Pollinators and their Foraging Behaviour in Arctic Bramble (*Rubus Arcticus L.*) Plantations in Estonia

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Summary

The movement patterns of the foraging behaviour of bees were observed in the EAU experimental garden in the second year after the planting of the arctic bramble, i.e. in the first harvest year. The track of a foraging honeybee on a row was followed from its arrival to departure. The length of the row covered during one flight was taken for the forage distance. Bees moved along a row choosing the nearest flowers irrespective of the cultivar. Fifty-eight per cent of the bees covered no more than one metre of the row (three plants) and 23% – up to two metres. Therefore, alternately planted cultivars are needed to increase berry production. Plastic mulch around the bramble planted in rows prevents the plants from spreading and reduces the danger of geitonogamy.

The arctic bramble is a self-incompatible and insect-pollinated plant, therefore its productivity largely depends on pollinators. That is why the arctic bramble is suitable for cultivation in regions where the equilibrium of nature is preserved and wild pollinators are found. Based on reasons mentioned above, there was a need for a survey of pollinators in Estonian conditions, as we have a lack of that kind of data. Moreover, the culture should grow in a clear natural environment if the intact natural population is preserved. One important question considered was whether our environment is the kind of environment where enough pollinators exist.

Introduction

The natural habitats of the European arctic bramble (*Rubus arcticus* L. ssp. *arcticus*) spread over Northern Eurasia. These berries famous for their special aroma and flavor are used for liqueur production in Finland. Mostly wild berries are picked; however, their yield varies from year to year. For this reason, arctic bramble cultivation in plantations has been started. Widespread cultivars 'Pima', Mespi' and the new ones 'Marika', 'Elpee' and 'Muuruska', are being cultivated (Pirinen et al., 1998). Yields of the arctic bramble are not high; however, the liqueur industry buys the berries at a high price.

The arctic bramble has been under protection in Estonia since 1958 (The Red Data ..., 1998). Its area of distribution has been diminishing constantly due to extensive amelioration activities. At present the preservation of the wild population of the arctic bramble is problematic, as its habitats have narrowed considerably.

The Department of Horticulture of the Estonian Agricultural University (EAU) started experiments on arctic bramble cultivation in 1995. The first studies have demonstrated that cultivation of the arctic bramble in Estonia is quite promising; however, more investigations must be carried out before the final recommendations can be presented to the prospective producers (Karp, Starast, 1998). In the wild the arctic bramble grows in semishade under trees and therefore blooms later than in plantations, when the danger of night frosts is over and there are more pollinators available.

The arctic bramble is a self-incompatible insect-pollinated plant, therefore its productivity largely depends on pollinators (Tammisto, Rautanen, 1970). Their pollinating efficiency is limited by the thermal constrains on flight activity, and each species has a microclimatic 'window' within which foraging flight can be sustained (Corbert et al., 1993). On the other hand, the qualitative pattern of bramble pollinators in a plantation depends on plant associations around it and on both the number of pollinator species inhabiting these associations and the number of individuals within each species (Kearns et al., 1998). However, there is little published information about the foraging behaviour of pollinators on the arctic bramble, although some data from Finland have been reported (Ryynänen, 1973, Kangasjärvi, Oksanen, 1989). In Central Finland the most frequent visitors to arctic bramble flowers included bumblebees (Bombus spp.) and honeybees (*Apis mellifera*) from among Hymenoptera, and hover flies (Syrphidae) and some other larger flies from among Diptera (Ryynänen, 1973). It is not known which insects would utilize the arctic bramble as a food plant in Estonia. For this reason we had to determine the economically important bramble pollinators and to study their behaviour in Estonia where the arctic bramble has not been cultivated before and there are no data on the set of effective pollinators of this plant.

This is why the arctic bramble is suitable for cultivation in regions where the equilibrium of nature is preserved and wild pollinators are found. Based on reasons mentioned above, there was a need for a survey of pollinators in Estonian conditions, as we have a lack of that kind of data. Moreover, the culture should grow in a clear natural environment if the intact natural population is preserved.

One important question considered was whether our environment is the kind of environment where enough pollinators exist.

Materials and Methods

The two different experimental plantations were located in the southern part of Estonia, Tartu County, both in production conditions. One trial plot was located in the experimental garden of Estonian Agricultural University (EAU).

The experimental cultivation sites were placed 20 km from each other, so it was unlikely that the same pollinators visited more than one experimental area. The first experimental plot (Vasula, planted in August 1996) was surrounded by the apple-trees and strawberry plantations of a horticultural firm, there were cherry and plum-tree orchards (60 ha altogether) not far away as well. No plant protection means were employed in the experimental plantation; however, disease and pest control procedures were carried out in the nearby productive plantations. The second experimental plot (Kambja, planted in June 1997) was located at a small farm growing strawberries (0.15 ha) and blackcurrants (1 ha). Woods and thickets surrounded the farm. The farmer had 5 hives of bees. No plant protection measures had been taken at the farm or in its surroundings. The plants were planted as in Vasula. The third plot was situated in the experimental garden of the EAU and surrounded by various cultures on little plots (apple-trees, currants, flowers).

The number of various pollinators and their taxonomic attribution were determined in plantations at Vasula and Kambja where rows around bramble plants were covered with plastic mulch. The distance between plants within the rows was 33 cm that between the rows – 1.20 m. Plants of the Finnish cultivar 'Pima' and the Estonian clone were planted alternately.

Pollinators were counted on 2 m (six replications) after recording the number of opened flowers. During the flowering period insects visiting the flowers within a 30 minute interval in the morning, at noon and in the afternoon were counted and their species determined. The number of flowers visited by a single pollinator was recorded as well. The relationship between the number of opened and visited flowers, and the number of bees and bumblebees were studies based on regression analysis.

The foraging behaviour of bees was observed in the experimental garden of the EAU in the second year after planting, i.e. in the first year of production. The planting distance in a row was 30 cm; the space between the rows 1 m apart was covered with peat mulch. There were 10-30 flowers on a plant during the observation period. The track of a bee on a row was followed from its arrival till the departure from the row. The length of the row covered during one flight was taken for the forage distance. On every harvest day the number of druplets on ripe fruits was determined.

Results and Discussion

The arctic bramble flowers are usually five-petalled with numerous stamens and styles, each of the latter attached to an ovary that will develop into the fleshy druplet after fertilization. After hibernation the plants start to grow with the arrival of the first warm days. In plantations covered with black plastic mulch the earth warmed up quickly, and plants renewed their growth during the first warm April days. The first flowers opened in the first half of May already; in the wild where the arctic bramble grows in semi shade in the grass under trees it starts to bloom at the end of May. Under favourable conditions flowering lasted the whole summer until September, with a maximum intensity (up to 120 flowers per m^2) in June. In warm and dry summers flowering ended in July (no irrigation was used). The cultivars studied differed significantly ($t = -7.01167$, $df = 22$, $P = 0.000$) in the number of flowers at the peak of flowering when 'Pima' had 27 ± 7 and the Estonian clone 40 ± 6 flowers on a plant (Fig. 1, A).

Observations made during the flowering period showed that flowers of the arctic bramble were visited mainly by honeybees (*A. mellifera*) which constituted 75% of the total number of pollinators. They visited the flowers continuously during the whole period of intensive flowering (Fig. 1, B). Honeybee density was closely dependent on flower density. The number of honeybees increased steadily to a maximum on 21 May, a little after maximum flower density. Hover flies (*Syrphidae*) constituted 18% of the visitors to the flowers. However, in view of their small body size they are less valuable pollinators. Anthers in arctic bramble flowers are strongly pressed against each other and warped downward towards the centre, therefore larger insects are more efficient pollinators.

Bumblebees (*Bombus* spp.) made up only 7% of flower visitors in the plantations in spite of the fact that in Estonian conditions there were no significant differences in the density of bumblebees in cultivated and natural habitats (Mänd et al., 2002). The *Bombus lapidarius* and *B. lucorum* were the major bumblebee species. Bumblebees visited the plantation at the beginning of May and in June, i.e. at the beginning and at the end of the flowering period of the arctic bramble, not at its peak flowering (Fig. 1,B). In May the flowers of the arctic bramble were visited by queens (who tasted 1 or 2 flowers, then flew to new ones a couple of rows further and left the plantation pretty soon). In June the flowers attracted bumblebee workers who were more assiduous than the earlier queens. The phenology of bumblebees and their cast representation on the arctic bramble was closely related to the seasonal cycles of colony growth. Overwintered queens were seen to forage on the plantation at the beginning of flowering in May, but not later when the arctic bramble was in peak flowering. Presumably queens had established colonies and reared workers by that time. Observations of bumblebee workers were confined to the end of June. Unfortunately, the emerging of the first workers (foragers) in colonies occurred during a rapid decline in flowering intensity, at the end of flowering, and they could not contribute much in pollination.

The pattern of arctic bramble pollinator communities in Finland is close to our results – there, too, honeybees are the major pollinators of these flowers (Kangasjärvi, Oksanen, 1989). In Estonia plantations the arctic bramble started to flower in the first half of May already when the weather is chilly and windy. The low temperatures strongly affect the number of honeybees, but not bumblebees to the same extent. It is well known that bumblebees continue to work in the field under weather conditions that deter honeybees from foraging, and they work longer hours (Wratt, 1968, Corbet et al., 1993). However, bumblebees foraged more quickly in terms of flower visits per minute, carried more pollen on their bodies than bees, and also deposited more pollen on stigmas (Willmer et al., 1994). Thus, at the beginning of flowering in the low temperatures of early spring, bumblebees may be considered better bramble pollinators than honeybees. However, honeybees should be supplied if natural populations of bumblebees are low.

As the arctic bramble is a self-incompatible insect-pollinated plant, the experimenter has to consider the behaviour of pollinators when choosing the planting distance between cultivars. Honeybees were the major pollinators on our experimental plots, so we observed their behaviour in a young plantation. Bees moved along a row choosing the nearest flowers irrespective of the cultivar. 58% of the bees covered no more than 1 m of the row (3 plants) and 23% up to 2 m (Fig. 2). Therefore cultivars characterized by abundant flowering ought to be planted alternately with other cultivars, one plant of the first cultivar between every 1-2 plants of the other one. The behaviour of pollinators was studied in Finland in an older plantation where in all probability there were more flowers. Pollinators moved along the rows as in our experiments; 62% of the foraging flights were limited to just one plant, 34% were made between plants of the same row, and only 37% of the flights occurred between the rows (Kangasjärvi, Oksanen, 1989).

The behaviour of the pollinators is economical in preferring the individual area with the greatest number of flowers rich in nectar (Heinrich, 1979, Zimmerman, 1983). At the flowering intensity of our experiments, the number of bumblebees was affected by the number of flowers in the plantation ($r = 0.4$, $n = 33$, $P < 0.05$), while the number of honeybees remained unaffected ($r = 0.1$, $P > 0.05$) (Fig. 2). All bumblebees prefer flowers that offer abundant nectar, because they are large insects with a high energy requirement, both for flight and for the muscular effort (Heinrich, 1979). Bumblebees prefer blackcurrants and raspberries, plus all berries and fruit trees; they visit flowers of redcurrant and gooseberry less often (Mänd et al., 1996). Our experimental plots were located in different surroundings. At Vasula the plot was situated within a large production area where in May and

June other berries and fruit trees were also in bloom. At Kambja there were blackcurrants and strawberry competing with the brambles.

In the case of same other plants, for instance *Cynoglossum officinale*, it was established that the amount of pollinators did not depend on the number of flowers (Vrieling et al., 1999). A greater number of flowers may attract more pollinators; however, more flowering may lead to more frequent geitonogamy (pollination between flowers of the same plant or clone) which has a negative effect on the yield of berries in self-incompatible plants through inbreeding depression. The arctic bramble belongs to the incompatible group of plants; therefore it is not recommendable to grow it without plastic mulch: without mulching, plants cover the whole row densely, and the resulting increase in the number of flowers in a row favours geitonogamy and decreases the probability of cross-pollination.

The fruit of arctic bramble resembles raspberry in its general appearance and size; however, the mature fruit does not fall apart from the receptacle. An average arctic bramble fruit weighs 1 g and consists of 15-30 single drupes. This number may range from 2 to 55 depending on the pollination rate (Ryynänen, 1973). In the case of self-pollination, fertilization does not take place at all, or poor fruits are formed. In our young experimental plantation the harvesting season lasted two months, July and August. The fruits consisted of 19...37 single drupes each (Fig. 3). Their number was markedly more at the 3rd, 4th and 5th harvest when the fruits had been fertilized during the height of flowering. Formation of normal fruits is an evidence of sufficient pollination having occurred in our experimental plantations.

When looking for a proper site of a new plantation, one has to consider the distance from the nest the pollinators are able to cover. It depends on a number of factors including the weather, the foraging area and the state of the nest. As a rule, nesting areas are located in permanent associations around a plantation as well. Bumblebees make foraging flights ranging between 70 and 631 m from the nest; the average foraging distance of bumblebees depends on the distribution of plants in the plantation. In a case of uniform distribution the flight is relatively short, while it increases with an aggregated distribution (Cresswell, 2000). For the best use of the resources of wild pollinators it is advisable to plant the arctic bramble in the form of a narrow strip or a small plantation near permanent associations. At the same time it would be necessary to employ honeybee colonies even in the vicinity of biotopes rich in wild pollinators.

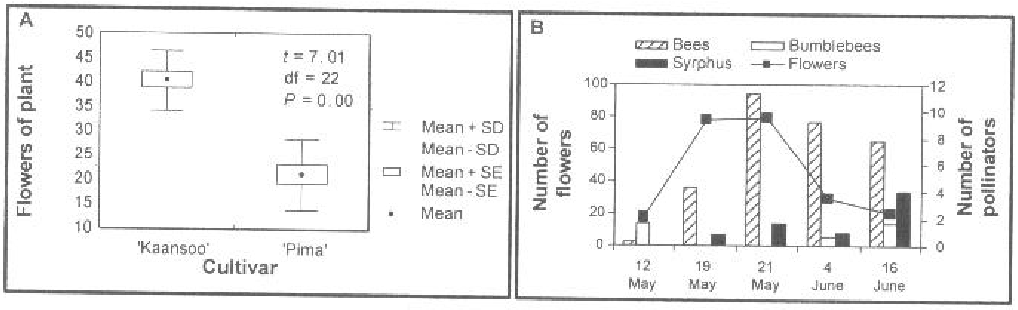

Fig. 1: The number of flowers per plant (A) and the number of pollinators and flower density at full blooming (B).

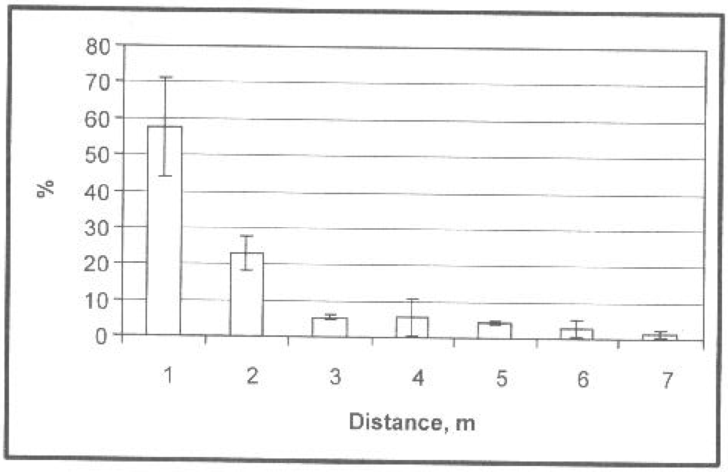

Fig. 2: Distribution (%) of honeybee foraging distances in arctic bramble plantation in the first year of production (mean, STDEV).

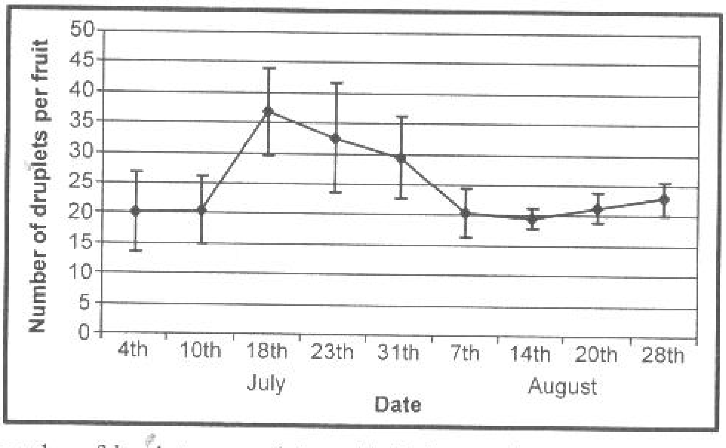

Fig. 3: The number of druplets per arctic bramble fruit on various harvest days (mean, STDEV).

Conclusions

On the basis of investigations under various production conditions carried out in South Estonia in 1996-1998, one may draw the following conclusions. In arctic bramble plantations honeybees are the major pollinators. The share of bumblebees and hover flies is much less. Bumblebees are more fastidious pollinators, and they prefer other wild forage plants when these are in bloom simultaneously. Honeybees make their foraging flights along the rows, and in a young plantation the foraging distance does not usually exceed 1 m. Our experiment showed that the environment in South Estonia has preserved its natural equilibrium, which is why there is no need for an additional supply of pollinators on plantations.

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References

Corbet, S.A., Fussel, M., Ake, R. Fraser, A., Gunson, C., Savage, A., Smith, K. 1993. Temperature and the pollinating of social bees. Ecological Entomology, 18: 17-30.

Cresswell, E. 2000. A comparison of bumblebees' movements in uniform and aggregated distributions of theit forage plant. Ecological Entomology, 25: 19-25.

Kangasjärvi, J., Oksanen, J. 1989. Pollinator behaviour in cultivated and wild Arctic Bramble (Rubus arcticus L.). Journal of Agricultural Science in Finland, 61: 33-38.

Karp, K., Starast, M. 1998. Domestication of Estonian Arctic Bramble. Forestry Studies, No. 30, Tartu 1998: 70-75.

Karp, K., Starast, M., Tiido, T. 2000. Frost damages of Arctic Bramble (Rubus arcticus) and half-highbush blueberry (Vaccinium corymbosum x Vaccinium angustifolium) depend on cultivation methods. Proceedings of the International Conference: Fruit Production and Fruit Breeding. 244-247.

Krearns, C.A., Inouye, D.W., Waser, N.M., 1998. Endangered mutualisms: The Conservation of Plant-Pollinator Interactions. Annual Review of Ecology Systems., 29: 83-112.

Mänd, M., Bender, A., Kase, K., Martin, A.-J. 1997. Õietolmu koguvate mesilaselaadsete jaotumus konkureerivatel ristikuliikidel. Magistrantide ja doktorantide teaduslike tööde kogumik. Tartu, 193: 52-57 (In Estonian).

Mänd, M., Mänd, R., Williams, I.H. 2002. Bumblebees in the agricultural landscape of Estonia. Agriculture, Ecosystems and Environment, 89: 69-76.

Osborne, J.L., Clark, S.J., Morris, R.J., Williams, I.H., Riley, J.R., Smith, A.D., Reynolds, D.R., Edwards, A.S. 1999. A landscape-scale study of bumblebee foraging range and constancy, using harmonic radar. Journal of Applied Ecology, 36: 519-533.

Pirinen, H., Dalman, P., Kärenlampi, S., Tammisola, J., Kokko, H. 1998. Description of three new arctic bramble cultivars and proposal for cultivar identification. Agricultural and Food Science in Finland, 7 (4): 455-468.

Rubar, N., Kurlovich, T. 2000. Productivity of nectar of Oxycoccus macrocarpus. Problems of Rational Utilization and Reproduction of Berry Plants in Boreal Forests on the Eve of the XXI Century. Proceedings of the Conference 11-15 September 2000, Belarus. 210-213.

Ryynänen, A. 1973. Rubus arcticus L. and its cultivation. Ann. Agric. Fenn.,12: 1-75.

Teuber, L.R., Barnes, D.K. 1979. Environmental and genetic influences on quantity and quality of alfalfa nectar. Crop Science, 19: 874-878.

Vrieling, K., Saumitou-Laprade, P., Cuguen, J., Dijk, H., Joung, T.J., Klinkhamer, P.G.L. 1999. Direct and indirect estimates of the selfing rate in small and large individuals of the bumblebee pollinated Cynoglossum officinale L. (Boraginaceae). Ecology Letters, 2: 331-337.

Willmer, P.G., Bataw, A.M., Hughes, J.P. 1994. The superiority of bumblebees to honeybees as pollinators: insect visits to raspberry flowers. Ecological ntomology, 19: 271-284.

Wratt, E.C. 1968. The pollinating activities of bumblebees and honeybees in relation to temperature, competing forage plants, and competition from other foragers. Journal of Apicultural Research, 2 (7): 61-66.

Zimmerman, M. 1983. Plant reproduction and optimal foraging: environmental nectar manipulation in Delphinium nelsonii. Oikos, 41: 57-63.