Weed Management Strategies for Conservation-Tillage Sunflower (*Helianthus annuus*)[1]

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Abstract. We compared applications of trifluralin or ethalfluralin granules incorporated with a sweep plow or pendimethalin (ec) applied without incorporation to incorporating trifluralin (ec) by tandem-disk harrowing for sunflower production. The study was established in winter wheat stubble at three sites in the northern and central Great Plains. Crop residues on the soil surface following sunflower planting was greater than 30% (level required to protect soil from erosion) with all conservation-tillage strategies, but not with disk incorporation. Weed control and sunflower seed yield with conservation-tillage strategies were similar to the disk incorporation practice, demonstrating that producers can use these strategies for sunflower production and to protect soil from erosion. **Nomenclature:** Ethalfluralin, *N*-ethyl-*N*-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluromethyl)benzenamine; pendimethalin, *N*-(l-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; trifluralin, 2,6-dinitro-*N,N*-dipropyl-4-(trifluoromethyl)benzenamine; sunflower, *Helianthus annuus* L.; winter wheat, *Triticum aestivum* L.

Additional index words: Duration of weed control, erosion control, residue cover compliance, ethalfluralin, pendimethalin, trifluralin.

INTRODUCTION

Winter wheat-fallow is the most common rotation in the semiarid Great Plains, as precipitation stored during fallow stabilizes wheat production (11). However, replacing tillage operations with herbicides for weed control has increased precipitation storage (17, 20) to the extent that more intensive cropping is now feasible. Producers have expanded the wheat-fallow rotation to include corn (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench], safflower (*Carthamus tinctorius* L.), or proso millet (*Panicum miliaceum* L.) (3, 22).

Sunflower, grown extensively in North Dakota, South Dakota, and Minnesota (4), is also well-adapted to the central Great Plains when planted after winter wheat (7, 12, 14). One advantage with growing sunflower is that it is classified as a non-compliance crop in the government farm program; thus, producers can grow sunflower without affecting their wheat base.

One obstacle to sunflower production in semiarid regions is maintaining sufficient crop residues on the soil surface throughout the crop rotation to prevent soil erosion. The prevalent herbicides used for sunflower currently grown in Kansas and Colorado are trifluralin (ec) or pendimethalin (ec). Optimum weed control with these dinitroanilines occur when tandem-disk harrowing is used to incorporate the herbicides into soil (10, 18). Presently, producers in this region incorporate these herbicides with two passes of the tandem-disk harrow[3]. However, disking buries surface residue, leaving fields without the 30% residue cover on the soil surface needed for erosion control (19) and farm program compliance.

Incorporation of herbicides with less intensive tillage has been successful in eastern North Dakota. For example, trifluralin granules (G)[4], incorporated with one pass by a sweep plow in late fall, adequately controls weeds in sunflower when trifluralin is applied at 1.1 kg ai/ha (1, 8). This technique, relying on precipitation to aid incorporation of trifluralin, minimizes residue burial.

However, success with trifluralin G or ethalfluralin G at a drier site in central North Dakota required the following modifications: 1) a spring application incorporated by two passes of the sweep plow, with the second tillage at least 3 wk later; 2) individual sweeps must be 80 cm or less in width; and 3) depth of tillage must be shallow, preferably 5 cm (6).

Producers can use two tactics to enhance effectiveness of trifluralin G or ethalfluralin G in conservation-tillage

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[4]Abbreviations: G, granules.

systems. One tactic is applying the appropriate rate of herbicide in two applications separated by time, referred to as split application (15, 24). With each application, a sweep plow operation occurs, thus aiding incorporation. A second tactic is attaching a mulch treader to the sweep plow to increase incorporation. The split application technique increases the opportunity for precipitation to move herbicide into soil, thus improving consistency of control when compared to a single application before planting (24). The mulch treader improves herbicide incorporation by providing additional mixing of the surface 5 cm of soil (1).

Producers also have a no-till option with pendimethalin. In northeastern Colorado, pendimethalin applied in late May at 1.1 kg/ha without incorporation controlled weeds for 90 d during fallow (2), and for 60 d in no-till safflower when applied in early April (3). However, pendimethalin requires rainfall after application for incorporation, which may not occur consistently in semiarid regions.

Tillage systems impact crop growth in the Great Plains. For example, grain yield of no-till corn is increased 35 to 50% compared to corn grown with tillage for weed control and seedbed preparation (3). This corn yield response is related to residue levels maintained on the soil surface (23). The tillage effect, however, is crop-related, as safflower seed yield increased only 10% with no-till (3). Tillage effect on sunflower seed yield has been inconsistent. In Texas and eastern North Dakota, sunflower seed yield was not affected by tillage system (9, 21, 22), while in central North Dakota, no-till systems increased seed yield during drought years, but not in years with normal precipitation (6, 7).

This study was conducted to compare combinations of tillage and herbicides for their effect on crop residue levels at planting, weed control, and yield of oil-seed sunflower in the northern and central Great Plains. Our goal was to develop weed management options for sunflower production systems that protect soil from erosion.

MATERIALS AND METHODS

Site description. This study was conducted at Akron, CO, in 1993 and at Akron, Sidney, NE, and Mandan, ND, in 1994. Average yearly precipitation and growing season temperature (April through October) at Akron are 420 mm and 16 C, 410 mm and 16 C at Sidney, and 410 mm and 14 C at Mandan. Soils at Akron were a Weld and Rago silt loam (Aridic Paleustoll) with 1.2% organic matter and pH of 6.9; at Sidney, a Duroc loam (Pachic Haplustoll) with 2.3% organic matter and pH of 6.5; and at Mandan, a Temvik-Wilton silt loam (Typic and Pachic Haploborolls) with 1.5% organic matter and pH of 7.5.

Table 1. Weed management strategies compared at three sites in the Great Plains.

Strategy	Strategy description
1. Disk incorporation	Trifluralin ec at 1.1 kg ai/ha, applied 1 to 2 WBP[a], incorporated twice by tandem-disk harrow
2. Trifluralin G	Trifluralin (granules) at 1.1 kg/ha, applied 1 to 2 WBP, incorporated with sweep plow
3. Ethalfluralin G	Ethalfluralin (granules) at 1.1 kg ai/ha, applied 1 to 2 WBP, incorporated with sweep plow
4. Split application	Trifluralin[b] (granules) at 1.1 kg/ha in October and 0.6 kg/ha 1 to 2 WBP, incorporated with sweep plow each time
5. No-till pendimethalin	Pendimethalin ec at 1.7 kg/ha, applied 1 to 2 WBP, no incorporation

[a]WBP: weeks before planting.

[b]Rate at Mandan: 0.6 kg/ha in October and 0.7 kg/ha before planting. Strategy not tested at Sidney.

Weed management strategies. We compared four conservation-tillage weed management strategies to weed control with trifluralin ec incorporated with a tandem-disk harrow (Table 1). Two strategies involved trifluralin G or ethalfluralin G applied with an air-assist applicator attached to a sweep plow. Tillage occurred simultaneously with application of granules. A split application strategy consisted of trifluralin G applied in October and May. Pendimethalin ec was applied to the soil surface without incorporation for the fourth strategy.

Equipment resources varied among sites, resulting in tillage differences within strategies involving granules (Strategies 2, 3, and 4). A mulch treader was used with the sweep plow during incorporation at Akron and Sidney, but not at Mandan (Table 2). Number of passes with the sweep plow for incorporation at each site are listed in Table 2. With the split application strategy, a sweep plow operation occurred with each trifluralin application. Sweep size at all sites was 80 cm or less. At all sites, two passes occurred with the tandem-disk harrow. Depth of tillage was 5 cm with the sweep plow and 10 cm with the tandem-disk harrow.

Treatments were established following winter wheat harvest, with each plot 9 by 13 m. For the disk incorporation and granular formulation strategies, weeds present after winter wheat harvest until herbicide application were controlled as needed by tilling with a sweep plow. One to

Table 2. Agronomic and equipment factors in establishing management strategies at three sites.

Factor	Site		
	Akron	Sidney	Mandan
Sunflower cultivar	'Triumph 565'	'Dahlgren 855'	'Sigco 651'
Planting rate (seed/ha)	47 000	40 000	44 500
Row spacing (cm)	76	76	91
Planting date			
1993	June 7		
1994	June 2	June 3	May 23
N fertilizer (kg/ha)	67	0	56
Sweep plow			
Mulch treader[a]	Yes	Yes	No
Passes for incorp. (no.)	1	1	2

[a]Attachment with the sweep plow.

three tillage operations were used depending on site. With no-till pendimethalin, herbicides controlled weeds during the fallow period. At Akron and Sidney, atrazine [6-chloro-*N*-ethyl-*N*′-(1-methylethyl)-1,3,5-triazine-2,4-diamine] plus clomazone {2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolidione}, both at 0.6 kg ai/ha, were applied in August. Emerged weeds at this time were controlled by glyphosate [*N*-(phosphonomethyl)glycine] at 0.5 kg ai/ha. At Mandan, weeds emerging during fallow were controlled by glyphosate applied as needed. At all sites, glyphosate was included in the tank-mix with pendimethalin to control weeds present at planting.

Sunflower cultivar, planting rate, row spacing, planting date, and N fertilizer rate (Table 2) were indicative of production practices at each location.

Study procedures. Soil surface residue levels were measured after sunflower planting by the line-transect method (13), which the U.S. Dep. Agric.-Natural Resources Conservation Service uses to evaluate producer fields. Within each plot, 8-m transects were laid out diagonally across the plot, with residue counted at 25 predetermined points along each transect.

Weed control was evaluated weekly during the crop season until canopy closure (10 wk after planting at all sites). Measuring criterion was a visual estimate of percent of plot area that was weed-free. When level of weed infestation exceeded 15% of the plot area, weed species were identified and counted in two 1-m^2 quadrats in each plot. If weed cover did not exceed 15%, species data were collected at canopy closure.

At crop maturity, seed was harvested from eight rows 13 m long with a field combine. Seed yield is expressed as kg/ha and adjusted to 10% moisture. Volume weight was determined from grain samples, while seed oil concentration was determined at a commercial laboratory and standardized to a 10% moisture basis.

Experimental design at all locations was a randomized complete block with four replications at Akron and Mandan, and three replications at Sidney. Data for each site were subjected to ANOVA, and differences among means determined with Fisher's Protected LSD test at the 0.05 level of significance. Data were not compared among sites because of differences in herbicide rates and equipment. Akron data were examined for year by treatment interaction, and if an interaction occurred, yearly means were expressed separately.

RESULTS AND DISCUSSION

To protect soil from erosion, at least 30% of the soil surface should be covered with residue (19). At all sites, the four conservation-tillage weed management strategies exceeded this level (Table 3). At two sites, Akron in 1993 and Sidney, disk incorporation of trifluralin left less than 30% cover at planting. Residues were highest with no-till pendimethalin at all sites, being greater than 90% at Akron in 1994 and Mandan. Residue cover for all strategies at Sidney was low because hail damaged the previous wheat crop and reduced residue production.

All weed management strategies controlled weeds for at least 7 wk after planting (Table 4); however, duration of weed control differed among strategies. At Akron, ethalfluralin G and the split application strategy were more effective for weed control than no-till pendimethalin. At Mandan, trifluralin G, ethalfluralin G, and the split application strategies controlled weeds longer than disk incorporation and no-till pendimethalin. Strategies did not differ in weed control at Sidney. At all sites, at least 10 mm of

Table 3. Percentage of crop residue cover on the soil surface after sunflower planting, as affected by weed management strategy.

Strategy	Site			
	Akron-93	Akron-94	Sidney	Mandan
	%			
1. Disk incorporation	22	59	26	58
2. Trifluralin G	58	84	30	77
3. Ethalfluralin G	59	82	48	75
4. Split application	62	79	—[a]	78
5. No-till pendimethalin	72	93	51	97
LSD (0.05)	10	11	20	6

[a]Strategy not tested.

Table 4. Duration of weed control (> 85% of plot area weed-free) for all sites. Akron data are averaged across 2 yr.

Strategy	Site		
	Akron	Sidney	Mandan
	wk after planting		
1. Disk incorporation	8.3	6.3	7.5
2. Trifluralin G	8.5	7.3	8.8
3. Ethalfluralin G	9.5	7.7	9.1
4. Split application	9.6	—[a]	9.0
5. No-till pendimethalin	7.1	7.0	8.0
LSD (0.05)	1.6	NS	0.7

[a]Strategy not tested.

Table 5. Sunflower seed yield, as affected by weed management strategy. Akron data are averaged across 2 yr.

Strategy	Site		
	Akron	Sidney	Mandan
	kg/ha		
1. Disk incorporation	1230	1220	1800
2. Trifluralin G	1250	1300	1700
3. Ethalfluralin G	1150	1390	1840
4. Split application	1320	—[a]	1950
5. No-till pendimethalin	1020	1620	1910
LSD (0.05)	280	230	NS

[a]Strategy not tested.

precipitation occurred within 10 d after pendimethalin application.

At Akron, the main weeds were kochia [*Kochia scoparia* (L.) Schrad. #[5] KCHSC], Russian thistle (*Salsola iberica* Sennen & Pau # SASKR) and common purslane (*Portulaca oleracea* L. # POROL). Volunteer wheat, redroot pigweed (*Amaranthus retroflexus* L. # AMARE), and Russian thistle were prevalent at Sidney, while at Mandan, volunteer wheat, yellow foxtail [(*Setaria glauca* (L.) Beauv. # SETLU], and green foxtail [*Setaria viridis* (L.) Beauv. # SETVI] were common. A weed species by strategy association was not observed at any site.

At all sites, all conservation-tillage weed management strategies, except one, yielded favorably compared to disk incorporation (Table 5). The exception was at Akron, where plots treated with no-till pendimethalin yielded less than disk-incorporated plots because of less effective weed control (Table 4). At Sidney, strategies involving granules or disk incorporation had high populations of volunteer wheat when the sweep plow was used for weed control after wheat harvest; however, atrazine and clomazone controlled volunteer wheat in no-till pendimethalin plots. The volunteer wheat consumed soil water before being controlled by tillage in the spring, and may have subsequently reduced sunflower seed yield. Seed yield did not vary among strategies at Mandan.

Seed volume weight and oil content were not affected by weed management strategy (data not shown), except for oil content at Sidney. The oil content was lower with trifluralin G and no-till pendimethalin than with disk incorporation of trifluralin, which we are unable to explain.

[5]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from 1508 West University Ave., Champaign, IL 61821-3313.

In semiarid regions, tillage systems can affect crop yield dramatically, as shown with corn (3, 23). Sunflower yields in our study were comparable across a range of tillage systems, even though fallow plus crop-season precipitation among sites varied from 86 to 109% of normal. Our data indicate that sunflower does not respond to tillage system like corn, which agrees with other research in this region showing minimal effect of tillage on sunflower yield (9, 21).

Our study demonstrates that conservation-tillage production systems enables producers to grow sunflower in semiarid regions and still protect their soil from erosion. Conservation-tillage strategies without tillage, such as no-till pendimethalin, are especially favorable for maintaining high residue cover after sunflower planting. A drawback with no-till pendimethalin, however, is its dependence on rainfall for incorporation. Producers also will be able to protect their soil from erosion after sunflower harvest with new developments in residue management systems for fallow after sunflower (5, 16).

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