Lagascalia 19(1-2): 845-850 (1997)

FLORAL SIZE VARIABILITY OF CYTISUS SCOPARIUS ALONG AN ALTITUDINAL GRADIENT

JORGE BAONZA & JUAN E. MALO.

Abstract

The variability of *Cytisus scoparius* floral size is analyzed along an altitudinal gradient in Central Spain and through its flowering season. Flower size shows a clinal variation with bigger flowers at higher elevations, as well as a non-directional seasonal change within individuals. These results are discussed in terms of resource allocation.

Introduction

Many floral traits are related to selective pressures exercised by pollinators (STEBBINS, 1981), being pollination by animals a driving force in angiosperm evolution (CREPET, 1983; LEPPIK, 1966). Thus, floral morphology is basic for the taxonomy of many plant groups, as it happens among genisteae (BISBY, 1981).

The interest on the size variability of hermaphrodite flowers among conespecific individuals has recently increased as it is a potential source of diferential reproductive success mediated by pollinator behaviour (WASER, 1983). Bigger flowers have been found to be more attractive to pollinators (GALEN & STATON, 1989; ECKHART, 1991; YOUNG & STATON, 1990) due to a greater pollen production (STATON, & al. 1992), or to a differential efficiency of pollinators (ANDERSON, 1988). Thus, flower selection by pollinators plays a role on the evolution of some species' flower size (GALEN, 1989).

This could be the case of *Cytisus scoparius*, as 1, it has an explosive floration, 2, its zygomorphic flowers are pollinated by bees (Hymenoptera, apoideae) searching for pollen, and 3, only one effective insect visit is possible, due to the explosive mechanism released by the visitor (similar to the one of *C. grandiflorus*, HERRERA, 1987). Finally (iv), *C. scoparius* is among to the biggest-flowered species within its genus (FRODIN & HEYWOOD, 1968). MALO & al. (1995) found that, within the altitudinal range of the species in central Peninsula Ibérica, a peripheric population had smaller flowers than a population located in the center of the altitudinal range. Also, flower size of the species varies among years, probably associated to wheather conditions.

This paper analyzes flower size variability of *Cytisus scoparius* among different moments of the blooming season and among locations along the altitudinal gradient of the species in central Peninsula Iberica.

Material and methods

Cytisus scoparius (L.) Link. is a shrubby genisteae (Leguminosae, papilionoidea) frequent on acid substrata in central Peninsula Iberica, where it grows through the 700-1500 m altitudinal range.

The study was carried out in the Madrid Province (Central Spain). Populations of the species growing on gentle South facing slopes lacking trees were selected along the altitudinal gradient. Three populations were used in 1994: Tres Cantos (740 m a.s.l.), Colmenar Viejo (920 m a.s.l.) and Bustarviejo (1400 m a.s.l.). Eighteen plants from each population were chosen and 5-8 flowers of each were taken for measurement in 1-3 moments during the blooming season. This procedure was repeated in the blooming peak of 1995 for all plants but 15 of them (3 in Tres Cantos, 6 in Colmenar Viejo and 6 in Bustarviejo) that did not produce enough flowers due to different reasons (death, senescence, late frost, floral herbivore attack and/or livestock browsing). Due to the same reasons, some collections of the previous year were also incomplete. In 1995 a very extreme population (Puerto de Navacerrada, 1840 m a.s.l.) was also included in the study, though only 7 plants had enough flowers for collection.

Regional climate is Mediterranean, but the altitudinal gradient modifies its major parameters. Mean temperature varies from 13° in lower areas to 6.3° in the higher part of the gradient, and precipitacion increases with altitude from 500 mm to 1331 mm. The climate at higher altitudes is colder, wetter and more constant among years, as summer drough is retarded, and its duration and intensity diminish. This leads to a phenological retard with altitude and conditions sampling dates: March-April in Tres Cantos, April in Colmenar Viejo, May in Bustarviejo and June in Puerto de Navacerrada.

Floral size is analyzed through standard length measure, as it is the most attractive petal and its length is highly correlated with all floral pieces (MALO & al., 1995). Data analysis is carried out with parametric procedures because no significant deviations from normality were found among the values of variables. Type III ANOVAs for unbalanced samples (SYSTAT 1992) were carried out with locality as a fixed factor and year as a random one. The individual factor is analyzed nested within locality and moment within individual.

Results

Standard length varied significatively during the 1994 blooming season in Tres Cantos (10 plants in three moments; $F=1.8$; $p<0.05$) and in Colmenar Viejo (4 plants in two moments; $F=2.7$; $p<0.05$), but not in Bustarviejo, where flowers were in fact almost significatively equal in size in two moments (9 plants; $F=0.5$; $p=0.9$). Such intra-seasonal variation of standard length shows no common trend among plants (fig 1). Thus, variability between years and among localities is analyzed only for flowers collected in the blooming peak.

Flowers were smaller the second year in all three populations. In Tres Cantos, a significant decrease from 18.4 to 17.7 mm in standard size was detected (paired t-test for mean standard size of $n=7$ plants; $t=2.64$; $p<0.05$). However, standard size decrease in the two other populations was non-significant: from 18.6 to 18.2 in Colmenar Viejo ($n=7$) and from 20.5 to 20.2 in Bustarviejo ($n=4$).

Differences in flower size among years and among individuals are significant in 1994 (table 1) and 1995 (table 2). Flower size increased in 1994 with altitude (mean

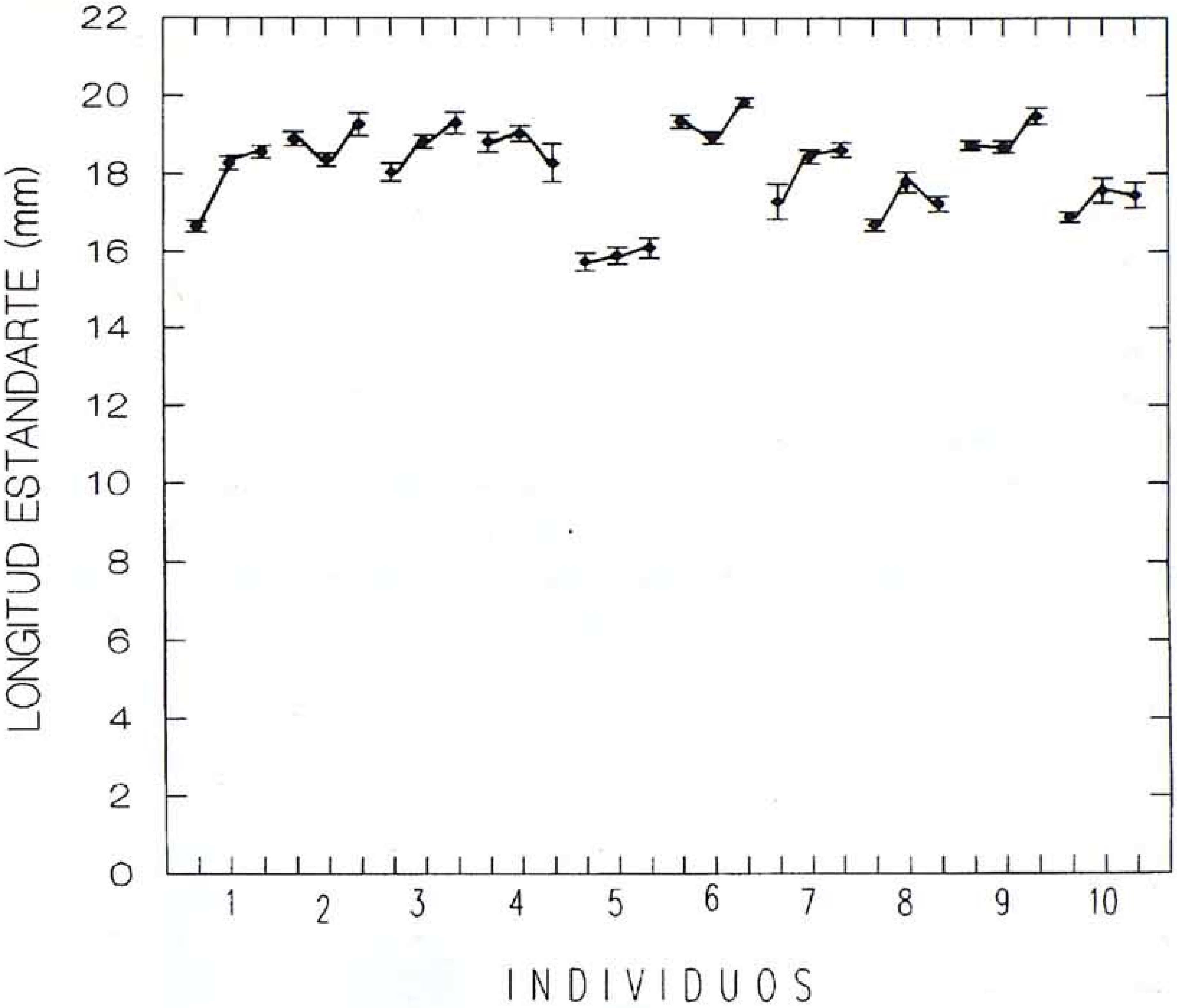

Fig. 1. Standard size variability (mean + standard error) of 10 plants from Tres Cantos (740 m a.s.l.) in three moments during the 1994 blooming season.

Factor	S.S.	d.f.	M.S.	F	p
Locality	64,71	2	32,36	3,33	<0,05
Individual[Locality]	300,90	31	9,71	18,52	<0,001
Error	114,25	218	0,52		

Table 1. Results from the ANOVA of the locality and individual effects on standard size of three localities in the 1994 blooming season (n=7 plants in Tres Cantos, N=8 in Colmenar Viejo and n=9 in Bustarviejo).

Factor	S.S.	d.f.	M.S.	F	p
Locality	927,75	3	309,25	15,20	<0,001
Individual[Locality]	712,232	35	20,35	41,47	<0,001
Error	122,19	249	0,49		

Table 2. Results from the ANOVA of the locality and individual effects on standard size of four localities in the 1995 blooming season (n=10 plants in Tres Cantos, n=11 in Colmenar Viejo, n=11 in Bustarviejo and n=7 in Puerto de Navacerrada).

standard size in Tres Cantos, Colmenar Viejo and Bustarviejo: 18.2; 18.6 and 19.6 mm) and an almost similar trend was found in 1995 with the inclusion of the Puerto de Navacerrada extreme population (17.9; 17.8; 19.5 and 22.7 mm, fig 2).

Discussion

Results show an important flower size variability within individuals (along the blooming season and between years), among individuals within a population and specially so along an altitudnal gradient. Within-individuals variability could reflect the role of phenotipic plasticity on the inmediate response to environmental changing conditions and it is probably related to to different patterns of resource acquisition and allocation (FITTER, 1986: 395-396). The variability among individuals can also reflect a genetic diferentiation due to long-term differences in environmental pressures.

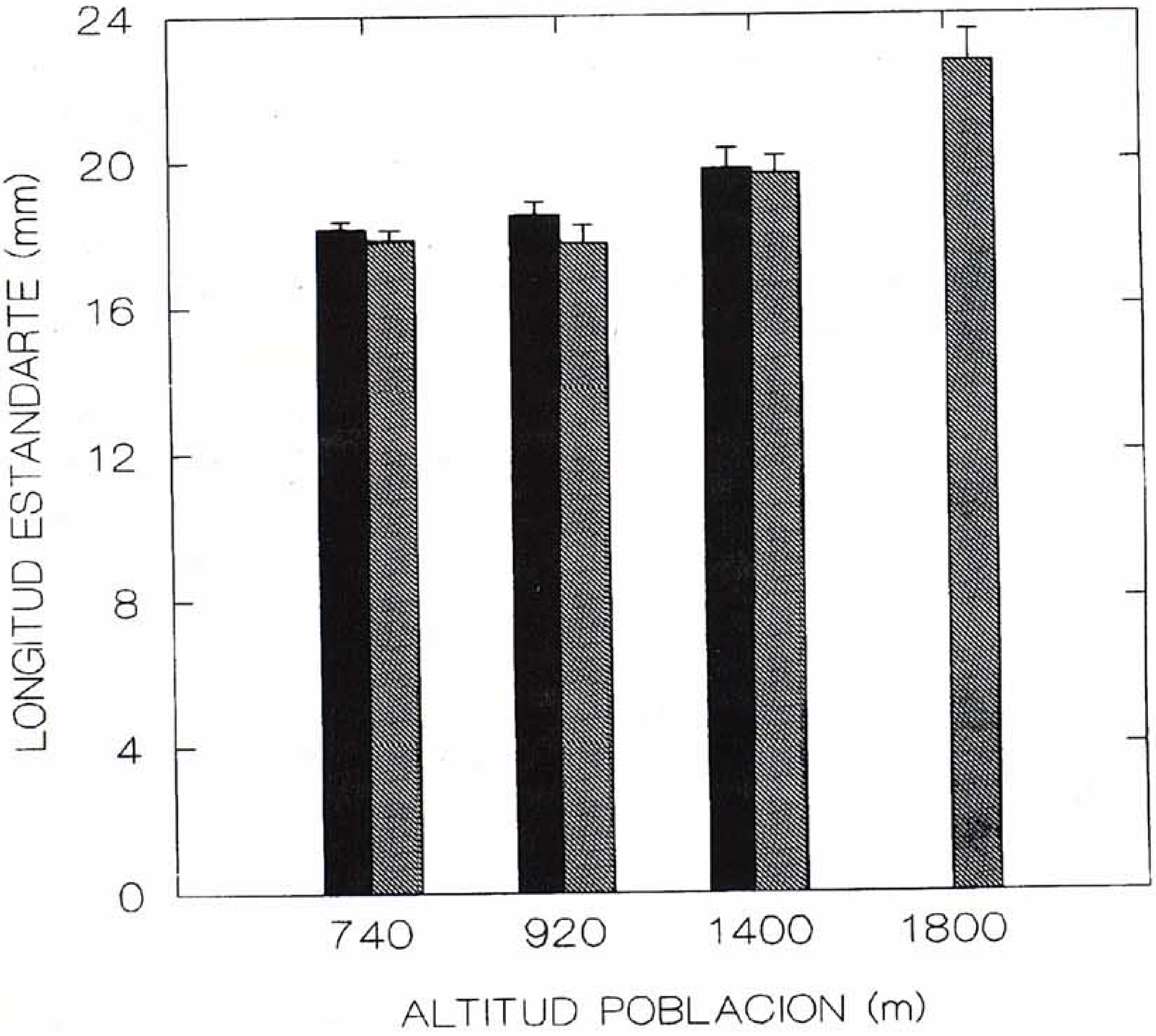

Fig. 2. Mean (+ standard error) standard lenght of plants in each locality and year (filled, 1994; stripped, 1995). Sample size in 1994 and 1995 are n=17 and n=10 in Tres Cantos (740 m a.s.l.), n=8 and n=11 in Colmenar Viejo (920 m a.s.l.), and n=9 and n=11 in Bustarviejo (1400 m a.s.l.). Sample size in 1995 data for Puerto de Navacerrada (1800 m a.s.l.) is n=7.

As branch growth and legume development beging before the end of blooming, there could be a trade-off between vegetative and reproductive resource (energy, nutrients, water) allocation in that moment (SILVERTOWN, 1987: 133-137; WILSON, 1983: 5-9). Also, a trade-off could appear between flowering and fruiting (LAWRENCE, 1993). However, other factors such as wheather, plant age and the interaction with herbivores affect the physiological state of plants and can therefore influence resource allocation (WALOFF & RICHARD, 1977). The lack of a common pattern of flower size variation within a blooming season among plants can mirror the heterogeinity of factors affecting resource allocation at the individual level.

Water is probably the resource with a variability which best parallels that of flower size. Thus, flower size decrease the second year coincides with a very severe drought (a similar result to the one reported by MALO & al., 1995). Also, bigger flowers at higher altitudes could be a consequence of higher precipitation and a less severe drough at the upper parts of the altitudinal gradient.

Floral size variation of *C. scoparius* in the study area shows a clinal variation with altitude and not a central-peripherical population pattern (PARSONS, 1991) as it had been suggested (MALO & al., 1995). Floral size measured in that study (16.2 mm and 18.2 mm in a population at 680 m a.s.l., and 19.9 and 18.8 at 840 m a.s.l.) would also reinforce the clinal variation trend. The very big flower size of the extreme population (up to 27% bigger than the two at low altitudes) shows that no peripherical effect is noticeable in populations at higher altidues. A clinal increase of flower size with altitude is thus present.

Anyhow, the floral size of *C. scoparius* could show a central-peripherical pattern along its distribution range. The species has a wide distribution in Europe for which all populations of this study are peripherical (FRODIN & HEYWOOD, 1968). In fact, many environmental conditions as temperature and water availability are in the center of distribution of the species (Central-Eastern Europe) more similar to those in the upper extreme of the altitudinal gradient studied here. Thus, the clinal variation stated here could anyhow be the result of a central-peripherical response at a much broader spatial scale.

Acknowledgements

Francisco Suárez collaborated in many stages of this study. J. Baonza has a Tercer Ciclo grant from the Universidad Autónoma de Madrid.

Bibliography

ANDERSON, S. (1988). Size-dependent pollination efficiency in Anchusa officinalis (Boraginaceae): causes and consequences. *Oecologia (Berlin)* **76**:125-130.

BISBY, F. A. (1981). Tribe 32. Genisteae (Adans.) Benth. (1865). In: R. M. POLHILL & P. H. RAVEN (eds.) *Advances in legume systematics*: 409-425. Royal Botanic Gardens. Kew.

CREPET, W. L. (1983). The role of insect pollination in the evolution of angiosperms. In: L. Real (ed.) *Pollination Biology*: 29-50. Academic Press. London.

ECKHART, V. M. (1991). The effects of floral display on pollinator visitation vary among populations of Phacelia linearis (Hydrophyllaceae). *Evol. Ecol.* **5**: 370-384.

FITTER, A. H. (1986). Acquisition and utilization of resources. In M. S. CRAWLEY (ed.) *Plant Ecology:* 375-405. Blackwell Scientific Publication. Oxford.

FRODIN, D. G. & V. H. HEYWOOD (1968). Cytisus. In: T. G. TUTIN & al. (eds.) *Flora Europaea* **2**: 86-90. Cambridge.

GALEN, C. (1989). Measuring pollinator-mediated selection on morphometric floral traits: bumblebees and the alpine sky pilot, Polemonium viscosum. *Evolution* **43**: 882-890.

— & M. L. STANTON (1989). Bumblebee pollination and flower morphology: factors influencing pollen dispersal in the alpine sky pilot, Polemonium viscosum (Polemoniaceae). *Am. J. Bot.* **76**: 419-426.

HERRERA, J. (1987). Biología reproductiva de algunas especies del matorral de Doñana. *Anales Jar. Bot. Madrid* **44**: 483-497.

LAWRENCE, W. S. (1993). Resource and pollen limitation: plant size-dependent reproductive patterns in Physalis longifolia. *American Naturalist* **141**: 296-313.

LEPPIK, E. E. (1966). Floral evolution and pollination in the Leguminosae. *Annales Bot. Fennici* **3**: 299-308.

MALO, J. E., J. BAONZA & F. SUAREZ (1995). Diferencias intra e interpoblacionales, y entre años, en la morfología floral de Cytisus scoparius (L.)Link. *Anales Jar. Bot. Madrid* **53**: 33-40.

PARSONS, P. A. (1991). Evolutionary rates: stress and species boundaries. *Ann. Rev. Ecol. Syst.* 22:1-18.

SILVERTOWN, J. (1987). *Introduction to plant population ecology*, ed. 2. Logman scientific & technical. Hulow.

SYSTAT, Inc. (1992). *SYSTAT for Windows: statistics. Version 5.0 Edition.* Evantson, Illinois.

STANTON, M. L., T. L. ASHMAN, L. F. GALLOWAY & H. J. YOUNG 1992. Estimating male fitness of plants in natural populations. In: WYATT (ed.), *Ecology and evolution of plant reproduction*: 62-90. Chapman & Hall. New York.

STEBBINS, G. L. (1981). Why are so many species of flowering plants. *Bioscience* **31**: 573-577.

WALOFF, N. & O. W. RICHARDS (1977). The effect of insect fauna on growth, mortality and natality of broom, Sarothamnus scoparius. *J. Appl. Ecol.* **14**: 787-798.

WASER, N. H. (1983). The adaptative nature of floral traits: Ideas and evidence. In: L.Real (ed.) *Pollination Biology*: 242-285. London.

WILSON, M. F. (1981). *Plant Reproductive Ecology.* Wiley & Sons. New York.

YOUNG, H. L. & M. L. STANTON (1990). Influences of floral variation on pollen removal and seed production in wild radish. *Ecology* **71**: 536-574.

Address of the authors:

Dr. J. Baonza & J. E. Malo, Departamento Interuniversitario de Ecología, Facultad de Ciencias, Universidad Autónoma, 28409 Madrid, Spain.