Stale Seedbed Practices for Vegetable Production

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Abstract. Effects of several stale seedbed procedures on weed density and biomass were evaluated on a silt loam soil in central New York. After an initial rotary tillage, weeds were allowed to emerge and either single or multiple applications of glyphosate, propane flame, spring tine weeder, springtooth harrow, or rotary tiller were used to kill the weeds over a 4-week period. The last (or only) application occurred immediately prior to simulated seeding of a crop performed by passing an empty seeder through the plots. These stale seedbed treatments were compared with a control consisting of a single rotary tillage just before simulated planting. Flaming or glyphosate stale seedbed techniques significantly reduced density and biomass of the principal broadleaf species, common purslane (*Portulaca oleracea* L.) and common chickweed [*Stellaria media* (L.) Cyrillo], in most cases. A single delayed flame or glyphosate stale seedbed treatment was usually as effective as multiple treatments. None of the stale seedbed techniques was effective against yellow nutsedge (*Cyperus esculentus* L.). A flexible tine weeder was not effective as a stale seedbed weed-killing treatment in this study because of poor penetration of crusted soil. Penetration was better with a springtooth harrow, but this failed to reduce weed density. None of the stale seedbed treatments fully controlled weeds. However, glyphosate or flaming a stale seedbed could be incorporated into integrated weed management programs to improve control and reduce the need for herbicides. Broadleaf weed density within 3.8 cm of the center of the seeder wheel track was greater than elsewhere in the plot. Chemical name used: *N*-(phosphonomethyl)glycine (glyphosate).

The premise behind the stale seedbed practice is that by delaying seeding after crop seedbed preparation, flushes of weeds can be induced to sprout, and then be killed. If the weeds are killed with minimal soil disturbance, the weed seedbank in the upper few centimeters of soil will be depleted, resulting in less weed pressure against subsequent crops.

Most investigations of the stale seedbed technique have involved herbicide-based soybean [*Glycine max* (L.) Merrill] systems (Heatherly et al., 1993; Lanie et al., 1993, 1994; Oliver et al., 1993), despite wide use of the

procedure by organic growers (Stopes and Millington, 1991; Wookey, 1985). Use of stale seedbeds in vegetable crops has received little systematic study. Balsari et al. (1994) found that a single flaming 4 d after irrigation and 1 d before transplanting lettuce (*Lactuca sativa* L.) seedlings reduced weed densities by 62%. In their experiment, flaming the stale seedbed produced a net income similar to a chemical treatment with pronamide [3,5-dichloro-*N*-(1-dimethyl-2-propynyl)benzamide]. Johnson and Mullinix (1998) compared several stale seedbed systems for cucumber (*Cucumis sativus* L.) production and found that shallow tillage provided better weed control than glyphosate. Thus, the stale seedbed practice may improve weed control in vegetable cropping systems, and can potentially reduce herbicide use when incorporated into integrated weed management programs.

In both years of this study, initial seedbed preparation occurred in mid-June for an early-to-mid-July seeding date. Many problem weeds are past their primary period of germination by this point in the season. However, common purslane (*Portulaca oleracea* L.), large crabgrass [*Digitaria sanguinalis* (L.) Scop.], and other species germinate profusely in midseason, and late plantings of many vegetable crops are made in New York at this time.

The present study compared weed density and biomass, following several stale seedbed methods, to density and biomass in a conven-

tional tillage program. The intent was to determine the best method for killing seedlings in stale seedbed systems and the usefulness of a single weed removal pass vs. several passes with brief intervening fallow periods.

Materials and Methods

Studies were conducted at the NRCS Big Flats Plant Materials Center, at Big Flats, N.Y., during the 1997 and 1998 growing seasons. The soil type was a Unadilla silt loam (course-silty, mixed, mesic, typic Dystrochrept), and the fields were nearly level.

The fields had cover crops of winter-killed oats (*Avena sativa* L.) and were initially field cultivated and harrowed in Apr. 1997 and May 1998. Treatments were replicated four times in a randomized complete-block design. Plots measured 3.6 × 3.6 m.

Initial seedbeds were prepared with a tractor mounted 1.5-m John Deere rotary tiller (Deere & Co., Moline, Ill.) on 16 June 1997 and 9 June 1998. The following weed killing treatments were applied to the prepared seedbeds during the delay period using single or multiple applications: glyphosate; flaming; shallow harrowing with a tine weeder; cultivation with a rotary tiller (single application only); and cultivation with a springtooth harrow (1998 multiple applications only). Glyphosate was applied with a hand sprayer as a 2% solution until the weed foliage was wet. Flaming was done with a 422 MJ/h propane backpack flame weeder traveling at 3.2 km/h. The tine weeder (Lely Corp., Wilson, N.C.) was a 3-m tractor-mounted unit, equipped with 6-mm round spring tines set for maximum penetration. Actual penetration varied from 0 to 10 cm depending on hardness of the surface crust. Operating speed was 10 km/h. The springtooth harrow penetrated 13 cm and had an operating speed of 6.4 km/h.

The delay period between initial seedbed preparation, and final seedbed preparation and simulated crop seeding was 28 d in 1997 and 24 d in 1998. Single treatments were applied at the end of the delay period. Multiple application treatments generally consisted of three applications, with the final one occurring at the end of the delay period (Table 1). However, in 1997, the final glyphosate application occurred 6 d before simulated seeding in accord with label restriction for use prior to crop production, and the multiple glyphosate treatment included only two applications that year. In 1998, an updated label allowed similar timing and number of applications in the herbicide and mechanical treatments.

Stale seedbed treatments were compared with a control treatment, in which an initial seedbed was not prepared in early June and the soil was rotary tilled once, just before seeding. In addition, the rotary tillage-1 stale seedbed treatment approximated the common practice of plowing or disking down weeds or a cover crop, waiting 2 to 3 weeks for the residues to decompose, and then preparing and planting a final seedbed.

Precipitation was sufficient to promote a flush of seedling emergence between all field operations (Table 1). Weeds were in the cotyle-

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Table 1. Dates of field operations and weed sampling, and precipitation (mm) since the preceding field operation.

Operation	Treatment types	Date	Precip.
<i>1997</i>			
Initial rotary tillage	All except control	16 June	17 ^z
Glyphosate, flame, tine	Multiple	23 June	31
Flame, tine	Multiple	1 July	16
Glyphosate	Single, multiple	8 July	12
Flame, tine, rotary till., plant	Single, multiple, control	14 July	43
Count	All	29 July	20
Biomass	All	12 Aug.	27 ^y
<i>1998</i>			
Initial rotary tillage	All except control	9 June	53 ^z
Glyphosate, flame, tine, springtooth	Multiple	17 June	39
Glyphosate, flame, tine, springtooth	Multiple	24 June	33
Glyphosate, flame, tine, springtooth, rotary till., plant	Single, multiple, control	3 July	125
Count	All	15 July	27
Biomass	All	29 July	42 ^y

^zPrecipitation during the preceding 2 weeks.

^yTotal rainfall following the final weed killing operation.

don stage at the multiple application operations except for individuals that had escaped previous treatments (primarily observed in the tine weeder treatments). For the single operation stale seedbed treatments, the tallest grasses were 12 cm in height, but the more abundant broadleaves were <5 cm. In the control treatment, weeds were up to 40 cm tall at tillage.

The seeding operation was simulated by passing an empty tractor-mounted 2-row Planet Junior vegetable seeder (Powell Manufacturing Co., Benettsville, S.C.) twice (four rows) over all plots after the final stale seedbed treatments were completed. Final seedbed treatment and simulated seeding occurred in all treatments on the same day (Table 1). Rows were 60 cm apart with a 107-cm tractor wheel aisle between each set of two rows. A simulated seeding was made in this study to allow weed responses to be clearly measured without interaction with a particular crop.

In 1997, weeds were counted 15 d after the seeding date (DAS), and then sampled for above ground biomass 29 DAS (Table 1). Counts were taken in four 30×60-cm quadrats placed over the two middle seeder tracks of each plot. Counts in and out of the 7.5-cm-wide seeder presswheel track were recorded separately. Procedures were similar in 1998 except that 15×60-cm quadrats were used for counts 12 DAS and 30×30-cm quadrats were used for biomass 26 DAS (Table 1).

Weed counts were taken in three categories in 1997: 1) common purslane; 2) other broadleaves; and 3) yellow nutsedge (*Cyperus esculentus* L.) plus grasses. In 1998, categories were common purslane, common chickweed [*Stellaria media* (L.) Vill.], other broadleaves, grasses (all annuals), and yellow nutsedge.

Data were subjected to analysis of variance after log₁₀(x+1) transformation to stabilize variance. Differences among means were evaluated using LSD. Back transformed means of the log-transformed data are reported.

Results

In these experiments, weed density included both weeds that survived the stale seedbed

treatments and those that emerged after simulated seeding (Tables 2 and 3). In contrast, weed biomass heavily reflected the weeds that escaped the stale seedbed treatments, since weeds that emerged after simulated seeding were relatively smaller at the time of sampling (Tables 2 and 3).

In 1997, common purslane and yellow nutsedge were the dominant weed species (Table 2). In the 1998 trial, conducted on a neighboring field, common purslane was still a dominant species, but common chickweed was also abundant (Table 3). In both years, annual grasses present included stinkgrass [*Eragrostis cilianensis* (All.) E.Mosher], yellow foxtail [*Setaria glauca* (L.) Beauv.], and large crabgrass. In 1997, yellow nutsedge accounted for most of the individuals and biomass in the yellow nutsedge plus grasses category. Yellow nutsedge was recorded separately in 1998, but occurred too sporadically for analysis. In 1998, many minute purslane speedwell (*Veronica perigrina* L.) seedlings contributed to total weed density, but added negligible biomass. Other broadleaf species present included common lambsquarters (*Chenopodium album* L.), tumble pigweed (*Amaranthus albus* L.), redroot pigweed (*Amaranthus retroflexus* L.), common ragweed (*Ambrosia artemisiifolia* L.), ladythumb (*Polygonum persicaria* L.), and shepherd's-purse [*Capsella bursa-pastoris* (L.) Medicus].

Relative to the control, one or both of the flaming and glyphosate treatments significantly reduced weed pressure by common purslane

in both seasons, and by common chickweed in 1998, when it was sufficiently abundant to tally separately (Tables 2 and 3). In several cases, total density or biomass of all weeds was also lower in the flame and glyphosate treatments. A single application of glyphosate or flaming at the end of the delay period was at least as effective in controlling the two major broadleaf weeds as were three weekly applications. Cultivation with the flexible tine weeder, rotary tiller, and springtooth harrow were not effective, and in some cases these implements significantly increased weed pressure relative to the control.

Weed responses to the stale seedbed treatments varied according to weed type and species. Common purslane and common chickweed experienced density and biomass reductions >75% in several cases. Monocot weed pressure was not reliably reduced by the stale seedbed treatments in these experiments. The treatments were particularly poor at controlling yellow nutsedge. Both glyphosate treatments and the single flame treatment increased yellow nutsedge and grass density and the tine weeder increased their biomass, relative to the control (Table 2).

The two standard practice treatments, namely the single tillage control and the rotary tiller-1 treatments, never differed significantly in either weed density or biomass for any weed taxa. Thus, a 3- to 4-week lag between initial tillage and final seedbed preparation did not improve weed control.

Densities of common purslane and common chickweed were significantly higher in the seeder track than in the rest of the plots in both years (Fig. 1). The various other broadleaf species showed the same trend (data not shown). Annual grass and yellow nutsedge densities were not significantly different in and out of the seeder tracks (Fig. 1). No interactions occurred between treatments and the seeder track effect except for common purslane in 1997. For this case, density in the seeder track relative to outside the track was inexplicably higher for the glyphosate-2 and flame-3 treatments than for other treatments.

Discussion

Flaming and glyphosate treatments appear to have good potential for use in stale seedbed systems. Both treatments killed most weed seedlings but did not prompt weed seeds to germinate by stirring them to the soil surface. Consequently, density and biomass of weeds

Table 2. Weed density (number/m²) and biomass (g·m⁻²) in 1997. Values are back-transformed means of log₁₀(x+1) transformed values.

Treatment	No. appl.	<i>Portulaca oleracea</i>		<i>Cyperus esculentus</i> & grasses		All weeds	
		Density	Biomass	Density	Biomass	Density	Biomass
Control		127 ab ^z	16.3 c	10 d	4.1 cd	157 a	21.8 cd
Rotary tiller	1	150 a	39.1 bc	11 b-d	0.8 d	180 a	42.0 bc
Glyphosate	1	25 e	2.4 d	22 b	3.1 cd	86 bc	8.5 d
	2	51 cd	1.3 d	47 a	5.0 b-d	131 ab	9.1 d
Flame	1	32 de	1.0 d	22 bc	10.4 a-c	71 c	11.1 d
	3	62 c	0.2 d	11 cd	0.6 d	79 c	0.7 e
Tine weeder	1	---	173.0 a	---	34.0 a	---	269.0 a
	3	81 bc	67.4 ab	21 b-d	24.0 ab	140 a	136.1 ab

^zMean separation within columns by LSD, *P* ≤ 0.05.

Table 3. Weed density (number/m²) and biomass (g·m⁻²) in 1998. Values are back transformed means of log₁₀(x+1) transformed values.

Treatment	No. appl.	<i>Portulaca oleracea</i>		<i>Stellaria media</i>		Annual grasses		All weeds	
		Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
Control		252 a ²	18.6 bc	539 a	7.0 b	10 ab	5.5 ab	965 a-c	37.2 bc
Rotary tiller	1	244 a	20.8 bc	356 ab	9.7 b	14 ab	3.4 a-c	1190 ab	49.7 b
Glyphosate	1	60 c	1.2 e	105 c	0.5 d	3 b	0.2 c	546 a-c	3.4 e
	3	139 ab	9.8 cd	111 c	0.7 cd	17 a	1.6 bc	697 a-c	14.8 d
Flame	1	67 c	7.6 d	122 c	0.9 cd	13 ab	2.6 a-c	490 bc	16.3 d
	3	114 bc	11.3 b-d	159 bc	2.4 c	10 ab	1.9 bc	357 c	20.0 d
Tine weeder	1	245 a	101.0 a	418 a	22.3 a	26 a	10.6 a	1280 ba	169.0 a
	3	114 bc	23.3 b	347 ab	6.3 b	9 ab	1.4 bc	869 a-c	43.8 bc
Spring tooth	3	197 ab	10.7 b-d	537 a	9.2 b	6 ab	0.2 c	1518 a	24.3 cd

²Mean separation within columns by LSD, $P \leq 0.05$.

were reduced relative to the standard practice treatments (Tables 2 and 3). A single, delayed flame or glyphosate treatment was usually as effective as multiple treatments. Apparently, 4 weeks was not sufficient time for the weeds to grow large enough to escape the effects of a single treatment.

The flexible tine weeder was ineffective in this study, mostly because poor penetration on crusted soil resulted in many weed escapes (Tables 2 and 3). The silt loam soils common in New York State are prone to crusting. The springtooth harrow easily penetrated the soil crust. However, it disturbed the soil more, and apparently brought buried weed seeds to the surface. Consequently, three weekly passes with the springtooth harrow failed to reduce weed densities relative to the control treatment (Table 3). Cultivation for stale seedbed management of weeds apparently requires an aggressive tool that works only the topmost layer of soil. Some growers use basket weeders for stale seedbeds on soils similar to the type used in these experiments.

Annual broadleaf weeds were reduced most by the flaming and glyphosate treatments, and thus appear to be the best candidates for management with stale seedbeds. However, since annual grasses were only abundant in 1998, more work with these species is needed. Studies on stale seedbed systems for rapeseed (*Brassica napus* L.) in Alberta (Darwent and Smith, 1985) and soybean in Louisiana (Lanie et al., 1994) demonstrated substantial control of wild oat (*Avena fatua* L.) with cultivation and barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] with nonresidual herbicides. Thus, stale seedbed is not necessarily incompatible with control of annual grasses. Yellow nutsedge is moderately resistant to glyphosate, and its primary shoot meristem remains below ground for several weeks after leaf emergence and is therefore protected from damage by flaming. Also, its large storage tuber probably facilitates recovery after physical damage by cultivators, and it can emerge from tubers buried beyond the reach of tine cultivators (Bell et al., 1962). Consequently, that yellow nutsedge was not controlled by stale seedbed treatments is not surprising (Table 2). The greater density of yellow nutsedge in the glyphosate and single flaming treatments relative to the control may have resulted from release of additional buds following damage to shoots. Relaxed competition due to the elimination of annuals was probably not the cause of the observed increase in yellow nutsedge in these treatments since the

Fig. 1. Mean density of seedlings inside and outside of the seeder tracks. Comparisons marked with an asterisk are significant at $P < 0.05$.

annuals were still small at the time of the weed count; even 2 weeks later total biomass of the control was only 22 g·m⁻².

In the experiments reported here, final seedbed preparation and simulated planting were timed to correspond with planting dates for late season cole crops (*Brassica* sp.), spinach (*Spinacia oleracea* L.), lettuce, summer squash (*Cucurbita pepo* L.), beans (*Phaseolus vulgaris* L.), beets (*Beta vulgaris* L.), and some herb species. The stale seedbed approach may be best suited for late-planted crops, since plenty of time is available for application of cultivation and rest periods prior to planting. Additional research is needed for earlier planting times.

Broadleaf weed densities were generally two to three times as high in seeder tracks than outside of the tracks (Fig. 1). By firming the row for better crop emergence, the seeder press wheel apparently also created better conditions for weed emergence. Unfortunately, weeds in the crop row compete most intensively with crops and are harder to remove with cultivation than are between-row weeds. The higher density of broadleaf weeds in the seeder tracks suggests that seeder design may influence subsequent weed pressure on the crop. Modification of seeders so that soil around the crop seed was firmed but a layer of loose soil was left on the surface could potentially reduce germination of small-seeded weeds like common purslane and common chickweed without inhibiting emergence of large-seeded crops.

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