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No-Till Establishment of Perennial, Warm-Season Grasses for Biomass Production

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ABSTRACT

*Herbaceous biomass crops have the potential to capture solar radiation and store energy as a renewable fuel resource. Establishment procedures that can be used successfully without damage to the environment are essential. The objective of this research was to develop procedures to establish perennial, warm-season grasses, such as switchgrass (*Panicum virgatum *L.) and lovegrass (*Eragrostis curvula *L.), without tillage and preparation of a fine seedbed. Two applications of paraquat spaced 3 weeks apart or a single application of glyphosate can be used to suppress sod before no-till plantings. Carbofuran applied in the row at 1·1 kg ha^{-1} with the seed increased seedling vigor and populations. Application of 1·1 kg ha^{-1} of atrazine when seedlings began to emerge provided post-planting weed suppression. Weed encroachment occurring in years after establishment was halted by 2 kg ha^{-1} of simazine applied before first growth in the spring. These data provide guidelines for successful establishment of herbaceous perennial, warm-season grass biomass crops.*

Key words: conservation tillage, soil erosion, biomass crops, herbicides, insecticides, switchgrass, lovegrass, tall fescue, *Panicum virgatum* L., *Eragrostis curvula* L., *Festuca arundinacea* (Shreb.).

INTRODUCTION

Capture of solar radiation through photosynthesis and subsequent biomass production constitutes a renewable energy resource. If suitable energy cropping systems can be developed, marginal (often idle) agriculture land can be made energetically and economically productive. Establishment is a first priority for utilizing land resources for production of herbaceous biomass crops. In many cases, the land to be

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dedicated to energy cropping is sloping and therefore subject to erosion. Establishment is particularly problematic in such situations, but perennial species have special advantages if they can be successfully established. On erodible land, sowing is best done using equipment that allows proper seed placement without tillage. The term 'no-till' is used here to distinguish it from minimum or conservation tillage practices which disturb the soil, but leave some residue on the surface. No-till establishment has been widely adapted for several row crops, but only recently has the technology been adapted for perennial, warm-season grasses that can be used for biomass production. Sowing without tillage typically requires herbicidal, as opposed to mechanical, control of vegetation growing in a field before sowing.[1] Prominent in the no-till methodology are paraquat (1,1-dimethyl-4,4-bipyridinium chloride) and glyphosphate (*N*-(phosphonomethyl) gylcine) which have been shown to be effective herbicides for control for vegetation present before sowing.[2-4]

Establishment often poses a major problem with the herbaceous, warm-season species. Conventional planting methods often result in establishment failures or the need to wait for two complete growing seasons before strong stands develop. No-till planting typically provides for greater soil moisture retention and a reduction of soil erosion when compared with conventional seeding methods and, consequently, can hasten or improve establishment.[5] The objective of this research was to develop no-till establishment procedures for the production of perennial, warm-season grasses as biomass crops.

METHODS AND MATERIALS

All plantings were made with a no-till drill equipped with bands attached to the double-disk openers that regulated seed placement to a 3-cm depth. Granular insecticides, when used, were metered into the row along with the seed. Herbicides and insecticides, when broadcast sprayed, were applied in 280 liters of water per hectare using 276 kPa pressure and flat fan nozzles with a back-pack sprayer. All experiments included four replications using a randomized complete block design. Harvests for biomass yield (dry basis) were made with a mower by removing a 1·5 m × 5·7 m strip. All data were subjected to an analysis of variance and all differences were considered to be significant at the 0·05 level.

Insecticide influence

Switchgrass (*Panicum virgatum* 'Pathfinder') was no-till planted on 15 May 1987. Treatments included carbofuran (2,3-dihydro-2,2-dimethyl-7 benzofuranyl methylcarbamate) as granules in the row at 1·1 kg ha^{-1} and a flowable formulation broadcast at 2·2 kg ha^{-1} after planting. Also, chloropyrifos [*O,O*-diethyl-*O*-(3,5,6-trichloro-2-pyridyl)-phosphorothioate] was applied as granules at 1·1 kg ha^{-1} in the row to determine the influence of an insecticide on establishment. Plant populations were determined and seedling vigor was rated 4 weeks after planting. Accumulated biomass was measured on 11 August 1987.

Weed control during establishment

Switchgrass ('Cave-in-rock') was planted on 16 May 1987 into an area that had previously been treated with 2,4-D (2,4 dichloro phenoxy acetic acid) and a dual application of paraquat to eliminate existing vegetation.[6] Atrazine [2-chloro-4-(ethylamino)-6-isopropylamine-*S*-triazine] was applied either 2 weeks before planting, at planting, or when new seedlings were about 2 cm tall. The atrazine was broadcast applied at 0, 1·1 or 2·2 kg ha^{-1} at each application time. Population and vigor ratings of switchgrass seedlings and estimates of weed control were made on 13 June 1987. Biomass yield and botanical composition were determined from a harvest on 7 August 1987.

Weed control in established stands

A 2-year-old stand of switchgrass in an area that had a high potential for a weed infestation was treated with broadcast applications of atrazine or simazine [2-chloro-4,6-bis(ethylamino)-*S*-triazine] at 0, 1·1, 2·2 or 4·4 kg ha^{-1} when initial spring growth of the switchgrass was approximately 5 cm tall on 15 May 1987. Measurements included estimates of weed control and biomass on 24 July. Early influence of herbicides on plant development was indicated by leaf elongation rates calculated from daily measurements of the length of leaves 5, 6 and 7 during 18 days beginning on 5 May. Height above the ground of each leaf tip was measured after emergence from the whorl. Heights of leaf tips above the ground were summed and considered as total leaf length. Leaf elongation rates were obtained from the slope of regression analyses using daily measurements of total leaf length.

Species establishment for biomass production

A species screening study was initiated in 1985 to compare the biomass productivity of several perennial, herbaceous crops on marginal sites in the Piedmont region of Virginia. Sites were characterized by sloping, eroded and acidic soils. The biomass crops included weeping lovegrass (*Eragrostis curvula*) and switchgrass no-till planted in early June of 1985. Tall fescue (*Festuca arundinacea*), a common cool-season forage species, was no-till planted in early September of 1985. Tall fescue was used in the comparison because of familiarity with its production and establishment. Twelve experiments were conducted on sites underlaid by Appling (three sites), Cecil (six sites) and Davidson (three sites) soils. The Appling sandy loam (fine-loamy, kaolinitic, thermic, typic Hapludult) study sites were on 7–10% slopes which occur in Lunenburg County, Virginia. Lunenburg County is in the south central Virginia Piedmont. The Cecil sandy loam (clayey, kaolinitic, thermic, type Hapludult) study sites were on 9–12% slopes in Amelia County, located in central Virginia Piedmont. The Davidson clay loam (clayey, oxidic, thermic, rhodic Paleudult) sites were on 7–9% slopes in Orange County, located in northern Virginia Piedmont. Previously accumulated vegetation on each site was removed to leave a 5-cm stubble in mid-May of 1985. Glyphosphate was broadcast sprayed in early June to suppress existing vegetation. Each species was planted into 4·2 m × 6·0 m plots in mid-June. Granular carbofuran was applied in the row with the seed at 1·1 kg ha^{-1}. Biomass was harvested in early November 1986.

RESULTS AND DISCUSSION

Insecticide influence

Carbofuran granules applied at 1·1 kg ha^{-1} in the row at seeding increased switchgrass seedling populations by nearly 50% compared to treatments receiving no carbofuran (Table 1). Broadcast placement of carbofuran as a spray was as effective as placement in the row. Chloropyrifos, an insecticide with a different mode of action, did not increase plant population. Carbofuran increased vigor rankings of seedlings by more than three-fold. Some increase in seedling vigor was also observed with chloropyrifos. These data and other studies by the authors[6,7] indicate that carbofuran increased plant populations, seedling vigor and biomass yields during establishment. Since chloropyrifos did not

TABLE 1

Seedling Populations and Vigor Rankings of 'Pathfinder' Switchgrass as Influenced by Carbofuran and Chloropyrifos Rates and Placement

Treatment		*Rate (kg ha⁻¹)*		
Insecticide	*Placement*	*0*	*1·1*	*2·2*
			Population[a] (no. m⁻²)	
Carbofuran	In row	177b*	258a	250a
	Broadcast	177b	—	262a
Chloropyrifos	In row	177b	178b	172b
			Vigor rank[b]	
Carbofuran	In row	2·7c	9·3a	9·2a
	Broadcast	2·7c	—	9·0a
Chloropyrifos	In row	2·7c	4·8b	5·4b

*Means within populations and vigor ranks follows by same letters do not differ significantly at the 0·05 level.

[a]Data are averages of no-till plantings on 2 and 15 May 1987 using 4·6 kg pure live seeds hectare^{-1}.

[b]Vigor rankings were averages of visual estimates (10 = best) made by two individuals.

influence seedling population and had less influence on vigor, it is speculated that carbofuran caused some response other than that attributable to its insecticidal action. These data indicate that, at least under similar conditions, carbofuran at 1·1 kg ha^{-1} applied at the time of seeding would benefit no-till establishment of switchgrass.

Weed control during establishment

Atrazine tended to decrease seedling populations and vigor when applied before or at planting, but it was beneficial when applied after seedling emergence had occurred (Table 2). Higher rates of the herbicide were required to control weeds when the herbicide was applied before planting than when it was applied post-emergence. Yields and percentage of switchgrass in the harvested biomass were increased by use of atrazine regardless of time of application, but the greatest benefit was obtained from application after planting. These data indicate that atrazine applied at 1·1 and 2·2 kg ha^{-1} shortly after emergence of switchgrass seedlings can increase biomass production, with 1·1 kg ha^{-1} resulting in the greatest benefit.

TABLE 2
Plant Population, Vigor, Weed Control, Yield and Botanical Composition of 'Cave-in-Rock' Switchgrass as Influenced by Rates and Times of Application of Atrazine

Time of application	*Rate of atrazine (kg ha⁻¹)*			*Regression coefficients*		
	0	*1·1*	*2·2*	*Inter.*	*Linear*	*Quad.*
Population (no. m^{-2})[a]						
Preplant	390a*	260b	200b	390*	−159	32
At planting	380a	150c	250b	382*	−390	160
Post-plant	340a	430a	370a	345*	150	−67
Vigor rank[a]						
Preplant	10·0a	6·2a	3·0b	10·0*	−4·0*	0·2
At planting	8·8ab	3·0b	1·2b	8·8*	−7·8*	2·0*
Post-plant	7·8b	8·8a	8·2a	7·8*	1·8	−0·8
Weed control (rank)[a]						
Preplant	0·0b	7·0a	8·8a	0·0	11·1*	−3·4*
At planting	1·4a	8·2a	8·8a	1·7	9·4*	−2·9*
Post-plant	0·0a	8·4a	8·9a	0·0	11·6*	−3·6*
Biomass dry wt (Mg ha^{-1})[b]						
Preplant	3·02a	5·00b	3·20b	3·00*	3·86*	−1·88*
At planting	2·42a	2·82c	3·00b	2·41	0·49	−0·09
Post-plant	1·72c	7·30a	4·26a	1·72	10·08*	−4·40*
Botanical composition (%)[b]						
Preplant	35a	65b	55b	35	50	−20
At planting	28a	52b	45b	28	41	−16
Post-plant	20a	100a	100a	20	120*	−40*

*Means within a column of any measurement followed by the same letter do not differ at the 0·05 significance level; also indicates significance of regression coefficients at, or less than, the 0·05 level.
[a]Seedling counts, vigor (10 = best) and weed control (10 = few weeds) were measured on 13 June after 16 May 1987 no-till planting.
[b]Yield and botanical composition (% switchgrass) were determined on 11 August 1987.

Weed control in established stands

Unpublished data obtained from previous studies indicated that simazine did not influence the biomass productivity of established, weed-free switchgrass. In the present study, where triazine herbicides were applied to a 2-year-old switchgrass stand, atrazine and simazine were both effective in suppressing weeds. Simazine was more effective than atrazine in suppressing weeds when evaluated on 3 June. Evaluation of weed control on 24 July indicated that atrazine no longer suppressed weeds except for a slight benefit at the highest rate of 4·4 kg ha^{-1} (Table 3). Leaf elongation rate (LER) during spring-time tiller development indicated that neither of the herbicides was detrimental to switchgrass growth, even at the 4·4 kg ha^{-1} rate when compared with the control. Regression analyses indicate no differences in LER with increasing atrazine rates. A quadratic response to increased simazine rates indicated the highest LER (10·9 mm day^{-1}) occurred at 2·2 kg ha^{-1}. Decreased LER at 4·4 kg ha^{-1} simazine may have been caused by toxicity of the herbicide, since no weeds were present to compete for soil moisture. Biomass yields of switchgrass increased as the application rate of simazine increased, with a slight increase occurring from 2·2 as compared to 4·4 kg ha^{-1} application (Table 3). Predictions from regression equations indicate that simazine applied at 2·0 kg ha^{-1} during spring emergence of established switchgrass would suppress weeds adequately and result in maximum biomass yields (5·75 Mg ha^{-1}).

TABLE 3

Weed Control, Total Biomass Yield (Includes Weeds) and Leaf Elongation Rate (LER) as Influenced by Atrazine and Simazine Application to an Established Stand of Switchgrass

Herbicide	*Herbicide rate (kg ha^{-1})*				*Regression coefficients*		
	0	*1·1*	*2·2*	*4·4*	*Inter.*	*Linear*	*Quad.*
Weed control (rank) 3 June 1987[a]							
Atrazine	1·7a*	3·3b	4·0b	5·3b	7·9*	−0·4	−0·07
Simazine	1·5a	6·0a	7·7a	8·7a	7·5*	−4·2*	0·67
Yield (Mg ha^{-1}) 24 July 1987							
Atrazine	3·40a	3·90a	4·41b	4·17b	3·38*	0·77	−0·13
Simazine	3·52a	4·41a	5·49a	5·70a	3·47*	1·35*	−0·20
Weed control (rank) 24 July 1987[a]							
Atrazine	1·8a	1·7b	2·0b	3·7b	8·6*	−0·1	−0·11
Simazine	1·8a	4·3a	7·0a	9·0a	7·8*	−2·8*	0·27
LER (mm day^{-1})[b]							
Atrazine	8·4a	9·8a	9·9a	8·8a	8·1*	1·8*	−0·42*
Simazine	8·4a	9·1a	10·1a	7·2b	8·5*	1·6*	−0·47*

*Means within a column followed by same letters do not differ at the 0·05 significance level; also indicates significance of regression coefficients at, or less than, the 0·05 level.

[a]Weed control ranking was a visual score (10 = few weeds).

[b]Leaf elongation rates were calculated from daily measurements of leaf lengths 5, 6 and 7.

Establishment for biomass production

Excellent stands of switchgrass and lovegrass were established by no-till planting on three different soil types over 12 sites in a 1985 planting (Table 4). Tall fescue establishment was not successful on two sites with Davidson soils. Biomass accumulation for tall fescue during June through September was less than 25% of that achieved by the two warm-season perennial grasses.

TABLE 4
Biomass Production in 1986 of Tall Fescue, Switchgrass and Weeping Lovegrass Planted in 1985 into Three Soil[a] Types Using No-Till Procedures

Soil[b] type	*Tall fescue (Mg ha⁻¹)*	*Switchgrass grass (Mg ha⁻¹)*	*Weeping lovegrass (Mg ha⁻¹)*
Davidson	0·8d*	5·8b	5·6b
Cecil	2·0c	8·0a	8·2a
Appling	0·8d	4·2b	7·6a

*Means within columns followed by same letters do not differ at the 0·05 significance level.

[a]Appling is a sandy loam (fine-loamy, kaolinitic, thermic, typic Hapludult), Cecil is a sandy loam (clayey, kaolinitic, thermic, typic Hapludult) and Davidson is a clay loam (clayey, oxidic, thermic, rhodic Paleudult).

[b]Data are averages of three experiments each for Davidson and Appling soils and six for Cecil soils.

These data and experience by the authors from other plantings using similar methods indicate that the no-till technology can be used successfully for establishment of perennial, herbaceous biomass crops such as switchgrass. Additionally, soil erosion estimates made from the Universal Soil Loss Equation[8] indicated a loss of 1·2 Mg ha^{-1} year^{-1} from the no-till establishment method as compared with an average of 22 Mg ha^{-1} year^{-1} of soil loss that could be anticipated following conventional establishment on our sloping sites.

Summary

No-till planting resulted in excellent stands and yields of two herbaceous, perennial biomass crops. Suppression of competitive plant species before planting was successful using either glyphosate (one application)

or paraquat (two applications 3 weeks apart). Use of 1·1 kg ha^{-1} of carbofuran resulted in increased seedling populations and vigor of switchgrass. Atrazine applied at 1·1 kg ha^{-1} as a broadcast spray reduced weeds and improved first-year biomass. Simazine applied to established switchgrass stands reduced weeds without reducing plant growth rate or biomass yields. Additional experience by the authors supports a recommendation for paraquat application at 0·26 kg ha^{-1} along with the simazine if cool-season weeds are present that might cause competition before activation of the simazine. If paraquat is used, the application should be made when switchgrass tillers first emerge in the spring. Additional research is needed to evaluate the response of other perennial warm-season crops to these recommended practices.

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