



Fitness components of the hybrid *Phlomis* × *margaritae* Aparicio & Silvestre (Lamiaceae)

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Studies of microsporogenesis, pollen germination, pollen stainability, fruit and seed set and ovary predation have been undertaken to evaluate the fitness of the hybrid genotype of *Phlomis* × *margaritae* relative to its parents (*P. purpurea* and *P. × composita*) and allied taxa (*P. × composita* nothom. *composita*, *P. × composita* nothom. *trullenquei*, and *P. lychnitis*). *Phlomis* × *margaritae* shows irregular meiosis with very low pollen germination rate and very high pollen sterility, no seed set, and very high ovary predation. It thus has very low reproductive success and fitness. *Phlomis* × *composita* nothom. *trullenquei* also shows low pollen germination and seed set, but these follow regular microsporogenesis. The existence of cryptic structural sterility is suggested for this taxon. The rest of the studied taxa (*P. purpurea*, *P. lychnitis* and *P. × composita* nothom. *composita*) were fertile and can support the specific or subspecific taxonomic status of *P. × composita*. A fixed ovule abortion pattern in the taxa with yellow flowers was found, since ‘brood size’ consisted just of one seed per fruit. On the contrary, *P. purpurea* was found to produce from one to four seeds per fruit. Some conservation implications are suggested.

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ADDITIONAL KEY WORDS:—brood size – conservation – fruit set – microsporogenesis – ovary predation – pollen germination – pollen viability – seed set – S Spain.

CONTENTS

Introduction	332
Material and methods	332
Site and studied plants	332
Cytological study	333
Pollen germination and stainability	333
Fruit and seed setting	334
Statistical analysis	336
Results	336
Microsporogenesis	336
Pollen germination and stainability	336
Ovary predation and seed setting	337
Discussion	339
Conservation implications	340
Acknowledgements	341
References	341

INTRODUCTION

The role of hybridization in plant evolution has been discussed many times and has been considered as a major phenomenon since it supposedly releases a large amount of genetic recombination, thus enabling the founding of new evolutionary lineages (Stebbins, 1959; Arnold & Hodges, 1995). However, Rieseberg (1995) has argued that this main role of hybridization in plant evolution is still unclear, underlining the scarcity of studies dealing with hybrid fitness and the necessity of knowing how hybrids are formed and maintained. In any case, the stabilization of the reproductive behaviour of hybrid plants is an essential part of the process of speciation by means of hybridization (Grant, 1989).

According to Azizian & Moore (1982), the genus *Phlomis* is composed of more than 100 species distributed in Eurasia and north-west Africa, with two main centres of diversity in south and east Anatolia and north-west Iran. In the Iberian Peninsula, *Phlomis* is represented by only four species: *P. crinita* Cav. and *P. lychnitis* L. with yellow or brick-orange flowers, and *P. purpurea* L. and *P. herba-venti* L. with pink ones. Moreover, an array of presumably hybrid forms has been described between the two yellow flowered species, wherever they occur together in south and south-east Spain (Pau, 1918a, b, 1922, 1925). These have been named *P. × composita* nothom. *trullenquei* (Pau) Mateu, *P. × composita* nothom. *almijarensis* (Pau) Mateu, *P. × composita* nothom. *composita* (Pau) Mateu and *P. × composita* nothom. *malacitana* (Pau) Mateu, this sequence representing a morphological gradient from *P. lychnitis* to *P. crinita* (Mateu, 1986). However, a different taxonomic status has been considered for some of these taxa (Cabezudo, Nieto & Navarro, 1991; Rivas Martínez *et al.*, 1991). Recently, a new and singular hybrid (*P. × margaritae* Aparicio & Silvestre) formed between a yellow and a pink flowered plant (*P. × composita* × *P. purpurea* respectively) was described for the first time (Silvestre & Aparicio, 1986). Morphologically it is intermediate between the parents, although other hybrids are not always so (Stace, 1980; Rieseberg, 1995).

Although these *Phlomis* taxa are frequently found in disturbed Spanish Mediterranean vegetation, there is a general scarcity of biological studies concerning this genus. Scattered data on floral biology (Herrera, 1985, 1988; Talavera *et al.*, 1988; Hidalgo & Cabezudo, 1995) and phenology (Arroyo, 1988; Hidalgo & Cabezudo, 1994) have been published, but extensive morphological, phytochemical and karyological studies are available for this genus (Mateu, 1986; Azizian & Cutler, 1982; Azizian & Moore, 1982).

The present study, which has been undertaken within a broader project dealing with the study of endangered plants in a preserved area in southern Spain, aimed to investigate and evaluate microsporogenesis, pollen viability and seed set ratios as fitness components of the *P. × margaritae* hybrid compared with its parents and some related taxa that are supposedly fertile. Further, for conservation purposes, it was intended to mitigate the lack of biological information that exists for rare and hybrid plants (Tear *et al.*, 1995).

MATERIAL AND METHODS

Site and studied plants

The study has been conducted in a preserved area in southern Spain, the Sierra de Grazalema Natural Park (Cádiz province). A detailed floristic study of this area

can be found in Aparicio & Silvestre (1987). The area is a limestone zone which possesses a typical Mediterranean climate with a mean annual rainfall reaching 2000 mm in some meteorological stations and a mean annual temperature close to 15°C.

In June 1983 some individuals of *Phlomis* were collected in this Natural Park in 'Sierra Margarita' (UTM 30S TF8076) at about 950 m altitude, living in *Quercus rotundifolia* forest highly disturbed by goat and sheep browsing. *Phlomis purpurea* and *P.* × *composita* nothom. *composita* (for simplicity nomenclature follows Mateu, 1986) occurred in the area and at first sight some plants were noteworthy because they showed a bicolour corolla with a pink upper lip and a yellow lower lip. *Phlomis* × *margaritae* was then described (Silvestre & Aparicio, 1986) as a hybrid between these two taxa. *Phlomis* × *composita* nothom. *trullenquei* and *P.* × *composita* nothom. *malacitana* were also growing in the study site. Due to the fact that *P. crinita* and *P. herba-venti* are not in the area and that *P.* × *composita* nothom. *malacitana* rarely produces flowers, these three taxa have been discarded from this study. The studied plants of the related *P. lychnitis* belonged to a population (UTM 30S TF9868, 900 m altitude) located 20 km away from 'Sierra Margarita'.

All the studied *Phlomis* taxa are phanerophytes up to 200 cm high, setting flowers in verticillasters borne in flowering stalks up to 100 cm long. These taxa are distributed in the Iberian Peninsula and north Morocco, except *P.* × *composita* which is endemic to southern Spain and north-west Africa (Ubera, 1987) and *P.* × *margaritae* whose unique population in 'Sierra Margarita' occupies less than 100 m² with about 50 patches that are presumably ramets of the same clone maintained by slow vegetative spread (Silvestre & Aparicio, 1986; Aparicio, 1993).

Cytological study

Microsporogenesis was studied in flower buds collected in the field in April–May 1995 and 1996. These were fixed in a mixture of chloroform, acetic acid and absolute ethanol (1:1:5) for about 24 h and then stored in 70° ethanol at 4°C. Pollen mother cells were stained with hydrochloric-acid carmine (Snow, 1963), and meiotic phases photographed using a phase contrast light microscope. Chromosome pairing configurations were observed in as many flowers as possible (5–18) belonging to 2–5 individual plants of each taxon.

Pollen germination and stainability

In May 1995 (for *P.* × *margaritae*, *P.* × *composita* nothom. *composita*, *P.* × *composita* nothom. *trullenquei* and *P. purpurea*) and 1996 (for *P. lychnitis*), young flowering stalks bearing fresh flowers close to anthesis were collected from five individual plants of each taxon and placed in plastic bags which were closed and refrigerated immediately. Five to six hours later, Brewbaker and Kwack pollen germination medium (Kearns & Inouye, 1993) supplemented with 30% sucrose was used to test pollen germination. This medium gave the best results in other Mediterranean Lamiaceae such as *Lavandula stoechas* (Muñoz & Devesa, 1987). Fresh white pollen taken from 2 to 7 flowers of each individual plant was inoculated on the above medium placed in Petri dishes with nine 1 cm² squares drawn underneath. The pollen from each flower

TABLE 1. Mean (\pm SD) percentages of pollen tube formation, sterile pollen, fruiting and ovule predation in the studied *Phlomis* taxa. Different superscripts within a column indicate significant differences of means at $P < 0.05$ (Tukey-B test)

	% pollen germination	% non-stained pollen	$N^{(1)}$	% fruiting	% ovary predation	$N^{(2)}$	$n^{(2)}$
<i>P. × margaritae</i>	0.03 \pm 0.10 ^a	97.10 \pm 1.58 ^a	23	0	53.8	299	13
<i>P. × composita</i> nothom. <i>trullenquei</i>	7.64 \pm 6.19 ^b	18.29 \pm 5.25 ^b	29	9.9	12.9	102	7
<i>P. × composita</i> nothom. <i>composita</i>	22.09 \pm 24.91 ^c	4.36 \pm 3.94 ^c	17	86.9	14.5	504	18
<i>P. lychnitis</i>	17.32 \pm 7.27 ^c	3.17 \pm 1.8 ^c	29	66.5	37.3	276	7
<i>P. purpurea</i>	26.11 \pm 11.33 ^c	7.29 \pm 7.0 ^c	17	69.5	43.1	387	17

$N^{(1)}$ number of flowers studied for pollen germination and stainability

$N^{(2)}$ number of flowers studied for fruiting and ovary predation

$n^{(2)}$ number of individual plants studied for fruiting and ovary predation

TABLE 2. Fruiting percentage of studied flowers according to the number of developing seeds and brood size (mean number of seeds within a fruit, Wiens, 1984) in the corresponding *Phlomis* taxa. The number of flowers studied is indicated in brackets

	Number of developing seeds					Brood size
	0	1	2	3	4	
<i>P. × margaritae</i>	100	0	0	0	0	
<i>P. × composita</i> nothom. <i>trullenquei</i>	90.1	9.9	0	0	0	1 \pm 0 (8)
<i>P. × composita</i> nothom. <i>composita</i>	13.4	85.9	0.7	0	0	1 \pm 0.89 (373)
<i>P. lychnitis</i>	33.5	66.5	0	0	0	1 \pm 0 (115)
<i>P. purpurea</i>	30.4	15.4	20.4	24.0	9.5	2.39 \pm 0.98 (153)

was spread on the nutrient medium contained in one of the squares. The Petri dishes were left overnight on a bench top at room temperature. After 19–24 hours, a small drop of carmine was spread over each 1 cm² pollen culture area. A sample of such pollen of each square was then transferred to a microscope slide containing a drop of 45% acetic acid and observed under a light microscope \times 400. All the pollen grains in the preparation were examined and recorded as (1) germinated (pollen tube longer than its width), (2) stained but not germinated, and (3) non-stained. Only data regarding germinated and non-stained pollen were further considered as a fitness component since it is unknown whether stained pollen grains were fertile and because pollen stainability ‘may depart considerably from real values of pollen viability’ (Dafni, 1992).

Fruit and seed setting

In June–July 1996, just before full seed maturation, complete fruiting stalks were collected from different numbers of individuals of each taxon (Tables 1, 3). The four lowest verticillasters were used for the study, numbered upwards from 1 to 4. Every flower in some or all of these verticillasters (see Table 3) was investigated for seed production. In the Lamiaceae the fruit is a tetranucule when completely developed. The number of developing nutlets (0–4) and the number of predated ovaries was recorded. In this way, ‘brood size’ defined as the mean number of

TABLE 3. Mean (±SD) percentage of predated ovaries in verticillasters 1 to 4 and values of *G* test (Sokal & Rohlf, 1995) within each taxon (the number of verticillasters studied in each taxon is indicated in brackets). Different superscripts within columns 1 and 2 indicate the existence of significant differences of the means at *P*<0.05 (Tukey-B test)

	Verticillaster				<i>G</i>	df	<i>P</i>
	1	2	3 ⁽¹⁾	4 ⁽¹⁾			
<i>P. margaritae</i>	56.89 ± 32.05 ^a (13)	60.77 ± 30.70 ^a (13)	49.24 ± 30.43(12)	43.31 ± 26.50(8)	5.17	3	0.159
<i>P. × composita</i> nothom. <i>tullenqueti</i>	3.32 ± 7.42 ^b (5)	34.43 ± 21.26 ^{ab} (6)	33.25 ± 40.68 (4)	—	6.08	2	0.047
<i>P. × composita</i> nothom. <i>composita</i>	22.20 ± 29.70 ^b (18)	12.93 ± 17.64 ^b (18)	18.48 ± 22.76 (18)	16.50 ± 19.60(14)	3.93	3	0.269
<i>P. bychinskis</i>	32.80 ± 37.41 ^{ab} (13)	38.44 ± 39.31 ^{ab} (13)	44.86 ± 38.86 (13)	33.32 ± 44.08(7)	2.79	3	0.425
<i>P. purpurea</i>	55.12 ± 26.23 ^a (13)	50.11 ± 27.20 ^a (13)	48.51 ± 16.18(3)	—	0.53	2	0.767

(1) not significant differences within the column at *P*<0.05

developing ovules (Wiens, 1984), was calculated within every fruit formed by ovaries that had not aborted fully. Fruiting percentage was also calculated on the basis of non-predated ovaries only.

Statistical analysis

Data expressed as percentages were transformed ($x' = \arcsin \sqrt{x}$) prior to statistical analysis (Sokal & Rohlf, 1995). Differences in percentages of pollen germination, non-viable pollen and ovule predation at verticillaster level among taxa were analysed by one-way ANOVA and multiple range Tukey-B test at $P < 0.05$. The number of seeds developing within the ovaries was compared using a non-parametric Kruskal-Wallis one-way ANOVA. All these analyses were performed using the software package SPSS 6.0 for Windows. To investigate differences in ovary predation among verticillasters for each taxon, 4×2 or 3×2 contingency tables (G test) were used (Sokal & Rohlf, 1995).

RESULTS

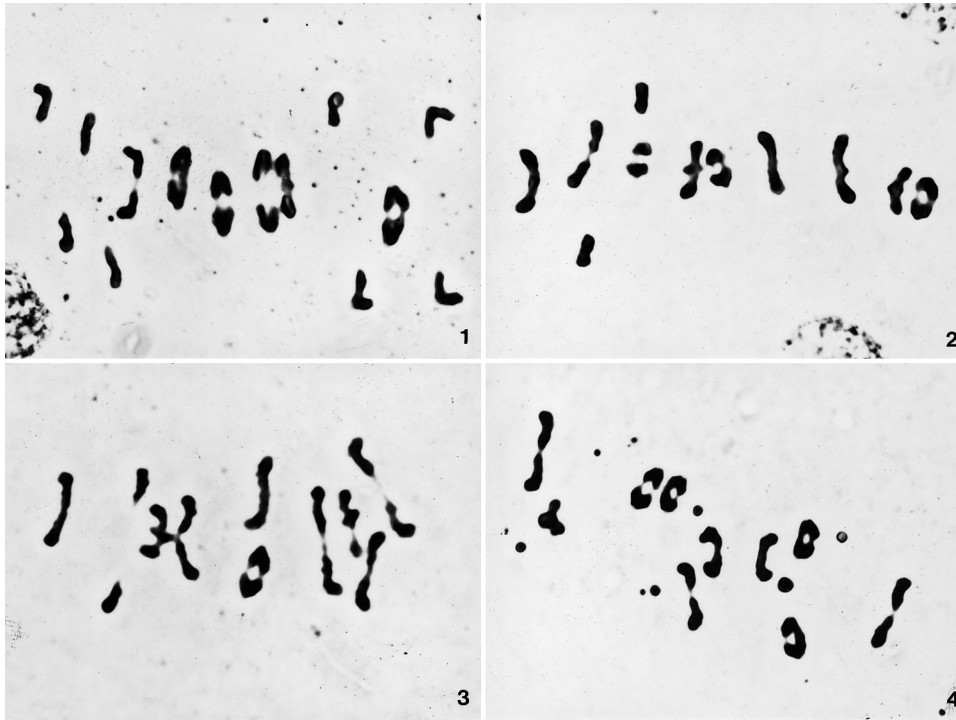
Microsporogenesis

All the studied taxa with regular meiosis (*P. purpurea*, *P. × composita* nothom. *composita*, *P. × composita* nothom. *trullenquei* and *P. lychnitis*) showed $2n = 20 = 10\text{II}$ (Figs 1–4), with regular formation of 10 bivalents (10II) during diakinesis and metaphase I. Anaphase I and the second meiotic phase were also regular, forming tetrads in these taxa as a general rule.

Phlomis × margaritae clearly showed irregular microsporogenesis (Figs 5–10). Despite the pairing configuration being indistinct in most cells, several univalents were very easily observed during diakinesis and metaphase I. It was also found that $2n = 20 = 6\text{I} + 7\text{II}$ appeared to be the most frequent pairing configuration. Unexpectedly, 10II was observed just in one cell (Fig. 8), and the occasional formation of 1IV or multivalents could not be ruled out. Thus, the first meiotic phase usually concluded in unbalanced nuclei containing different chromosome numbers. In the second meiotic phase, chromatin bridges and lagging chromosomes led to the formation of micronuclei, unreduced sporads, dyads, triads and polysporads, although tetrads were the most common. These irregularities led to an extremely variable pollen size, from minute cells containing small fragments of chromatin to large unreduced ones (Fig. 10). All pollen grains completed exine development and large amounts of white pollen were finally set in every anther.

Pollen germination and stainability

The overall mean (\pm SD) number of pollen grains examined on each 1 cm^2 culture area was 254 ± 150 ($n = 150$ flowers, range 16–833). Mean (\pm SD) percentages of pollen germination in each taxa are shown in Table 1, which were observed to be significantly higher in the group formed by *P. purpurea*, *P. lychnitis* and *P. × composita*



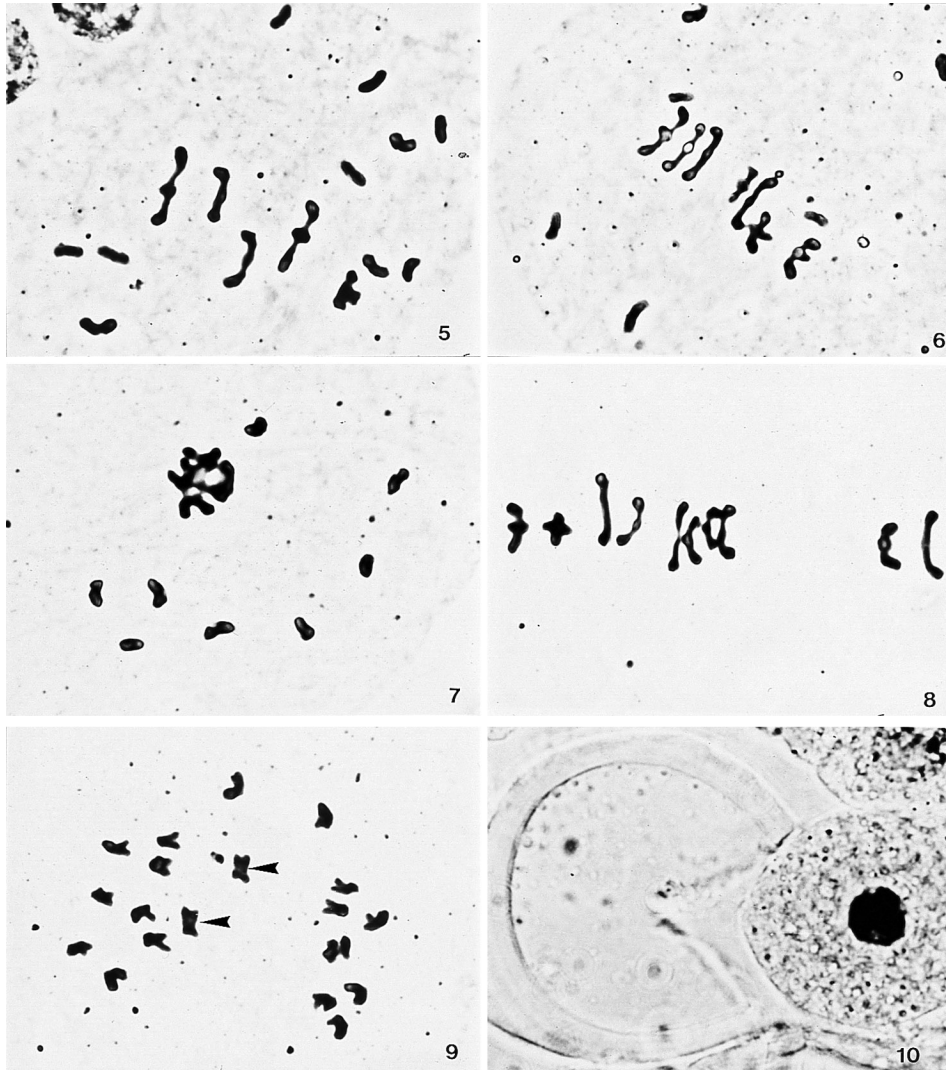
Figures 1–4. Metaphase I chromosome pairing configurations in the fertile *Phlomis* taxa. Fig. 1. *P. × composita* nothom. *composita* late metaphase I with 10II. Fig. 2. *P. × composita* nothom. *trullenquei* late metaphase I with 10II. Fig. 3. *P. lychnitis* metaphase I with 10 II. Fig. 4. *P. purpurea* late metaphase I with 10II.

nothom. *composita* (c. 20%) than *P. × composita* nothom. *trullenquei* (7%) and *P. × margaritae* (0.03%). The percentage of non-viable (non-stained) pollen (Table 1) was significantly lower for *P. purpurea*, *P. lychnitis* and *P. × composita* nothom. *composita* (c. 5%) compared to *P. × composita* nothom. *trullenquei* (18%) and *P. × margaritae* (97%).

Ovary predation and seed set

All studied verticillasters of the yellow flowered taxa (*P. lychnitis*, *P. × composita* nothom. *trullenquei* and *P. × composita* nothom. *composita*) showed six flowers except for an occasional flower abortion. Those of *P. purpurea* showed 10 flowers, while verticillasters 1 and 2 of *P. × margaritae* had six flowers, with verticillasters 3 and 4 possessing up to eight flowers. Fruiting and ovary predation percentages are also presented in Table 1. In the studied years, these ranged from 0% for *P. × margaritae* to 86.9% for *P. × composita* nothom. *composita* and between 14.5% for *P. × composita* nothom. *composita* to 53.8% for *P. × margaritae* respectively.

Table 2 shows the fruiting percentage (excluding non-predated ovaries) derived from the number of developing seeds and the mean number of mature seeds and brood size. Brood size was statistically different among the taxa (excluding *P. ×*



Figures 5–10. Metaphase I chromosome pairing configurations and microsporogenesis in *P. × margaritae*. Fig. 5. Metaphase I with 5II + 10I. Fig. 6. Metaphase I with 7II + 6I. Fig. 7. Metaphase I with 8I + ? Fig. 8. Metaphase I with 10II. Fig. 9. Anomalous anaphase I with 10/8 separation and 2 univalents (arrows). Fig. 10. Unreduced microspore.

margaritae in the analysis) ($\chi^2 = 453.4$, $df = 3$, $P < 0.00001$) since all the taxa with yellow flowers were almost invariably found to produce only one seed per fruit, while *P. purpurea* (pink flowers) formed from one to four seeds.

The percentage of ovule predation was not statistically different among the verticillasters within the taxa. However, some significant differences in verticillasters 1 and 2 were observed among the taxa (Table 3). It was also observed that pollen germination percentages and fruiting percentages did show a positive correlation among the taxa ($r = 0.94$, $P = 0.014$, $n = 5$).

DISCUSSION

From a karyological point of view, all studied taxa showed $2n=20$ but displayed different pairing configurations, which is consistent with previous chromosome studies (Vernigor, 1975; Azizian & Cutler, 1982; Castroviejo & Valdés-Bermejo, 1991; Pastor, 1993). Meiotic irregularities produce sterility (Bittrich & Kadereit, 1988), and hybrids can suffer chromosome sterility due to the lack of homology between the chromosomes, leading to the presence of univalents, irregular behaviour of chromosomes and the formation of spores with different chromosome number (Stebbins, 1950, 1971). This seems to be the case of *P.* × *margaritae* in which meiotic irregularities are followed by high pollen sterility and, subsequently, no seed set. Unexpectedly, *P.* × *margaritae* is occasionally able to produce full chromosome pairing with 10 bivalents, which seems to match the case of *P.* × *composita* nothom. *trullenquei*. In these taxa, the regular formation of bivalents is followed by very low pollen germination and seed set. It is known that “pairing of chromosomes is mainly due to affinities between specific chromosome regions rather than chromosomes as a whole” (Stebbins, 1971) and to the existence of a genetic control (Jackson, 1976). Even with full pairing at meiosis, cryptic structural sterility (Stebbins, 1950, 1971) can produce low rates of viable pollen. Indeed, the results presented in this paper showed that mean pollen sterility was higher in sterile species and lower in the fertile ones, similarly to the findings of Bao-Rong (1993) in *Elymus*.

Determining what factors can limit seed production in plants is important since seed production is an integral component of plant fitness (Vaughton & Ramsey, 1995). Defoliation, plant density, population structure, inflorescence size, climate or microclimate pollination conditions and both pollen and resource limitation are common arguments to explain the amount of seed set (Corbet, 1990; Crawley, 1992; Burd, 1994; Ohara & Higashi, 1994; Vaughton & Ramsey, 1995; Herrera, 1995), although genetically controlled ovule or fruit abortion has also been taken into consideration (Casper & Wiens, 1981; Wiens, 1984). In the present study, a positive correlation between mean pollen germination and fruiting rate was found. The taxa showing higher percentage of pollen germination corresponded to those showing the higher percentage of fruit set. This could point towards the existence of intrinsic factors related to the hybrid origin of some of the studied taxa (i.e. cryptic structural sterility) affecting pollen viability and final seed set, although the effect of extrinsic factors related to the mating system (i.e. self-incompatibility) has not been evaluated in this paper.

Phlomis purpurea, *P.* × *composita* nothom. *composita* and *P. lychnitis* have the highest levels of pollen germination and fruit set, while *P.* × *composita* nothom. *trullenquei* and *P.* × *margaritae* showed very poor or zero pollen viability and fruit set. However, it should be stressed here that the possible production of seeds at very low rates, e.g. one seed in a thousand ovaries, has not been evaluated in this paper. This occurrence could be of a remarkable biological and ecological importance, since very low seed set rates in hybrids which can propagate vegetatively can play a very important role in the overall hybrid fitness (Stebbins, 1959).

Brood size (mean number of seeds within a fruit, Wiens, 1984) of the taxa with yellow flowers (*P. lychnitis*, *P.* × *composita* nothom. *composita* and *P.* × *composita* nothom. *trullenquei*) consists of just one large seed per fruit. I have also observed this phenomenon in other populations throughout their distribution range. On the contrary, mean brood size in the pink-flowering *P. purpurea* is more than two seeds,

the fruit being able to mature from one to four seeds. This appears to support the finding by Casper & Wiens (1981) in *Cryptantha flava* (Boraginaceae) of a fixed post-fertilization ovule abortion producing an abundance of one-seeded fruits. Both pollen and resource limitation would be expected to affect the total fruit set instead of the number of seeds contained within each individual fruit (Burd, 1994). Casper & Wiens (1981) related such a strategy as a selected mechanism to favour wind seed-dispersal in one-seeded calyces. An interpretation similar to that by Casper & Wiens (1981) could apply to the studied *Phlomis* taxa, since the taxa with yellow flowers and one-seed fruit shed the calyces at maturity, while *P. purpurea* calyces, containing several smaller seeds, become hardened and seed dispersal takes place possibly by other means. The ecological and evolutionary significance of seed size has been debated because it has been correlated with germination ability and post-emergent reproductive success influencing adult plant fitness (Silvertown, 1989; Greipsson & Davy, 1994; Montalvo, 1994; Bretagnolle, Thompson and Lumaret, 1995; Salonen & Shuonen, 1995; Swanborough & Westoby, 1996; Moegenburg 1996).

Recently, Arnold & Hodges (1995) and Rieseberg (1995) have argued about hybrid fitness relative to that of their parents. These authors pointed out that hybrid genotypes are not uniformly unfit and several traits towards non-fitness were discussed (Arnold & Hodges, 1995). In the present study *P. × margaritae* is more unfit than *P. × composita* nothom. *composita* and *P. purpurea* with regard to pollen viability and seed set, due mainly to its irregular microsporogenesis. It is maintained by slow vegetative propagation and is restricted to a small patch within the study site (Aparicio, 1993). At the same time, the results presented here show that *P. × composita* nothom. *composita* is a fertile and successful taxon with both high levels of pollen viability and seed set, similar to *P. lychnitis* and *P. purpurea*. Thus, these results provide further support for the taxonomic status recently proposed for *P. crinita* subsp. *composita* (Pau) Rivas-Martínez, Asensi, Molero & Valle (Rivas Martínez *et al.*, 1991) and *P. composita* (Pau) Cabezudo, Nieto & Navarro (pro. hybr.) (Cabezudo *et al.*, 1991).

Herbivory in general and seed predation in particular are important in plant population biology since they can prevent the display of new genetic variation, among other consequences (Harper, 1977). Moreover, a hypothesis of 'hybrid susceptibility' to predation has been investigated as a component of the hybrid fitness (Fritz *et al.*, 1996). The results in the present paper, although inconclusive, could support the view about a higher susceptibility to predation in hybrids (Arnold & Hodges, 1995) since *P. × margaritae* suffered the highest predation rate. Although it has been reported in other Lamiaceae that predators can discriminate between flowers and fruits within an inflorescence (Herrera, 1991), no highly significant differences in predation levels were found within or among the fertile taxa of *Phlomis* studied.

Conservation implications

The small population size and the apparent sterility of *P. × margaritae* make the survival of this taxon reliant on its ability for vegetative propagation. Goat and sheep browsing have already destroyed some of the scarce *P. × margaritae* plants in the population, and fencing the area seems to be an appropriate action. Nevertheless, success in the management of endangered plants depends on identifying general risks (Ellstrand & Ellam, 1993). Despite the general tendency to exclude hybrids

from threatened plant lists, the conservation of hybrids appears necessary since they can be incipient new species (Given, 1994) and can represent very interesting case studies of speciation, reproductive isolation and survival mechanisms. Actually, *P.* × *margaritae* has been included in a list of threatened plant in Andalusia (S Spain) as a 'rare' plant by Hernández-Bermejo, Pujadas & Clemente (1993) and it is also cited as 'endangered of extinction' by Aparicio (1993) but it is not in any official red list of endangered plants subject to conservation action plans.

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