Efficacy of Non-Chemical Weed Control during Plug Establishment of a Wildflower Meadow[1]

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Abstract

The efficacy of non-chemical weed control during plug establishment of a wildflower meadow on glyphosate-killed turf grass was studied. Each field sub-block (not-tilled or twice-tilled to 15 cm (6 in) depth) on killed grass received the following sub-plot soil cover treatments: no cover, woven polypropylene weed fabric, double shredded hardwood/softwood mulch at 7.5 cm (3 in) depth, or fabric covered by mulch. Each 3 × 3 m (10 × 10 ft) subplot was planted in late spring with 100 plugs on 30 cm (1 ft) centers at the following frequency: *Baptisia australis* (10), *Coreopsis lanceolata* (20), *Solidago speciosa* (10), *Panicum virgatum* (20), and *Schizachyrium scoparium* (40). Tillage of the killed grass not only failed to benefit wildflower establishment, but increased weed shoot biomass during the second growing season. Greater wildflower shoot dry weights at 120 days after transplanting with mulch (with or without underlying fabric) than with fabric alone or no cover was associated with greater soil moisture, reduced soil temperature range, and reduced weed cover and shoot biomass. Weed fabric compared to no cover failed to affect wildflower shoot dry weights during either growing season but decreased weed growth during the second growing season. Fabric under mulch compared to mulch alone generally failed to affect wildflower growth and had no effect on weed growth during either growing season. During the second growing season, weed shoot dry weights remained low in mulched plots and remained high in non-mulched plots. Regardless of cover, wildflower shoots underwent considerable dry weight gain, while weed shoot dry weights generally remained constant or declined during the second growing season compared to the first. We conclude that, at least under our experimental conditions, applying a 7.5 cm (3 in) layer of wood chip mulch directly over glyphosate-killed turf was the most efficaceous and cost effective method of establishing a wildflower meadow using wildflower plugs. Neither placing weed fabric under the mulch nor twice-tilling the killed turf before mulch application benefitted wildflower shoot growth.

Index words: wildflower establishment, weed fabric, mulch.

Species used in this study: false indigo (*Baptisia australis* (L.) R. Br.), lanceleaf coreopsis (*Coreopsis lanceolata* L.), showy goldenrod (*Solidago speciosa* Nutt.), switch grass (*Panicum virgatum* L.), and little bluestem (*Schizachyrium scoparium* (Michx.) Nash.).

Chemicals used in this study: Roundup Pro, glyphosate (N-(phosphonomethyl)glycine).

Significance to the Nursery Industry

Results of this study have shown that in establishing a wildflower meadow from plugs, tillage of glyphosate-killed turf is unnecessary since tilling twice 7 days apart to 7.5 cm (3 in) depth failed to increase wildflower shoot growth above that occurring in non-tilled plots. Weed fabric compared to no cover failed to affect wildflower growth during either growing season. Weed fabric under mulch compared to mulch alone generally failed to affect wildflower growth and had no effect on weed growth during either growing season. Thus, the most efficaceous and cost effective method of site preparation for establishing a wildflower meadow from plugs was to place 7.5 cm (3 in) of woodchip mulch directly over untilled glyphosate-killed turf.

Introduction

Because perennial wildflowers are often slow to grow during their first year, the wildflower meadow is susceptible to intense invasive weed competition (2, 16). Not only do weeds aesthetically detract from the landscape, they also

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compete with desired plants for space, light, water, and nutrients, serve as a habitat for insects and pathogens, and in some cases cause allelopathic growth suppression of desired plants (14).

Initial site preparation can greatly reduce weed growth in the wildflower meadow. Herbicide use, soil fumigation, or repeated cultivation are principle methods during site preparation to reduce weed establishment from dormant or quiescent residual ('weed bank') seeds (5, 16). The few herbicides labeled for use on herbaceous perennials are generally effective only for short periods, are often only marginally effective, and have variable effects depending on timing of application and the species and age of the herbaceous perennial crop (9). There is little information regarding the tolerance of herbaceous perennials to herbicides, and few herbicides are labelled for use in herbaceous perennial production systems and landscape plantings. Derr (11) established that although the preemergence herbicide metochlor controlled yellow nutsedge and annual grasses, when combined with preemergence herbicides for broad-leafed weeds (simazine, isoxaben or oxadiazon), the latter caused unacceptable phytotoxicity in *Coreopsis lanceolata* L., *Chrysanthemum leucantheum* L., *Echinacea purpurea* (L.) Moench, and *Gaillardia aristata* Parsh. Harkness and Lyons (13) found that oryzalin herbicide was more effective than mulch in weed control, but reduced wildflower plant stand due to phytotoxicity. Soil fumigation can kill most dormant or quiescent weed seed, but it is a temporary weed control method since weed seed will germinate as they are introduced into the planting area. Some fumigants such as metham and dazomet remain in the soil for long periods so a waiting period is needed before planting (12). One technique to reduce the residual quiescent weed seed is repeated tillage at one to two week intervals (18). Tillage can bring quiescent weed seeds near to the soil surface which may promote their germination, and subsequent tillage kills seedlings by disrupting or burying them. The stale seedbed technique for weed control involves initial tillage to encourage weed growth that is followed by killing weeds without soil disturbance so that the weed seed bank in the upper soil will be depleted, resulting in less weed pressure against subsequent crops (7). This technique differs from our repeated tillage to control weeds by using a herbicide to kill weeds stimulated to establish from the seed bank using initial tillage.

Weed fabrics and mulch have become popular methods of non-chemical weed control. Weed fabrics are composed of synthetic plastics woven or spun into a blanket that is laid over the soil, while mulch is a layer of usually organic material spread over the soil surface. Mulch has the additional benefit of moderating soil temperature and moisture to levels more favorable for plant growth (3, 6). Several brands of landscape fabric provided good to adequate control of various annual weed species (17). Spun polypropylene fabric provided excellent weed control in a planting of mixed vegetables (4). Though effective, weed fabrics are better covered with mulch as fabrics can be penetrated by both creeping perennial weeds, such as johnsongrass (*Sorghum halapense*) and yellow nutsedge (*Cyperus esculentus*), and the summer annual, large crabgrass (*Digitaria sanguinalis*), and they are prone to breakdown with high exposure to ultraviolet radiation (10, 17). Weeds were able to germinate below spunbond fabric when they were not covered by mulch, since sunlight was able to penetrate the fabric (10). Weed control in a planting of five vegetables and two woody species was improved by combining mulch and fabric compared to when either one was used alone (3). Powell et al. (21), likewise, found mulch plus underlying fabric resulted in greater weed suppression than using either alone. Barker and O'Brien (4) found that woven or spunbond landscape fabrics were as effective in controlling weeds as 4 mil polyethylene plastic or diphenamid herbicide under 1.3 cm (0.5 in) thick mulch of co-composted biosolids and woodchips, and a mulch layer at least 3.8 cm (1.5 in) thick was needed for weed suppression without an underlying material. Landscape fabric manufacturers usually recommend that mulch be placed on the fabric. However, weed seeds can germinate and develop in the mulch. Derr and Appleton (10) found that weed weights and hand-weeding times were greater for mulch-covered fabrics than for non-mulched fabrics. Weed seeds either blew in or were carried in via irrigation water, or may have been contaminants of the mulch itself.

While wildflower meadows are most commonly established by direct-seeding, sod (13, 20) or plugs (1) can be used. The use of fabrics or mulch would prevent meadow establishment by direct seeding. The Virginia Tech transplanted meadow (VTTM) technique uses annual plants started in cell packs (4 × 4 × 2 in, 10 × 10 × 5 cm) that are transplanted at 30 by 30 to 60 cm (1 ft by 1 to 2 ft) spacing (13). These authors found that oryzalin herbicide was more effective than mulch (no details provided) in weed control but reduced wildflower plant stand through phytotoxicity. Mulch, compared to herbicide, resulted in larger, more vigorous transplanted plants which reduced light transmission to the mulch thereby reducing weed competition. Plugs can be used to establish or augment a wildflower site by transplanting species that are slow to germinate or establish, or that have limited or expensive seeds (1). Andropogon Associates (Philadelphia, PA), an ecological planning firm, uses wildflower plugs in meadow establishment. Since plugs are transplanted with an established root system, these plants may be able to compete more effectively with weeds during meadow establishment.

The purpose of this research was to examine the growth of plug-established wildflowers and weeds over two consecutive growing seasons in response to initial tillage (twice-tilled vs non-tilled) of turf killed with a systemic, non-selective herbicide (glyphosate) and the use of weed fabric and/or wood chip mulch over the wildflower meadow site.

Materials and Methods

Seeds of three wildflower species (false indigo, *Baptisia australis* (L.) R. Br.; lance-leafed coreopsis, *Coreopsis lanceolata* L.; and goldenrod, *Solidago speciosa* Nutt.) and two native warm-season grasses (little bluestem, *Schizachyrium scoparium* (Michx.) Nash.; and switchgrass, *Panicum virgatum* L.) were sown (April 20) at 2 to 3 seeds per cell in 3 × 3 × 5 cm deep (45 cm^3) (1.2 × 1.2 × 2 in deep, 2.9 in^3) inverted truncated pyramid cells of a 128 plug tray (128 cells per 25 × 52 cm (10 × 20.5 in)) tray (TLC Polyform, Plymouth, MN) containing peat-lite (Pro-Mix BX, Premier Brands, New Rochelle, NY). Seeded flats were placed under mist (5 seconds every 10 min) until seedling emergence, then each cell was thinned to one seedling and the flats were maintained in a greenhouse set at 24/21C (75/70F; day/night) under natural light (April through May). Flats were watered as needed and solution fertilized weekly for 4 weeks, and then

PV	ScS	ScS	CL	CL	PV	SS	ScS	SoS	BA
ScS	SoS	CL	ScS	PV	BA	PV	CL	SoS	ScS
ScS	PV	CL	PV	BA	ScS	PV	SoS	CL	ScS
CL	ScS	ScS	ScS	BA	ScS	CL	ScS	PV	PV
PV	ScS	PV	CL	ScS	BA	CL	ScS	ScS	ScS
ScS	SoS	CL	SoS	ScS	SoS	SoS	PV	BA	PV
ScS	PV	ScS	ScS	PV	PV	BA	ScS	CL	CL
CL	CL	PV	ScS	CL	ScS	ScS	BA	ScS	SoS
BA	PV	ScS	ScS	CL	BA	ScS	CL	SoS	ScS
SS	ScS	PV	CL	SoS	ScS	CL	ScS	PV	ScS

BA = *Baptisia australis*, CL = *Coreopsis lanceolata*, PV = *Panicum virgatum*, ScS = *Schizachyrium scoparium*, and SoS = *Solidago speciosa*.

Fig. 1. Diagram indicating the position and frequency of wildflower species in each sub-plot.

daily with 100 mg N/liter (ppm) from 21N–2.2P–12.4K (Peters All Purpose Fertilizer, The Scotts Company, Marysville, OH). At 31 days after planting, flats were moved to an open-sided polyethylene-covered greenhouse for hardening for 10 days.

The wildflower meadow plots, located in Newark, DE, were of Matapeake silt-loam (fine silty, mixed mesic Typic Hapladult, pH 6.4, 2.1% organic matter) that had been sown with a 1:1 (by weight) perennial ryegrass (*Lolium perenne*):rough fescue (*Festuca campestris*) mixture two years earlier and had been mowed regularly. The area was sprayed with a solution of 2% Roundup Pro (41% glyphosate) at 1.11 liters/Ha (3 qt/A) (Monsanto, St. Louis, MO) in late April (41 days before transplanting). Plots were arranged in a randomized split block design, with each main block (12 × 6 m; 40 × 20 ft) split as no-till and twice-tilled sub-blocks (6 × 6 m; 20 × 20 ft). Tilled subplots were rotovated to 15 cm (6 in) deep at 20 and 27 days after spraying, rolled with a water ballast roller, and raked smooth. These plots received no further weed control. Within each sub-block were four 3 × 3 m (10 × 10 ft) sub-plots comprising the cover treatments: no cover, weed fabric only, mulch only (7.5 cm, 3 in depth), or fabric plus mulch (7.5 cm, 3 in depth). The woven propylene weed fabric (Typar; DuPont, Wilmington, DE) was held in place by burying excess fabric with soil at the plot edges. The double-shredded mulch, was a mixture of 50% hardwood and 50% softwoods with particle lengths ranging from 1 cm (0.4 in) to 5 cm (2 in).

The plugs were transplanted into each subplot at 41 days after sowing (June 1, 14 days after the second tillage) at 30 cm (1 ft) square spacing in the arrangement shown in Fig. 1, and at the following frequency: *Schzachyrium scoparium* (ScS, 40), *Panicum* virgatum (PV, 20), *Coreopsis lanceolata* (CL, 20), *Baptisia australis* (BA, 10), *Solidago speciosa* (SpS, 10) as recommended by Andropogon Associates Landscape Architects (Philadelphia, PA). Planting through fabric involved cutting a small cross-shaped incision in it before planting the plug. After transplanting, plots were irrigated every other day for one week and thereafter received no further maintenance. Soil temperature and moisture were monitored weekly at midday at randomly selected locations within each plot from early June through early September. Soil temperature at 5 cm (2 in) below the soil surface was determined with a digital, probed thermometer (Fisher Scientific, Philadelphia, PA). Soil cores, 2.5 cm (1 in) diameter by 5 cm (2 in) were extracted from the 2.5–7.5 cm (1–3 in) soil depth in each sub-plot and sealed in plastic bags. From core fresh weight and oven dry weight (105C (221F) for 72 hours), percentage soil moisture (dry weight basis) was calculated.

Weed species density (percentage of soil cover) was rated visually at 90 days after transplanting (DAT) the plugs. Weed species occurring at ≥1% of weed density (percentage of soil cover) were reported as percentage seed density. At 120 DAT (early-October), shoots of three plants per planted species were harvested from one-half of each subplot, and from the same position in each subplot. Also at 120 DAT, shoots of all weeds within a randomly selected 1 m^2 (10.6 ft^2) area in the same half subplot were harvested. Shoots of wildflowers and weeds were dried (10 days at 65C, 149F) then weighed. Plots received no maintenance during the second year. On the same date as harvest during the first year, shoot dry weights of planted species and weeds were determined, but from the half of each sub-plot not harvested during the first season.

Wildflower and weed shoot dry weights at the end of each growing season, weed density at 90 DAT (first growing season), and soil moisture and temperature during the first growing season were subjected to analysis of variance.

Results and Discussion

Weed density (visual estimate of soil cover) at 90 DAT in the first growing season was similar in tilled and no-till plots (Table 1), except in mulched subplots where tillage increased weed density to 8.5% from the 0.8% in non-tilled subplots. Thus, tilling the plots twice (at 20 and 27 days after glyphosate treatment) failed to reduce weed density, although repeated tillage at one to two week intervals is a recommended technique to reduce weed populations in a wildflower site (18). Mulch or fabric plus mulch resulted in much lower weed density (2.6% average) than fabric alone or no cover (98.2% average) (Table 1). Extensive weed growth was evident in fabric and no cover plots within one week of transplanting the wildflower plugs. By two weeks, weeds had pushed the

Table 1. Effect of tillage and soil covers on weed density and species at 90 days after transplanting the wildflower plugs (first growing season).

Tillage	Cover	Weed density (% soil cover)[z]	Weed species[y] (% weed density)
No- till	Fabric	93.0a	DIGSA (95) SETVI (2) AMARE (1) ECHCG (1)
	Mulch	0.8c	DIGSA (98) SETVI (2)
	Fabric + mulch	0.3c	CYPES (100)
	None	100.0a	DIGSA (82) PANDI (4) AMARE (3) SETVI (S) CHEAL (3)
Tilled	Fabric	99.8a	DIGSA (92) SETVI (3) CHEAL (2) PANDI (1)
	Mulch	8.5b	SOLCA (66) DIGSA (23) SETVI (13) ECHCG (3)
	Fabric + mulch	0.8c	DIGSA (65) CYPES (33)
	None	99.8a	DIGSA (90) CHEAL (3) PANDI (2) AMARE (2) SETVI (2)
Significances[x]:	Tillage	*	
	Cover	***	
	Tillage × cover	*	

[z]Based on visual observation.

[y]Weeds that represented ≥1% weed density. DIGSA = *Digitaria sanguinalis*, AMARE = *Amaranthus retroflexus*, CHEAL = *Chenopodium album*, CYPES = *Cyperus esculentus*, ECHCG = *Echinochloa crus-galli*, PANDI = *Panicum dichotomiflorum*, SETVI = *Setaria viridis*, and SOLCA = *Solanum carolinense*.

[x] ***, * significant at $P \leq 0.001$ or $P \leq 0.05$, respectively. Means in a column followed by the same letter are not significantly different by $LSD_{0.05}$.

fabric above the soil surface and weeds grew through the cross-shaped slits through which the wildflower plugs had been planted. Derr and Appleton (10), likewise, noted weed growth under Typar weed fabric, since sunlight was able to penetrate the fabric. Ashworth and Harrison (3), however, observed excellent weed control with spun polypropylene weed fabric in vegetable plantings. By six weeks after transplanting, wildflower transplants in both the fabric and no cover plots were obscured by weeds.

Fabric under the mulch resulted in a slight reduction in weed density (0.4% with fabric, 2.8% without fabric) in tilled plots (Table 1). Ashworth and Harrison (3) noted improved weed control with fabric plus mulch than with either alone. Barker and O'Brien (4) found that at least a 3.8 cm (1.5 in) deep mulch was needed to provide the same weed suppression as 1.3 cm (0.5 in) deep mulch with underlying fabric.

In no-till subplots, weed species were reduced to two with mulch alone and to one with fabric plus mulch, compared to four species with fabric alone and five with no cover (Table 1). Tillage, compared to no-till, doubled weed species to four with mulch and to two with fabric plus mulch. Large crabgrass was the dominant weed species in all sub-plots, except in no-till with fabric and mulch (yellow nutsedge was dominant) and in tilled with mulch (Carolina horsenettle, *Solanum carolinense*, was dominant and large crabgrass second dominant). Weedy species of Poaceae are highly competitive with rapid root and shoot growth and high rates of dry matter accumulation (22). Large crabgrass exhibited rapid shoot growth through the fabric slits and quickly outgrew all the transplants. In fact, Derr and Appleton (10) reported that large crabgrass shoots could penetrate intact fabric of all six polypropylene landscape fabrics tested. Since tillage would be expected to decrease horsenettle density, we can not explain this weed's dominance in tilled subplots covered with mulch. Common lambsquarters (*Chenopodium album*) and redroot pigweed (*Amaranthus retroflexus*) were the main dicot weeds. Fabric plus mulch resulted in 100 and 33% yellow nutsedge in no-till and tilled subplots, respectively. We can not explain why nutsedge occurred only in subplots covered with fabric and mulch. Lytton (15) suggested that weed fabrics should be pinned around transplants to reduce opening size through which weeds could grow.

Tillage (no-till vs twice-tilled) had no effect on wildflower shoot dry weights in either year (Table 2). Weed shoot dry weights were unaffected by tillage in the first year, but were 133% greater in tilled than in no-till plots at the end of the second season. Tillage may have brought deeply buried weed seeds nearer to the soil surface where they were able to become established (22) by the second growth season. Calkins and Swanson (8) showed that cultivation, by disturbing the seed bank, increased the growth and number of weed species, a weed-free condition being possible only with repeated cultivation.

Mulched plots, with or without underlying fabric, resulted in greater wildflower shoot dry weights and lower weed shoot dry weights than non-mulched plots at the end of the first season (Table 2) suggesting that a main benefit of the mulch was reduced competition by weeds. Fabric alone and no cover produced similar and very low shoot dry weights of wildflower species, and almost an 8-fold greater weed shoot dry weight than the mulched plots at the end of the first growing season. Between the end of the first and second growing seasons, wildflower shoot dry weights had increased greatly although this gain was greater in subplots not covered with mulch (fabric alone or no cover) than in those covered with mulch (fabric plus mulch or mulch alone). At the end of the second growing season, weed shoot dry weights remained low in mulched plots and remained high in non-mulched subplots. Thus, during the second growing season, wildflower shoots showed considerable dry weight gain while weed shoot dry weights generally remained constant or declined. Greater shoot dry weights of wildflowers in mulched than in non-mulched subplots during the second growing season could be attributed, at least partially, to decreased weed density and growth and thus reduced competition for resources. While others have reported greater weed control using both mulch and an underlying weed fabric than when using either alone (3, 21), our results agreed with those of Barker and O'Brien (4) who found that weed suppression was achieved without underlying fabric or herbicide barrier when mulch was at least 3.8 cm (1.5 in) deep. Harkness and Lyons (13) reported that mulch, compared to no mulch, stimulated growth of transplanted wildflower cell packs so as to reduce light transmission between the transplanted cell packs (planted at 30 × 30

Table 2. Effect of tillage and soil cover on wildflower and weed shoot dry weights at 120 days after transplanting during the first growing season and on the same date during the second growing season.

Growing season	Treatments		Shoot dry weight (g/plant)					Weed shoot dry weight (g/m²)
			ScS[z]	BA	CL	PV	SoS	
First	Tillage:	No-till	11.1a	2.2a	68.1a	14.9a	8.9a	198.8a
		Tilled	14.7a	2.7a	60.7a	12.1a	9.1a	174.7a
	Cover:	Fabric	1.0c	1.8b	11.4b	0.7b	2.7b	324.0a
		Mulch	31.3a	3.1a	108.5a	27.6a	13.9a	13.0b
		Fabric + mulch	19.2b	4.7a	135.7a	25.8a	19.0a	31.7b
		None	0.0c	0.1b	1.9b	0.0b	0.3b	378.4a
	Signficances[y]:	Tillage	ns	ns	ns	ns	ns	ns
		Cover	***	***	***	***	***	***
		Tillage × cover	ns	ns	ns	ns	ns	ns
Second	Tillage:	No-till	34.6a	7.6a	263.8a	120.1a	194.0a	102.3b
		Tilled	33.3a	11.8a	295.5a	111.8a	181.7a	237.9a
	Cover:	Fabric	6.7c	12.3a	167.8b	139.8a	61.2b	209.4b
		Mulch	34.1b	13.1a	390.5a	155.9a	115.8ab	12.5c
		Fabric + mulch	86.4a	9.8a	463.0a	158.0a	249.5a	1.3c
		None	8.6c	3.8b	97.2c	10.3b	124.8ab	458.4a
	Signficances[y]:	Tillage	ns	ns	ns	ns	ns	*
		Cover	***	***	***	***	*	***
		Tillage × cover	ns	ns	ns	ns	ns	ns

[z]ScS = *Schizachyrium scoparium*, BA = *Baptisia australis*, CL = *Coreopsis lanceolata*, PV = *Panicum virgatum*, SoS = *Solidago speciosa*.

[y]***, *, ns significant at $P \le 0.001$, $P \le 0.05$, or not significant, respectively. Means in a column for a main effect within a season followed by the same letter are not significantly different by $LSD_{0.05}$.

to 60 cm, 1 × 1 to 2 ft) and thereby reduce weed competition. Lower weed shoot dry weight with fabric alone than in no cover subplots could be attributed, at least partially, to increased competition resulting from increased growth of three wildflower species (BA, CL, and PV). The minimal population of winter annual weeds that established between the first and second growing seasons was not controlled.

The inverse relationship between wildflower and weed shoot growth in all subplots (Table 3) reflects the negative effect of vigorous weed growth on the growth of wildflower species. Greater weed growth led to greater competition for resources such as light, water and nutrients, and possibly to allelopathic effects (3). In weedy subplots, weeds quickly formed a canopy over the wildflowers thereby reducing irra-

Table 3. Soil moisture and temperature during the first growing season in response to soil covers (averaged across tillage) in the wildflower meadow.

Cover	Date (day/month)									
	10/7	17/7	24/7	2/8	7/8	15/8	21/8	29/8	4/9	Mean
	Temperature (C)[z]									
Fabric	27.1a	31.1a	26.0a	26.2a	23.9a	24.8bc	20.0b	24.3a	23.9a	25.3a
Mulch	24.7b	26.4c	25.4a	24.0b	23.9a	25.8ab	20.9a	24.7a	21.3c	24.1b
Fabric + mulch	25.0b	26.2c	25.4a	24.2b	24.1a	25.9a	20.9a	24.6a	20.7c	24.1b
None	27.3a	28.9b	24.6b	24.1b	22.9b	24.3c	20.4b	24.4a	22.2b	24.3b
Significance[y]:	***	***	***	***	***	***	**	ns	**	**
	Soil moisture (%, oven dry weight)[x]									
Fabric	21.2bc	10.8b	20.9c	21.8b	17.7b	20.8b	19.9c	19.0b	16.4b	18.7b
Mulch	24.9a	16.4a	22.9a	26.5a	23.2a	25.9a	24.0a	21.2a	19.1a	22.7a
Fabric + mulch	22.3b	15.5a	21.9b	22.4b	22.8a	24.8a	22.3b	21.2a	17.6b	21.2a
None	19.4c	11.9b	20.3c	22.0b	17.4b	21.9b	19.6b	19.6b	16.2b	18.9b
Significance[y]:	***	***	*	**	***	**	*	*	*	**

[z]Soil temperature at 2.5 cm (1 in) depth.

[y]***, **, *, ns significant at $P \le 0.001$, $P \le 0.01$, $P \le 0.05$, or not significant, respectively. Means in a column for a main effect followed by the same letter are not significantly different by $LSD_{0.05}$. Tillage (not-tilled or twice-tilled) and the interaction of tillage with cover were not significant for both variables.

[x]Soil moisture at 2.5–7.5 cm (1–3 in) depth.

diation on the foliage. Reduced air movement in weedy subplots, by reducing air circulation and increasing relative humidity, may increase wildflower disease probability, although we observed no disease. Mulches can moderate soil temperature and moisture to levels more favorable for plant growth (3, 6). When averaged over the nine sample dates during the first growing season, mulched subplots had a smaller soil temperature range (5.5C, 9.9F) than those covered with fabric alone (7.1C, 12.8F) or non-covered ones (8.5C, 15.3F). This soil temperature moderating effect of mulch, together with greater soil moisture content of mulched plots than non-mulched ones on all but two sampling dates, may have contributed to greater growth of the wildflower species in mulched subplots than in non-mulched subplots during the first growing season. We can not explain why mulch alone resulted in greater soil moisture than fabric plus mulch at one-half of the sample times. However, wildflower shoot growth was unaffected by this difference. The soil cooling effect of mulches has delayed growth of warm season perennials such as *Liatris psicata* and *Schizachyrium scoparium* (8).

Results of this study have shown that tillage of a wildflower meadow site failed to affect the shoot growth of five wildflower species over two growing seasons. Covering the site with a 7.5 cm (3 in) depth of wood chip mulch resulted in the greatest wildflower growth and least weed growth, with underlying spunbond weed fabric generally providing no additional benefit.

Literature Cited

1. Aldrich, J.H. 2002. Factors and benefits in the establishment of modest-sized wildflower plantings: a review. Native Plants J. 3:67–73, 77–86.

2. Anon. 1989. The National Wildflower Research Center's Wildflower Handbook. (ed.) Annie Paulson. Texas Monthly Press, Austin, TX.

3. Ashworth, S. and H. Harrison. 1983. Evaluation of mulches for use in the home garden. HortScience 18:180–182.

4. Barker, A.V. and T.A. O'Brien. 1995. Weed control in the establishment of wildflower sods and meadows. Proc. Northeastern Weed Science Soc. 49:56–60.

5. Bartels, E. 1992. Restoring the northeastern meadow. Landscape Architecture December:74–77.

6. Borland, J. 1990. Mulch. Amer. Nurseryman 172:132–141.

7. Caldwell, B. and C.L. Mohler. 2001. Stale seedbed practices for vegetable production. HortScience 36:703–705.

8. Calkins, J.B. and B.T. Swanson. 1995. Comparison of conventional and alternative nursery weed management strategies. Weed Technol. 9:761–767.

9. Calkins, J.B., B.T. Swanson, and D.L. Newman. 1996. Weed control strategies for field grown herbaceous perennials. J. Environ. Hort. 14:221–227.

10. Derr, J.F. and B.L. Appleton. 1989. Weed control with landscape fabrics. J. Environ. Hort. 7:129–133.

11. Derr, J.F. 1993. Wildflower tolerance to metolachlor and metolachlor combined with other broadleaf herbicides. HortScience 28:1023–1026.

12. Gallitano, L., W.A. Skroch, and D.A. Bailey. 1992. Weed management for wildflowers. Horticulture Information Leaflet 645, North Carolina Coop. Ext., Raleigh, NC.

13. Harkness, R.L. and R.E. Lyons. 1997. A comparison of seeding rate, spacing, and weed control methods in the Virginia Tech Transplanted Meadow. HortTechnology 7:39–41.

14. Kolb, T.E. 1988. Allelopathic effects of Kentucky bluegrass on northern red oak and yellow poplar. J. Arboriculture 14:281–283.

15. Lytton, P. 1990. Miraculous textile mulch: a fabrication? Amer. Horticulturist 69:10.

16. Martin, L.C. 1990. The Wildflower Meadow Book: A Gardener's Guide. p 59. The Globe Peqout Press, Chester, CT.

17. Martin, C.A., H.G. Ponder, and C.H. Gilliam. 1991. Evaluation of landscape fabrics in suppressing growth of weed species. J. Environ. Hort. 9:38–40.

18. Paulson, Q. (ed.). 1989. Wildflower Handbook. Texas Monthly Press, Austin, TX.

19. Phillips, H.R. 1985. Growing and Propagating Wildflowers. University of North Carolina Press, Chapel Hill, NC.

20. Pill, W.G., E.E. Veacock, and C.E. Polston. 2000. Priming wildflower seed mixtures increases sod production rate. J. Environ. Hort. 18:114–118.

21. Powell, M.A., T.E. Bilderback, and W.A. Stroch. 1987. Landscape mulch evaluation. Proc. Southern Nurserymen's Assoc. Res. Conf. 32:345–346.

22. Zimdahl, R.L. 1993. Fundamentals of Weed Science. Academic Press, San Diego, CA.