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Notes on floral traits and gender expression of *Dryas octopetala* under a simulated environmental change

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Abstract: This study presents empirical data for variations of floral traits and gender expression in Arctic *Dryas octopetala* L. under a simulated environmental amelioration using an open-top chamber (OTC). The short-term experiment (from 8 August 1997 to 2 August 1998) demonstrated in Ny-Ålesund, Svalbard that dry weights of gynoecium, peduncle, and hermaphrodite flowers were significantly heavier, whereas petal and androecium weight were significantly lighter in OTC-manipulated shoots than in controls. As a result, "femaleness" (dry-weight allocation to the female organs) showed a significantly higher value in OTC-manipulated shoots as compared to the controls. Moreover, femaleness was significantly positively correlated with flower weight both in OTC-manipulated and control shoots. Thus, it was experimentally demonstrated that the gender as a reproductive effort of *D. octopetala* flowers changed from male- to female-biased expression under a less stressful condition.

key words: Arctic, *Dryas octopetala*, femaleness, gender expression, OTC

Introduction

Floral traits and gender expression change in response to both small- and large-scale environmental variations in some species of arctic and alpine plants (Alatalo and Molau, 1995; Kudo, 1997; Wada *et al.*, 1999). In a previous study, Wada *et al.* (1999) found that the dry weight of hermaphrodite flowers and the floral sex allocation to the female organs (=femaleness) in *Dryas octopetala* L. significantly decreased under more stressful environmental conditions, along a latitudinal gradient from the Subarctic to the High Arctic. This suggests that flower weight and dry-matter allocation to the female organs will increase when environmental stress factors such as strong wind and low temperature are ameliorated (*e.g.* Wada, 2000), and also if those floral traits do not genetically fix but could change plastically.

In this paper, we examine the responses of floral traits and sex allocation to the female function in the flowering stage to a simulated environmental amelioration, using an open-top chamber (OTC), in hermaphrodite flowers of *Dryas octopetala*. The aims of this study are to answer the following questions: 1) Do floral parts such as petals, androecium, gynoecium, calyx and receptacle, and peduncle change their dry weight by the environmental amelioration using an OTC? 2) As a consequence, does floral sex allocation to the female organs within flowers increase under the amelioration?

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Materials and methods

This study was carried out in *Dryas octopetala* dominated vegetation in front of the Brøgger Glacier in the High Arctic Ny-Ålesund (78°55′N, 11°56′E), Svalbard (Fig. 1; left figure). Monthly mean air temperatures in June, July and August during 1992–1996 in Ny-Ålesund were 2.4°C, 4.5°C, and 3.5°C, respectively (Norwegian Polar Institute, unpublished data).

In order to confirm the high plasticity of floral traits and gender expression in simulated environmental conditions such as low temperature and strong wind, we installed an open-top chamber (OTC) on the *Dryas* vegetation on 8 August 1997. The OTC was hexagonal, made of six acrylic boards, and its upper and basal area were 0.3 m^2 and 0.6 m^2, respectively; the height of the OTC was *ca.* 20 cm (Fig. 1).

We also measured temperature on the ground at hourly intervals inside (at the center of the chamber) and outside the OTC, with Optic StowAway temperature data loggers (Onset Computer Co., USA) from 8 August 1997 to 29 July 1998. We calculated the difference of temperature between the inside and outside of chamber, until the end of the growing season (from 8 August to 9 September 1997: daily mean temperature > 0°C) and from the begining (just after snow-melting) to the middle of the growing season (from 25 June to 29 July 1998).

Dryas octopetala has two types of flowers: male flowers and hermaphrodite flowers (Wada *et al.*, 1999). However, in this study year 1998, most flowers were hermaphrodite both inside and outside the chamber.

In late July and early August 1998, we collected twenty-two flowering shoots in a 0.6 m × 0.6 m area (0.36 m^2) inside the OTC (Fig. 1; right figure) and twenty-four flowering shoots in a 0.6 m × 0.6 m area just outside the chamber. We dissected each flower into petals, androecium, gynoecium, calyx and receptacle, and peduncle, and dried them at 80°C for 48 hours. The dry weight of each floral part of *D. octopetala* was measured by an electronic balance (Sartorius New MC1, Sartorius AG, Germany).

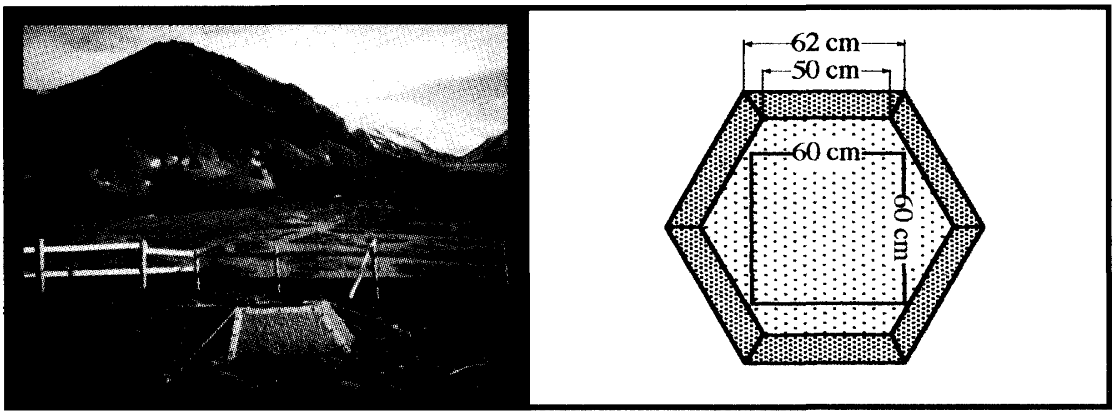

Fig. 1. Landscape of study site and open-top chamber (OTC, left figure) and size of the chamber (upper view), and sampling quadrat (right figure). The upper and basal areas of the OTC were 0.3 m^2 and 0.6 m^2, respectively.

To clarify the variation of sex allocation based on dry weight in hermaphrodite flowers inside and outside the chamber, we calculated the "femaleness", defined by the following formula:

$$\text{Femaleness} = \text{GW}/(\text{GW} + \text{AW}),$$

where GW is the dry weight of gynoecium and AW is that of androecium (*cf.* Lloyd, 1980; Molau, 1991). In this paper, we use "femaleness" as an indicator of the reproductive effort (phenotypic gender) of the female function (Wada, 2000).

Results and discussion

The OTC increased temperature on the ground to 0.3±1.5°C (mean±SD, $n = 792$ measuring points) in the late growing season of 1997 and 1.0±4.0°C ($n = 840$ measuring points) in the early to middle growing season of 1998.

The dry weight of floral parts differed between the OTC-manipulated shoots and controls (Table 1). Petals and androecium weight were significantly lighter in the OTC-manipulated shoots than in controls. In contrast, gynoecium, peduncle, and then flower (petals + androecium + gynoecium + calyx and receptacle + peduncle) weights were significantly heavier in the OTC-manipulated shoots than in controls. As a result, femaleness showed a significantly higher value in the OTC-manipulated shoots than in controls (Table 1), although the dry weight of androecium plus gynoecium did not differ significantly between the OTC-manipulated shoots (mean±SD: 5.7±1.6 mg) and controls (5.2±1.1 mg)($P = 0.293$, by Student *t*-test). Because the effective period of the artificial warming was short, only 33 days in the late growing season of 1997 and 35 days in the early to middle growing season of 1998, the short-term OTC manipulation might not strongly influence net-production by photosynthesis on dry weight of pistils plus stamens, but greatly affects the allocation to female organs (pistils). This suggests a trade-off relationship between the resource investments to stamens and pistils. From the viewpoint of the physiological mechanism (*i.e.* dry matter production by photosyn-

Table 1. Comparison of dry weight of floral parts and femaleness (mean ±sd) in *D. octopetala* flowering shoots between the OTC manipulation ($n = 22$) and controls ($n = 24$).

Floral traits	OTC	Control	Difference
Petals (mg)	3.4 ±0.5	4.0 ±0.6	* $P = 0.002$
Androecium (mg)	1.9 ±0.2	2.8 ±0.4	† $P = 0.001$
Gynoecium (mg)	3.8 ±1.5	2.4 ±0.9	† $P = 0.001$
Calyx and receptacle (mg)	5.5 ±0.7	5.9 ±0.9	* $P = 0.087$
Peduncle (mg)	9.7 ±2.8	5.6 ±2.1	* $P < 0.001$
Flower (mg)	24.3 ±4.7	20.7 ±4.1	* $P = 0.007$
Femaleness	0.65±0.09	0.46±0.07	† $P < 0.001$

*; Student *t*-test (when the variance was not significantly different between the OTC and control, analyzed by *F*-test); †; Mann-Whitney *U*-test (when the variance was significantly different between them, analyzed by *F*-test at $P > 0.05$ level).

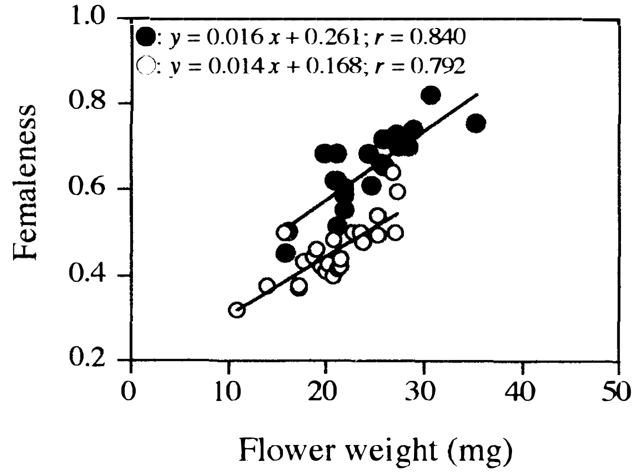

Fig. 2. Relationships between flower size (dry weight) and femaleness. ●, OTC-manipulated shoots; ○, control shoots.

thesis and then the allocation to reproductive organs), however, it is unclear why gynoecium and peduncle weights were increased while androecium and petal weights were decreased by means of the OTC-manipulation. Further detailed physiological studies are necessary to clarify this question.

Femaleness was significantly positively correlated with flower weight both in the OTC-manipulated shoots ($r=0.840$, $P<0.001$, $n=22$) and controls ($r=0.792$, $P<0.001$, $n=24$; Fig. 2), as reported by the previous study (Wada *et al.*, 1999). However, analysis of covariance (ANCOVA) showed that the slope of the regressions did not differ ($F_{1,43}=0.204$, $P=0.654$) but the intercept of the regressions differed significantly between inside and outside the OTC ($F_{1,44}=31.466$, $P<0.001$), indicating that femaleness at a given flower size was significantly higher in the OTC-manipulated shoots than in controls (Fig. 2).

Thus, it was experimentally demonstrated that the gender of *D. octopetala* flowers changed from male- into female-biased expression as flower weight increased and also even at the same flower weight, under a less stressful condition. This high investment to gynoecium might positively affect seed production, the number of seeds and/or individual seed weight, in response to unpredictable good weather conditions.

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