人工被陰下での光合成特性と実生の生存からみたハルジオンの耐陰性

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Tsuyoshi Kobayashi[1, 2], Satoko Kawarasaki[1] and Yoshimichi Hori[1] : Shade tolerance of *Erigeron philadelphicus* with respect to photosynthetic traits and seedling survival under artificial shade

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Erigeron philadelphicus L. (Asteraceae) is a herbaceous plant of typical winter-green perennial habit, naturalized in Japan from North America. In our country, it occurs as herbaceous vegetation of upland crop fields, on levees along paddy fields, grazed grasslands, roadsides, wastelands and so on (Takematsu and Ichizen 1987). *Erigeron philadelphicus* plants establish seedlings mainly from summer to autumn, overwinter as a rosette and flower with a tall stalk in spring (Masuzawa 1975). Then, these plants often dominate at these habitats in spring when other tall species are less dominant. Conversely, from early summer to autumn when other tall species grow well, the rosettes of *E. philadelphicus* are suppressed in the understory due to their low stature. The relative light intensities at the bottom of the dense herbaceous vegetation are below 0.1 in summer (e. g. Kobayashi et al. 1997). Therefore, *E. philadelphicus* rosettes would appear to need a shade tolerance to survive at the bottom of tall communities. In the present study, *E. philadelphicus* seedlings were grown in artificial shade and their shade tolerance with respect to photosynthetic acclimation to light intensity and their survival rate under low light conditions were evaluated.

Materials and methods

Seeds of *E. philadelphicus* were collected from a sunny roadside in Mito City, Ibaraki Prefecture, Japan (36°23′ N, 140°28′ E), during April to May 1992. The following experiments were conducted in 1993. Seedlings obtained from these seeds were planted in containers (57cm length × 19cm width × 15cm depth) filled with andosol. One week after the planting, containers with 30 seedlings were transformed under conditions of natural day-length and air temperature, and treated with artificial shading (relative light intensity : RLI = 1, full-sunlight ; 0.13 ; and 0.04) using neutral black screens at the experimental garden of Ibaraki University with four replicates (details in Kobayashi and Hori 1999). The seedlings were grown from 25 May and the numbers of surviving seedlings were recorded until 31 August. Photosynthesis of individual leaves from 2-3 plants grown at 1 RLI and 0.13 RLI was measured in September using an open gas exchange system (Kobayashi and Hori 1999). Light response curves of photosynthesis were obtained at ca. 24℃, which was found to be the optimal leaf temperature (Kobayashi unpublished). Leaf dry mass per leaf area (LMA) was obtained from the area and dry weight of the leaves (heated in an oven at 70℃ for 48 h) used for the above measurements. All plants used in the experiments were at the rosette stage.

Results and discussion

LMA of *E. philadelphicus* was reduced by shading (Table 1). This is a common phenomenon in shade acclimation (Muraoka et al. 1997 ; Lambers et al. 1998). The maximum photosynthetic rate (Amax) detected near saturating irradiance (above 460 μmol photon m^{-2} s^{-1}) was also reduced by shading (Table 1). These reductions suggest that, on a leaf-area basis, investment in

Table 1. Net photosynthetic rate near saturating irradiance (above 460 μmol photon m^{-2} s^{-1}; Amax), dark respiration rate (*R*d), light compensation point (LC) from the light-response curves of photosynthesis, and leaf dry mass per leaf area (LMA) in the leaves of *Erigeron philadelphicus* rosettes under exposed (1 RLI; full-sunlight) and shaded conditions (0.13 RLI). Mean ±standard errors (n = 2–3).

	Amax	*R*d	LC	LMA
	(μmol CO_2 m^{-2} s^{-1})	(μmol CO_2 m^{-2} s^{-1})	(μmol m^{-2} s^{-1})	(mg cm^{-2})
Exposed	14.8±0.7	0.58±0.13	7.1±2.2	3.6±0.2
Shaded	5.4±0.6	0.26±0.09	4.3±1.3	1.4±0.1

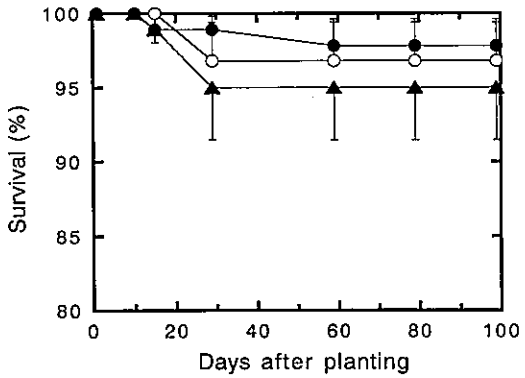

Fig. 1. Time course of the survival rate in *Erigeron philadelphicus* seedlings under three light conditions. ○: 1 RLI; ●: 0.13 RLI; ▲: 0.04 RLI. Bars represent standard errors (n = 4).

compounds that determine photosynthetic activity at a higher irradiance level was reduced by shading. The light compensation point (LC) and dark respiration rate (*R*d) of shaded *E. philadelphicus* leaves were also lower than those of sun-exposed leaves (Table 1), suggesting that the shaded leaves could effectively assimilate at low irradiance. The survival of *E. philadelphicus* seedlings was little affected by shading over the experimental period ($P>0.05$, Kruskal-Wallis test). The mean survival rate was above 95 % at all RLI conditions (Fig. 1). The high survival may be partly due to the plant's shade-acclimated photosynthetic responses (Table 1). Therefore, *E. philadelphicus* rosettes appear to be able to persist in summer even when the other tall species dominate, by means of the flexibility of morphological (LMA) and photosynthetic traits in response to light conditions (Table 1). The optimal temperature of photosynthesis in *Erigeron* species decreases from autumn to winter, and thus these species can assimilate successfully during this lower temperature period (Regehr and Bazzaz 1976).

In a soil desiccation experiment at an open field in summer (described by Kobayashi and Hori 1999), no *E. philadelphicus* seedlings survived after one month without irrigation (Kobayashi unpublished). However, it is likely that shade-tolerant *E. philadelphicus* seedlings would be able to establish in summer at the bottom of tall communities with less soil drying due to the shelter provided by the overstory plants.

Conclusion

Shade-tolerance in the rosette (seedling) stage may enable *E. philadelphicus* to survive under severe shading of community foliage during summer to autumn, and then to flower in spring when there is less shading by other species.

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小林剛[1,2]・河原崎里子[1]・堀良通[1]：人工被陰下での光合成特性と実生の生存からみたハルジオンの耐陰性

北米原産の帰化雑草ハルジオン（キク科多年生草本）の耐陰性を被陰下での光合成特性と実生の生残率から評価した。ハルジオンは主に初夏に発生し，ロゼットで越冬後，春に花茎を伸ばして開花する。人工被陰処理の下で生育させたハルジオン実生（ロゼット）の個葉は，光補償点と暗呼吸速度を低下させており，弱光を効率よく利用することが可能になるような光合成特性を示した。また，相対照度がわずか4%のときでも実生の生残率は95%以上と高かった。背丈の高い草本が旺盛に生育する夏期のあいだ，ハルジオンのロゼットはその耐陰性によって群落の下層で持続することが可能であると考えられた。

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