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Reintroduction of a rare arable weed: Competition effects on weed fitness and crop yield

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ABSTRACT

Arable weeds have severely declined due to intensification of farming during the past decades, and some of them are close to extinction in large parts of western and central Europe. Recent conservation strategies suggest reintroduction of rare arable weeds to suitable types of land use, for example organic fields. To test the feasibility of this conservation option we investigated the effects of spring wheat and a common weed (*Stellaria media*) on growth and reproduction of a rare weed (*Legousia speculum-veneris*) in a semi-open glasshouse experiment. Additionally, the impact of the weeds on crop yield was assessed. Aboveground biomass and seed production of *L. speculum-veneris* were significantly reduced under competition with the crop and the common arable weed. With increasing competition *L. speculum-veneris* allocated disproportionally more resources to seeds. Wheat yield was not affected by the arable weeds. We conclude that *L. speculum-veneris* is a subordinate species that is negatively affected by more competitive plants. In the presence of wheat the addition of other weeds does not further harm the species. Enhanced allocation to reproduction might be a specific strategy of the species to maintain populations under competition. Reduced crop densities would help reintroducing the species, while yield losses due to reintroduction of that rare arable weed are unlikely.

1. Introduction

Arable fields can harbour a high diversity of plants, insects, birds and other organisms, but intensification of agricultural management has led to drastic losses in abundance of most species (Sutcliffe and Kay, 2000; Storkey and Westbury, 2007). Thus, a new type of multi-functional land use is needed (Barberi et al., 2010), with biodiversity acting as insurance by increasing the resilience of ecosystems (Marshall and Moonen, 2002; Jackson et al., 2007). Within arable fields, weeds significantly contribute to the overall species diversity providing food and habitat for associated consumers (Marshall et al., 2003; Asteraki et al., 2004; Bengtsson et al., 2005). However, arable weed diversity is strongly declining and many species have become rare, mostly due to management changes (Sutcliffe and Kay, 2000; Storkey et al., 2012). To prevent further losses of arable weeds and their associated organisms, including generalist pollinators, conservation management should combine regular disturbance with reduced weed control and only moderate fertilization (Albrecht et al., 2009; Fried et al., 2009; Storkey et al., 2012). Such conditions are provided by organic farming which often hosts a higher biodiversity (Bengtsson et al., 2005; Roschewitz et al., 2005). Recovery of rare arable plants from organically operated fields, however, is unlikely since the corresponding seed banks were usually depleted by the preceding management (Marshall et al., 2003; Ring et al., 2006). Therefore, a transfer of populations to these fields will be necessary to maintain the rare species within their original regions, as investigated in on-going field experiments (Prestele et al., 2013).

Conservation of rare arable weeds has been done in fields with irregular cultivation but was criticized by Storkey and Westbury (2007), because these sites are often dominated by perennials suppressing rare weeds. It is therefore necessary to develop new conservation methods integrated into arable management. Since this approach involves the risk of establishment of pernicious weeds and yield losses, reintroduction of rare arable plants will only gain acceptance among farmers if losses due to weed competition are low (Storkey and Westbury, 2007). On the global scale, potential losses in arable crop yields by weeds amount to 34%; this significantly exceed damages caused by pests and pathogens (Oerke, 2006). However, such weed infestations are usually caused by a few highly competitive species, while many arable weeds have little negative impact on yield (Albrecht, 2003; Storkey, 2006),

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and the effects of reintroducing rare arable weeds on crop yield have received little attention so far. When growing under competition, weeds face shortages in light, water, nutrients and space. Plant populations exposed to resource limitation usually decrease their reproductive outcome (Snell and Burch, 1975), and enforce the growth of organs that are used for the uptake of limiting resources (Bazzaz et al., 2000), while seed production is reduced under competition (Weiner, 1988). However, there is little published information on the effects of interspecific competition on allocation to reproduction in rare arable weeds.

To study competition effects occurring under reintroduction of rare weed species to arable fields we selected *Legousia speculum-veneris*, a species included in associated field experiments (Prestele et al., 2013). The species occurs in autumn- and spring-sown cereals (Bischoff et al., 2006), and is quite sensitive to herbicide applications (Schneider et al., 1994). *L. speculum-veneris* is a prime example of annual arable weeds that are adapted to the regular disturbance of the agricultural setting, albeit threatened by intensified agriculture. We aimed at investigating the response of *L. speculum-veneris* to a competing common weed (*Stellaria media*) and a crop (spring wheat). Further, we tested competition effects on biomass allocation to seed production of the rare arable weed. Finally, we analysed potential yield losses of spring wheat due to reintroduction of the rare weed.

The following specific questions were investigated:

1. Does the competition with a common arable weed and spring wheat affect aboveground biomass and seed production of the rare arable weed *L. speculum-veneris*?
2. Is allocation to seed production of *L. speculum-veneris* reduced under competition?
3. Does *L. speculum-veneris* reduce the wheat grain yield?

2. Materials and methods

2.1. Species

L. speculum-veneris (L.) Chaix (European venus' looking glass, Campanulaceae) is a segetal, winter annual (Schneider et al., 1994); being a seed contaminant it is well adapted to historical types of agriculture found in Europe, mainly on calcareous soils (Kästner et al., 2001). The main range is in south-eastern Europe and Anatolia, with its north-eastern limit in Germany where the species is regarded as archaeophyte. In 11 of 17 European countries it is considered as rare or threatened (Storkey et al., 2012), mainly due to use of herbicides and increasing crop densities (Schneider et al., 1994). The growth of *L. speculum-veneris* is favoured by wide-spaced crop rows and late stubble cultivation, while more competitive plants suppress the species under high levels of fertilization (Schneider et al., 1994).

S. media (L.) Vill. (common chickweed, Caryophyllaceae) and *Triticum aestivum* cv. TRISO (spring wheat, Poaceae) were chosen to test the sensitivity of *L. speculum-veneris* to competition in a semi-open glasshouse experiment. *S. media* is common in cereal crops and can still cope with current agricultural practice with regular herbicide use and fertilization (Turkington et al., 1980; Moss et al., 2004), although it has declined in some regions (Fried et al., 2009). Our comparison of a common and uncommon weed in winter cereals is supported by Fried et al. (2012). Similarly to *L. speculum-veneris* it is a prostrate annual plant that produces numerous small seeds (Storkey, 2006). Particularly during the initial development of the crop *S. media* can become a problem by overgrowing young plants resulting in considerable yield losses (Mann and Barnes, 1950; Fryer and Makepeace, 1977).

Spring wheat, being a competitor of low to intermediate strength (O'Donovan et al., 2005), was used as experimental crop in our study. Spring wheat instead of a winter-sown crop was chosen due to logistic and practical constraints of the experimental set-up.

Seeds of *L. speculum-veneris* were provided by a local seed producer (J. Krimmer, Pulling) who propagates autochthonous seed material from populations of the Munich Gravel Plain; the germination rate was 98%. Seeds of *S. media* were supplied by Appels Wilde, Darmstadt, and those of spring wheat by Bayerische Landesanstalt für Landwirtschaft, Freising.

2.2. Experimental design

All three species were sown in trays of $40 \times 60 \times 8\,cm^3$ in a mixture of peat, quartz sand and clay powder (2:1:1), on 23 March 2012. Wheat was sown in rows with 14 cm spacing (seed distance 2.4 cm, depth 2–3 cm) with a density recommended for field experiments, i.e. 350 plants m^{-2} (Bundessortenamt, 2000). The weed species were sown at spots with intermediate strength of interaction between the crop rows. The trays were fertilized with 47 kg N ha^{-1}, 31 kg P ha^{-1} and 47 kg K ha^{-1} of which 60% were given at the development stage EC 37-42 of the crop and 40% at EC 55-59 (cf. Tottman and Broad, 1987). Agronomic amount of fertilization as recommended for spring wheat was reduced due to the high content of nitrogen present in the substrate at the beginning of the experiment. The trays were kept in a randomized order in a semi-open glasshouse, and watering was done when necessary. To homogenize light conditions within the glasshouse the tables were covered with a thin white fleece sheet. Losses due to herbivores, birds and diseases were negligible.

Eight different treatments were sown with five replicates each in a partial additive design: Monocultures of *L. speculum-veneris* (L) and spring wheat (W); three combinations of two species, i.e. *L. speculum-veneris* with spring wheat (LW), *S. media* with spring wheat (WS), and *L. speculum-veneris* with *S. media* (LS_{150}); and three treatments with increasing densities of the common weed species *S. media* (75, 150, 300 plants m^{-2}; LWS_{75}, LWS_{150}, LWS_{300}), while densities of *L. speculum-veneris* (150 plants m^{-2}) and spring wheat (300 plants m^{-2}) were kept constant. All species started germinating in early April, and excess seedlings were removed or missing seedlings replanted until late April to achieve the predefined densities. To record seed production of *L. speculum-veneris* without seed shedding, five randomly selected capsules were bagged per tray before seed maturity.

2.3. Harvest

Harvest took place when the wheat plants had reached maturity (EC 89; Tottman and Broad, 1987), i.e. on 31 July 2012, 18 weeks after sowing. First, all flowers and capsules of *L. speculum-veneris* were recorded in the central area of each tray ($42 \times 29\,cm^2$), and the bagged capsules of the species harvested; the seeds within the five capsules per tray were counted. Then the aboveground biomass of the central area was cut at ground level, and the plants were separated by species. The biomass could sometimes not be differentiated by individuals, because of secondary rooting of the highly entangled plants. Thus, the final number of plants and mortality rates could not be determined. The wheat ears were cut off and kept at room temperature to mimic agricultural storage conditions, while the harvested biomass was dried at 60 °C for 2 days before weighing. Grains were removed from the wheat ears to determine grain yield; wheat grain yield was adjusted to 14% residual moisture.