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THE EFFECT OF NEIGHBOURING ENVIRONMENTS AND THE ACREAGE OF THE WINTER RAPESEED PLANTATION ON THE DIVERSITY AND DENSITY OF *APOIDEA* (HYMENOPTERA)

1. Introduction

Due to intensification of the research into the effect of landscape structure on animal populations it was possible to present a number of interesting relationships between a landscape structure and species diversity of various groups of animals (Huhta, Koskenniemi 1975; Łuczak 1979; Andrzejewska and Gyllenberg 1980; Gałęcka, Karg 1980; Kajak 1980; Axelson et al. 1984; Dąbrowska-Prot 1986; Karg 1989). The similar investigations concerning the wild bees (*Apoidea*) revealed a significant relation between the general density of *Apoidea* in a landscape and general proportion of the refuge habitats in this landscape which constitute a permanent source of food plants and nesting site (Banaszak 1983, 1986).

The aim of this paper is an attempt to determine the effect of the number of refuge habitats surrounding rapeseed plantations (*Brassica napus* var. *oleifera* Metz.) on the diversity and density of *Apoidea* feeding on this crop. At the same time the effect of the crop itself (acreage) on the diversity and density of these insects was determined.

2. Terrain and methods

The research was carried out in 1976-78 on three plantations (Turew, Rogaczewo I, Rąbiń) and in 1987-90 on the other three plantations (Rogaczewo II, Szoldry I, Szoldry II). All the plantations are located about 40 km south of Poznań in the vicinity of Kościan (Western Poland). Each plantation was visited 2-3 times during full bloom of the rapeseed.

The fields differed with respect to the degree of closeness of the habitats which fulfill the function of refuge for the wild bees in the agricultural landscape. The Rąbiń plantation was surrounded in about 75% by a mixed forest and in about 20% by the field shelterbelts. Its acreage was 3 ha. The field in Turew (25 ha) was in about 75% surrounded by fields and lane shelterbelts. The remaining 25% constituted arable fields. The plantation dubbed Rogaczewo II was in half (50%) in contact with shelterbelts and grooves and in 20% with roadside swards. The vicinity of the Rogaczewo I plantation consisted only in 10% in shelterbelts while 45% were roadsides with rich vegetation. The Szoldry I plantation did not have a contact with trees, 10% constituted roadsides and the remaining part were roadsides with rich vegetation. The Szoldry II field was in 20% in touch with shelterbelts and with 10% with roadsides.

The density of *Apoidea* was determined by means of the stripe method which facilitates rather fast examination of considerable area by one researcher, and gives repeatable and representative results (Banaszak 1980).

In 1976 and additional evaluation of *Apoidea* number was carried out in Wierzenica (15.5 ha) using scoop method according to Tarwid (1953). The plantation was surrounded by a mixed forest, a meadow and dirt road with adjacent alfalfa crop. To determine the possible effect of the plantation vicinity on the species composition and density of *Apoidea* from each side of the plantation adjacent to these habitats and from its central part a series of 8 samples was taken which yielded a total of 32 samples from the crop. One sample was 25 hits with the scoop during a walk through 10 m of the crop. A total of 96 samples were taken during three days. Since this method yields on only relative evaluations of the number it was rejected in the following years.

The evaluation of faunistic representativeness of all the collected samples was carried out with Beklemiszev's criterion which is able to determine the sample size representative for an investigated environment type with respect to the more numerous species with appropriately high probability (Tarwid 1956). This method facilitated determination of the species predominant on the tested plantations.

To define the magnitude of species diversity in the studied plantations for the wild *Apoidea* the index of species differentiation of Shannon-Weaver (Odum 1977) was calculated,

$$H = - \sum_{i=1}^s p_i \cdot \ln p_i$$

where p_i is the participation of the i -th species in the community consisting of s species. The species differentiation was calculated only for numerical evaluations. To assess the significance of differences occurring between the H' values calculated for a given group, the parametric test of significance was used on the statistics t (Poole 1974), computing the variance of the obtained H' values, the magnitude of the statistics t and number of degrees of freedom for the confidence level of 0.05.

To determine the effect of plantation acreage on differentiation and density of the wild bees for each plantation the index L/A was calculated, which is proportion of the length of the refuge habitats surrounding a plantation to its acreage (Table 1).

The relationship between the vicinity of a plantation and its acreage and the differentiation and density of *Apoidea* was determined using the analysis of regression and the correlation coefficient.

3. Results

The analysis of faunistic representativeness of the collected material from each studied plantation indicated that the size of the sample series collected from particular plantations was large enough to determine the species predominating with respect to number. In the Wielkopolska Region, so far, 47 *Apoidea* species were found on the plantations of the winter

rapeseed (Banaszak 1982). On the plantations presented here 33 species were found of which, however, only 19 can be considered as the most frequent and predominating ones.

The mean *Apoidea* density for the six tested plantations in the vicinity of Kościan was 816.2 individuals/ha. This result was highly affected by the presence of *Apis mellifera* L. whose percentage was on average 91.3 %, though there was no apiary nearby. The number of honey bees ranged from 370.0 to 1287.5 ind./ha, mean 744.3 ind./ha (Table 2). The participation of the wild bees was on average 8.7 %, while the bumblebees constituted only 1.8 % and the solitary bees 6.9 %. Among all wild bees the greater percentage (> 1%) concerned only four species: *Andrena haemorrhoa* (Fabr.) - 20.4 ind./ha, *A. sabulosa* (Scop.) - 7.2 ind./ha, *A. nigroaenea* (K.) - 5.5 ind./ha and *A. fulva* (Schrk.) - 4.9 ind./ha.

While analysing the density of wild *Apoidea* on each plantation and the degree to which these crops are surrounded by refuge habitats a significant relationship between these values was observed. The correlation coefficient was 0.93 (Figure 1). The Rąbiń and Szoldry I plantations are spectacular examples of this relationship. The most density (145.0 ind./ha) was found for the Rąbiń plantation, which was surrounded by refuge habitats in 90 %, whereas for the Szoldry I plantation, where refuge habitats constituted only 10 % of a surround, the density was null.

Comparison of the magnitude of species diversity of the wild *Apoidea* defined with Shannon-Weaver's index (H') indicates significant differences among almost all plantations. Only the plantations in Rogaczewo I and Szoldry II, and Rąbiń and Turew did not show considerable differences. Table 3 presents verification of the H' value with respect to the significance of differences between the calculated values. The greatest differentiation was found for the Rąbiń and Turew plantations which had the largest degree of contact with the refuge habitats (90 % and 75 %). With decrease in the proportion of shelterbelts and swards in the vicinity of plantation also the index of species differentiation was falling. The analysis of correlation indicated that between these variables there was a statistically significant relation. The correlation coefficient between the degree of rapeseed crop

contact with the refuge habitats (expressed in %) and the differentiation coefficient H' was 0.86 (Figure 2).

Large effect of landscape (environment) differentiation in the direct vicinity of rapeseed plantation on variability of *Apoidea* fauna is also seen from the comparison of the H' indices calculated for different parts of the Wierzenica plantation (Table 4). Depending on the plantation orientation with respect to a meadow, forest or road, the magnitude of the H' indices changes. The greatest differentiation was observed on the plantation edges, particularly in the part adjacent to dirt road being a nesting site for bees. The smallest number of species and their differentiation occurs in the central part of the plantation, the farthest from the nesting sites.

The above observations show that the field acreage affects bees density. Using the L\A index a statistically significant correlation was found between this index and the density of wild *Apoidea*. The regression line determined for these variables has indicated that the increase of the plantation acreage with respect to the length of the adjacent refuge sites resulted in decrease in wild *Apoidea* density (Figure 3).

4. Discussion and conclusions

Generally the researchers agree that bee flight on rapessed flowers at blooming resulting in cross pollination is beneficial for the yield of seeds (Free 1970; McGregor 1976; Crane, Walker 1984).

Among the observed species the greatest role in rapeseed pollination had the honey bee whose proportion was on average 90.6 % of all the *Apoidea*, which confirms the reports of other researcher (Gałuszkowa 1965; Free 1970; Pawlikowski 1978; Andersson, Olsson 1961). The density and species composition of *Apoidea* on rapeseed plantations were presented by Banaszak (1982), while the honey bee density in the vicinity of Toruń was examined by Pawlikowski (1978), who found, on average, 1800 ind./ha near an apiary with 63 hives. An estimation of the number of bees necessary good pollination of rapeseed crop seems to be the most important task for further studies. From the practical experience it results that this can be achieved at 2.5 to 5 hives per ha (Demianowicz 1968; Guderska 1974).

The proportion of wild bees ranged from 0.0 to 16.4 %, mean 8.7 %. It should be added that solitary bees predominated decisively since the bumblebees are much less numerous at rapeseed blooming time. Hence, the wild bees have only an auxiliary (supplementary) role which can increase in conditions unfavourable for the honey bee breeding. However, the potential possibilities of pollinating rapeseed by the wild *Apoidea* are considerable. It was found that in Poland flights on rapeseed can be carried out by 105 species, and only in the Wielkopolska Region 47 species were found (Banaszak 1982). It seems possible to increase their role in pollination by reducing the factors limiting the growth of wild bee populations. An improvement can be obtained with more rational application of chemicals and protection of the habitats of these insects. This study indicates clearly that the magnitude of differentiation and density of the wild *Apoidea* is affected by the location of a plantation in the landscape. The greatest differentiation and density of bees were found on the plantations surrounded to considerable degree (75-90 %) by tree communities and swards. A decrease in the number of refuge habitats in the direct vicinity of plantations resulted in the fall in the species differentiation and density of the wild *Apoidea* on the rapeseed crop. As it was shown, this relationship had a linear course and was statistically significant. At the same time it was shown that the density of pollinating bees depends also on the plantation acreage, or more accurately, its relation to the length of the borderlines with the surrounding refuge habitats. With the increase of the crop acreage the density of wild *Apoidea* decreased.

The wild *Apoidea* visit the blooming rapeseed plantation as a source of abundant though short term nectar. Their number and differentiation depend, however, on the presence of nesting sites and fodder plant during the whole vegetative period. These plants occupy the edges of forests and shelterbelts, the roadsides etc., as well as other attractive cultures like alfalfa, clover and a number of farmacological plants.

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STRESZCZENIE

Na kilku plantacjach rzepaku ozimego w Wielkopolsce oceniono wpływ środowisk otaczających i wielkości plantacji na zróżnicowanie i zagęszczenie pszczoł (*Apoidea*). Największe zróżnicowanie gatunkowe pszczoł i ich zagęszczenie stwierdzono na plantacjach w znacznym stopniu (75-90 %) otoczonych przez zespoły roślinności murawowej lub zadrzewienia śródpolne i lasy. Jednocześnie udowodniono, że wielkość powierzchni pola wpływa na zagęszczenie pszczoł. Stwierdzono istotną statystycznie korelację między wskaźnikiem stosunku długości otoczenia plantacji do jej powierzchni a zagęszczeniem *Apoidea*.

Table 1.

Elementary character of *on* investigated winter rape plantations and Apoidea communities

Plantation	Plantation's contact with refuge habitats x(%)	area of plantation ha	L/A coefficient m/m ²	H'	number of species	density ind./ ha
Rąbiń	90	3	209	1,99	10	145,0
Turew	75	25	60	2,11	11	115,0
Rogaczewo I	55	13,5	65	1,55	6	80,0
Rogaczewo II	50	21	43	1,73	6	33,4
Szoldry I	10	5	18	0	0	0
Szoldry II	30	3,5	65	1,47	5	58,3

x - forests, shelterbelts and swards

Table 2.

Density of *Apoidea* on the investigated plantation of rapeseed

	Rąbiń		Turew		Rogaczewo I		Rogaczewo II		Szoldry I		Szoldry II	
	ind/ha	%	ind/ha	%	ind/ha	%	ind/ha	%	ind/ha	%	ind/ha	%
wild bees	145,0	12,0	115,0	16,4	80,0	13,0	33,4	2,5	0	0	58,3	8,4
honey bee	1055,0	87,9	585,0	83,6	535,0	87,0	1320,9	97,5	370,0	100	633,3	91,6
sum	1200,0	100,0	700,0	100,0	615,0	100,0	1354,3	100,0	370,0	100,0	691,6	100,0

Table 3.

Estimation of species diversity (H') on the basis of statistics t (for $P < 0.05$)

Plantation			1	2	3	4	5	6
Rąbiń		1	x					
Turew		2	-	x				
Rogaczewo I		3	+	+	x			
Rogaczewo II		4	+	+	+	x		
Szoldry I		5	+	+	+	+	x	
Szoldry II		6	+	+	-	+	+	x

+ - significant difference

- - insignificant difference

Table 4.

Species diversity (H') in different parts of Wierzenica plantation

H' - Shannon-Weaver's coefficient

P - statistic difference H' , + significant, - - insignificant (for $P \leq 0.05$)

part of plantation at:	H'	P	number of species
cart-roat	2.440	+	16
forest	1.944	+	7
meadow	1.648	+	6
centre of plantation	1.099	+	3

Figure 1. Regression line of *Apoidea* density on plantation's contact with refuge habitats

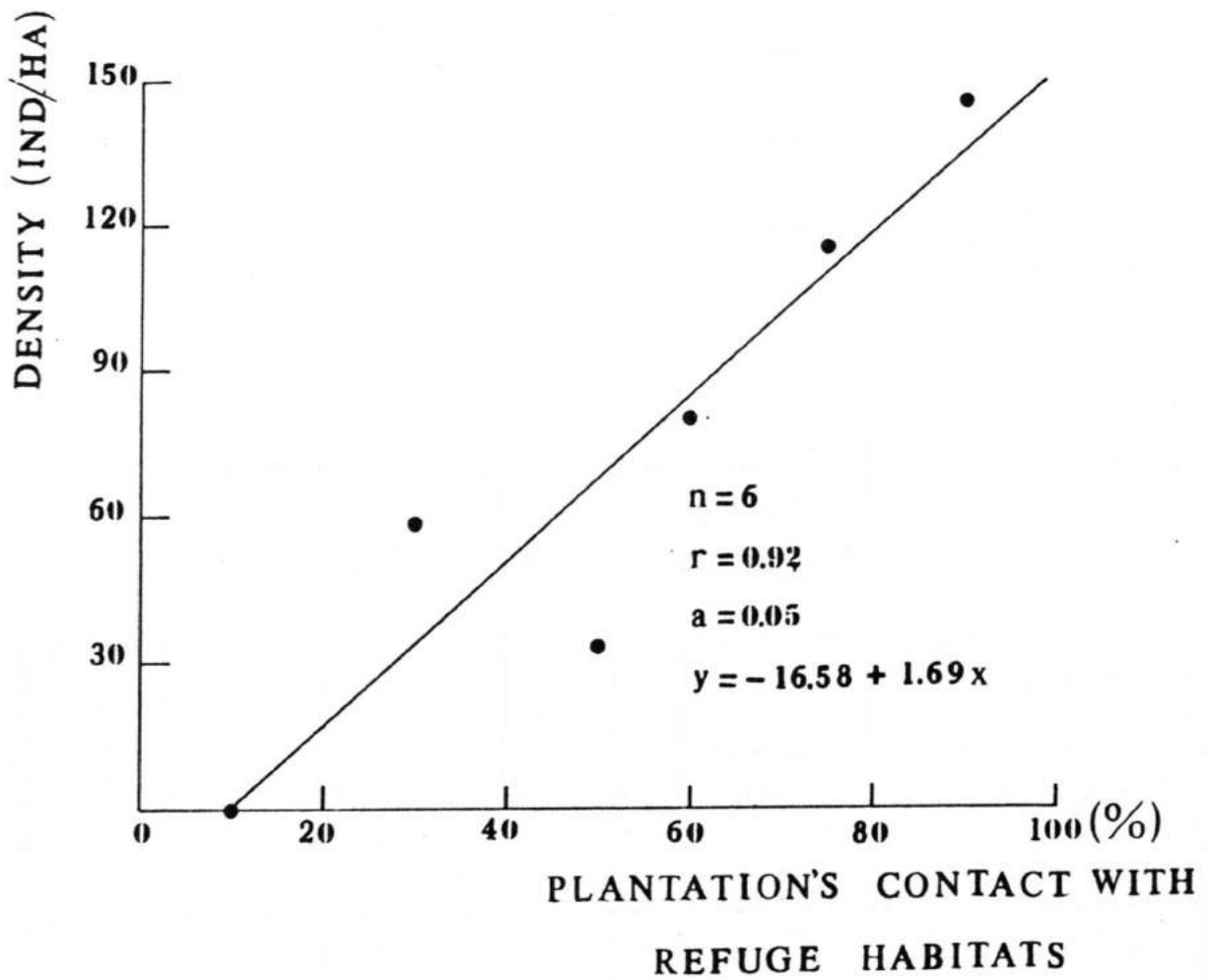


Figure 2. Regression line of *Apoidea* species diversity (H') on index L/A - proportion of the length of the refuge habitats surrounding a plantation to its acreage

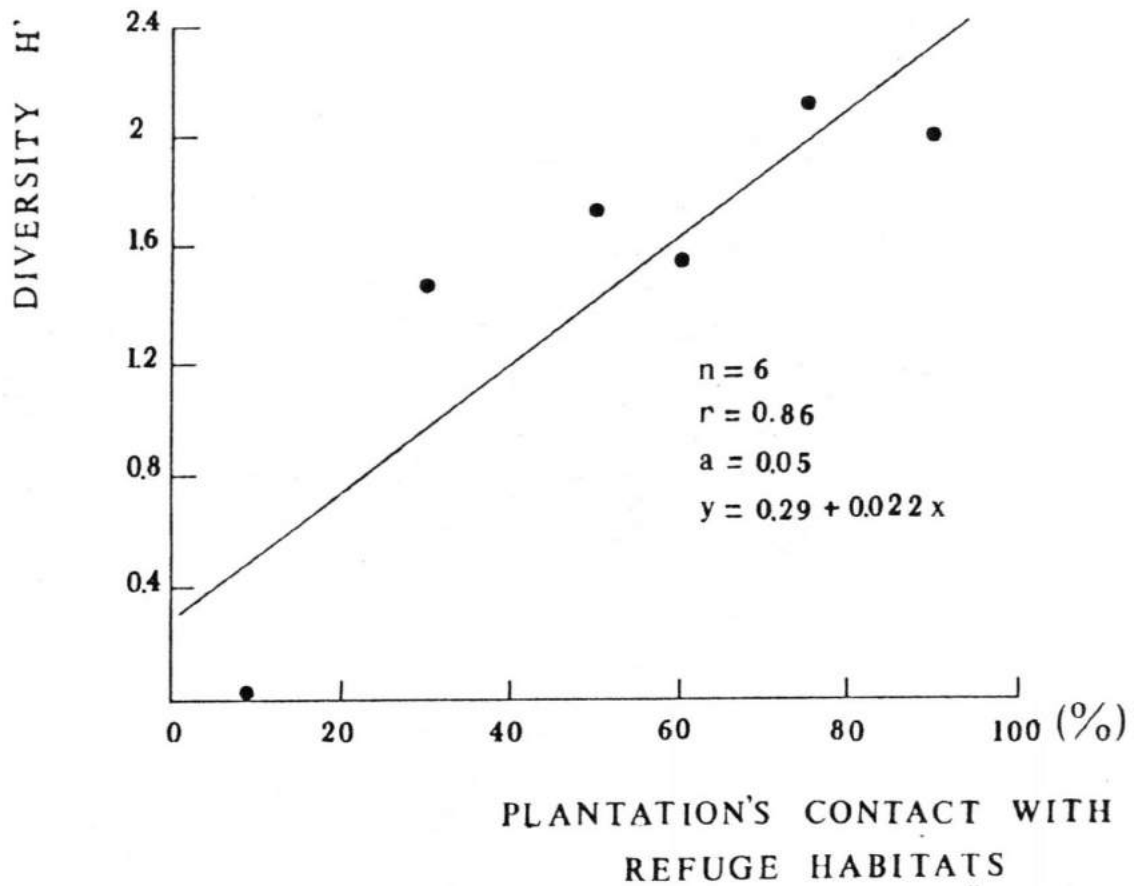


Figure 3. Regression line of Apoidea density on index L/A - proportion of the length of the refuge habitats surrounding a plantation to its acreage

