Pericarp imposed seed dormancy in *Zygophyllum xanthoxylum* (Bunge) Maxim. favours its adaptation to desert environments

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Abstract

This study investigated the role of the seed pericarp in regulating germination of *Zygophyllum xanthoxylum* (Bunge) and its influence on the long term persistence of buried seeds under field conditions. Laboratory studies showed that the presence of the pericarp almost completely prevented seed germination; removal of the pericarp or flushing seeds with tap water significantly increased the level of germination. We suggest that the pericarp is responsible for imposing seed dormancy in *Z. xanthoxylum*, acting through the combined effects of mechanical resistance and chemical inhibitors. When seeds were buried in the field, pericarp, burial time and burial depth all showed significant effects on field germination and the number of decayed seeds. Seeds without a pericarp germinated across the entire burial period, but seeds with pericarp mainly germinated during the extended wet season. The presence of a pericarp significantly reduced the extent of seed decay. This implies that the pericarp has an important role in determining the time and place of seed germination and favours seedling establishment and seed persistence (longevity) under field conditions. These conclusions may have practical relevance for the use of this species in grassland rehabilitation and plant conservation programs.

Introduction

The germination traits of the naturally dispersed seed unit govern the population dynamics in both natural and agricultural ecosystems (Baskin & Baskin, 1998) and are of particular importance when considering the rehabilitation of degraded and desertified lands. For *Z. xanthoxylum*, an economically and ecologically important fodder shrub in the arid environment, its dispersed seeds are enclosed by a three winged perianth which originated from extending exo-and endocarps (Beier *et al*., 2003). Previous research related to the seed germination characteristics of *Z. xanthoxylum* has used naked seeds (Tobe *et al*., 2001; Zeng *et al*., 2002), and these results may lead to some false expectations about field performance.

For the present study, we investigated the effect of the pericarp of *Z. xanthoxylum* on seed germination characteristics and its implications for adaptation of the species to local environments.

Materials and methods

Materials

The seeds were collected from the Alxa desert in northern China (105°34′E, 39°05′N, and 1360 m.a.s.l.) in 2007. After drying at room temperature, seeds were enclosed in a plastic bag and stored at 4°C.

Laboratory experiments

Four types seeds were used to test the germination as presented by Zeng et al.(2002): 1) seeds with pericarp (WP), 2) seeds without pericarp (WOP), 3) seeds with the pericarp near the radical end (RRP) removed, 4) seeds with the pericarp near the cotyledon end (opposite to radical, RCP) removed. Germination was recorded every day in the first fourteen days and a final germination percentage was recorded at 28 days. Also, WP, WOP, RRP or RCP were flushed with tap water for 24 hours (WP+F, WOP+F, RRP+F, RCP+F, respectively), and then test germination as described above.

Field experiment

Seeds with and without a pericarp were placed into permeable nylon bags (20 cm × 15 cm) and buried at two depths (surface and 5 cm) on 25 September 2007, with five recovery times (two monthly intervals beginning on 8 December 2007).

Recovered samples were pooled into a 11-cm diameter Petri dish and tested for germination as described in Section 2.2. The numbers of germinated (field germination), decayed (dead) and dormant seeds (viable, non-germinated seeds) were assessed after 28 days. Enforced dormancy was defined as seeds that subsequently germinated in the laboratory.

Statistical analysis

Germination data were arc-sine transformed in order to meet the assumption of normality of variance. All data are presented as means $\pm$ SE.

Results

Effects of pericarp on seed germination in the laboratory

Seeds germinated significantly higher than that in the control (WP) when the pericarp was removed or partly removed or flushed with tap water except seeds with the pericarp removed near cotyledon end only (RCP). Seeds with pericarp or RCP germinated to less than 6%, seeds with pericarp near radical end removed (RRP) significantly increased germination to 44%, and completely removal of the seed pericarp germinated to 94%. Also, flush treatment increased seed germinate but response depends on the seedlot treatment, e.g. it increased RRP germination from 44% to 93%, and increased RCP or WP from 6% and 2% to 53% and 37%, respectively(Figure 1.).

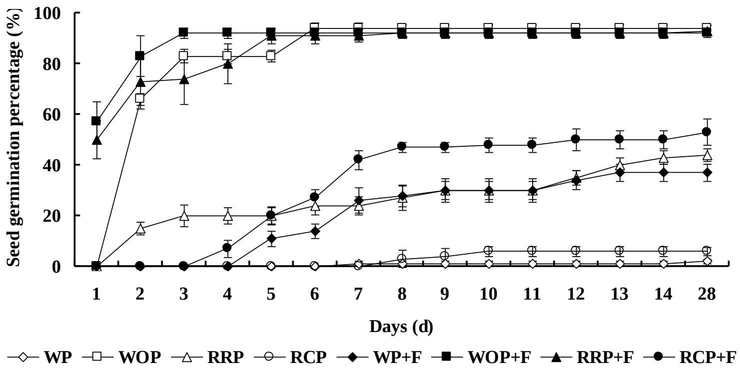

Figure 1. Cumulative germination of *Zygophyllum xanthoxylum* seeds subjected to different physical treatments (WP, seeds with pericarp; WOP, seeds without pericarp; RRP, seeds of pericarp near radical removed; RCP, seeds of pericarp near cotyledon removed; F, flush with tap water for 24hours)

Effect of pericarp and seed burial on seed persistence in the field

Field germination was significantly influenced by pericarp, burial depth and burial time (Figure 2.). Seeds without pericarp germinated earlier compared to seeds with pericarp, and as burial depth increased, seed germination increased early in the season (from February to June) but no difference was observed between 2 and 5cm burial depths late in the season (from August to October). Most buried seeds (at 2 and 5 cm) with or without a pericarp germinated during the August to October period. However, nearly all seeds exposed on the soil surface failed to germinate at any time of the year. A significantly higher proportion of decayed seed was observed in treatments without a pericarp compared to seeds with a pericarp, regardless of burial depth, and increased over time.

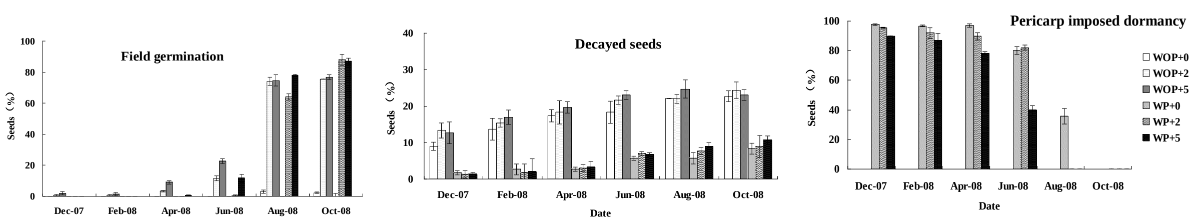

Figure 2. Status of seeds recovered over time in the burial experiment, expressed as a proportion of field germination (%), decayed seeds (%) and pericarp imposed dormancy (%). WOP+0, 2 or 5 are seeds without pericarp buried at 0, 2 or 5 cm depth; WP+0, 2 or 5 are seeds with pericarp buried at 0, 2 or 5 cm depth.

Discussion

This study clearly shows that pericarp is responsible for seed dormancy in *Z. xanthoxylum* because the pericarp almost completely inhibits seed germination and removal of the pericarp increases germination to its potential percentage (Figure.1). Also the pericarp seems to not affect gas exchange because removal of the pericarp near cotyledon (RCP) did not increase seed germination significantly, but interesting, removal of the pericarp near radical (RRP) largely improves seed germination, this implies that a mechanical resistance on radical protrusion is imposed by the pericarp. Further, the pericarp mechanical resistance just partly explains pericarp imposed seed dormancy because RRP germinated to 44% only which indicate other factors are involved in the dormancy of the remaining seeds. In the present study, water flushing significantly increased germination percentage of seeds with pericarp or with a part of pericarp, and this result is consistent with previous research (Clrak, et al., 2007) and implies a germination inhibitor existed or generated by the pericarp. Based on this, we suggest that pericarp imposed dormancy in *Z. xanthoxylum* seed is a combination of mechanical resistance and chemical inhibition generated by pericarp.

Seed dormancy has an important role in determining the time and place of seed germination in the field to spread the risk of germination failure, and thus may help ensure long-term seed survival, especially for wild species growing in harsh environments (Baskin & Baskin, 1998). It is clear from the current field experiment that pericarp imposed dormancy is responsible for the lack of germination from December 2007 to June 2008. During this period seeds with pericarp do not germinate even when returned to optimum conditions for germination (Figure. 2), and this is consistent with previous research in other species (Hu *et al*., 2009b). Seeds without a pericarp can germinate readily at any time of the season depending on environmental conditions. Hu *et al*. (2009a) also reported that seeds with a pericarp exhibited a lower germination but higher seedling establishment compared to seeds without a pericarp because most seedlings from naked seeds had a greater spread of germination time and many died from subsequent drought conditions.

Seed decay is another factor affecting seed persistence in addition to changes in dormancy. Present experiment clearly showed that the presence of a pericarp significantly reduced the number of decayed seeds regardless of burial depth and burial time. Low levels of seed decay early in the season may be a consequence of low soil moisture at the experimental site (similarly slowing the process of seed aging). When soil moisture rapidly increases late in the season, environmental conditions become optimum for seed germination and most seeds germinate rather than lose viability and decay. In addition, more than 90% of the variance in terms of seed decay could be explained by the pericarp, suggesting that the presence of the pericarp plays a determent role in limiting seed decay across a range of conditions.

Acknowledgements

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