ROLE OF CLONAL INTEGRATION IN LIFE STRATEGY OF SANDY DUNE PLANT, *EREMOSPARTON SONGORICUM* (LITV.) VASS (FABACEAE): EXPERIMENTAL APPROACH

ABSTRACT: A systematic knowledge of clonal integration is an important step in understanding the ecological implication of clonality. This study focuses on the performance of rhizomatous clonal plants under different situations and we proposed a hypothesis that clonal integration will significantly improve the disturbance and drought resistance ability and the competitive ability of *Eremosparton songoricum*. In 2009, the experiments were carried out in two natural populations. Rhizome was either severed (S) or not (I) in four treatments that include control (C), drought (D), disturbance (E), and competition (F). The biomass and the root-shoot ratio were compared in different experimental treatments. Under drought and disturbance treatments, the biomass of ramet with severed rhizome was significantly less than that of intact ramets, and both were lower than the samples under the control treatment. The differences in root-shoot ratio were opposite to the biomass in drought and disturbance treatments. The ramet biomass under the competition treatment had the same result as that under the drought and disturbance treatments. However, the root-shoot ratio was highest in FS (competition treatment with severed rhizome) and lowest in FI (competition treatment with intact rhizome) under competition and control treatments. Our results suggest that clonal integration enhances the disturbance and drought resistance ability rather than the competitive ability of *Eremosparton songoricum*. This may be one of the various reasons why *E. songoricum* is distributed in sand dunes of droughty conditions with more disturbances but less competition. Integration proved to be important for the species occupying adverse patches. For *E. songoricum*, the existence of rhizome reduces the impact of environmental stress and improves the fitness in association with its location at the dune.

KEY WORDS: clonal plant, *Eremosparton songoricum*, rhizome, root-shoot ratio, water content

1. INTRODUCTION

Clonal growth allows plants to form large systems consisting of a variable number of ramets located at some distance from each other and remaining connected by stolon or rhizome internodes for a variable period of time (Roiloa and Retuerito 2006). In this case, connected ramets that can share resources by physiological integration become specialized to preferentially acquire the most abundant resource in a microsite, particularly when the abundance of light and soil-based resources is negatively correlated in space (Price and Marshall 1999). Physiological integration may protect the clonal plants against local effects resulting from spatial and temporal changes in the quality of a habitat. Physiolog-
ical integration may also enable clonal plants to colonize rapidly and exploit stressful patches that would otherwise be unexploitable by independent ramets or plants (Roiloa and Retuer to 2006). Moreover, extensive physiological integration is a significant adaptation in clonal plants in resource-poor environments. It makes possible to conserve and recycle scarce resources within clonal fragments (Niva et al. 2003). These and numerous other studies have helped to elucidate the mechanisms, preconditions, and constraints of carbohydrate, water, and mineral nutrient sharing in clonal plants. They have also provided clear evidence for the ecological importance of clonal integration for enabling plant species to provide their (clonal) offspring with postnatal care, for avoiding the vulnerable life-cycle processes of seed germination and seedling establishment, and for allowing an efficient resource extraction from heterogeneous environments and the provisioning of internal support to damaged or stressed ramets (Stuefer et al. 2004).

At the same time, there are several potential costs of clonal integration, such as the costs of maintenance of the connecting tissues between ramets, the energy required for translocation between ramets, the spread of pathogens through the connecting tissues, and the costs of translocation incurred by the source ramets (Fischer and van Kleunen 2002). These costs seem much more difficult to quantify (Eckert 1999). Many clonal plants fragment early, thus discarding the connections that the model predicts to be potentially beneficial. This clearly shows there must be important forces that in the field that counteract the effect of integration (Herben 2004).

Drought, disturbance, and competition are three normal factors that affect plants. Clonal integration may play an important role in these processes. However, our knowledge about the role of integration in these processes is still quite limited. The performance of clonal plant under different situations will benefit help in further understanding the significance of clonal integration. In this study, rhizome clonal plant *Eremosparton songoricum* (Litv.) Vass. was chosen as the research subject and we test the hypothesis that clonal integration will significantly improve the disturbance and drought resistance ability and the competitive ability of *E. songoricum*. The importance of physiological integration for ramet growth and survival was studied by severing ramet connections. The measurement used here was plant yield in patches of different quality because these are the immediate products of the process of searching and acquiring resources, and yield is strongly correlated with plant fitness (Hutchings and Wijesinghe 2008).

2. STUDY AREA

The study site is located on two sand dunes in the Gurbantunggut Desert: one is situated at 46°31′05″N, 88°33′04″E (designated population A) and the other is situated at 46°28′04″N, 88°33′04″E (designated population B). Gurbantunggut Desert is situated at the center of the Junggar Basin in Xinjiang, China, and is the second largest desert in China with an area of 48,800 km² (Chen et al. 2007). The climate of the desert is temperate continental (Zhang and Chen 2002), with an annual precipitation of 80–160 mm and annual evaporation of 2,000–2,800 mm. Annual average temperature is 5–5.7°C (the extreme temperatures exceed −40°C and 40°C). There are a large number of ephemeral species and semi-shrub species in the desert (Zhang and Hai 2002). Due to frequent human disturbance, including oil and gas resources exploitation, illegal collection of medicinal plants, unreasonable land-use, and overgrazing (Chen et al. 2007), the mobile sand dunes widely exist instead of fixed sand dunes.

3. MATERIALS AND METHODS

3.1. Plant species

*Eremosparton songoricum* (Litv.) Vass is a dwarf clonal shrubby legume. It is a rare endemic Central Asian species and also the only species of the genus in China (Yin et al. 2006). *E. songoricum* is only distributed in the Gurbantunggut Desert of China (Chen et al. 1983, Zhang and Hai 2002) and in sands around Lake Balkash in Kazakstan (Yin et al. 2006). It is confined to severely wind-eroded mobile and semi-mobile sand dunes
Clonal integration in life-strategy of dune plant on the windward slopes of the foredunes and usually distributed from the lower to upper part of a dune and seldom in dune slack. It has intermediate-sized ramets (10–80 cm in height) and widespread clones due to its rhizomatous, guerilla growth form. The aboveground stems of \textit{E. songoricum} die in winter and sprout new branches from the stems remained from the previous year or from rhizomes. The rhizomes of sprouting branches are normally distributed beneath the soil surface at a depth no more than 10 cm (Zhang \textit{et al.} 2008). Thus, clonal propagation seems particularly important. The degraded leaf is generally recognized as a good and vigorous medium in arid areas. Leaf degradation, combined with clonal propagation, contributes to our understanding of \textit{E. songoricum}, a plant suitable for a desert habitat. Due to its ecological functions as a wind breaker and sand stabilizer, \textit{E. songoricum} plays an important role in the maintenance of the stability of the desert ecosystem.

### 3.2. EXPERIMENTAL TREATMENTS

The experimental design is presented in Table 1. Initially, 150 and 50 rhizomes with 6 mm diameter were randomly chosen in populations A and B, respectively which had buds and no elder root in early April 2009. One-third of the marked 150 rhizomes had competitive species (\textit{Artemisia ordosica} Krasch) within 1 m² area, and two-thirds had no competitive species in the same area in population A. All of the 50 chosen rhizomes had no competitive species within 1 m² area in population B. Redundant buds were removed and one was kept on rhizome about 1 m in length. After each treatment, the rhizomes were buried and watered properly.

Afterwards, 160 ramets with approximately the same crown width from the above chosen 200 rhizomes were chosen in mid-May. Two-thirds of the branches were removed on 40 ramets among them in order to serve as the disturbance treatment. There were four treatments: control (C), drought (D), disturbance (E), and competition (F). The rhizome was either severed (S) or not (I).

The height of the ramets was recorded in the last 10 days of July 2009. Both the aboveground part and the underground part at the depth of 0–50 cm were harvested. The whole plants, rhizomes excluded, were subdivided into roots, branches, and fruits and dried to a constant mass at 80°C. Then, the biomass of each of the three parts belonging to each ramet was measured. Soil samples were obtained at depths of 0–10 cm, 10–20 cm, 20–30 cm, 30–40 cm, and 40–50 cm in five random samples in each population by aluminum boxes. Each aluminum box was weighed before the experiment. The fresh samples were

<table>
<thead>
<tr>
<th>Treatment code</th>
<th>The early 10 days of April 2009</th>
<th>The middle 10 days of May 2009</th>
<th>The last 10 days of July 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The number of rhizome</td>
<td>The existence of competition species</td>
<td>Population</td>
</tr>
<tr>
<td>CI</td>
<td>25</td>
<td>No</td>
<td>A</td>
</tr>
<tr>
<td>CS</td>
<td>25</td>
<td>No</td>
<td>A</td>
</tr>
<tr>
<td>DI</td>
<td>25</td>
<td>No</td>
<td>B</td>
</tr>
<tr>
<td>DS</td>
<td>25</td>
<td>No</td>
<td>B</td>
</tr>
<tr>
<td>EI</td>
<td>25</td>
<td>No</td>
<td>A</td>
</tr>
<tr>
<td>ES</td>
<td>25</td>
<td>No</td>
<td>A</td>
</tr>
<tr>
<td>FI</td>
<td>25</td>
<td>\textit{A. ordosica}</td>
<td>A</td>
</tr>
<tr>
<td>FS</td>
<td>25</td>
<td>\textit{A. ordosica}</td>
<td>A</td>
</tr>
</tbody>
</table>
weighed and then oven-dried at 105°C to a constant mass. The water content of the soil samples was calculated as: (weight of water / the dry weight of soil) × 100%.

3.3. Data analysis

The statistical package ORIGIN was employed for all analyses. Data were presented as mean ± SE. Tukey-HSD methods of one-way ANOVA were performed to compare biomass and root-shoot ratio among different treatments and to examine the possible effects of clonal integration. Independent-samples T test was used to analyze differences of water content between two sand dunes. Data normality was comprehensively considered by Kolmogorov-Smirnov and Shapiro-Wilk Index. The Levene test was used for homogeneity of variance.

4. RESULTS

There was a soil-water gradient at different depths (Table 2). High evaporation of rainwater made the surface of the dune dry. Water content was similar in the surface sand layer (0–10 cm) of the two populations of *E. songoricum*. However, water content in the sand layer (>10 cm) of population B was significantly lower than that of population A ($P < 0.05$).

*E. songoricum* showed phenotypic plasticity of morphology in order to adapt to local conditions (Fig. 1). Total biomass of *E. songoricum* in population B was significantly lower than that in population A. Furthermore, biomass in DS treatment was significantly less than that in DI treatment. The differences in root-shoot ratio were opposite to the biomass.

Comparison was made between the ramets from the treatments of control and disturbance; the biomass decreased significantly on ramets with disturbance (Fig. 2). This was attributed to the lack of aboveground shoot. Comparing the two disturbance treatments, the ramet biomass of samples under EI treatment was significantly higher than that in samples under ES treatment. The root-shoot ratio in ES was significantly higher than that in the three other treatments, and this was attributed to the limited aboveground part in ES treatment.

The interspecies competition would decrease the accumulated biomass in *E. songoricum*.

Table 2. Comparison of soil moisture (%) in two populations of *Eremosparton songoricum*. The different letters show a distinct significance at the 0.05 level.

<table>
<thead>
<tr>
<th>Depth in soil</th>
<th>0–10 cm</th>
<th>10–20 cm</th>
<th>20–30 cm</th>
<th>30–40 cm</th>
<th>40–50 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population A</td>
<td>0.92±0.07a</td>
<td>1.35±0.09a</td>
<td>1.55±0.08a</td>
<td>1.89±0.11a</td>
<td>2.20±0.14a</td>
</tr>
<tr>
<td>Population B</td>
<td>0.80±0.04b</td>
<td>1.00±0.07b</td>
<td>1.22±0.05b</td>
<td>1.57±0.07b</td>
<td>1.50±0.09b</td>
</tr>
</tbody>
</table>

Fig. 1. Comparison of biomass and root-shoot ratio between control and drought treatment. For explanation of treatment codes see Table 1. The different letters show a distinct significance at the 0.05 level. Data are presented as mean±SE.
Clonal integration in life-strategy of dune plant

oricum (Fig. 3). Within the two competition treatments, the ramet biomass of samples under FI treatment was significantly higher than those of samples under FS treatment. Compared with the root-shoot ratio in competition and control treatments, the root-shoot ratio of FS were the highest and that of FI were the lowest among all root-shoot ratios in these treatments.

5. DISCUSSION AND CONCLUSIONS

Water content in desert soils is quite limited (A et al. 2005) and, therefore, is an important environmental factor influencing all life functions (Zhang et al. 2005). The soil water content was used as an environmental indicator. The differences of the local conditions between two sand dunes are shown in Table 2. The different behaviors between the two populations can be attributed to the changes in the local conditions. The reduction in branch biomass helped to reduce the evaporation of limited moisture and this was beneficial to saving limited resources. There was no adequate resource to make the plants grow bigger in population B. Each ramet needed more roots (e.g. roots remained from ramets whose aboveground stems died in the previous year) to supply resources in population B. This variability of root-shoot ratio in drought treatment increased the ability of the plants for absorption of resources to improve their viability under adversity. After the rhizome was severed, the decreasing biomass and increasing root-shoot ratio were both more outstanding, which meant that these ramets with intact rhizomes accepted external

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Fig. 2. Comparison of biomass and root-shoot ratio between control and disturbance treatment. For explanation of treatment codes see Table 1. The different letters show a distinct significance at the 0.05 level. Data are presented as mean±SE.

Fig. 3. Comparison of biomass and root-shoot ratio between control and competition treatment. For explanation of treatment codes see Table 1. The different letters show a distinct significance at the 0.05 level. Data are presented as mean±SE.
resources through rhizomes. These evidences clearly indicated that *E. songoricum* benefited from clonal integration under drought condition. This result is consistent with previous experiments that clonal integration was beneficial to clonal plants suffering from local environmental stresses (Liu *et al.* 2007, Xiao *et al.* 2010).

Comparing the two disturbance treatments, the ramet biomass under EI was significantly greater than those under ES, which means that clonal integration can accelerate the recovering ability of the damaged individual plants. Clonal integration plays a role in disturbance-defense. In many clonal plants, clonal integration has been proven to be beneficial to the regrowth of ramets facing disturbance (Bullock *et al.* 1994, Bach 2000, Liu *et al.* 2007). This is consistent with our findings in the case of *E. songoricum*. Wind and sand are the most obvious examples among all kinds of disturbance. In early spring, sand and wind factors gave the strongest influence and might make the damage to fresh individual plants. Some of the shoots were snapped off by the sand or the wind. Because of the physical factors, the wind speed was higher at the top of dune than at the bottom of dune (Wang *et al.* 2003). Clonal integration contributed to the adaptability of *E. songoricum* to sand dune environment.

The accumulated biomass of samples under FI was significantly more than that in samples under FS, which means that resources were transported to ramets grown in competitive areas. As regards the root-shoot ratio, FS got the highest value and FI got the lowest value, which showed that clonal integration made the ramets in competitive area give up the chance to compete with other species for the limited water resource. These caused negative effects on the species grown in water-limited habitats. On the other hand, these were beneficial to the other species for obtaining water easily and further holding favorable habitat. Clonal integration played a role in decreasing the competitive ability of *E. songoricum*. Wang *et al.* (2008) also found that stolon connections increased *Alternanthera*’s biomass allocation to roots without competition, but decreased it with competition. Similarly, clonal integration was of little importance for the competitive ability of several other clonal plants (Amsberry *et al.* 2000, Peltzer 2002, Brezina *et al.* 2006).

In summary, the results of the present work offered actual field evidence of the kind of behavior of guerrilla-type clonal species *E. songoricum* in an infertile habitat. Clonal integration enhances the disturbance and drought resistance ability rather than the competitive ability. This may be the one of various reasons why *E. songoricum* is distributed on the slope of sand dunes with droughty conditions and more disturbances but with less competition and why *E. songoricum* is rarely distributed at the bottom of the dune or on a fixed sand dune with favorable conditions but drastic competition. Integration proves to be important for the species occupying adverse patches (Pennings and Callaway 2000, Peltzer 2002). For *E. songoricum*, the existence of the rhizome reduces the impact of environmental stress and improves the fitness in association with its location at the dune.

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6. REFERENCES


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