Available online at www.sciencedirect.com
ScienceDirect
Forest Ecology and Management 255 (2008) 1243–1250
Forest Ecology and Management
www.elsevier.com/locate/foreco

Differences of dispersal fitness of large and small acorns of Liaodong oak (*Quercus liaotungensis*) before and after seed caching by small rodents in a warm temperate forest, China

Hongmao Zhang [a,b,c], Yu Chen [b], Zhibin Zhang [a,*]

[a] *State Key Laboratory of Integrated Management of Pest Insects and Rodents in Agriculture, Institute of Zoology, The Chinese Academy of Sciences, Beijing 100101, China*
[b] *College of Fisheries, Huazhong Agricultural University, Wuhan 430070, China*
[c] *Graduate School of the Chinese Academy of Sciences, Beijing 100049, China*

Received 1 April 2007; received in revised form 19 September 2007; accepted 16 October 2007

Abstract

Though effect of seed size on seed fates has been widely studied, differences of dispersal fitness of large and small acorns before and after seed caching by small rodents is largely unknown. In this study, by tracking the seed fates of 2400 tin-tagged acorns (1200 large acorns with 3.2 ± 0.6 g weight, and 1200 small acorns with 0.9 ± 0.2 g weight) of Liaodong oak (*Quercus liaotungensis*) in three habitats, we compared the differences of seed consumption, removal, caching and survival between large and small acorns at four dispersal stages (at seed station, after removal, after caching and seedling recruitment) in a warm temperate forest in the Dongling Mountains, northwestern Beijing, China. This study was carried out during the period of October 2005 to May 2006. The results demonstrated that, (1) at seed stations where tagged seeds were released, large acorns had higher proportion of removal (and more quickly) and lower proportion of seed consumption by rodents than small ones; (2) after removal, large acorns were dispersed longer, and had higher proportion of seed caching than small acorns. But there was no difference in the proportions of seed consumption between large and small acorns; (3) after seed caching, large acorns had significantly lower proportions of survival than small acorns within the observed 30-days period, and the final survival proportions of initially released seeds by the next spring were very small for both large and small acorns and the difference was not significant; (4) large acorns had higher dispersal fitness before seed caching but lower dispersal fitness after seed caching than small acorns; there was no difference in total dispersal fitness between large and small acorns. In general, our findings suggest that large acorns of *Q. liaotungensis* have similar total dispersal fitness to small ones.

Keywords: Small rodents; Seed size; Seed dispersal; Seed consumption; Cache survival; Seedling establishment; Fitness

1. Introduction

The interaction between plants and animals is one of the most important mechanisms in the ecology and evolution of mutualistic systems. Several studies have demonstrated that scatter-hoarding rodents, both as consumers and dispersers of seeds, play an important role in the seed-to-seedling phase of plant regeneration (e.g. Jansen et al., 2004; Zhang et al., 2005; Theimer, 2005). Many factors, such as seed characteristics and environmental factors, may affect seed hoarding behavior of rodents (Li and Zhang, 2003; Lu and Zhang, 2004), and subsequent seedling recruitment (Duncan and Chapman, 1999; Li and Zhang, 2003).

The nutritional quality of plant seeds and fruits is an important factor affecting seed-eating vertebrates' decisions to forage and cache (Vander Wall, 1990). Janzen (1971) suggested that large seeds (heavier and larger) might experience a lower probability of survival due to higher predation before dispersal and higher discovery and pilferage after being cached (also see Clarkson et al., 1986). However, Jansen et al. (2002) demonstrated that large seeds were dispersed further distances from parent trees, and then they suffered from smaller pilfering and rediscovering. The higher-quality caching of large seeds can subsequently translate into a greater probability of large seeds escaping consumption (Jansen et al., 2002, 2004) and subsequently germinating to the seedling stage (Jansen, 2003).

* Corresponding author. Tel.: +86 10 6480 7213; fax: +86 10 6480 7099.
E-mail address: zhangzb@ioz.ac.cn (Z. Zhang).

0378-1127/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.foreco.2007.10.028

Large seeds may have higher probability for seedling establishment (Harper et al., 1970; Stanton, 1984, 1985; Leishman et al., 2000). Several studies have indicated that large seeds were more likely selected by rodents for their abundant nutrition (e.g. Vander Wall, 1995; Forget et al., 1998; Jansen and Forget, 2001; Jansen et al., 2004; Xiao et al., 2004a), and dispersal distance increases with seed size (e.g. Jansen et al., 2002; Xiao et al., 2004a; but see Brewer, 2001). Unfortunately, most of these studies did not compare the difference of seed survival after caching between large and small seeds, and thus the total effect of seed size on dispersal fitness (survival of scatter-hoarded or cached seeds) of large or small seeds is largely unknown. Previous studies showed that low-quality seeds suffered higher consumption *in situ* (e.g. Xiao et al., 2004b), and large cache suffered higher losses (Zhang and Zhang, 2006). These observations suggest that seed dispersal fitness of large or small seeds may differ before and after seed caching.

Liaodong oak (*Quercus liaotungensis*) is one of the common climax tree species in warm temperate broad-leaved deciduous forest in north China (Chen, 1992). Fresh acorn of *Q. liaotungensis* is ovoid, 13.3 ± 2.1 mm width, 17.8 ± 2.7 mm length and 2.0 ± 0.9 g weight ($n = 50$). Acorns of *Q. liaotungensis* mature and fall during the last 10 days of August to the end of September, and become seedlings next spring. Due to the high predation by small rodents, the natural seeding regeneration rate of *Q. liaotungensis* is very low (<0.1%), even in the acorn mast-years (Li and Zhang, 2003, 2007).

The purpose of this study aims to compare differences of seed consumption, removal, scatter-hoarding and survival between large and small acorns of *Q. liaotungensis* at four dispersal stages (at seed stations, after removal, after caching and seedling recruitment). We want to test the two opposite hypothesis: (1) large acorns have lower predation and higher survival or seedling establishment (Jansen et al., 2002); and (2) large acorns have higher predation and lower survival or seedling establishment (Janzen, 1971). We also want to test our hypothesis that large acorns have higher dispersal fitness before seed caching but lower dispersal fitness after seed caching than small ones. Our hypothesis is based on the assumption that large acorns with high nutrition values are more likely cached by rodents for future consumption, but large acorns with large smell are more likely pilfered or re-discovered by rodents. Because only scatter-hoarding seeds benefit seedling recruitment, we define the survival proportion of scatter-hoarded (cached) seeds as the seed dispersal fitness in this study.

2. Methods

2.1. Study site

We carried out the study in a hill nearby the Liyuanling village (40°00′N, 115°30′E, 1140 m ASL), Mentougou district, Beijing, China, in the Dongling Mountains with a temperate continental monsoon climate. Shrublands, secondary forests and abandoned farmlands are main types of vegetations. The area had been heavily disturbed by human activities in the last several decades. *Q. liaotungensis*, wild walnut (*Juglans mandshurica*), wild apricot (*Prunus armeniaca*) and larch (*Larix principis-rupprechtii*) are the predominant tree species, with some Chinese pine (*Pinus tabulaeformis*) and cultivated walnut (*Juglans regia*) trees occurring sparsely throughout the region. Forests of *Q. liaotungensis* are a typical vegetation type in the study site. Due to extensive cutting by local residents, only small patches of secondary grown oaks remain among scattered shrublands (Sun et al., 2004). Detailed information about the study site has been described in our several previous publications (e.g. Li and Zhang, 2003, 2007; Lu and Zhang, 2004, 2005).

2.2. Experimental plots

We selected three areas of about 3.0 ha each in shrubland, secondary forestland and abandoned farmland, respectively as experimental plots. The dominant plant species in the shrubland plot include young trees of *Q. liaotungensis* and elm (*Ulmus laciniata*) with 2.2 ± 1.7 m ($n = 100$) tall and 65% total cover. This shrubland plot is located in a southeastern-facing slope of 30–45°. *Q. liaotungensis* and *L. principis-rupprechtii* are the dominant plant species with 8.2 ± 3.2 m ($n = 100$) tall and nearly 100% cover in the secondary forest plot. Except for some grass and shrubs, most part is leaf litters or bare ground underneath the canopy. The secondary forest plot is located in a northeastern-facing slope of 45–65°. *Artemisia Linn* spp., *Elymus excelsus*, *Poa* spp. and *Dendranthema (DC.) Des Moul.* spp. are dominant grass plants with 0.9 ± 0.5 m tall and >80% cover in the abandoned farmland plot, and some *J. regia* and *P. armeniaca* trees sparsely distributed in it. This farmland plot is located in a southeastern-facing slope of 40–55°.

Within each experimental plot there was a transect about 300 m long along the slope. Previous study indicated that most acorns of *Q. liaotungensis* are dispersed within 15 m by small rodents (Li and Zhang, 2003; Lu and Zhang, 2005), we located 20 seed stations at interval of 20 m apart along each transect.

2.3. Seed marking and releasing

During seed-fall period in 2005, fresh acorns of *Q. liaotungensis* were collected in the study area. We selected intact large and small acorns for seed release according to visual size. Among them, we randomly selected 50 large and small acorns to measure the sizes and weights of them, respectively. The large acorns were 3.2 ± 0.6 g weight, 21.1 ± 1.9 mm length and 15.8 ± 1.5 mm width, while the small acorns were 0.9 ± 0.2 g weight, 14.6 ± 1.6 mm length and 10.3 ± 0.9 mm width (mean ± S.D.). A tiny hole of about 0.5 mm width in diameter was drilled at the base of each acorn (the drilling may partially damage kernels of acorns). A small, light, uniquely coded tin-tag (3.0 cm × 1.0 cm) was tied to each acorn with a fine steel wire (3 cm long) (Zhang and Wang, 2001; Li and Zhang, 2003, 2007; Lu and Zhang, 2005). This tin-tagged method has been shown to be more effective in tracking seed fates by small rodents than the thread-marking method because the steel wire tied to the seeds is more resistant to cutting by rodents (Xiao et al., 2006).