Towards a No-Till No-Spray Future? Introduction to a Symposium on Nonchemical Weed Management for Reduced-Tillage Cropping Systems

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Symposium

Towards a No-Till No-Spray Future? Introduction to a Symposium on Nonchemical Weed Management for Reduced-Tillage Cropping Systems

Daniel C. Brainard, Erin Haramoto, Martin M. Williams II, and Steven Mirsky*

Reduced-tillage systems including no-tillage and strip-tillage have well-known benefits for conserving and improving soils, protecting vulnerable crops from extreme weather events, and reducing labor and fuel costs associated with full-width inversion tillage (Franzluebbers 2002, 2005; Parsch et al. 2001; Pesant et al. 1987; Spargo et al. 2008). Despite these benefits, reduced-tillage has not been widely adopted in many cropping systems due in part to the increased difficulty of managing weeds when tillage is not used. Not surprisingly, adoption of reduced-tillage has occurred primarily in crops for which low-cost, effective herbicides are available, including glyphosate-resistant soybean [*Glycine max* (L.) Merr.], corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), and sugarbeets (*Beta vulgaris* L.) (Horowitz et al. 2010; Tarkalson et al. 2012). Increased use of a narrow range of herbicides in these cropping systems has exacerbated problems of herbicide resistance (Duke and Powles 2009; Heap 2012). Conversely, adoption of reduced-tillage has been limited in crops where effective herbicides are not available (e.g. in "minor crops" like vegetables) or prohibited (e.g. in organic production systems). Research aimed at identifying nonchemical approaches to managing weeds in reduced-tillage production systems has the potential to increase adoption of reduced-tillage while minimizing herbicide use and selection pressure for herbicide resistance in production systems currently using reduced tillage (Figure 1).

With these issues in mind, the WSSA Sustainable Agriculture Committee organized a symposium entitled *"Towards a no-till no-spray future? Non-chemical weed management for reduced-tillage cropping systems"* held at the 2012 WSSA annual meeting. Although we recognized that complete elimination of both tillage and herbicides is unrealistic in most cropping systems, our goal was to take stock of progress towards reduction of both herbicides and tillage in a diversity of cropping systems and regions. Specific objectives for the symposium were to: (1) share current innovative research on reduced-tillage, nonchemical weed management, (2) build new worldwide collaborations, (3) develop future research priorities, and (4) disseminate information to stakeholders and policy makers through published review articles. Recognizing that weed management practices in reduced-tillage cropping systems are region-specific, we invited speakers representing different agro-ecosystems, including various regions within the U.S., as well as international perspectives from Canada, Europe, and India.

Research efforts among symposium participants can be roughly categorized according to the unique starting point and trajectory of the cropping systems in which they work. Figure 1 shows the range of noninversion tillage systems and levels of herbicide intensity discussed in the symposium. Symposium papers review research efforts primarily aimed at either: (1) reducing tillage in tillage-intensive organic systems (e.g., Légère et al. 2013; Mirsky et al. 2013), (2) reducing herbicides in herbicide-intensive no-till systems (e.g., Kumar et al. 2013), or (3) discussing opportunities to reduce both herbicide and tillage inputs in conventional production systems (e.g. Brainard et al. 2013; Melander et al. 2013).

Although the cropping systems and climates represented in the symposium are very diverse, several common themes and research needs emerged from the symposium. Currently, across all regions and cropping systems, consistent weed control in continuous no-tillage crop production, without chemical weed control, is not considered possible. Tillage plays an important role in preparing a fine seedbed for establishment of certain crops (Brainard et al. 2013; Price and Norsworthy 2013), as well as for incorporation of fertilizers and other soil amendments necessary for crop growth (Légère et al. 2013). Moreover, in all symposium papers, some tillage was described as critical for preventing buildup of problematic weeds—particularly perennials—when herbicides are not used. For example, Mirsky et al. (2013) and Légère et al. (2013) advocate "rotational tillage" systems for organic grain production in which primary tillage is used periodically to disrupt potentially problematic weeds. In vegetable cropping systems, strip-tillage systems combined with purposeful rotation of strip location is discussed as one option for suppressing weeds while maintaining some of the benefits of no-tillage (Brainard et al. 2013).

Although complete elimination of tillage and herbicides is viewed as unrealistic, substantial reductions in both inputs are described as attainable with greater application of ecological knowledge to target weak points in the life-cycles of specific problematic species**.** Specific weeds with life history strategies well-adapted to reduced-tillage systems include perennials, early emerging spring broadleaf weeds like common ragweed (*Ambrosia artemisiifolia* L.) (Mirsky et al. 2013), and annual grasses including large crabgrass (*Digitaria sanguinalis* L.) (Brainard et al. 2013), blackgrass (*Alopecurus myosuroides* Huds.) (Melander et al. 2013), barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], and littleseed canarygrass (*Phalaris*

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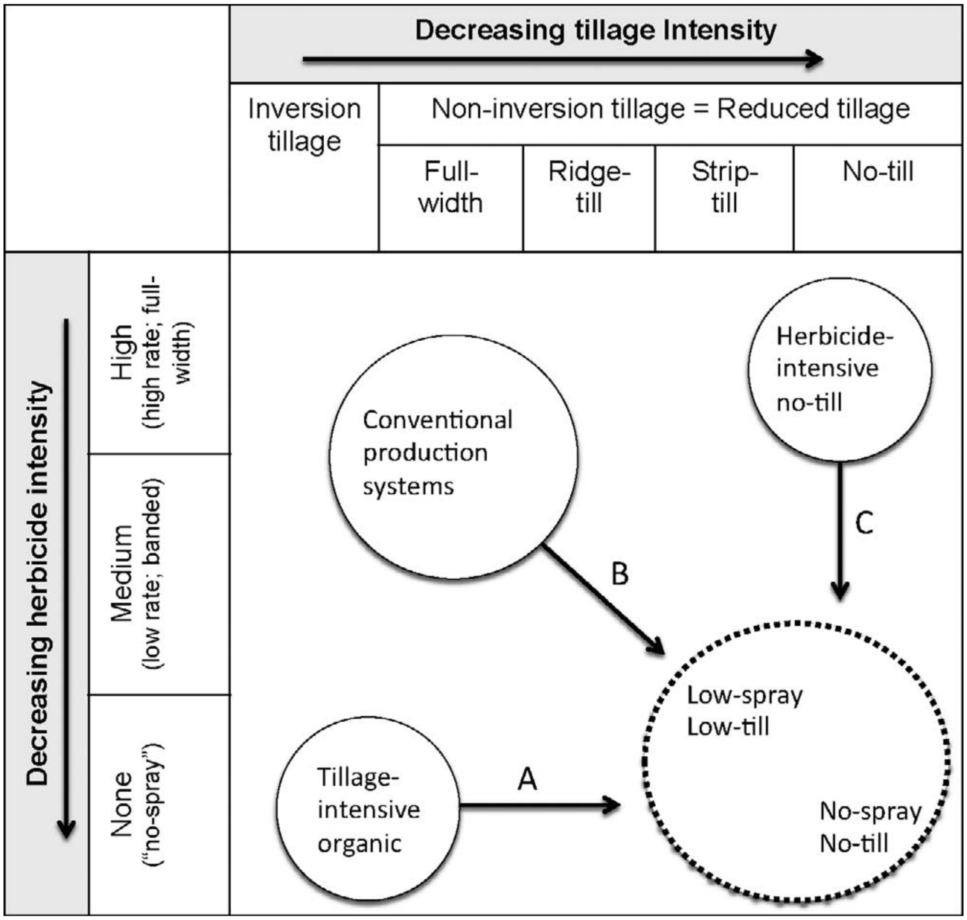

Figure 1. Diagrammatic representation of tillage–herbicide combinations in contrasting production systems, and potential trajectories associated with research findings from symposium papers.

minor Retz.) (Kumar et al. 2013). A more mechanistic understanding of how integration of multiple nonchemical weed management tactics impact these problematic species will be helpful for the long-term viability of low-input and organic reduced tillage crop production. Specific factors driving the performance of these problematic weeds that require more attention include allelopathic phytotoxicity (Price and Norsworthy 2013), seed predation and microbial decay (Brainard et al. 2013), physical weed control from cover crop and crop residues (Kumar et al. 2013; Mirsky et al. 2013), high residue cultivation equipment (Légère et al. 2013; Melander et al. 2013; Mirsky et al. 2013), and interactions with N availability from fertilizer amendments (Brainard et al. 2013; Mirsky et al. 2013).

In most cases, greater exploitation of cover crop and crop residue mulches are discussed as a key strategy for suppressing weeds, particularly in warm climates where sufficient biomass may be generated to provide season-long weed suppression. For example, recent research from U.S. aimed at maximizing cover crop biomass (Mirsky et al. 2013) and exploiting allelopathic potential (Price and Norsworthy 2013) of cover crops is described as critical for reducing tillage without increasing dependence on herbicides. Similarly, in India, Kumar et al. (2013) describe retention of rice residue as a key strategy for nonchemical suppression of weeds in a subsequent no-tillage wheat crop. Brainard et al. (2013) describe the role of cover crops in strip-tillage vegetable cropping systems, and the potential for improving system performance through segregated cover crop strips that match cover crop functions to the unique needs of in-row and between-row zones. Although cover crops were seen as an important tool for weed suppression in all systems, participants emphasized that cover-cropping strategies alone were insufficient to consistently provide adequate weed suppression in reduced-tillage systems, particularly in cool climates where the potential for sufficient biomass production is limited due to a short growing season (Légère et al. 2013).

Another common theme among symposium papers was the importance of integrating multiple tactics to suppress weeds, and identifying synergies between practices to facilitate more complete weed suppression. For example, Kumar et al. (2013) present data demonstrating that combinations of rice (*Oryza sativa* L.) residue and early wheat (*Triticum aestivum* L.) planting dates substantially reduced emergence of littleseed canarygrass. They also highlight breeding efforts aimed at improving weed-suppressive traits in both rice and wheat. Similarly, Mirsky et al. (2013) provide examples of synergistic combinations of cover crop residue with soybean planting density and high residue cultivation to improve weed suppression. Participants from more northern climates—where opportunities for cover crops are more limited—emphasized integration of multiple tactics including diversification of crop rotations, increased planting densities, planting of competitive cultivars, appropriate fertilizer placement, and advances in direct mechanical weed control methods based on rotating weeding devices such as rotary hoes (Légère et al. 2013; Melander et al. 2013).

Several symposium papers emphasized that advances in nonchemical weed management in reduced-tillage systems depended on continued innovations in equipment design to facilitate weed suppression without crop suppression. For example, in India, Kumar et al. (2013) reported that the development of affordable rotary disc drills and turbo-seeders capable of planting wheat through 8 to 10 tons ha^{-1} rice residue are critical to the success of rice mulch systems for weed suppression. Likewise, development of the roller-crimper for nonchemical termination of cover crops, and advances in equipment capable of planting soybeans through heavy rye residue were critical for advances in reduced till organic soybean in the eastern U.S. (Mirsky et al. 2013). For strip-tilled vegetable production systems, advances in GPS-tractor guidance systems to facilitate crop planting in tilled strips, as well as innovations in flame weeding and cultivation equipment targeted to the unique conditions of in-row and between-row zones are facilitating advances in nonherbicide based reduced-tillage (Brainard et al. 2013).

Overall, the symposium papers illustrate that the feasibility and desirability of moving cropping systems towards reduction or complete elimination of both tillage and herbicide use depends critically on details of the agro-ecosystem. From a short-term economic perspective, the appropriate tillage–herbicide balance will depend on several site- and crop-specific factors including the availability of effective low-cost herbicides, the level of weed infestation, the crop's competitive ability, and the importance of nonweed related functions of tillage including disease and insect pest management, soil fertility, and crop establishment. Research aimed at reducing tillage and herbicide inputs –must also balance economic and environmental tradeoffs. Increases in the cost of fuel and the incidence of extreme weather events suggest that reductions in tillage are becoming increasingly important to the sustainability of cropping systems. Weed scientists will play a critical role in ensuring that the adoption of reduced-tillage practices is done without exacerbating costs associated with over-use of herbicides. We hope these symposium papers stimulate new collaborations and help direct research priorities for improving agricultural sustainability through identification of efficient "win–win" approaches to reducing both tillage and herbicide inputs while retaining crop yields and profitability in a wide range of agro-ecosystems.

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