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Plants influencing the behaviour of Large White Butterfly (*Pieris brassicae* L.)

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Abstract. Large White Butterfly, *Pieris brassicae* L. (LWB) is one of the greatest pests of cruciferous cultures in Estonia, and, in the years of its biggest abundance, it can destroy a significant part of a crop. Many plants contain natural compounds that can repel and/or attract insects and protect neighbouring plants. This principle is used in a method known as companion planting. The aim of this paper was to establish to what extent it was possible to influence, by using companion plants, the oviposition intensity of adults of LWB on *Brassica oleracea* var. *capitata* f. *alba*. Cabbage plots were surrounded, as a border around garden beds, by the following plant species: *Salvia horminum* L. (syn. *viridis* L), *Chrysanthemum carinatum* Schousboe, *Tagetes patula* L., *Allium cepa* L. or *Calendula officinalis* L. Companion plants were replanted on the experimental plots in two rows. On control plots only cabbage was growing.

French marigold, *T. patula* and painted daisy, *C. carinatum* were oviposition repellent to *P. brassicae* – compared with the control variant; butterflies laid fewer eggs on cabbage of these variants. At the same time, flowers of *T. patula* were attractive to adults of *P. brassicae* as the butterfly fed intensively on the flowers. There were no butterflies on flowers of *C. carinatum*, allowing us to conclude that this plant was a repellent to adults of *P. brassicae*. Certain repellent effects of painted sage, *S. horminum*, appeared towards the end of the summer, when the plants were in full flower. Butterflies laid eagerly eggs on cabbage plants surrounded by calendula, *C. officinalis* and onion, *A. cepa*. Our experiments showed how important it is to reckon with a certain pest, the control of which is intended, in choosing plants for founding a garden with diverse vegetation.

Key words: *Pieris brassicae, c*ompanion plants, oviposition repellents

INTRODUCTION

Pollution of the environment accompanied by intensive use of poisonous chemicals and resistance developed by pests force scientists to find new ways for controlling pests. There has been an increase in the scientific interest in natural means of pest control, especially plants. In plenty of these plants there have been discovered substances repelling insects, inhibiting their eating and egg-laying, etc. There are more prospects in plants releasing compounds repelling pests away from cultures or hindering them from feeding and egg-laying. The basic truth is that it is easier to prevent damages by repelling pests than destroy the pests later. The easiest and cheapest way of repelling is to plant or sow odoriferous plants in the area near cultures in need of protection. It is a long-known means for controlling pests, the idea of which is to alternate cultures spatially in the same field, by creating a diverse composition of plant species, where cultures complement and protect one another. On the one hand, it disturbs pests in their moving from one food plant to another since plant plots have been separated by strips of plants inedible for them. Spreading of pests is the fastest in a monoculture, especially on plants sowed or planted in rows. On the other hand, in mixed vegetation, the odours released by some plants may mask the effect of those released by other plants (Root, 1973; Cromartie, 1975). The confused insects waste time by examining plants unsuitable for egg-laying and can devote less time on plants suitable for them (Root & Kareiva, 1984; Kareiva, 1985; Lamb, 1989). Thus, a varied plant composition may both reduce immigration of pests into a field and also accelerate their leaving the area (Osman et al., 2001).

Large White Butterfly (LWB), *Pieris brassicae* L. is a well-known pest in Estonia, causing, in the peak periods of its abundance, serious damage on cabbage cultivation. Since a young, freshly hatched, larva of *P. brassicae* is not capable of choosing a feeding site, it is the butterfly, whose success in selecting oviposition sites determines the number and development of the offspring. In choosing a place for oviposition, a butterfly considers the smell, chemical composition, leaf structure and also agrotechnics of the plant. Volatile compounds of the host plants are most likely responsible for the oviposition site selection of *P. brassicae* (Cole, 1976). LWB adults select a substrate for oviposition, based on the presence of glucosinolates (Schoonhoven, 1972; Chew, 1980). A butterfly who has detected a suitable object by its odour, is, being near the plant, influenced by other factors as well: shape and colour of the plant, chemical properties of its leaf surface, etc. They have taste organs primarily on lower sides of its tarsi, mouth appendages and ovipositor, and, a butterfly, having landed on a plant, drums the surface of the leaf to determine if the plant is suitable for oviposition, reducing thus the risk of food shortage for its offspring.

Literature data on the impact of varied vegetation on the behaviour of pests are often contradictory. Different authors have reached completely different results with the same plant and pest species. For example, Latheef and Irwin (1979) investigated repellent effects of *Tagetes patula* L., *Mentha piperita* L., *Salvia splendes* Ker-Gawl. and *Thymus spp*., planted in the vicinity of cabbage, on *P. brassicae* or *Pieris rapae* L. without obtaining any significant results. However, a few years later Koehler, Barclay and Kretchun (1983) studied several medicinal plants and herbs and found that the aforementioned plants, planted near cabbage, reduced the abundance of *P. rapae* on cabbage. An analysis of results gained by different authors, has revealed that there may be several reasons for the variation: weather, sowing time of both the principal and secondary cultures, species and varieties, spatial distribution, abundance of the pest, etc.

The aim of this research paper was to elucidate the extent to which non-hostplants of *P. brassicae*, planted around cabbage plots, influenced the oviposition of butterflies on *Brassica oleracea* var. *capitata* f. *alba*. Based on our earlier laboratory data and literature, we chose in our experiments plants having already recognised repellent or deterrent properties towards some insect species. As in our region signs of forays of the second generation of *P. brassicae* on head cabbage develop during head formation, when chemical control is prohibited, explaining the influence of mixed and intermediate cultures is of practical importance.

MATERIALS AND METHODS

The experiment was carried out in Raja experimental garden of the Estonian Agricultural University in Tartu. A variety of white head cabbage, 'Podarok', was chosen for the experiment. The choice was caused by the fact that in the year of the experiment it was the most widely known variety in Estonia. On each experimental plot four cabbage plants were planted in four rows, in total 16 plants on each plot. All the variants had three replications. The experimental cabbage plots were surrounded by the following plant species: *Salvia horminum* L. (syn. *viridis* L.), *Chrysanthemum carinatum* Schousb., *Tagetes patula* L., *Allium cepa* L. or *Calendula officinalis* L. The plants were planted in two rows around plots. On control plots there was only cabbage. The counting of egg clutches of *P. brassicae* was begun on 3 August 2001 and the experiment lasted until 14 September 2001. During each counting the egg clutches found were removed to avoid repeated counting of one and the same egg clutch. Observations were performed at weekly intervals, seven countings in total.

Data are presented as mean ± standard deviation. Statistical comparisons were performed with paired Student's *t*-test or repeated-measures ANOVA by Tukey test. All means were considered significantly different at the $P = 0.05$ level.

RESULTS

The number of *P. brassicae* was high in the year of the experiment. At the end of June butterflies of the second generation began their flight, at the beginning of August their started laying eggs, and we found most of their egg clutches in the first decade of August. Thereafter the activity of their egg-laying decreased gradually, and, in the last observation of August, there were only 4 egg clutches on control plots as the mean of all replications. Weather has a strong impact on the egg-laying activity of butterflies. The weather of mid-August was rainy and windy. At such weather butterflies keep to shelters and do not usually appear in fields. The flight of butterflies became again more intensive during the last days of August, which is confirmed by a large number of egg clutches in the control variant, in test samples from 1 September. In addition to our local population, the butterfly also immigrates to our country and in some years its migrations from southern regions may be remarkable. It is highly probable that there occurred a larger immigration of butterflies at the end of August, increasing the amount of egg clutches in the control. The flight of butterflies lasted, with shorter and longer decline periods, until mid-September.

Butterflies of *P. brassicae* seldom visited cabbages surrounded by a strip of *T. patula* as during the whole observation period there very few egg clutches found in this variant (Fig. 1). Compared with the control, the difference is statistically significant (t=7,18, $df = 20$, $P < 0.05$).

Butterflies visited cabbage plants growing on the plots surrounded by *Chrysanthemum carinatum* more intensively at the outset of August, when there were no full flowers. Later cabbages were less visited, indicated by a decreasing amount of egg clutches, compared with the control (Fig. 2). It must be noticed here that egg clutches laid later had unusually small numbers of eggs. Compared with the control, the number of egg clutches counted in the variant with *C. carinatum* is reliably smaller ($t = 5.35$, $df = 20$, $P < 0.05$).

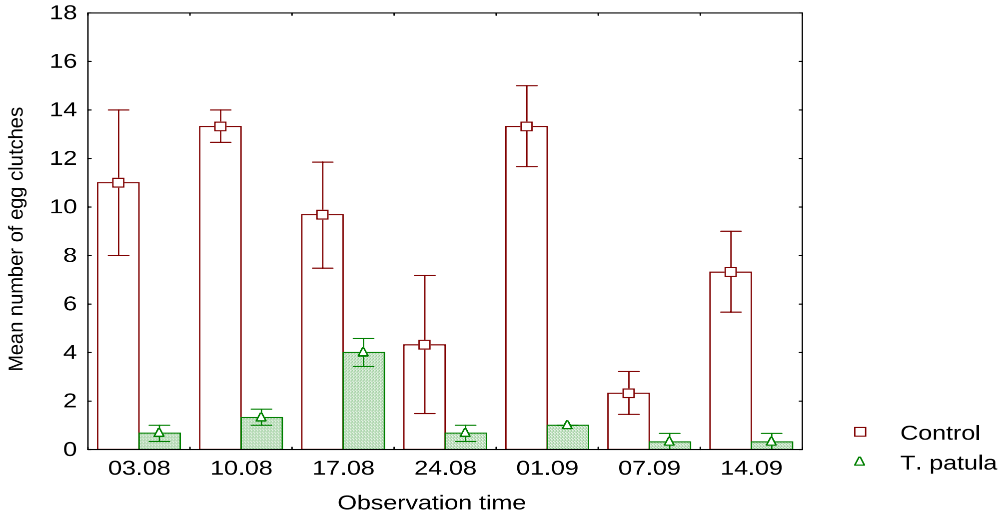

Fig. 1. Oviposition activity of *Pieris brassicae* in control cabbages and experimental plots surrounded by *Tagetes patula*.

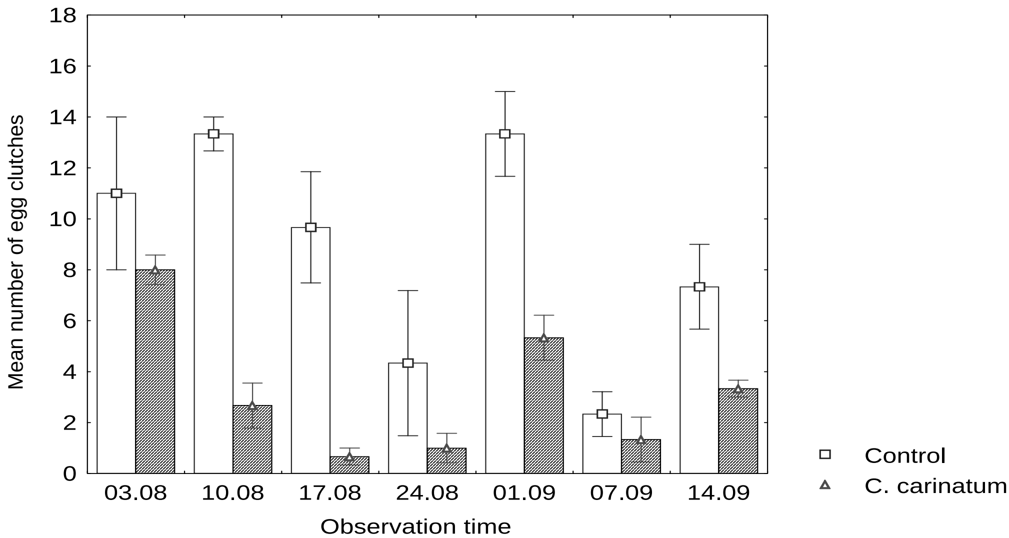

Fig. 2. Oviposition activity of *Pieris brassicae* in control cabbage and experimental plots surrounded by *Chrysanthemum carinatum.*

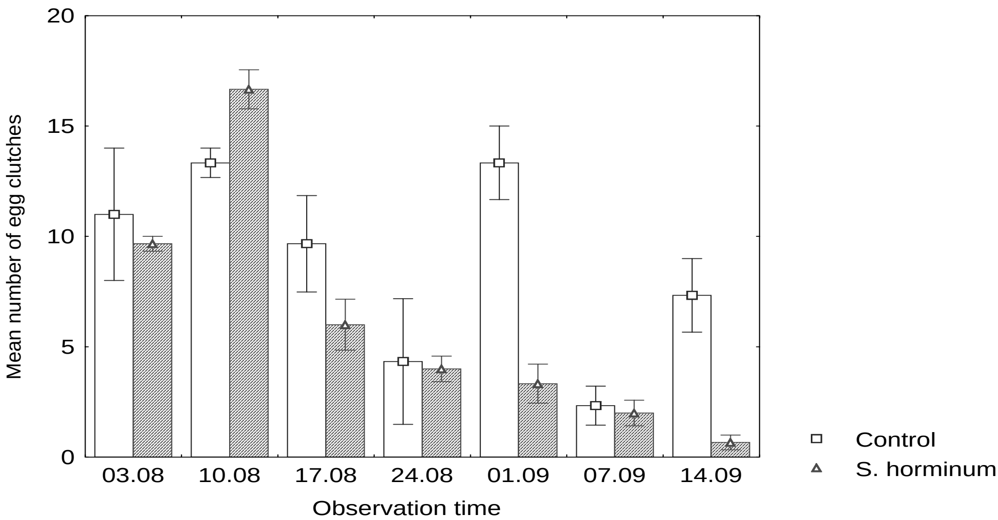

Fig. 3. Oviposition activity of *Pieris brassicae* in control cabbages and experimental plots surrounded by *Salvia horminum.*

At the beginning of August butterflies laid eggs on cabbage plots surrounded by *Salvia horminum* almost equally with the control, and even more during the second observation. The further observations showed that the higher grew *S. horminum* and the more intensive was its flowering, the less butterflies visited cabbage plots of this variant (Fig. 3). The comparison between egg clutches laid during the whole test period in the control and variant with *S. horminum* revealed reliably more eggs laid on cabbage in the control variant (t = 2.33, df = 20, P < 0.03).

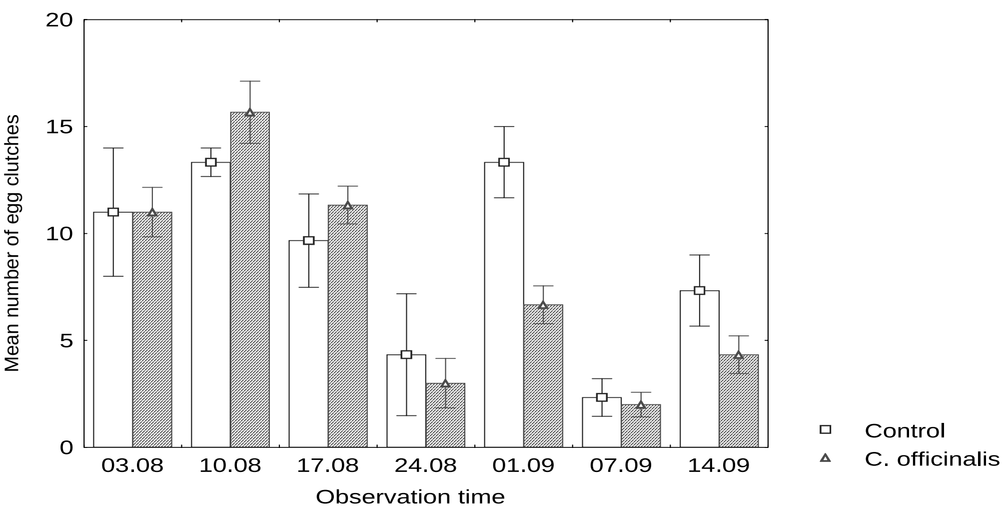

Fig. 4. Oviposition activity of *Pieris brassicae* in control cabbages and experimental plots surrounded by *Calendula officinali.*

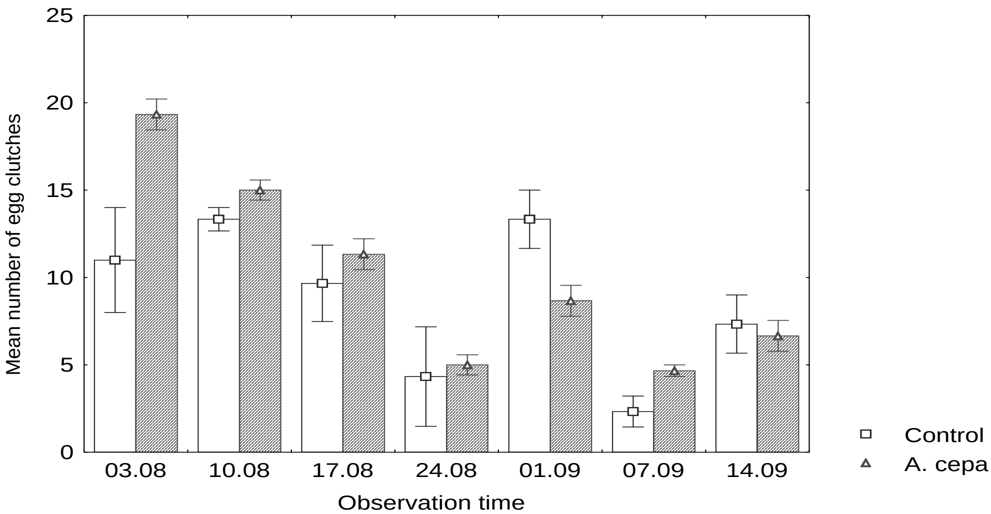

Fig. 5. Oviposition activity of *Pieris brassicae* in control cabbages and experimental plots surrounded by *Allium cepa.*

In the variant where test-plots were surrounded by *Calendula officinalis* butterflies laid eggs more intensively at the end of August, compared with the control. Later, when *C. officinalis* had grown higher and was in full flower, butterflies did not visit much cabbage on these plots, which is also indicated by a gradual decrease in the amount of egg clutches on plants (Fig. 4). An analysis of the results of the entire test variant showed that the more intensive egg-laying of the first half of August compensated the later lesser egg-laying, and, compared with the control, there was no reliable difference (t = 0.98, df = 20, P = 0.34).

On cabbage surrounded by *Allium cepa* butterflies laid eggs, especially at the beginning of the experiments, more willingly than on cabbage of the control variant (Fig. 5). There was no reliable difference in the comparison of the control and test variant (t = 1.30, df = 20, P = 0.21).

DISCUSSION

Plants have wide spectra of action, whereas the same plant may affect insects through completely different action mechanisms. In our experiments *T. patula* affected adults of *P. brassicae* by inhibiting their oviposition – butterflies laid a small amount of eggs on cabbage of this variant. At the same time, flowers of *T. patula* obviously contain compounds stimulating adults to feed as butterflies intensively visited the flowers and fed on nectar, choosing more willingly yellow flowers for feeding. Adults of *P. brassicae* prefer yellow flowers but lay their eggs mainly on green leaves (Luik, 1997). According to data by Hagen Dole (1999), adults of many lepidopteran species feed on different Tagetes species, however, the most preferred one is *T. patula*. Bee-like species also visit Tagetes flowers. At the same time, there are known numerous insect species repelled by the odour of *Tagetes* spp: for instance *Trialeurodes vaporariorum*, Aphididae (Endersby & Morgan, 1991), *Psila rosae* (Uvah & Coaker, 1984), etc. Our earlier tests have also shown that *Tagetes* spp. deterred *P. rosae* and *Trioza viridula* L. (Metspalu et al. 1997). In experiments conducted by Koehler *et al.* (1983), where cabbage rows alternated with *Tagetes* spp., there were considerably less larvae of *P. rapae* than in the control.

It is generally known that *Tagetes* spp. contain nematocidal substances as well, because of which they are used for controlling nematodes, especially *Meloidogyne* spp. Tagetes release large amounts of root exudates which can be taken up by adjacent plants (Rovira, 1969), and it is possible that any host plant growing among or between the rows of another crop could be affected directly by chemicals taken up through its roots (Theunissen, 1994) rather than by having its odour masked (Finch & Collier, 2000). Hydrocyanic acid has been found in the Tagetes (Golob *et al.*, 1999). The toxic properties of hydrocyanis acid were known to the Egyptians and the Romans, and the compounds were used as a fumigant more than a hundred years ago (Fernandez, 2001).

Our experiments demonstrated that *C. carinatum* also inhibits the egg-laying of *P. brassicae*. There are almost no literature data on insecticidal properties of this plant, nevertheless at present many plant species from the family of *Chrysanthemum* are known as typical insect repellents (Kaufman et al., 1998). Pyrethrum produced on the basis of *Chrysanthemum cinerariaefolium* Trev. is now one of the dominant botanical insecticides in the world. Extracts and powders from this plant were used already centuries ago, first as a repellent mainly against Tineidae, and even small amounts of pyrethrum exerted repellent effect on insects. Most of the active components containing in *C. cinerariaefolium* are found in young flowers of the plant.

In our experiment the action of *C. carinatum* also occurred at the beginning of the plant's flowering. Butterflies did not visit the flowers, although there were also yellow flowers. This allows us to think that *C. carinatum* is repellent to adults of *P. brassicae*. Of toxic substances containing in the plant, camphor, caproic acid, carvone, pyrethrin I, II and pyrethrum can be named (Golob *et al.*, 1999). Modern uses of camphor have been as an insect repellent, particularly for moths.

In our experiments painted sage (salvia), *S. horminum* started to repel adults of *P. brassicae* towards the end of the summer, when plants grew high and were in full flower. Observation of the behaviour of the butterflies showed that butterflies never landed on flowers of the plant. It can be concluded from there that the complex of odours in *S. horminum* is repelling to *P. brassicae.*

Salvia include essential oils (thujone, borneol, cineol, camphor, pinene), bitter principle (picrosalvine), flavonoids, tannin, phenolic acid (rosmarinic, caffeic, labiatic), phytoestrogens, and resin (Lawrence & Reynolds, 1991; Golob *et al*., 1999). Several of these substances have been reported to possess high repellent properties against various insects (Perttunen, 1957; Moore, 1974). Little (1989) regarded *S. horminum* as one of the numerous medicinal plants or herbs repellent to cabbage pests. This plant is usually used for repelling garden pests, and therefore it is often planted near cabbage and carrots to keep away *Plutella xylostella* L., *Phyllotreta* spp. ja *Trioza viridula* Zett. (Golden Harvest, 1997–2003). But Dover (1986) believed the sage acted as a physical barrier by extending the search area of *P. xylostella* and not from repellent volatile stimuli. According to Lundgren (1975), adults of *P. rapae* did not lay eggs on cabbage plants in the company of *S. horminum*. Volatile compounds released by *Salvia* spp. have been used for repelling larvae of *Pieris* spp. (Endersby & Morgan, 1991).

Our tests with calendula, *C. officinalis,* showed again how important it is to reckon with a certain pest, the control of which is intended. Thus it appeared that *P. brassicae* willingly laid eggs on cabbage plants surrounded by *C. officinalis* and consumed nectar as food. It is also known that the abundance of certain pests can be reduced by means of calendula, but these are usually other factors than the repelling action of calendula. For example, *C. officinalis* planted near roses will greatly reduce attacks by aphids. This is because these plants attract hoverflies (Diptera, Syrphidae), which lay eggs, and the larvae in turn, eat aphids (Owen, 1999). Calendula tinctures and infusions have been exploited for controlling flies, gnats and several pests feeding on leaves and flowers. In addition, it is a recognised anti-inflammatory and antibiotic medicinal plant for humans. Calendula contains triterpene saponins, calenduladiol, carotenoids, and flavonoids.

The versatile properties of onion, *A. cepa* have been known for a very long time, it is also a recognised culture in pest control. Onion is usually grown between or next to plants in need of protection since its repellent action on many insects and diseases is well known. Onions contain allicin, ajone, hydrocyanic acid, oxalic acid, pyrocatechol, quercitin, saponin (Golob *et al*., 1999). Already centuries ago, onions were added to grain in warehouses. The phytoncides of onion forced *Sitophilus* sp. to move out of the grain. Onions have also been exploited for controlling Acarina (Kuusik, 1977). Growing of carrots between onion rows have reduced damage caused by *P. rosea* and *T. viridula* (Uvah & Coacer, 1984). According to our earlier data, the number of *P. rapae*, *P. xylostella* as well as *Evergestis forficalis* L. diminished on cabbage plots surrounded by onions (Metspalu *et al*., 1999). In our present experiments *P. brassicae* willingly laid eggs on test patches surrounded by onions, whereas the number of egg clutches at the beginning of the test period exceeded the number in the control. We obtained similar results in our earlier experiments of mixed cropping (Metspalu *et al*., 1999).

At last, it must be mentioned that one of the biggest problems in creating a biogarden rich in species may be the fact that the cultures may start competing both for living space and food. Apart from that, roots and overground parts of one plant species may discharge physiologically active substances inhibiting the growth of another species. The same connections appear in the interaction between pests and plants. Consequently, mixed cultures cannot be created with no consideration, instead there must be a clear system checked earlier, and plants must be selected according to pests, whose control is intended.

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