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Role of post-dispersal seed and seedling predation in establishment of dandelion (*Taraxacum* agg.) plants

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ABSTRACT

Dandelion *Taraxacum* agg. (formerly *Taraxacum officinale* G.H. Weber ex Wiggers) is a common weed species associated with pastures, grasslands and no-tillage cropping systems throughout its native range in Europe, and more recently introduced into North America, Australasia and elsewhere. Following wind-dispersal from the parent plant, its seeds are subject to predation from a host of invertebrate predators. Similarly, seedling predation may also significantly limit dandelion recruitment. Although such post-dispersal mortality is central to our understanding of dandelion population dynamics and therefore weed control, the precise spatio-temporal role played by different putative seed and seedling predators is poorly understood. Here we studied how seed viability, and seed and seedling predation influenced dandelion recruitment at two contrasting sites in central Europe. The abundance in the field and seed and seedling consumption in the laboratory were determined for the main groups of predators—ground beetles (Coleoptera: Carabiade), terrestrial isopods (Isopoda: Oniscidea) and molluscs (Gastopoda: Pulmonata). At particular sites, seed viability and seedling predation were negatively correlated while the percentage of seeds that succumbed to seed predation was similar. Combined factors accounted for the death of 98% and 87% of exposed seeds. Ground beetles (particularly *Amara* spp.) and terrestrial isopods (*Armadillidium vulgare*) were efficient and dominant seed predators, while slugs (*Arion lusitanicus*) and isopods were important predators of seedlings. While there was no seasonal trend in the intensity of seed predation it decreased towards autumn in parallel with the feeding activity of the declining population of *A. lusitanicus*. The mortality factors thus varied in their importance, largely between sites and less with the course of the season. Although seed inviability, seed and seedling predation did not stop the recruitment of dandelion seedlings they are crucial factors limiting dandelion populations. Methods of increasing the efficiency of predation of seed as a means of managing weeds are worthy of further study, particularly in areas where dandelion is an invasive species.

1. Introduction

The increasing awareness of the need for a scientific basis for weed management (Fernandez-Quintanilla et al., 2008; Van Acker, 2009) stimulated the search for biological agents that reduce weed population densities or stop their population growth or dispersal. A sensitive stage in the development of weed populations that could be intervened by biological means is the period between seed dispersal and seedling establishment, a critical stage in plant development during which there is enormous mortality attributable to non-germination and seed and seedling predation (Harper, 1977). The percentage of seeds that succumb to each of these mortality factors differs between plant species, environments and in time (Fenner and Thompson, 2005). It is therefore necessary to study factors limiting weed dispersal at this crucial period. Here we report the results of a four year study on seed and seedling predation in dandelion.

Dandelion *Taraxacum* agg. is an aggregate consisting of 1500 microspecies in Europe (Grime et al., 2007). The populations of *Taraxacum* studied belong to an aggregate of c. 250 microspecies recognized in the Czech Republic (Kirschner et al., 2002) and classified as section Ruderalia Kirschner, H. Œllgaard et Štěpánek (formerly identified as *Taraxacum officinale* G.H. Weber ex Wiggers). In Europe this perennial Asteraceae colonizes a wide variety of habitats, most frequently meadows, pastures, waysides and wasteland, less frequently arable land and woody habitats (Grime et al., 2007). Dandelion is a troublesome weed of gardens (Grime et al., 2007), frequently mown meadows and overgrazed pastures (Pavlu et al., 2007). From Europe dandelion spread to America and Australasia (Stewart-Wade et al., 2002) where it is an

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important weed of arable land under no-tillage cropping systems (Hacault and Van Acker, 2006; Franssen and Kells, 2007). Dandelion flowers throughout the vegetative season with a distinct peak in spring when c. 90% of the inflorescences are produced. Windborn seeds start to disperse 12 days after flowering (Martinkova and Honek, 2008). Most of the seed germinates on the surface of the ground of disturbed land immediately after dispersal (Novak, 1994). In spring germination typically occurs within 10–15 days of the seed being shed while a part of the seed produced in September–November overwinters (Collins, 2000; Grime et al., 2007). If buried, less than 5% of the seed can survive for up to four years (Chepil, 1946; Roberts and Neilson, 1981) but how and the percentage of seed that is buried are unknown.

As a consequence of these regenerative characteristics post-dispersal and seedling stages are critical periods in the life history of dandelions. Seed inviability and post-dispersal predation are important mortality factors and account for c. 95% of the mortality that occurs before the establishment of dandelion seedlings in grassland in central Europe (Honek et al., 2005). Ground beetles (Honek et al., 2003, 2005) together with terrestrial isopods (Saska, 2008) and vertebrates (Moorcroft et al., 2006) are the main seed predators. Ground beetles (Coleoptera: Carabidae) are large and mostly carnivorous with some species, belonging mostly to the tribes Harpalini and Zabrini, granivorous (seed-feeding). Adults of more than 30 species eat dandelion seed in laboratory tests (Honek et al., 2007). The most important predators of dandelion seed belong to the genus *Amara* (Honek et al., 2005). Except for the species of the genus *Zabrus* (Kreuz and Engelhardt, 1991) the green parts of plants are less acceptable to carabid beetles. Larvae of granivorous species may also feed on seeds, including those of dandelion (P. Saska, unpublished). Terrestrial isopods (Isopoda: Oniscidea) are detritivores (Sutton, 1972; Hassall and Rushton, 1982; Zimmer, 2002) but are also known to consume seeds (Saska, 2008). The most abundant species at our experimental sites was *Armadillidium vulgare* Latreille.

Slugs and snails (Mollusca: Pulmonata) consume dead or living plant material, including seeds, in different proportions (Hanley et al., 1995a; Cardina et al., 1996; Kollmann and Bassin, 2001). Slugs, particularly the recently spreading and invasive species *Arion lusitanicus* (Mabille) (Rabitsch and Essl, 2006; Soroka et al., 2009), are important grazers of living plants (Hanley et al., 1996a,b; Briner and Frank, 1998; Kozlowski and Kozlowska, 2000; Hanley, 2004). Their preferred food is seedlings (Fenner et al., 1999) and their grazing may even change the species composition of plant communities (Hanley et al., 1995b; Bruelheide and Scheidel, 1999; Frank, 2003; Buschmann et al., 2005). Slugs prefer tall vegetation (Grimm and Paill, 2001) from where they spread to surrounding cut stands and their numbers vary greatly between sites and years (Honek and Martinkova, 2007).

A long-term study of post-dispersal seed predation (Honek et al., 2005) revealed spatial and temporal variation in the mortality of young dandelion plants. Percentage and rate of seed germination vary between sites depending on soil moisture (Z. Martinkova and A. Honek, unpublished) and thus determine the quantity and time for which seed and seedlings are available to predators. In addition the abundance and voracity of seed and seedling predators also varies. The aim of this study was to (i) partition the mortality that occurs before the establishment of young plants into that attributable to inviable seed, seed predation and seedling predation, and quantify the relative importance of these mortality factors at different sites. We further (ii) determined the relative importance of particular invertebrate predator groups, carabids, isopods and molluscs, in determining the mortality of seed and seedlings. Using results obtained over a period of four years the (iii) temporal variation in the intensity of predation during the course of a season and in successive years was determined.

2. Material and methods

2.1. Study sites

The experiments were carried out in 2004–2007, in an 0.5 km^2 area surrounding the Crop Research Institute in Prague-Ruzyne (50°05′11.2″N, 14°18′09.3″E, altitude 320 m a.s.l.). The experimental area has a mild continental climate with an average (1971–2000) annual mean temperature of 8.5 °C (minimum January −1.2 °C, maximum July 18.1 °C) and total precipitation of 477 mm (minimum February 20 mm, maximum June 67 mm). Weather data for the experimental period are available from http://www.vurv.cz/meteo/. The experimental areas were two grassland sites c. 300 m apart, both with naturally established dandelion plants. Site (i) was a pear orchard consisting of standard trees planted in a 5 m × 7 m rectangular grid, which shade the ground for c. 70% of a day. The grass was cut twice per season. Site (ii) was an apple orchard of bush sized trees, planted in lines 3.5 m apart, with the area between trees under grassland kept short by cutting 4–5 times a year. The trees shaded the ground in this experimental area for <20% of a day. At both sites soil water capacity (percent water in saturated soil) was measured according to Dahiya et al. (1988) and soil type determined by a commercial laboratory. Soil water capacity, which indicates the availability of water for plants, was slightly higher (29.2%) for the loamy soil at site (i) than for the loamy–sandy soil (27.6%) at site (ii). Although microclimatic and soil differences between sites were rather small high levels of humidity persisted for longer in the surface soil layer at site (i) than site (ii). This was established while monitoring seedling mortality at 2–3 day intervals.

2.2. Predator activity in the field

The activity density of carabids (in 2005 and 2006) and isopods (2006) was monitored at both experimental sites using pitfall traps (Honek et al., 2003). At each site five traps were placed 1.5 m apart along a linear transect. Traps were emptied at 3 or 4 day intervals, seed predators determined, counted and immediately released. At each of the experimental sites the average catch (individuals d^{-1} trap^{-1}) of each predator species was calculated for each census period (n_i) and for the whole season (n_t). The differences in activity density of carabids and isopods were tested using two-way ANOVA with average catches at particular census periods n_i as the response variable and site ((i) vs. (ii)) nested within months (May–August) as factors.

Feeding activity and abundance of slugs was established using plasticine baits (Honek and Martinkova, 2007). The baits were put out in tin trays (2.5 cm in diameter, 0.5 cm deep) and consisted of white plasticine (modelling clay), which was protected from mice by 7 cm × 7 cm wire mesh cages (mesh size 1 cm × 1 cm), 6 cm high and pressed 3 cm into the soil and shielded from rain by a metal sheet. Feeding activity was measured by determining the amount of plasticine consumed by the slugs. Eight baits were exposed at each of the experimental sites within 5 m of the plots with seedlings. Plasticine consumption was measured at weekly intervals.

2.3. Seed predation in the field

Predation of seed before germination was established, by exposing seed in twin arenas. Each pair of arenas was established in a 10 cm × 20 cm gap, where the vegetation was removed, the soil loosened to a depth of 10 cm, roots and rhizomes removed, and the soil compacted. Both circular arenas of 33 cm^2 area were separated by a distance of 3 cm. One was protected from and the other exposed to predation. The "protected" area was surrounded