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Entomophilous plant species inhabiting the southern limestone slopes of Mt. Vitoša (SW Bulgaria) and their pollinators

Abstract

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This study deals with the co-evolutionary determined interrelationships between the complex of plants flowering in mid-summer on the southern limestone slopes of Vitosha Mts. and their pollinating agents. The most numerous are the plant species with flag and gullet (zygomorphic) blossoms. Numerous are also the plants with dish/bowl (actinomorphic) blossoms. As a whole dominate the purple coloured blossoms, followed by the yellow ones. The pollinators visit most actively the plants with zygomorphic blossoms, mainly those that are purple in colour. Most numerous pollinators of the entomophilous plant complex flowering in the mid-summer on the southern limestone slopes of Mt. Vitosha are bees.

Introduction

In macro-evolutionary aspects the basic syndromes of pollination (complex of flower characteristics: shape, symmetry, colour, smell etc.) could be referred as adaptation to different pollinating agents. Many different methods have been used to quantify floral characters and many hypotheses have been proposed (Leppik 1956, 1957, 1958, Grant & Grant 1965, Faegri & van der Pijl 1970, Stebbins 1974, Grinfeld 1978, Richards 1990, Dafni 1992, Dafni & O'Toole 1994, Herrera 1996, Proctor & al. 1996, Dafni & Kevan 1996, Dafni & Neal 1997, Neal & al. 1998, Giufra & al. 1999).

The calcareous regions are specific habitats with specific calciphilous flora complexes often rich with many endemic species – these are some of the important Bulgarian "fire-places of speciation". On the other hand open calcareous terrains offer to the bees wide spectra of nesting niches, and rich food resources. This is a condition for rich and diverse bee fauna. Complicated relationships between bees and plants could be expected having on mind that Bulgaria is on a cross-road of different zoogeographical and phytogeographical influences (Kozuharova & Dimitrov 1999).

The plant-pollinator relationships have been studied in the subalpine meadows on the

Northern slopes of Vitoša Mts., at 1800-2200 m altitude in order to reveal the distribution of the insects on the blossoms (flowers or inflorescences) according to their functional morphology (Kozuharova 1997 a).

This study deals with the probable co-evolutionary determined interrelationships between the complex of plants flowering in mid-summer on the southern limestone slopes of Vitosha Mts. and their pollinating agents.

Material and methods

The field investigations were conducted during the mid-summer (July) of 1990, 1991, 1992 and 1994, at a study site (size 50 × 100 m) at 1000 m altitude in a plant community on limestone basic rock. The entomophilous plant species flowering during that period were identified after Flora of PR Bulgaria (Jordanov 1963-1995), "Guidebook of the higher plants" (Kozuharov 1992). Approximate abundance evaluation of the flowering plant species was done after Drude scale (Jaroshenko 1961).

The term "blossom" in this study refers to both individual flowers and compact inflorescences (such as the capitula of *Asteraceae* and *Dipsacaceae* assuming that they function as a single flower, cfr. Faegri & van der Pijl 1970). According to their blossom morphology the plant species were classified after the scheme of Faegri & van der Pijl (1970) with some modifications as follows 1) dish/bowl - free access to the nectar and pollen, radial symmetry of the "blossom"; 2) bell and tube - more or less hidden nectar, radial symmetry to slight zygomorphy; 3) flag (sexual organs are found in the lower part, pollen is deposited on the abdominal side of the insect, sternotribic pollination) and gullet (sexual organs are restricted to the functionally upper side, pollen is deposited on the abdominal side of the insect back and upper part of the head, nototribic pollination); more or less hidden nectar, medial zygomorphy. These categories correspond to those accepted by Leppik (1956, 1957, 1958) as follows: actinomorphic, stereomorphic and zygomorphic, that we have used in other papers of ours (Kozuharova 1997 a, b).

The insect visitors were observed on transects along the study site (Dlusskii pers. comm.; Dafni 1992). The observations were conducted in these 4 years – totally for 27 hours of 14 days. All observed visitors and their behaviour (frequency of visitation and flower constancy) were recorded. A sample of 114 insects was collected for detail identification. The insects are deposited in The Museum of Natural History, Bulgarian Academy of Sciences and in personal collections.

Results

The highest number of plant species have flag and gullet (zygomorphic) blossoms. Also a high number of plant species have dish/bowl (actinomorphic) blossoms (Table 1, Fig. 1). Here it should be mentioned that *Cichorium intybus* L., *Centaurea stoebe* L., *Knautia arvensis* (L.) Coult and *Scabiosa ochroleuca* L. are included in the dish/bowl structural class with respect to the capitula, despite their single flowers belonging to the tube structural class with more or less medial zygomorphy and some restriction to the nectar (cfr. Faegri & van der Pijl 1970).

The highest number of species have purple blossoms. Next highest number of species

Table 1. The complex of plants flowering at Mid July on the limestone southern slopes of Vitosha Mts.; *cyan+purple, **yellow/purple center of the flower, ***known to be wind pollinated. Approximate abundance evaluation of the flowering plant species was done after Drude scale descendingly as follows: Soc. (sociales), Cop.$_3$ (copiosae$_3$), Cop.$_2$ (copiosae$_2$), Cop.$_1$ (copiosae$_1$), Sp. (sparsae), Sol. (solitariae).

Blossom type	**white**	**yellow**	**cyan**	**purple**
dish/bowl **actinomorphic**	*Sedum italica* (L.) Perz. **Sol.** *Achillea millefolium* L. **Sol.** *Pimpinella tragium* Vill. **Sol.** *Scabiosa ochroleuca* L. **Sol.**	*Helianthemum nummularium* (L.) Mil. **Cop.$_2$** *Hypericum perforatum* L. **Sol.** *Alyssum murale* W. et K., **Sol.** *Potentilla pilosa* Wild. **Sol.** *Potentilla. argentea* L. **Sol.** *Galium verum* L. **Sol.** *Hypericum perforatum* L. **Sol.** *Leontodon crispus* Vill. **Sol.**	*Cichorium inthibus* L. **Sol.**	*Galium purpureum* L. **Cop.$_1$** *Geranium columbinum* L. **Sol.** *Centaurea stoebe* L. **Sp.** *Knautia arvensis* (L.) Coult **Sol.** ****Sanguisorba minor* Scop. **Sol.**
Bell and tube **stereomorphic**			*Gentiana cruciata* L. **Cop.$_3$** **Campanula lingulata* W. et. K. **Sp.** **Campanula trachelium* L. **Cop.$_1$** **Campanula rapunculoides* L. **Sp.** **Campanula bononiensis* L. **Sp.** **Campanula sparsa* L. **Sp.**	*Dianthus cruentus* Griseb **Sp.** *Petrorhagia illyrica* Ball. et Heyw. **Sol.** *Centaurium pulchellum* (Sw.) Druce **Sol.**
flag **zygomorphyc**	*Dorycnium herbaceum* Vill. **Cop.$_3$**	*Medicago falcata* L. **Cop.$_3$** *Medicago lupulina* L. **Cop.$_2$** *Lotus corniculatus* L. **Cop.$_2$** *Trifolium ochroleucum* Huds. **Sol.** *Melilotus officinalis* Medic. **Sol.** *Ononis pusilla* L. **Sol.** *Anthyllis vulneraria* L **Sol.**.		*Coronilla varia* L. **Sol.** *Onobrychis alba* (W. K.) Desv. **Sol.** *Vicia cassubica* L. **Sol.** *Trifolium campestre* Schreb. **Sol.** *Trifolium pratense* L. **Sol.** *Viola tricolor* L. **Sol.** *Polygala major* Jack. **Sol.**
gullet **zygomorphyc**	*Teucrium polium* L. **Sp.** ***Euphrasia picta* Wimm. **Sol.**	*Teucrium montanum* L. **Sp.**		*Thymus pannonicus* All. **Cop.$_3$** *Teucrium chamaedris* L. **Cop.$_3$** *Origanum vulgare* L. **Cop.$_1$** *Salvia nemorosa* L. **Cop.$_1$** *Acinos alpinus* (L.) Moench. **Sp.** *Clinopodium vulgare* L. **Sp.**

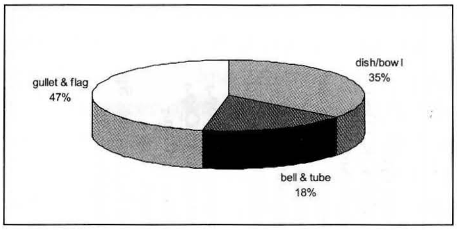

Figure 1. Distribution of blossom structural classes according to morphology.

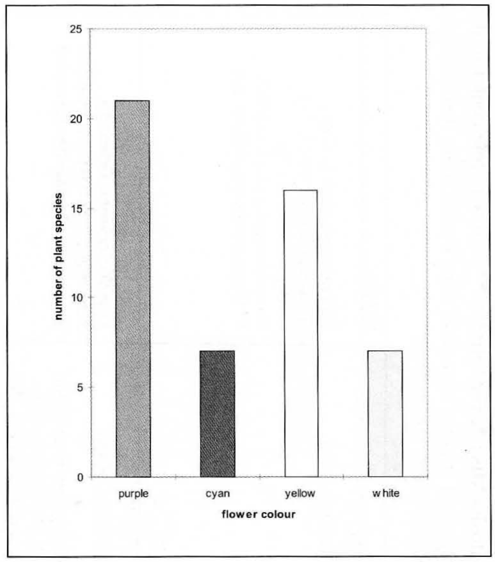

Figure 2. Distribution of blossom structural classes according to colour.

have yellow blossoms. (Table 1, Fig. 2).

Specifically, in the structural classes of flag and gullet (zygomorphic) blossoms purple and yellow colours dominate. The highest number of plant species with purple and yellow blossoms belong to this structural class. Also two purple coloured plant species of this class, *Thymus pannonicus* All. and *Teucrium chamaedrys* L., as well as one yellow coloured, *Medicago falcata* L., are most abundant (Table 1, Fig 3). The two other most abundant species in this study site, *Gentiana cruciata* L., and *Dorycnium herbaceum* Vill., belong respectively to cyan, bell and tube (stereomorphic), and white, flag and gullet (zygomorphic) classes (Table 1). The dominant colour of the blossoms in the dish/bowl (actinomorphic) structural class is yellow (Table 1, Fig 3).

The pollinators visit most actively the plants with flag and gullet (zygomorphic) blossoms, mainly those that are purple in colour (Fig. 4). The highest number of species and the most abundant species belong to flag and gullet, purple and yellow blossom classes (Table 1, Fig. 1-3).

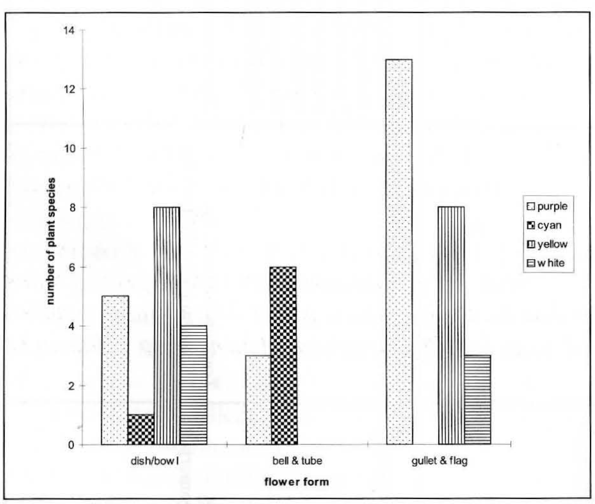

Figure 3. Distribution of blossom structural classes according to both morphology and colour

The most common bee species in the study site were as follows (in descending order): *Bombus terrestris* L., *Apis mellifera* L., *Halictus* sp. pl., *Bombus hortorum* L. and *Hoplitis* sp. pl. while *Bombus agrorum* F. were sporadic. *B. terrestris* , visited most often the flowers of *Teucrium chamaedrys*, and occurred also on

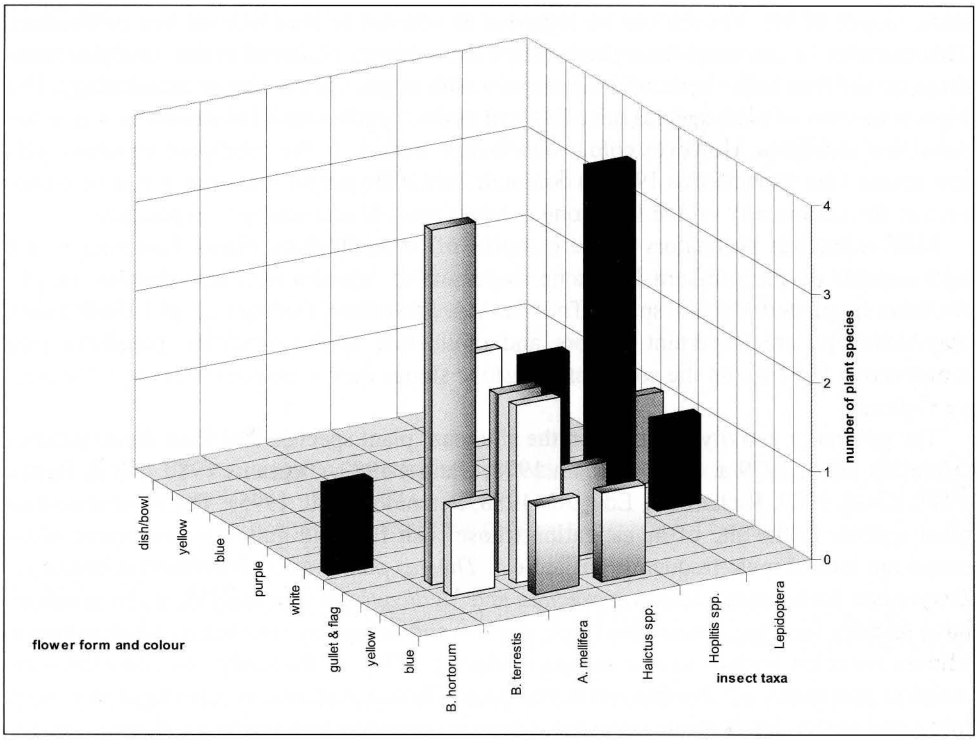

Fig. 4. Distribution of main pollinators on the blossom structural classes according to both morphology and colour of the blossom.

Thymus pannonicus, *Medicago falcata*, *Origanum vulgare* L., *Salvia nemorosa* L.; *Bombus hortorum* was observed only in the flowers of *Gentiana cruciata*; *Apis mellifera* preferred *Thymus pannonicus*, but visited also *Dorycnium herbaceum*, *Medicago lupulina* L., *M. falcata*, *Origanum vulgare*; *Halictus* sp. pl. were numerous on the flowers of *Gentiana cruciata, Dorycnium herbaceum*, and visited also *Thymus pannonicus*. *Hoplitis* sp. pl. preferred all of *Campanula* species in the region and were observed also in the flowers of *Helianthemum nummularium* (L.) Miller.; *Bombus agrorum* F. was sporadically observed on *Thymus pannonicus*, *Lotus corniculatus* L. and *Medicago lupulina* subsp. *lupulina.*

Lepidoptera, Diurna (butterflies and moths active during the day) in this study were presented by several species. *Ochlodes venatus* Turati pollinated the flowers of *Dianthus cruentus* Griseb., but visited also the flowers of *Gentiana cruciata*. *Macroglossum stellatarum* L. was observed to suck nectar from *Gentiana cruciata*. *Melamnargia galathea* L. visited *Knautia arvensis*.

Discussion

According to the syndrome hypothesis (Faegry & van der Pijl 1971, Proctor & al. 1996) the complex of entomophilous plants flowering in the mid-summer on the southern limestone slopes of Mt. Vitosha can be regarded as adapted to predominant bee pollination. This complex of entomophilous plants keeps the tendency observed in the subalpine meadows on the Northern slopes of the mountain with respect to the flower morphology. The highest number of plant species have flag and gullet (zygomorphic) blossoms as it is in the subalpine meadows. However colour distribution differs. In the subalpine meadows yellow colour (see Kozuharova 1997 b) dominate, while the purple blossoms are most numerous in the community on the limestone at lower altitude and southern exposition.

Most numerous pollinators of the complex of entomophilous plants flowering in the mid-summer on the southern limestone slopes of Mt. Vitosha are bees: *Bombus* sp. pl., *Halictus* sp. pl. and *Hoplitis* sp. pl.. The flies e.g. *Muscidae* (*Thricops* sp. pl.), *Tachinidae*, *Syrphidae* etc. are important visitors and pollinators in the subalpine meadows (see Kozuharova 1997 b), on the southern limestone slopes they were not observed to be active visitors.

The pollinator activity is higher on the abundant plant species, that form dense patches (Heinrich 1976, 1979 a, 1979 b, Levin 1978, Handel 1983, Pleasants 1980, Sih & Baltus 1987, Kwak 1987, Richards & Edwards 1988, Petanidou & al. 1995). The most abundant plant species in the site of investigation (those with flag and gullet, zygomorphic blossoms) are indeed most frequently visited e.g. *Thymus pannonicus, Teucrium chamaedrys, Dorycnium herbaceum, Gentiana cruciata* and *Medicago falcata.* Individuals bumblebees have primary foraging specialities (their majors) and secondary specialities (their minors). Minors are often bridges to new majors (Heinrich 1976). In the study site *Teucrium chamaedrys* was major for *Bombus terrestris*, while *Thymus pannonicus* was major *Apis mellifera* and minor for *Bombus terrestris. Gentiana cruciata* was major for *Bombus hortorum.* The other two most abundant species, *Medicago falcata* and *Dorycnium herbaceum* were minor foraging species for the bumblebees. However *Dorycnium herbaceum* was a major plant species for *Halictus* sp. pl. together with *Gentiana cruciata.*

Two or more species of bumblebees with tongues of similar length may often forage on the same flowers and as a result of competition the more efficient foragers replace the less efficient (Heinrich 1979 a, 1979 b, Bowers 1985 b). In this study site the workers of *Bombus terrestris* may be expected to be competitors to the workers *Bombus agrorum*, as their tongue lengths are quite similar (respectively 7.85 ± 0.57 and 7.89 ± 0.67, after Pekkarinen 1979). Further experimental analyses including specifics in the bumblebee colonization are necessary to prove that.

It is proposed that a first requirement for an efficient pollination system with many species of plants in a habitat is flower fidelity by individual pollinators; However fidelity breaks down if the flowers blooming at any one time are not sufficiently different from each other; The simultaneously flowering of common species may result in a diversity of flower types, while sequential flowering may result in flower convergence (Heinrich 1975). Waser (1983) review evidence that competition for pollination has produced or maintains differences in floral characters among sympatric plant species. The segregation of blooming periods minimizes competition as among the anthophilous insects for food resources so among the plants for pollinators (Reader 1975, Pleasants 1980, Petanidou & Vokou 1993). In addition mid- to late-summer bumblebee diversity correlates with meadow floristics (Bowers 1985 a).

This is a preliminary study of the complex of entomophilous plants flowering in the mid-summer on the southern limestone slopes of Mt. Vitosha and their pollinators. Further investigations on the phenology, comparative detailed data on functional flower morphology and tongue length of the pollinators are necessary. They will give more information on the competition among the anthophilous insects for food resources and among the plants for pollinators.

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