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Cropping systems alter weed seed banks in Pacific Northwest semi-arid wheat region

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Abstract

Arable land weed seed banks are dynamic and reflect cropping history, current management, and environment. Changes in crop rotation and tillage system can alter weed seed density and species composition. In the semi-arid region of the Pacific Northwest, USA, no-till spring cropping is being studied as an alternative to the traditional winter wheat (*Triticum aestivum* L.)/dust-mulch fallow (WWF) rotation. Weed seed bank density and species composition were assessed during the first 6 years of an ongoing cropping system study comparing WWF with three no-till rotations; spring wheat (*Triticum aestivum* L.)/chemical fallow (SWF), continuous spring wheat (CSW), and spring wheat/spring barley (*Hordeum vulgare* L.) (SWSB). Soil cores were collected at depths of 0–8, 8–15, and 15–23 cm in all plots during August each year following crop harvest. Weed seeds were washed from the soil, dried, and germinated in a glasshouse. Weed species most associated with the 0–8 cm depth was *Bromus tectorum* L., the major winter annual grass weed in WWF. Species most associated with 8–15 cm depth was *Chenopodium leptophyllum* (Moq.) Nut. ex S. Wats, a native warm season broadleaf weed that may have long seed bank persistence. An initial high density of *B. tectorum* was reduced with no-till spring crops and in WWF with intensive management strategies. In comparison an initial low weed seed density of *B. tectorum* remained low with no-till but increased in WWF with less management. Broadleaf weed species did not become management problems in no-till; however, seed bank weed shifts occurred where winter annual broadleaf species remained following reduction of high densities of *B. tectorum*. Summer annual broadleaf weed seeds such as *C. leptophyllum* and *Salsola tragus* L. were present but not at high densities. Summer annual grass weed seeds were not present and are not typical in this region. In this research, no-till spring cereal based systems did not result in an increase in total seed density at the soil surface. Results from this research show that no-till spring crop rotations are effective at controlling winter annual grass weeds as well as broadleaf weeds normally associated with WWF.

Keywords: Seed banks; Weed shifts; No-till cropping; Winter wheat; Dust-mulch fallow; Chemical fallow; Pacific Northwest

1. Introduction

Changes in weed seed bank density and species composition often occur when cropping strategies are altered (Cardina et al., 1991, 2002; Clements et al., 1996). Weed seed bank research has generally found that no-till cropping systems have greater weed density, diversity, or both, compared with tillage-based systems (Cardina and Sparrow, 1996; Menalled et al., 2001; Cardina et al., 2002; Tørresen and Skuterud, 2002; Davis et al., 2005). Lack of soil disturbance in no-till systems causes seeds to accumulate at the soil surface (Yenish et al., 1992; Hoffman et al., 1998) and selects for species that can germinate from shallow depths or from within the surface residue layer (Bàrberi and Lo Cascio, 2001). In contrast, tillage systems disperse seeds throughout the tillage profile (Ball, 1992; Yenish et al., 1992; Clements et al., 1996) and tend to favor species that require soil disturbance. Froud-Williams et al. (1983) found that annual broadleaf species were more prevalent on tilled plots, and that wind disseminated and grass species are more prevalent on untilled plots.

However, factors other than tillage or rotation regime can affect seed bank density and composition. Buhler et al.

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(1997) noted that species composition can vary due to local environmental conditions and farming practices that influence seed production, seed loss or mortality, and seed carry over to the next crop. Cardina et al. (2002) at a site in Ohio, USA, found the relative importance of *Chenopodium album* L., a small-seeded dicotyledonous (broadleaf) weed, higher in no-till plots compared with chisel plow or moldboard plow plots. At a second site with the same rotation and tillage practices, but with a different cropping history, they found *Setaria faberi* L., a warm season grass, had the highest relative importance in no-till and chisel plow, but not in moldboard plow. Buhler (1999) found increased seed densities from dry soil conditions that reduced herbicide efficacy, and from wet conditions that reduced effectiveness and timing of tillage treatments. Therefore, given the variable nature of arable land seed bank composition and diversity, it may be difficult to accurately predict changes in weed flora when cropping systems are changed.

In the semi-arid ($<300\,\mathrm{mm\,yr^{-1}}$) Columbia Plateau region of the Pacific Northwest, USA, no-till farming has the potential to reduce wind-borne soil erosion emanating from exposed soil during the dust-mulch fallow phase of the traditional winter wheat/fallow rotation. This reduction occurs primarily as crop residues are retained on the soil surface (Horning et al., 1998; Papendick, 1998; Thorne et al., 2003). Traditional winter wheat production relies on a year of dust-mulch fallow to retain soil moisture near the soil surface so that crop emergence can occur soon after planting in late summer or early fall (Schillinger and Papendick, 1997). Without the stored soil moisture, wheat seeds do not germinate until after late-fall rains, plants are small going through the winter, and yields are reduced in the following harvest (Donaldson et al., 2001).

No-till spring crop production would eliminate the need for the dust-mulch, thus reducing much of the wind-borne soil erosion; however, changes in cropping systems would also bring about changes in weed management. Weeds problematic for winter wheat in this region are *Bromus tectorum* L. and *Salsola tragus* L. *B. tectorum* is a winter annual grass that competes vigorously with winter wheat and can cause substantial wheat yield loss, especially when it germinates within 21 d of wheat emergence (Rydrych, 1974; Blackshaw, 1993). Occurrence of *B. tectorum* should decline in no-till spring crops since plants established through the fall and winter can be controlled with a herbicide prior to seeding. Furthermore, most *B. tectorum* seeds do not persist more than a year following dispersal in August (Wicks, 1997). *S. tragus* is a summer annual dicotyledonous (broadleaf) species that is most problematic in spring crops but can also be a problem for winter wheat (Young, 1988; Schillinger and Young, 2000).

To date, there have been no weed seed bank studies in the semi-arid winter wheat region of the Pacific Northwest. We hypothesized that broadleaf species already in the seed bank are the most likely candidates to become immediate weed problems in no-till spring crops; however, seed banks associated with the current winter wheat system may not contain species best adapted to no-till spring cropping systems. Species common to the mesic Palouse region of eastern Washington and northern Idaho, such as *Avena fatua* L. or *Chenopodium album* L., or warm-season species associated with irrigated cropland of the Columbia Basin, such as *Setaria* spp. or *Kochia scoparia* (L.) Scrad., may become prevalent in no-till spring crop systems in the semi-arid region.

The objectives of this study were to describe the composition of weed seed banks associated with traditional winter wheat production and no-till cropping systems in the semi-arid region of the Pacific Northwest, USA. Specifically, we evaluated seed bank density and composition in reduced-tillage WWF and three no-till crop rotations over 6 years. The overall intent is to develop knowledge of seed bank dynamics in this region so that weed problems associated with no-till cropping can be understood and managed proactively. Furthermore, knowledge of seed bank composition and dynamics may also aid weed management in current winter wheat production.

2. Materials and methods

The weed seed bank was assessed as a component of an ongoing large-scale cropping system study analyzing the potential of no-till cereal rotations for the semi-arid winter wheat production region of the Pacific Northwest, USA. The study was established in the summer of 1995 on a cooperator's non-irrigated farm located in central Adams County, Washington State, USA. Long-term plots were established in two adjacent, similar and relatively level field sites. Soil in both field sites is a Ritzville silt loam (coarse silty, mixed, mesic, Calcidic Haploxeroll) with a texture of 30% sand, 62% silt, and 8% clay. Organic matter in the top 30 cm averaged 2.0% and 1.9% in east and west sites, respectively. In the summer of 1995, the east site was in standing wheat stubble and the west site was in dust mulch fallow. Four crop rotations were established in each site and were (1) traditional winter wheat (*Triticum aestivum* L.)/dust-mulch fallow (WWF), (2) no-till spring wheat (*T. aestivum* L.)/chemical fallow (SWF), (3) no-till continuous hard-red spring wheat (CSW), and (4) no-till hard-red spring wheat/spring barley (*Hordeum vulgare* L.) (SWSB). Sixteen 9×152 m plots were established in each field site in a randomized complete block design with each rotation replicated four times per field site. By using the two adjacent field sites, the no-till rotations could be established in both phases of WWF simultaneously. In the initial crop year (1995–1996), east WWF and SWF rotations were in the fallow phase and SWSB was in the spring barley phase. Concurrently, west WWF and SWF rotations were in the crop phase and SWSB was in the spring wheat phase. The CSW rotation was in spring wheat in both field sites each year of the study.