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Weed Community and Species Response to Crop Rotation, Tillage, and Nitrogen Fertility[1]

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Abstract: Producers in the northern Great Plains are exploring alternative crop rotations, with the goal of replacing spring wheat-fallow. We characterized the weed associations occurring with tillage system and nitrogen level in two rotations, spring wheat (SW)-fallow (F) and SW-winter wheat (WW)-sunflower (SUN). Weed density was measured 10 yr after initiation of the study. With both rotations, weed community density was highest with no-till. For SW-F, green foxtail, yellow foxtail, and fairy candelabra comprised 99% of the weed community, whereas 13 species were observed in SW-WW-SUN. Fairy candelabra, a rangeland species, was observed only in the no-till system of SW-F. In SW-WW-SUN, no-till favored kochia, Russian thistle, and foxtails, whereas common lambsquarters and annual sowthistle were more common in tilled systems. Nitrogen fertilizer increased crop competitiveness in SW-WW-SUN with no-till, subsequently reducing weed density. Cultural strategies that disrupt weed associations will aid producers in managing weeds.
Nomenclature: Annual sowthistle, *Sonchus oleraceus* L. #[3] SONOL; common lambsquarters, *Chenopodium album* L. # CHEAL; fairy candelabra, *Androsace occidentalis* Lunell; green foxtail, *Setaria viridis* (L.) Beauv. # SETVI; kochia, *Kochia scoparia* (L.) Schrad. # KCHSC; Russian thistle, *Salsola iberica* Sennen & Pau # SASKR; yellow foxtail, *Setaria glauca* (L.) Beauv. # SETLU; wheat, *Triticum aestivum* L.; sunflower, *Helianthus annuus* L.
Additional index words: Cultural strategies, weed association, AMARE, AMBEL, AVEFA, CHEAL, EPHHT, KCHSC, POLCO, SASKR, SETLU, SETVI, SINAR, SONOL, TAROF.
Abbreviations: CT, conventional-till; F, fallow; N, nitrogen; NT, no-till; RT, reduced-till; SUN, sunflower; SW, spring wheat; WW, winter wheat.

INTRODUCTION

The prevalent crop rotation in the drier areas of the northern Great Plains is spring wheat-fallow (Black 1983). Producers rely on fallow to reduce yield variability; however, fallow is detrimental to long-term health and quality of soil (Doran et al. 1996; Peterson et al. 1993). To counter this degradation of soil quality, producers would like to crop more frequently and reduce fallow. More intensive crop rotations are possible with no-till systems, which maintain crop residue on the soil surface, increase precipitation storage (Tanaka and Anderson 1997), and improve water use efficiency of crops (Peterson et al. 1996). Land productivity is increased 50% by no-till continuous cropping compared to spring wheat-fallow (Black et al. 1981).

Producers in the northern Great Plains believe that weeds will be more difficult to control with intensive cropping. This belief is based on previous experiences, as in wet years, producers attempted continuous wheat, but serious weed problems developed. Growing spring wheat continuously resulted in severe infestations of foxtail species (Hume 1982) or wild oat (*Avena fatua* L.) (Donald and Nalewaja 1990), whereas continuous winter wheat led to high densities of downy brome (*Bromus tectorum* L.) (Moyer et al. 1994). Weed densities increased because the weeds and crops had similar life cycles (Froud-Williams 1988).

Density of selected weeds will increase if a cultural practice is imposed continuously on a weed community, a response termed "weed association" (Aldrich 1984). For example, no-till favors kochia and Russian thistle (Koskinen and McWhorter 1986; Miller and Nalewaja 1985), because weed seeds are not buried below their emergence capabilities (Aldrich 1984). Another association is nitrogen (N) fertilizer increasing nitrophilous

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[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

species such as common lambsquarters (Haas and Streibig 1982). Weeds also have been associated with other production factors such as soil type (Dale et al. 1992), herbicide choice (Haas and Streibig 1982), previous crop (Dale et al. 1992), nutrient management (Hume 1982), and fallow (Derksen et al. 1994).

Knowledge of weed associations with cultural practices can guide management strategies to minimize weed densities. However, production systems are composed of several cultural practices, such as tillage, herbicide choice, and nutrient management, which can result in interactions that alter weed associations with a single cultural practice. For example, no-till systems maintain crop residue on the soil surface. Residue level affects weed seedling emergence (Crutchfield et al. 1985), and this effect varies among weed species (Teasdale et al. 1991). Interactions among multiple cultural practices make it difficult to generalize weed associations across different cropping systems (Thomas and Frick 1993).

To prevent weed problems as found with continuous wheat, producers can diversify crops in more intensive rotations. Rotating crops with different life cycles aids weed management because this tactic disrupts weed associations (Blackshaw et al. 1994; Thomas and Dale 1991). Sunflower, winter wheat, and spring wheat are grown in this region; thus, producers can vary crop sequence in their rotations to minimize dominance of specific weeds.

With the goal of developing cropping systems without fallow, Black and Bauer (1990) established a long-term rotation study in 1984 comparing spring wheat-fallow to spring wheat-winter wheat-sunflower. In 1994, after 10 yr of cropping, we characterized weed associations occurring with rotation, tillage system, and nitrogen level. Our goal was to identify ecological trends in weed community dynamics as affected by multiple cultural practices and to suggest management strategies to aid producers in designing cropping systems for the northern Great Plains.

MATERIALS AND METHODS

The study was established on a Temvik-Wilton silt loam (Pachic Haploboroll) near Mandan, ND, where yearly precipitation averages 410 mm. Two rotations were compared: spring wheat-fallow (SW-F) and spring wheat-winter wheat-sunflower (SW-WW-SUN). Plot size was 135 by 75 m, and cultural practices used for crop management are listed in Table 1.

Each rotation plot was split by three tillage systems. Management of tillage systems was based on target quantities of crop residue at planting: conventional-tillage (CT), 30% or less crop residue on the soil surface; reduced-tillage (RT), 30 to 60% residue cover; and no-tillage (NT), 60% or greater crop residue cover. The CT and RT systems did not have a fixed pattern for tillage or herbicide applications during noncrop periods, but rather a combination of operations as needed for weed control and for obtaining target residue levels. Plots were either tilled with a sweep plow or sprayed with glyphosate (*N*-(phosphonomethyl)glycine) at 0.6 kg ai/ha. The CT plots were tilled one to four times a year, whereas RT was tilled at least once every year. The NT system relied on glyphosate for noncrop weed control.

Table 1. Cultural practices for establishing spring wheat, winter wheat, and sunflower.

Cultural data	Spring wheat	Winter wheat	Sunflower
Cultivar	'Butte 86'	'Roughrider'	'AgroPro 2057'
Planting date range	May 1 to 10	Sep. 20 to 30	May 20 to 30
Seeding rate (seeds/ha)	2.5 million	2.5 million	40,000
Row spacing (cm)	18	20	91
Harvest date range	Aug. 1 to 20	July 15 to 30	Oct. 1 to 20

Nitrogen as ammonium nitrate was applied broadcast before planting at three levels for each rotation: 0, 22, and 44 kg N/ha for the SW-F rotation, and 34, 64, and 100 kg N/ha for the SW-WW-SUN rotation. The N level, based on projected N needs for each rotation, was less for SW-F because fallow supplies soil N. The N treatments split each tillage system subplot.

The experimental design was a split-split plot in a completely randomized block design with three replications. All phases of each factor, rotation, tillage, and N fertility, were present in each year.

For in-crop weed management, spring wheat was treated with fenoxaprop plus 2,4-D [(2,4-dichlorophenoxy)acetic acid] plus MCPA [(4-chloro-2-methylphenoxy)acetic acid] plus bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) at 0.1 + 0.1 + 0.4 + 0.5 kg/ha, whereas winter wheat was treated with 2,4-D and bromoxynil at 0.2 + 0.5 kg/ha. For sunflower in the tilled systems, granular ethalfluralin [*N*-ethyl-*N*-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine] was applied at 1.3 kg/ha in April. For CT, ethalfluralin was incorporated with one tillage pass of a sweep plow followed by one pass with a tandem-disk harrow, whereas incorporation in RT occurred with two tillage passes of the sweep plow. For NT sunflower, oryzalin[4] [4-(dipropylamino)-3,5-dinitrobenzenesulfonamide] was ap-

[4] Oryzalin is currently not labeled for sunflower, but was used for experimental purposes.

Table 2. Species composition of weed communities in two crop rotations, Mandan, ND.

Bayer code	Species name	Common name	Crop rotation SW-F	Crop rotation SW-WW-SUN
AMARE	*Amaranthus retroflexus* L.	redroot pigweed	X	X
AMBEL	*Ambrosia artemisiifolia* L.	common ragweed	—	X
—	*Androsace occidentalis* Lunell	fairy candelabra	X	—
AVEFA	*Avena fatua* L.	wild oat	—	X
CHEAL	*Chenopodium album* L.	common lambsquarters	X	X
EPHHT	*Euphorbia humistrata* Engelm. ex Gray	prostrate spurge	X	X
KCHSC	*Kochia scoparia* (L.) Schrad.	kochia	X	X
POLCO	*Polygonum convolvulus* L.	wild buckwheat	—	X
SASKR	*Salsola iberica* Sennen & Pau	Russian thistle	—	X
SETLU	*Setaria glauca* (L.) Beauv.	yellow foxtail	X	X
SETVI	*Setaria viridis* (L.) Beauv.	green foxtail	X	X
SINAR	*Brassica kaber* (DC.) L. C. Wheeler	wild mustard	—	X
SONOL	*Sonchus oleraceus* L.	annual sowthistle	—	X
TAROF	*Taraxacum officinale* Weber in Wiggers	dandelion	—	X

[a] X indicates that species was present in rotation; — indicates species was not observed.

plied preemergence at 1.3 kg/ha. Glyphosate controlled weeds present at planting for all crops.

In 1994, we assessed weed flora and seedbank composition in the spring wheat plots of both rotations. For weed flora, eight 0.25-m^2 quadrats were randomly arranged in a W pattern across each plot, with quadrats 10 m apart. Weed seedlings were counted and identified in early June, before in-crop herbicides were applied, and in August, before harvest. For seedbank composition, 20 soil cores, 3 cm in diam and 12 cm deep, were collected and composited before spring wheat planting. Sampling sites were arranged in a W pattern across the plot, with sampling sites 6 m apart. Procedures for processing soil samples and identifying weed seeds were reported previously by Schweizer and Zimdahl (1984).

Treatment effects were similar between weed flora and seedbank data, with two exceptions. Therefore, only weed flora data are presented, with the seedbank exceptions discussed in the text. Weed species observed are listed in Table 2. Green and yellow foxtail plants were not counted separately because of difficulty in distinguishing between seedlings of these species. Weed flora densities are the sum of both assessment dates and were analyzed by ANOVA. Tillage by N fertility interactions were analyzed as a split-split plot design, and except for foxtails, species were analyzed separately within rotation because different weed species were present in each rotation. Treatment means were separated by either Fisher's Protected LSD test or Duncan's new multiple range test at the 0.05 level of probability.

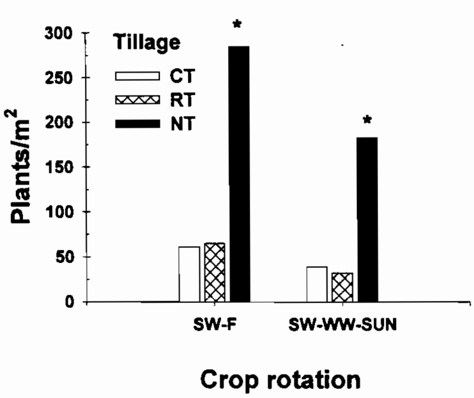

Figure 1. Weed community density in SW-F and SW-WW-SUN, as affected by tillage system. Data were averaged across N treatments. An asterisk indicates that the NT mean differs from the CT and RT means within each rotation.

RESULTS AND DISCUSSION

Weed Community Response to Rotation and Tillage. *Weed community density.* Weed density was highest in NT with both rotations. For SW-F, weed density increased from 62 plants/m^2 in CT to 292 plants/m^2 for the NT (Figure 1). A similar trend occurred with SW-WW-SUN. With both rotations, the magnitude of change was approximately fivefold when comparing weed densities in NT with CT. With most cropping systems, weed densities tend to increase with NT (Blackshaw et al. 1994; Froud-Williams 1988).

Weed community diversity. Integrating crops with different life cycles in a rotation leads to diversity of the weed community and minimizes the predominance of any one species (Froud-Williams 1988; Haas and Streibig 1982). In our study, foxtails and fairy candelabra comprised 99% of the weed community in SW-F. In contrast, the weed community in SW-WW-SUN was more diverse, with eight species—kochia, yellow and green foxtails,

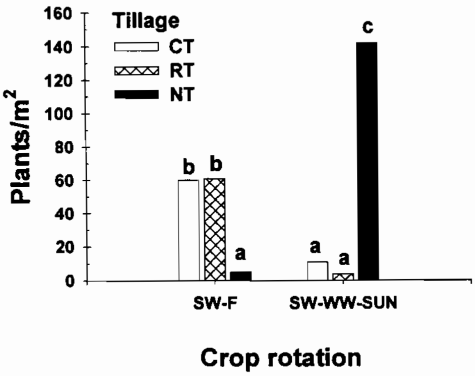

Figure 2. Foxtail response to tillage system in SW-F and SW-WW-SUN. Data were averaged across N treatments. Bars with identical letters do not differ as determined by Duncan's new multiple range test.

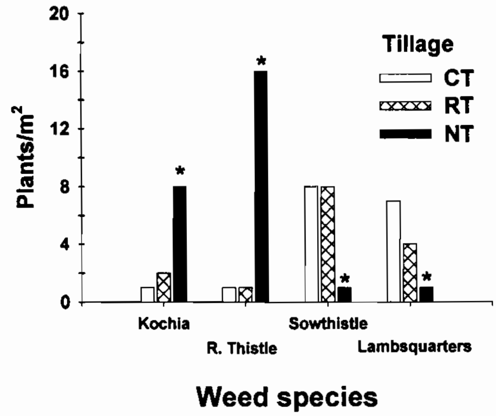

Figure 3. Response of four broadleaf weeds to tillage system in SW-WW-SUN. Data were averaged across N treatments. An asterisk indicates that the NT mean differs from the CT and RT means within each species, except for common lambsquarters, where the NT mean differed only from the CT mean.

Russian thistle, wild buckwheat, annual sowthistle, redroot pigweed, and common lambsquarters—comprising 91% of the seedlings observed.

Fairy Candelabra Response to Tillage and N in SW-F. Fairy candelabra, a rangeland species, was present in NT, with a density of 278 plants/m², averaged over N treatments. In contrast, fairy candelabra seedlings were not observed in either CT or RT of this rotation, even though seeds were observed in the seedbank samples (data not shown). This suggests that tillage prevents the establishment and invasion of fairy candelabra in cropland. Surprisingly, fairy candelabra was not observed in either the weed flora or seedbank of the NT system with SW-WW-SUN, which we attribute to the diversity of control opportunities with three crops.

Fairy candelabra responded dramatically to N fertility, as applying 22 kg N/ha to NT spring wheat increased the density of fairy candelabra 230% compared with the 0 N level (data not shown). Spring wheat yield was not increased by N fertilizer in any treatment (Black and Tanaka 1997), which suggests that N was not needed for spring wheat production in the rotation. The excess N stimulated fairy candelabra growth and seed production.

Response of Foxtails to Tillage in Both Rotations. Foxtails responded differently to tillage in the two rotations. With SW-F, foxtail density was less in NT than in either CT or RT, which contrasts with trends in SW-WW-SUN, where foxtail density was at least 10 times greater in NT than in CT or RT (Figure 2). We attribute the low density of foxtail with NT in SW-F to fairy candelabra competition. Fairy candelabra emerges earlier than the foxtails; thus, its early establishment may have dried out the soil and reduced foxtail seedling emergence or survival.

Increased foxtail density with NT in SW-WW-SUN reflects the trend of small-seeded species proliferating in no-till systems (Koskinen and McWhorter 1986; Moyer et al. 1994). Producers may be able to manage foxtails in diversified crop rotations by rotating tillage systems, as foxtail densities were reduced considerably by the tilled systems in SW-WW-SUN (Figure 2).

Broadleaf Species Response to Tillage in SW-WW-SUN. Broadleaf weed response to tillage in this rotation was species-specific. Kochia and Russian thistle densities increased in NT, whereas densities of annual sowthistle and common lambsquarters increased in tillage treatments (Figure 3). The seedbank data for wild mustard contrasted with the weed flora data. Wild mustard seed numbers were several-fold greater in CT or RT soil samples than in NT soil samples (data not shown), yet few seedlings emerged in any tillage system. The environmental conditions in 1994 may not have been favorable for wild mustard seedling emergence.

Our results agree with previous research that showed common lambsquarters densities increasing in tilled systems (Blackshaw et al. 1994; Teasdale et al. 1991), and NT favoring proliferation of Russian thistle (Blackshaw et al. 1994) and kochia (Anderson and Nielsen 1996). Tillage did not affect seedling densities of other species observed in the study (data not shown).

Weed Species Response to N Fertilizer in the NT System of SW-WW-SUN. Applying N fertilizer decreased the density of the most common species in this rotation—foxtails, Russian thistle, and kochia (Figure 4). Weed community density also decreased at higher N levels in NT, as 142 weeds/m² were present in spring wheat

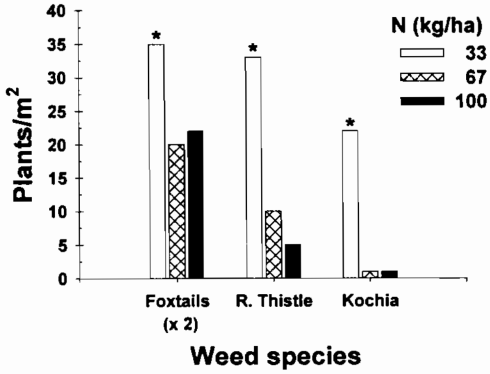

Figure 4. Response of three species to N fertilizer in the NT system of SW-WW-SUN. An asterisk indicates that the 33 kg N/ha mean differs from the other N treatment means within each species. The × 2 means that the foxtail density should be doubled for correct density.

when N was applied at 33 kg/ha, but only 58 weeds/m^2 were present when N was applied at 100 kg/ha (data not shown).

Higher N levels increased yield of all crops in this rotation (Black and Tanaka 1997), indicating that N was needed to maximize crop yields. Adding N also increased crop competitiveness with weeds, subsequently reducing weed growth and seed production.

Management Implications. This study demonstrates the ecological tendency of weeds to associate with cultural practices, such as fairy candelabra proliferating in the NT system with SW-F and the weed community density increasing in NT with SW-WW-SUN. Producers can counter this trend of increased weed density with NT by either rotating tillage systems (Figure 2), changing the crop sequence (Blackshaw et al. 1994), or alternating different rotations on the same field. These strategies will disrupt weed associations with NT, subsequently reducing weed densities in future crops.

Another potential weed management strategy is N placement (Di Tomaso 1995). For example, green foxtail responds more to N than spring wheat (Peterson and Nalewaja 1992). However, strategic N placement can improve crop competitiveness and subsequently inhibit green foxtail growth (O'Donovan et al. 1997). Applying N fertilizer early in the growing season to winter wheat reduces green foxtail densities because of greater crop canopy development (Black and Siddoway 1977). A second practice, banding N fertilizer, also reduces green foxtail densities because of improved crop competitiveness (O'Donovan et al. 1997). In contrast, if producers are not careful with N management, weed problems can increase because excessive N fertilizer can favor weed growth and higher weed densities in future crops, as shown with fairy candelabra in SW-F.

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