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Assessing winter cereals as cover crops for weed control in reduced-tillage switchgrass establishment

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ABSTRACT

Weed pressure is a major challenge in switchgrass (*Panicum virgatum* L.) establishment. The objective of this study was to assess whether cereal cover crops alone can control weeds and improve switchgrass stand establishment in reduced-tillage system or whether herbicide treatments should be applied. Field experiments were conducted at the University of Massachusetts Agricultural Experiment Station in Deerfield in 2010–2011 and 2012–2013 growing seasons. A split plot design with three replications was used. The main plots consisted of three cover crop treatments [fallow, oat (*Avena sativa* L.) and rye (*Secale cereale* L.)]. The sub-plots were herbicide treatments that consisted of no herbicide or post-emergence application of atrazine (A) (1.1 kg a.i. ha^{-1}) and quinclorac (Q) (0.37 kg a.i. ha^{-1}). Herbicides were applied when switchgrass was at 4-leaf stage (6 weeks after planting). Switchgrass tiller density was 100% improved with application of A + Q. Rye provided more effective weed control than oat; however, tiller density of switchgrass was also lower in rye treatment compared with oat and fallow. Switchgrass biomass yield was significantly lower in nontreated herbicide plots (0.22 Mg ha^{-1}) than plots receiving A + Q (0.41 Mg ha^{-1}). Our findings suggested that supplemental herbicide application is needed with using cover crops to improve switchgrass establishment.

1. Introduction

Switchgrass (*Panicum virgatum* L.) is a warm season C_4 perennial grass with a deep fibrous root system native to North America (Herbert et al., 2012; Sadeghpour et al., 2014a) often used either as an energy crop or to improve degraded soils (Sanderson et al., 2006; Anderson et al., 2013). Switchgrass is a week competitor with several warm-season annual grasses and broadleaf weeds because of its relatively small seed size, high dormancy rate, and slow germination (Duclos et al., 2013; Sadeghpour et al., 2014b,e). As a result, switchgrass establishment is challenging and stand failure often limits large scale crop adoption (Parrish and Fike, 2005; Berti and Johnson, 2013).

An integrated management practice is required to suppress weeds and therefore improve switchgrass stand establishment. Weed control with herbicides in conjunction with other management practices such as cover crops may significantly improve establishment success (Mitchell et al., 2010; Curran et al., 2012). Quinclorac controls a number of annual broadleaf and grass weeds, and has been recently registered for use in switchgrass (Boydston et al., 2010; Curran et al., 2011, 2012). Atrazine can be used also in some states in USA to control broadleaf weeds in switchgrass (Hashemi and Sadeghpour, 2013; Sadeghpour et al., 2014f). Mitchell et al. (2010) reported that a combination of A + Q provided satisfactory weed control for establishing both lowland and upland switchgrass cultivars in the Central and Northern Great Plains.

In row crop production systems, cereal cover crops play an integral role in controlling weeds (Blackshaw et al., 2006). Cereals are fast growing species which can produce high biomass and suppress weeds (Esmaeili et al., 2011; Jahanzad et al., 2013, 2014; Sadeghpour et al., 2013, 2014d). Among cereal cover crops, rye is the most widely used crop planted to recover nutrients and control weeds (Hashemi et al., 2013; Sadeghpour et al., 2014c). Several studies have shown weed suppression potential of rye in row crop production (Dhima et al., 2006; Mirsky et al., 2011; Ryan et al., 2011). Weed biomass reduction has also been reported with planting oat (*Avena sativa* L.) (Campiglia et al., 2012; Flower et al., 2012). Sadeghpour et al. (2014c) showed that switchgrass establishment was improved

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when it was no-till seeded into winter-killed oat cover crop. However, the literature is lacking data on the use of cover crops in reduced tillage systems to establish switchgrass specifically in the northeast region in USA. Therefore, the primary objective of this study was to assess whether cover crops alone could control weeds in switchgrass established with reduced tillage or whether a supplemental herbicide application would be required to successful switchgrass establishment.

2. Materials and methods

2.1. Experimental site

Field experiments were conducted in 2010–2011 and 2012–2013 growing seasons at the University of Massachusetts Agricultural Experiment Station Farm in South Deerfield located in the Connecticut River valley (42°28′37″ N, 72°36′2″ W). The soil type was Hadley fine sandy loam (mesic Typic Udifluvent). Soil samples were collected from 0.2 m depth. Soil pH was 6.7 with the organic matter of 1.4 g kg^{-1}. Soil nitrate, phosphorus, potassium, calcium, and magnesium was 13, 10, 38, 1105, and 132 mg kg^{-1}.

2.2. Experimental design and cultural practices

The experimental design was split plot design with three replications. The main plots consisted of three cover crop treatments (fallow, oat and rye) seeded the prior fall before the spring seeding of switchgrass. The sub-plots were herbicide treatments consisting of no herbicide and the application of a post-emergence mix of atrazine (2-chloro-4-ethylamino-6-isopropyl-amino-s-triazine) (1.1 kg a.i. ha^{-1}) and quinclorac (3,7-dichloro-8-quinolinecarboxylic acid) (0.37 kg a.i. ha^{-1}).

Winter rye and oat were drilled in mid-September (15th in 2010 and 10th in 2012, respectively) at the rate of 112 and 96 kg ha^{-1}, respectively. Oat and rye biomass were 1.6 and 2.4 Mg ha^{-1} in 2011 and 1.8 and 3.05 Mg ha^{-1} in 2013, respectively. Oat biomass was sampled in late-November while Rye was sampled in mid-May. Differences in cover crop biomass yield were due to rye re-growth after April. Oat often produces more biomass before winter whereas, most of rye growth happen after April. Oat was winterkilled, whereas winter rye and weeds in no cover crop plots were suppressed by an application of glyphosate [N-(phosphonomethyl) glycine] at a rate of 0.84 kg a.i. ha^{-1} in spring. Plots were disked two times to reach approximately 30% residue cover. An upland switchgrass variety 'Cave-in-Rock' was planted at a rate of 9 kg ha^{-1} pure live seed on 23 June in 2011 and in 5 July 2013. A Great Plains no-till drill modified for small plot research (Kincaid Manufacturing, Haven, KS) was used to plant switchgrass. The planter had seven rows with 15-cm row spacing. The plot size was 3 m wide and 6 m long. Herbicides were applied post-emergence with a custom-made sprayer approximately 6 weeks after switchgrass was planted (approximately 4-leaf stage). The plots were sprayed at 9.1 kg boom with xr8005 teejet nozzles (Spraying System, Wheaton, IL, USA). For each 0.4 ha, 0.11 m^{-3} water was used. In current study, no nitrogen fertilizer was applied due to lack of switchgrass response to switchgrass in previous studies in the study location (Sadeghpour et al., 2014a) and observing stand failure as a result of N application in the establishment year (Sadeghpour, unpublished data). According to typical agronomic practices in Massachusetts, no irrigation was applied to the experimental sites (Farsad et al., 2012).

2.3. Measurements

Cover crop biomass was harvested from the center rows with a hand mower (GS model 700, Black and Decker (U.S.) Inc., Towson, MD) at soil surface in late-November for oat and mid-May for Rye. Switchgrass tiller density was determined using five 0.1 m^2 quadrats from center rows of each plot approximately 6 weeks after herbicide application. Weed biomass was collected from five 0.1 m^2 quadrats from center rows of each plot using a hand mower (GS model 700, Black and Decker (U.S.) Inc, Towson, MD) at 10-cm height when tiller density was counted (Mid-September). At sampling time, 1.5 m from top and bottom of each plot was considered as border. Weed samples were dried in a forced air oven at 55 °C for 72 h and weighed. Switchgrass yield was determined from biomass samples collected using five 0.1 m^2 quadrats from the center rows of each plot in early November in 2013.

Table 1
Monthly growth degree days ($GDD_{10°C}$) and precipitation during 2011 and 2013 growing season at the experimental site.

Months	$GDD_{10°C}$		Precipitation (mm)	
	2011	2013	2011	2013
July	412	790	54	123
August	344	591	181	104
September	256	350	193	98
October	52	142	139	25
Total	1046	1873	567	350

2.4. Statistical analysis

All statistical was analyses were performed using GLM procedures of SAS, Version 9.2 (SAS Institute, 2009). Year, cover crops and herbicide treatments were considered fixed effects and only block was considered as random effect. Data were subjected to normality test and non-transformed data were used due to normality of residuals. Means were compared using the Duncan multiple range test. All differences reported are significant at $P \leq 0.05$ unless otherwise stated.

3. Results and discussion

3.1. Weather conditions

Cumulative growing degree days (GDD), observed from the Orange, MA, weather station, for 2011 and 2013 growing seasons (July through Oct) were 1046 and 1873, respectively (Table 1). Cumulative growing season precipitation was 567 mm in 2011, and 350 mm in 2013. Precipitation during the seeding month (July) was much higher (123 mm) in 2013 compared with 2011 (54 mm) which could explain year-to-year variation and the significant interaction of year by treatments.

3.2. Switchgrass density

Switchgrass tiller density was significantly influenced by year, herbicide treatment and interaction of year by herbicide and cover crop by herbicide treatments (Table 2). In 2011 switchgrass biomass yield was lower (0.27 Mg ha^{-1}) than that of 2013 (0.35 Mg ha^{-1}). Herbicide application (A + Q) significantly increased tiller density in 2011 (85 tiller m^{-2}) and 2013 (58 tiller m^{-2}) compared with plots that were not treated with herbicide (41 and 36 tiller m^{-2} in 2011 and 2013, respectively) (Table 3). The major weeds in the switchgrass stands were crabgrass (*Digitaria sanguinalis* L.) and yellow foxtail (*Setaria glauca* L.), which significantly competed with germinated switchgrass seedlings. Some reports indicated that herbicide application (quinclorac) may negatively impact the switchgrass stands. For example Curran et al. (2012) and Boydston et al. (2010) showed that post-emergence application of quinclorac reduced switchgrass stand which might be attributed to higher herbicide rates (0.56 and 0.42 kg a.i. ha^{-1}, respectively) in their studies