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To be or not to be—the effect of nature conservation management on flowering of *Paeonia mascula* (L.) Miller in Israel

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Abstract

Mount Meiron Nature Reserve is the largest Mediterranean reserve in Israel. Since its establishment, goat grazing and wood-cutting have been prohibited and dense oak maquis has developed by succession. The succession of vegetation poses the risk of losing species. The peony (*Paeonia mascullа*) is a locally endangered species in Israel, growing only in a small population in the Mount Meiron Nature Reserve with only 5% of plants flowering. We sought a management practice that would increase the flowering percentage of the peonies and secure the future of its population. We found that flowering peonies grew mainly in locations with about 47% direct sun radiation, while most plants grew under heavy shade with only 27% direct radiation. Creation of small gaps increased the flowering to 15–20%. To ensure the future of the peonies in the Mount Meiron Nature Reserve, small gaps must be created—even if this conflicts with broader current management policies.

Keywords: Conservation; Management; Mediterranean; *Paeonia*; Succession

1. Introduction

Nature reserves are a major tool of the authorities for implementing their nature conservation policy according to their objectives. Historically, preservation of rare and endangered species was one of the main goals of nature preservation, while nowadays priority is given to preservation of ecosystems and of their biodiversity, which positively affects their production and stability (Christensen, 1988; Nilson and Ericson, 1992; Given, 1994; Hawksworth, 1995). High diversity ecosystems and nature reserves are also more attractive to visitors. Despite the importance of species diversity, not all species are considered to be of equal value. Some are key-species of fundamental importance in the ecosystem's food web, while others may be rare or endangered species, which will tend to generate greater conservation effort (Nilson and Ericson, 1992). According to the IUCN formal definitions, plants are divided into Lower Risk (LR), Vulnerable (VU), Endangered (EN), Critically endangered (CR), Extinct in the wild (EW), and Extinct (EX), according to distribution area, population size, changes in the past, and future prospects (IUNC 2000 red list). These definitions are for the worldwide population of species, but similar criteria are used for the evaluation of the status of locally rare and endangered species in Israel (Cohen and Shmida, 1992). Regardless of this scientifically objective classification, not all species are treated equally (Hawksworth, 1995). Plants that support many animal species, or large, well known flowering plants that are more appreciated by the public and attract them to nature reserves, enjoy more attention and conservation effort than small and inconspicuous species do.

Mount Meiron Nature Reserve is the largest Mediterranean reserve in Israel. Its area is about 80 km^2; average elevation is 900 m above sea level, including the highest peaks of the Upper Galilee (Paz, 1981). The rainy season is mainly between November and March with an annual average rainfall of about 900 mm. The winter is cold compared with other regions; it does not snow every year, and when it does it lasts for only few days, mainly at elevations above 1000 m. The vegetation consists mainly of the species-rich Mediterranean oak maquis (*Quercus calliprinos–Pistacia palestina* association) dominated by evergreen species (Zohary, 1973).

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The reserve covers some areas that have been protected since the 1930s, as well as the Druze village of Beit Jan with its municipal area and agricultural lands. Before its declaration as a nature reserve in 1965 (Paz, 1981), the area endured woodcutting, intensive goat grazing, and deforestation for the preparation of traditional agricultural land. Because of the various intensities of land uses, the landscape presented a mosaic of plots at various stages of secondary succession. After its declaration as a nature reserve and legislation prohibiting grazing of black goats, grazing, woodcutting, and deforestation decreased drastically. Because of law enforcement and socio-economical changes in the Druze population, forest regeneration was enhanced, trees grew higher and their cover increased at the expense of areas and gaps exposed to variable amounts of sun radiation (Carmel and Kadmon, 1999). Consequently, secondary succession took place in the protected areas, which changed from a mosaic of open and closed plots to a dense and shaded oak maquis. The regeneration of vegetation signifies the successful implementation of nature protection legislation. However, it carries a high price in other currency of nature conservation, as will be discussed later.

Despite its relative height, Mount Meiron is not isolated, so its flora does not include any endemic species although it does contain many species that do not occur in other parts of Israel (Shmida, 1984). This group consists of Mediterranean species that grow in Turkey, Syria, and Lebanon, and reach their southernmost point of global distribution here. Such peripheral sub-populations often differ in their genetic composition, genetic diversity, and phenotypic variability from the core sub-populations (Safriel et al., 1994; Kark et al., 1999). Therefore, their protection and conservation are important even if they are not globally endangered. The peony [*Paeonia mascula* (L.) Mill] (Zohary, 1966), is one of the foremost species of this group. Furthermore, it is a main visitor attraction in the spring, during the flowering period.

The genus *Paeonia* has about 50 species in Asia, Europe, and North America. *P. mascula* is a circum-Mediterranean species that grows in semi-shaded habitats on rich organic soils (Polunin, 1969, Polunin and Huxley, 1972). As far as we know, there is no published information about the lifecycle of *P. mascula* concerning seedling establishment, age to first flowering and longevity. However, two surveys in 1973 (Ortal, 1975) and 1992 (Cohen and Shmida, 1992), revealed that the peonies grow only in a restricted area of 3 km^2 in the southern part of Mount Meiron Nature Reserve, and only about 5% of the plants, most of which grow under heavy shade, flower. As a result, the peony was declared an endangered species in Israel and was included in the Red Data Book of Israel Plants (Cohen and Shmida, 1992). The small area of distribution and mainly the low flowering percentage were attributed to the decrease in the abundance of semi-shaded habitats due to the decrease in the utilization of natural vegetation after the implementation of nature protection rules.

Given (1994), in his book setting forth the official attitude of the IUCN to plant conservation, listed the main human-related causes for the extinction of plant populations: loss of habitats, harvesting and overexploitation, alien plants and feral animals, pollution, climate change, and human population increase. However, the possibility that general nature protection policies may endanger rare species with different requirements, as is our case, is not mentioned.

The aim of the present research was to find a management practice that would increase the flowering percentage, namely to investigate whether small-scale woodcutting would increase the flowering percentage.

2. Methods

2.1. Plots

Fifteen permanent plots (5×5 m) in which peonies were detected were marked out in Mount Meiron Nature Reserve (35°25′E, 32°58′N). Five plots with flowering peonies were located in small open gaps (hereafter **open**), and 10 with non-flowering plants were found under closed canopies. Five of the latter were left untreated (hereafter **closed**); from the remaining five plots, all trees were cleared in November 1997 (hereafter **cleared**). On each plot, the number of peony plants and flowers was counted and height measured each spring at the end of the flowering season. Relative photosynthetic active radiation (RPAR) was measured on each plot.

In addition, in spring 1998, RPAR, basal stem diameter, and height were measured, and leaflets counted for all flowering plants and for neighboring non-flowering plants along the 'peony path' that was constructed by the authorities for visitors.

In 2001, 4 years after the treatment, all plant species growing in the plots were recorded (Nomenclature: Feinbrun-Dotan and Danin, 1991)

2.2. Radiation measurements

Photosynthetic Active Radiation (PAR; 400–700 nm) was measured by means of AccuPAR, Decagon Devices, Inc., Pullman, WA, USA. Radiation measurements were taken between 10:00 and 14:00. To determine the radiation of a single plant's site, five measurements taken above the plant were averaged. To determine the average radiation of a plot, four measurements were taken at each of 16 points 1×1 m apart, and all 64 measurements were averaged. Direct sun radiation was measured before and after the measurements on each plot at an almost fully exposed site. The proportion of the measurements on the plots to direct radiation is determined as relative PAR (hereafter **RPAR**).

3. Results

3.1. Flowering and non-flowering plants

The average (±S.E.) height of flowering and non-flowering peonies was 31.7±3.23 cm and 20.5±2.17 cm respectively, and the difference, tested by *t*-test, was significant ($T_{71}=-9.45$, $P<0.001$). Preliminary results indicate that flowering plants also had a thicker stem and more leaflets than non-flowering plants. Average (±S.E.) RPAR of the sites of flowering and non-flowering peonies was 47.4±1.47% and 27.3±1.25% respectively, and the difference, tested by *t*-test on Arcsin of square root transformed data, was significant ($T_{71}=-2.85$, $P=0.006$). To test the significance of height differences among peonies growing at various RPAR, the plants were divided into three RPAR classes: 0–20% ($n=58$), 21–40% ($n=12$), and 41–100% ($n=3$). Average (±S.E.) heights were 31.4±1.7, 41.9±2.6, and 37.0±4.5 cm respectively, and the differences tested by one-way ANOVA were significant ($F_{2,70}=3.97$, $P=0.023$), namely the peonies growing at 21–40% RPAR were the tallest.

Almost all flowers except damaged ones produced fruits, indicating no limitation of fruit set by pollination or breeding system.

3.2. Plots

Tree cutting caused a 10-fold increase in RPAR in the cleared compared to the closed plots (Fig. 1). Kruskal–Wallis (hereafter KW) test revealed significant differences in RPAR among treatments in all years (e.g. for 2001 KW Statistic = 9.740, $P=0.008$).

The percentage of flowering peonies was significantly different in the cleared plots (e.g. for 1998 KW Statistic = 10.599, $P=0.005$; for 2001 KW Statistic = 7.071, $P=0.029$). However, in 1998 the flowering percentage on the cleared plots was similar to that on the closed ones, but in the subsequent years it was much higher and similar to that on the open plots (Fig. 2).

In 1998, the height of peony plants on the cleared plots was significantly lower than that on the open plots but not different from that on the closed ones ($F_{2,12}=4.754$, $P=0.030$). In the subsequent years, the plants on the cleared plots grew higher and there was no significant difference between their height and that of the plants on the open plots (Fig. 3).

The relationship between the average height of the peonies on a plot and RPAR is best described by the shape of second power curve with a maximum at about 40% (Fig. 4), indicating that 40% RPAR was the optimal light regime for peony growth.

A significant linear regression was found between the percentage of flowering peonies and the average height of the plants on the plots in 2001 (Fig. 5), indicating that plots with high peony plants were also expected to have a high percentage of flowering plants.

The average (±S.E.) number of peony plants per plot was 23.3±2.4, but with no significant differences in the averages among treatments (e.g. for 2001 $F_{2,12}=1.019$, $P=0.390$).

In 2001, 4 years after the treatment, significant differences were found in the average total number of plant species in the plots (KW Statistic = 6.294, $P=0.043$) and in the number of annual species (KW Statistic = 7.085, $P=0.029$), but not in all the other growth forms (Fig. 6).

4. Discussion

4.1. Peony

Two earlier surveys (Ortal, 1975; Cohen and Shmida, 1992) revealed that most peony plants, *Paeonia mascula,* grew under heavy shade with only 5% flowering plants. The fact that the peony population grew in such conditions for more than two decades indicates that the plants were highly resistant to heavy shade and survived

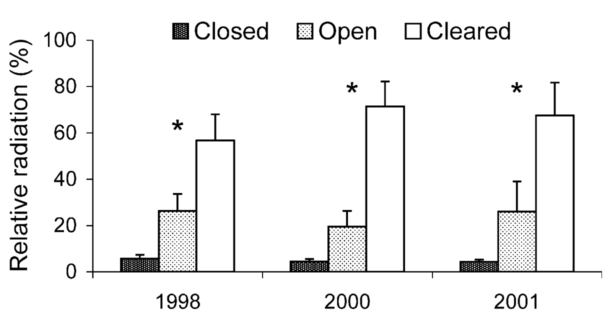

Fig. 1. Average (±S.E.) relative photosynthetic active radiation (RPAR) on the plots by treatment. * indicates a significant difference by Kruskal–Wallis test ($P<0.05$).

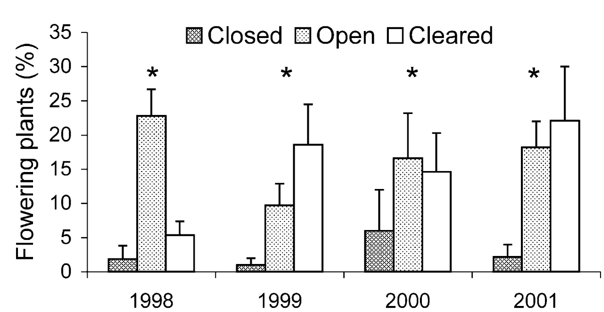

Fig. 2. Average (±S.E.)% of flowering peonies on the plots by treatment. * indicates a significant difference by Kruskal–Wallis test ($P<0.05$).

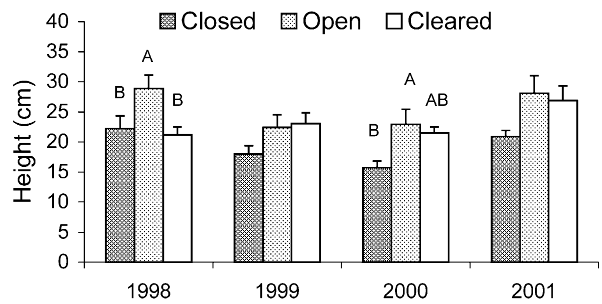

Fig. 3. Average (±S.E.) height (cm) of peonies on the plots by treatment. Identical letters above columns indicate no significant difference tested by one-way ANOVA and post-hoc Tukey tests ($P<0.05$).

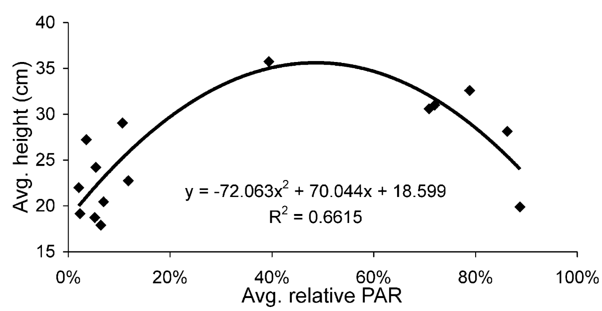

Fig. 4. Relationship between average height of peony plants and average RPAR on the plots in 2001.

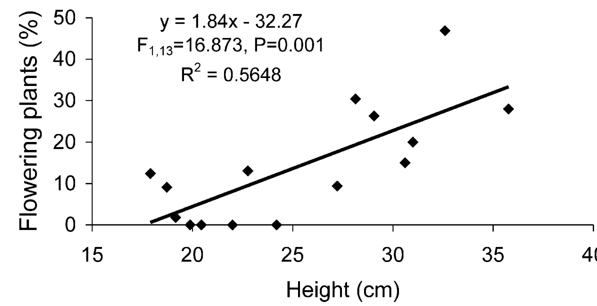

Fig. 5. Relationship between percentage of flowering peonies and their average height on the plots in 2001.

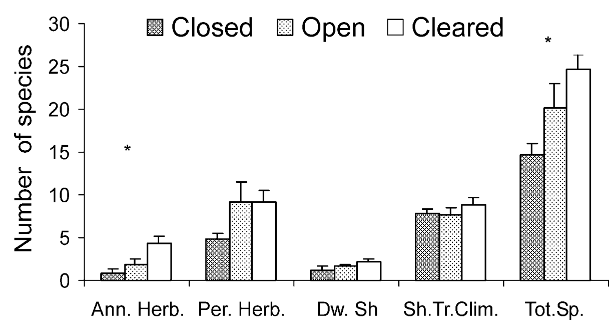

Fig. 6. Average (±S.E.) number of annual herbaceous (Ann. Herb.), perennial herbaceous Per. Herb.), dwarf shrubs (Dw. Sh.), shrubs trees, and climbers (Sh.Tr.Cl.), and total number of species (Tot.Sp.) on the plots by treatment.

despite the extreme suppression of their sexual reproduction. We found no improvement in the flowering percentage of the shade-inhabiting peonies. Sexual reproduction is a prerequisite for long-term existence of any plant population (Willson, 1983), and it is a major issue in management of endangered species (Given, 1994). Although it is a perennial species (but we have no data on its age to first flowering and longevity), it can be assumed that the future of the peony population in Mount Meiron is in grave danger, unless a way is found to increase its flowering rate.

The results indicate that flowering peony plants grow in semi-shaded sites with about 45% RPAR radiation; they can tolerate lower radiation, but no plants grow in fully exposed sites. Flowering plants are taller, and have a thicker stem and more leaflets than non-flowering ones. Because heavily shaded peonies are smaller, do not flower, and do not produce seeds, they are probably degenerated adult plants and not young immature plants as might be thought.

Our main goal, to increase the flowering percentage of the peonies, was achieved already in the second season in small gaps created by tree cutting. The percentage of flowering peonies on such treated plots was 15–20%, similar to what it was on the open untreated plots, and it stayed at that level for 3 years. A positive correlation existed between flowering percentage and average height of the plants in the plots, indicating that plots with tall plants also have a high flowering percentage. The tallest plants were found on plots with an average RPAR of 40%, which is similar to the average radiation measured at the growing sites of flowering peonies along the 'peony path'. This indicates that this is the optimal light regime for vegetative growing and flowering of the peonies. Creating small gaps by tree cutting, drastically increased radiation to about 70%, with no change 4 years later, indicating that the effect of the treatment will probably last for several more years. The relatively high radiation in the cleared plots may explain the taller and more vigorous peonies on them compared to the closed plots. Cutting did not affect the number of peonies probably because the time since the treatment was still not enough for seed germination and establishment of the seedlings.

Shade causes changes in both quantity and spectral quality of light. Several morphological and physiological traits have evolved in plants as adaptation to shade (Packham et al., 1992). Light intensity, spectral composition, and photoperiod also serve as morphogenetic signals during plant development mainly for germination and flowering (Vine-Prue, 1981). Sunflecks have been shown to affect photosynthesis, growth, flowering, germination and establishment of understorey plants (Chazdon, 1988). The fact that flowering peony plants were larger than non-flowering ones, and that exposure to light affected flowering only from the second year, indicates that shaded peonies lack light mainly as an energy source and not as a morphogenetic signal. This is in contrast to *Lilium candidum*, which also suffered from low flowering percentage in shaded habitat but began to flower in the first spring after experimental thinning of the trees on Mount Carmel, Israel (Oz and Dafni, 1991).

Paeonia mascula is an important species in Mount Meiron Nature Reserve even though it is not endemic or a keystone species in the ecosystem. This population is the southernmost border population, and it is likely to be of different genetic composition, diversity, and phenotypic variability from northern core populations, as was found with other plant and animal species (Safriel et al., 1994; Kark et al., 1999). Likewise, the southern peripheral population might be more resistant to global climate change than core populations (Safriel et al., 1994). However, the main importance of peonies in Israel is local; it has large and beautiful flowers that attract many visitors during its blooming season. Moreover, it is so closely identified with the Mount Meiron Nature Reserve that it is considered as its 'flag-ship species', like *Iris haynei* for the Gilboa Nature Reserve. Such 'flag-ship species' are important in public campaigns and as arguments in discussions with decision makers over issues of conservation in nature reserves.

4.2. Other species

The peony is possibly only one of many species whose optimal habitat are semi-shaded gaps; they cannot grow or reproduce on fully exposed or in heavily shaded sites (Packham et al., 1992; Fragman et al., 1999). These species can be divided into two groups. The first consists of species inhabiting mostly semi-shaded micro sites in the research area, which do not flower under conditions of heavy shade [Appendix (A)]. Such species are not exposed to immediate danger. The second consists of species inhabiting mostly heavy-shaded micro sites in the research area, which do not flower under such conditions of heavy shade [Appendix (B)]. Such species are exposed to immediate danger of local extinction. Both groups seem to suffer from the reduction in the number of small gaps due to the natural succession resulting from nature conservation policies. The creation of small gaps is also expected to positively affect these species.

The total number of species was highest in the treated plots due to the high number of annual herbaceous species, most of which are local opportunistic species that are common in agricultural fields in the nature reserve. Because of the small scale of disturbance, and the fact that the treated plots were surrounded by dense maquis, it can be assumed that those species originated from the soil seed bank and not from long-range dispersal. These species are expected to disappear in the near future, so the creation of small gaps seems to have only a minor short-term effect on species composition.

4.3. Management

Nature conservation policies can be considered to be composed of two contrasting views, passive and active, on the management of nature reserves (Wildes, 1995). The traditional and conservative attitude is the passive one, which opposes any active management but permits only guarding against disturbances and lets nature take its own course. The active attitude sets up explicit goals to be achieved, for example, the preservation of food webs, biodiversity, and populations of endangered species, or even the reintroduction of recently extinct species. Obviously, this attitude encourages active management that will affect the ecosystem in the desired direction. This controversy also exists in Israel (Perevolotski, 1994; Perevolotski and Polak, 2001).

In the Middle East, no virgin ecosystems remain for conservation. All existing ecosystems are the result of a dynamic equilibrium between long ongoing human interference and their natural regeneration ability (Naveh and Dan, 1973). During historical eras, proliferation of human society was correlated with an increase in domestic agricultural crops and a decline in the number and abundance of wild species, such as *Pinus halepensis* (Weinstein-Evron and Lev-Yadun, 2000). During the first half of the 20th century most of the land was intensively utilized while natural vegetation remained only in some remote locations. This was the background to the development of nature conservation and the establishment of Nature Reserve Authority in Israel in the early 1960s. Naturally, the passive attitude to nature conservation was adopted (Perevolotski and Polak, 2001), resulting in regulations that caused an increase in forest area and density (Carmel and Kadmon, 1999).

The success of nature conservation caused an accumulation of plant biomass, one consequence of which is increased fuel of forest fires; these have increased in number and area in recent decades in Israel and other Mediterranean countries (Keidar, 2001). The danger of wild forest fires and their drastic effect on the landscape have wrought a change in nature conservation policy. Now the regulations permit, and in some cases even encourage, goat grazing in nature reserves to decrease the danger and intensity of fires by reducing fuel load (Perevolotski and Haimov, 1992).

Clearly, the 'hands off' approach of passive conservation does not result in a static condition of the vegetation, but it enhances natural succession that alters vegetation structure, species composition and abundance. Old-field succession in Israel was described as: invasion by weeds and other pioneer perennial species; their replacement by dwarf shrubs typical of the 'Batha';

their replacement by higher shrubs of the 'garigue'; finally, their replacement by trees of the maquis (Zohary, 1962). This description of 'classical succession' is in accordance with early theories (e.g. Clement, 1916). More recent succession theories draw more divergent models and mechanistic explanations (e.g. Connel and Slatyer, 1977; Grime, 1977; Bazzaz, 1979; Tilman, 1987). Recent research in Israel revealed that succession is not deterministic as described before; species arrival depends on life-history traits and on the nature of the disturbance (Ne'eman and Izhaki, 1996; Schiller et al., 1997). The well-known phenomenon that old-field succession begins with high species richness that decreases with time was described also for the Mediterranean basin (Trabaud and Lepart, 1981). Competition for minerals and light can explain this process (Tilman, 1987). However, during this process important and endangered species could be threatened. The decrease in flowering of *Lilium candidum* because of shading trees was the first described instance of such a case in Israel (Oz and Dafni, 1991). Creating conditions that favor the regeneration of natural vegetation is important in nature reserves that include disturbed areas. However, successful regeneration may extract a high price in another currency of nature preservation, namely the protection of endangered species, as is the case of *Paeonia mascula* in Mount Meiron Nature Reserve.

5. Conclusions

We may conclude that gap formation is essential to enhance flowering of *Paeonia mascula,* which is the first stage in the recovery of this locally endangered species

We have presented a case of contradiction between two aims of nature preservation, which are reflected in management of nature reserves. The first is complete preservation to enhance the recovery of disturbed areas; the second is the protection of endangered species that cannot exist under conditions where the vegetation reaches its climax, or potential growth. Obviously, the two goals cannot be achieved at the same time and place or without active management interference. A practical solution is the division of nature reserves into areas with various degrees of protection, as in the case of 'Biosphere Reserves', which are divided into core, transition, and peripheral regions (Di Castri and Loope, 1997). Such a division in fact exists in Mount Meiron Nature Reserve, which is not a biosphere reserve. The peonies grow in an area where recreational activity and traditional agriculture are permitted. Therefore, there should be no principal nor legitimate argument against the necessary active management; namely creating small forest gaps to secure the future of *Paeonia mascula,* which is a peripheral and locally endangered species, the 'flag-ship species' of the reserve and a major attraction for visitors. Furthermore, the recommendation would not be different even if the plant grew in the restricted core area of the reserve.

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Appendix

(Shmida, A., personal communication).

(A.) Plant species inhabiting mostly semi-shaded micro sites in the research area, which do not flower under conditions of heavy shade:

Asperula libanotica Boiss., *Campanula rapunculus* L., *Cephalanthera longifolia* (L.) Fritsch, *Colchicum decaiseni* Boiss., *Crepis reutreiana* Boiss., *Delphinium ithaburense* Boiss., *Hyacinthus orientalis* L., *Lamium garancium* L. subsp. striatum (Sm.) Hayek, *Leopoldia comosa* (L.) Parl., *Lotus collinus* (boiss.) Heldr., *Rubus canescens* DC., *Salvia judaica* Boiss., *Silene italica* (L.) Pers., *Symphytum brachycalyx* Boiss., *Veronica leiocaroa* Boiss.

(B.) Plant species inhabiting shaded micro sites in the research area, which do not flower under conditions of heavy shade:

Crepis reuteriana Boiss., *Epipactis veratrifolia* Boiss. et Hohen., *Ferula meronensis* (undescribed new species), *Geranium libani* P.H. Davis, *Lapsana pisidica* Boiss. et Heldr., *Lilium candidum* L.*, Paeonia mascula* (L.) Miller, *Sison exaltatum* Boiss., *Teucrium stachiphyllum* P.H. Davis, *Verbascum qulebicum* Post.

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