. For example, sweetclovers (*Melilotus*) and mustards (*Brassica*) are especially attractive to honeybees (*Apis mellifera* L.), and therefore draw these away from numerous other crops (Bohart 1957). With specific regard to alfalfa, bumblebees (*Bombus*) usually prefer red clover (*Trifolium pratense* L.), especially as a pollen source, and it could be difficult to attract some bumblebee species to alfalfa when flowering red clover is nearby (Bohart 1958). Also, honeybees frequent other flowers in strong preference to those of alfalfa, and normally visit alfalfa only when competing bloom is scarce (Bohart 1958). Since the explosive tripping pollination mechanism of alfalfa is so specialized, it would seem that not all bee species would find it attractive (Pankiw and Bolton 1965). Bees native to North America are not the natural pollinators of alfalfa, which is native to Eurasia. However, some plants introduced from the Old World, notably the sweetclovers, are extraordinarily attractive to New World bees.

Some of the literature uses specialized jargon in relation to aspects of the subject discussed here. "Magnet species" are ones that attract large numbers of pollinators to a community (Thomson 1978). "Facilitation" is the enhancement of pollinator visitation resulting from proximity to co-flowering magnet species (Rathcke 1983; Laverty 1992). As noted in the papers cited, these phenomena have received little attention to date. In this paper, the increase of pollinators visiting alfalfa caused by proximity to other species is referred to as spill-over. Competition is the antithesis of facilitation (or spill-over).

The goal of this exploratory study was to examine the attractiveness of Canadian alfalfa plantations to wild pollinators, with reference to competition from other flowering species, either in the vicinity of or interspersed, e.g. in brush piles in an alfalfa crop seeded in recently cleared land. Additionally, alfalfa seed yield resulting from pollination by wild bees in the Ottawa area was compared to records of seed production in alfalfa fields with managed leafcutting bees.

MATERIALS AND METHODS

Bees gathering pollen and/or nectar were collected with a sweep net from 16 alfalfa populations (0.02–20 ha) in the Ottawa area of Ontario, and four (40–100 ha) in the Peace River region of northwestern Alberta and northeastern British Columbia. Brookes (1993) provides additional information on the sites. Alfalfa leafcutting bee shelters were present at the four western sites, and in order to avoid the interaction of leafcutting bees and wild bees, sampling was carried out no closer than 90 m to the shelters. Managed honeybee colonies were not present within 2 km of any of the sites examined; honeybee colonies in the vicinity of alfalfa seed fields may inhibit visitation from other bees (Pesenko and Radchenko 1993). Of 13 large (10–100 ha) monocultures examined, nine (those without managed leafcutting bees) were sampled at the centre only, while the four with bee shelters were sampled at the periphery only. A total of 81 h was spent collecting bees at the 20 locations. All the bees were collected during the peak flowering times of alfalfa (late June to mid July) by the same two individuals, on warm days (21–28°C), with limited or no wind, under sunny or slightly overcast skies, for recorded periods of time. The bees were killed using ethyl acetate, and mounted following Martin (1977). All collections are deposited in the National Insect Collection, Agriculture Canada, Ottawa, ON.

Table 1. Disposition of the 20 experimental alfalfa sites, classed by size of plantation and distance from wildflowers

Size of plantation	Distance of alfalfa from wildflowers			Totals
	0 – 10 m	200 – 500 m	> 500 m	
< 0.4 ha	6[z]	0[y]	1[x]	7
> 10 ha	4[w]	9[v]	0[u]	13
Totals	10	9	1	20

[z] Represented by small plantations close to wildflowers, and by intermixtures of alfalfa and wildflowers.
[y] Most small plantations are near wildflowers, and so this situation of a small plantation isolated from wildflowers is not normally encountered (see footnote[x]).
[x] An unusual situation in which a small plantation is highly isolated from wildflowers.
[w] Sample sites were at the periphery of large plantations, near wildflowers.
[v] Sample sites were in the centre of large monocultural plantations, and thereby distant from wildflowers.
[u] This situation would be realized by sampling in the centres of very large populations, more than 0.5 km away from wildflowers.

The 20 study sites were classed by proximity to wildflowers and size of plantation as in Table 1. At all of these sites except one, pollinating bees were present in appreciable numbers on surrounding wildflowers, and seemed to be the source from which bees were available to visit the alfalfa under study. At the unique site, the alfalfa was isolated from wildflowers by at least 600 m of lawns, non-flowering crops, weed-free fallow land, and parking lots. At nine other sites there was also a substantial separation of the alfalfa plants under study and wildflowers, but at these nine sites the intervening area was entirely occupied by alfalfa, so that nesting sites for bees were unavailable. At the unique site, at the Central Experimental Farm in Ottawa, there were numerous nesting possibilities for bees between the alfalfa under study and the nearest wildflowers.

The alfalfa cultivar Comsel is maintained at the unique site mentioned above. Dr. A. McElroy, the maintenance breeder, kindly supplied the total weight of seed harvested in 1991 for the 0.364-ha site, allowing calculation of the yield/area of alfalfa pollinated by wild bees.

Large stands of several species grew close to one of the alfalfa study sites. The comparative density of native pollinators attracted to these was also examined. The taxa sampled were: Virginia creeper (*Parthenocissus quinquifolia* (L.) Planch.), narrow-leaved meadowsweet (*Spiraea alba* Du Roi), and white clover (*Trifolium repens* L.). For these species, hundreds of plants and thousands of flowers were available within 1 ha, and 3 h were spent collecting on each species.

Although the number of collections is relatively small, some formal statistical analyses of the attractiveness to pollinators of alfalfa and other species were undertaken.

Table 2. Summary of number, frequency, and relative occurrence of genera of bees collected

Genus	Number of bees collected	Relative occurrence as % of 20 sites	Relative occurrence as % of total of 545	Order of frequency
Hylaeus	2	10	0.37	8
Agapostemon	4	10	0.73	7
Halictus	71	15	13.00	3
Lasioglossum	2	10	0.37	8
Evylaeus	2	10	0.37	8
Dialictus	10	10	1.83	6
Andrena	60	45	11.01	4
Megachile	261	40	47.89	1
Hoplitis	2	5	0.37	8
Osmia	1	5	0.18	9
Melissodes	2	5	0.37	8
Apis	19	30	3.49	5
Bombus	109	55	20.00	2

The mean numbers of bees observed per hour is regarded as having a (compound) Poisson distribution, and were analyzed using a generalized linear model, in the framework of the two-way classification of the 20 sites shown in Table 1 (three classes of distance between wildflowers and alfalfa, two classes of size of alfalfa plantation), and summarized by an analysis of deviance (McCullagh and Nelder 1989). Tests of significance were performed by comparing the deviance with the χ^2 distribution. All numerical procedures were performed using Genstat, Release 5.22 (Lawes Agricultural Trust 1987).

RESULTS

A total of 545 Hymenoptera, belonging to 13 genera, were obtained at the 20 alfalfa sites (Table 2). *Megachile*, a genus of solitary bees, was the most frequently collected, representing almost half of all bees collected. It was completely absent from the centres of large monocultures. The social *Bombus* was second in frequency, and represented 20% of the collections (Table 2).

Means and standard errors of hourly pollinator collection rates on alfalfa, in relation to size of alfalfa plantation and distance from the alfalfa to wildflowers, are shown in Table 3. The analysis of deviance (Table 4) shows that the effect of distance to wildflowers was significant, but that the size of the alfalfa plantation was not. Because of lack of data, it was not possible to make any evaluation of the possible interaction between these two factors.

The hourly rate of collection of pollinators attracted to the other three species examined were: Virginia creeper, 33.7; narrow-leaved meadowsweet, 25.5; and white clover, 89.0. All three attracted more pollinators than any of the 20 tested alfalfa populations; a formal test of this difference was not performed because of lack of available replication. Brookes (1993) found that most of the genera of pollinators visiting the three wild species also visited nearby purple-flowered and yellow-flowered alfalfa.

A yield of 240 kg ha^{-1} was calculated for the alfalfa cultivar Comsel pollinated by wild bees in Ottawa.

Table 3. Hourly rate of capture of hymenopteran pollinators in various spatial arrangements of alfalfa and wildflowers[z]

Spatial arrangement	Number of sites	Hourly rate of capture[y] (± SE)
Plantation size > 10 ha, distance from wildflowers > 200 m	9	0.65 (0.38)
Plantation size < 0.4 ha, distance from wildflowers < 10 m	6	5.05 (1.29)
Plantation size > 10 ha, distance from wildflowers < 10 m	4	8.00 (1.99)
Plantation size < 0.4 ha, distance from wildflowers > 500 m	1	23.60 (6.83)

[z]Values shown are predictions from the analysis of deviance (Table 4). Standard errors are approximate, since model is not linear.
[y]Collecting times at each of the 20 sites varied from 0.5 to 10 h, with more time spent at sites with relatively abundant pollinators. For hourly rate of capture, sites are equally weighted despite differences in collecting times.

Table 4. Analysis of deviance of the number of bee visits per hour in relation to distance between alfalfa and wildflowers, and the size of the alfalfa plantation

Source of variation	d.f.	deviance	*P*
Alfalfa-wildflower distance	2	92.714	<0.0001
Size alfalfa plantation	1	3.276	0.0703
Residual	16	31.650	

DISCUSSION

Significantly different numbers of native pollinators were attracted to alfalfa in three spatial arrangements relative to the surrounding flowers of other species. The three situations, and the mean numbers of bees/hour collected, were (cf. Table 3):

1. Alfalfa isolated by a pure stand of other alfalfa plants from wildflowers by at least 200 m: 0.65;
2. Alfalfa no more than 10 m from wildflowers: 6.23;
3. Alfalfa isolated by at least 600 m from wildflowers, with nesting sites for bees near the alfalfa: 23.60.

Three considerations can be used to explain the differences in pollinator density observed among these arrangements. First, wild pollinators require nesting sites, which can be found in the natural landscape surrounding stands of cultivated alfalfa. Second, other flowering species compete for the attention of the pollinators. And third, the flight distances of many species, especially the smaller solitary bees, are limited, and they will normally forage only short distances from their nesting sites (Bohart 1972).

The observation that almost no pollinators were found in the centres of the nine large monocultures examined is in agreement with earlier studies (Salt 1940; Stephen 1955). *Megachile*, the most frequently encountered genus in this study, was completely absent from the centre of large monocultures, although found in all of the other kinds of spatial situations examined. Native pollinators generally prefer wildflowers over alfalfa (Bohart 1957, 1958). Our observation

that wild pollinators visited three other plant species in higher numbers than they visited any of the 20 alfalfa study sites is consistent with Bohart's finding. Nevertheless, as noted below, wild bees will forage on alfalfa if it is near wildflowers. Limited flight range of many solitary species or a preference to remain close to nesting sites may have prevented their foraging in the centres of the large monocultures.

At 10 of the study sites, wildflowers were within 10 m of the alfalfa being visited by pollinators, and much higher numbers of bees visited the alfalfa flowers than was the case in the centres of large monocultures. Clearly, proximity to the pollinators visiting the flowers of other species benefitted the alfalfa. Spill-over of bees to the alfalfa seemed to account for the appreciable number of pollinators observed on the alfalfa.

The spatial situation attracting the most bees to alfalfa was a small monoculture of alfalfa isolated by a considerable distance (at least 0.6 km) from competing flowers, with habitats providing nesting sites for wild bees. Probably in this situation alfalfa was the only forage within the normal flight range of many bees in the area.

Seed yields of alfalfa commercially pollinated by honeybees have been reported to range up to 670 kg ha^{-1} in the northwestern U.S., while in the southwestern U.S., honeybees have produced yields of greater than 1120 kg ha^{-1} (Robinson et al. 1989). However, honeybees are unsuitable pollinators of alfalfa in Canada (Reinhardt 1953; Pankiw and Bolton 1965).

Seed yields of alfalfa commercially pollinated by alfalfa leafcutting bees in the southern prairie region of Canada have been reported to range from 300 to 900 kg ha^{-1} under irrigation, while yields of 150 to 300 kg ha^{-1} are considered satisfactory without irrigation (Goplen et al. 1982) although yields of up to 800 kg ha^{-1} have been obtained (Fairey et al. 1984). Little information has been published on Canadian alfalfa outside of the Prairie Provinces and the Peace River region of British Columbia, which collectively account for more than 95% of Canada's production of alfalfa seed (Fairey and Lefkovitch 1991). Trials utilizing leafcutting bees for seed production at New Liskeard in northern Ontario produced an average yield of 331 kg ha^{-1}, but this increased to 783 kg ha^{-1} based on careful hand harvesting (Skepasts and Taylor 1984). Despite the fact that native bees cannot be relied on to produce consistently high seed yields (e.g. Bohart 1972) the yield of 240 kg ha^{-1} in the Ottawa plot obtained using only wild pollinators suggests that if the ideal conditions can be found or manipulated there remains potential for using wild bees to produce alfalfa seed in parts of Canada.

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