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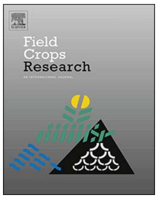

Growth performance and weed control effect in response to nitrogen supply for switchgrass after establishment in the semiarid environment

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ABSTRACT

Switchgrass (*Panicum virgatum* L.) adapts to a wide range of environments. It has been successfully planted in a semiarid region of China's Loess Plateau as a valuable forage species for restoring vegetation of grassland. However, growth performance of switchgrass needs to be further evaluated after establishment. Relationships between switchgrass growth and outcomes of weed control in terms of nitrogen (N) supply are especially not well understood. Field studies were conducted in 5-year and 8-year switchgrass stands at two semiarid sites. Nitrogen fertilizer (ammonium nitrate) was supplied at rates equivalent to 0 kg N ha^{-1}, 120 kg N ha^{-1}, and 240 kg N ha^{-1} in switchgrass stands consisted of three upland cultivars (Blackwell, Cave-in-Rock and Pathfinder). A split-plot experimental design was employed with 3 replications. Switchgrass and its associated weed growth were assayed. Switchgrass growth and production were generally improved with N rate increasing, although there were some cultivar and location variations. Cave-in-Rock switchgrass had advantages over other cultivars in plant height, biomass and seed production, as well as weed control effect. The N rate of 120 kg N ha^{-1} was suggested for seed production of switchgrass. In switchgrass stands, weed density was increased with N rate increasing, whereas biomass was decreased. Weed density was positively related with switchgrass height ($P < 0.05$), whereas weed biomass were negatively regressed with switchgrass height, tiller density and biomass ($P < 0.05$). These results demonstrate that N supply is necessary for established switchgrass stands, because there are production and weed control benefits from fertilizing switchgrass with N supply rate of 240 kg N ha^{-1}. Practical implications of this study are that culture practices, such as cultivars selection, N management and integrated weed management strategy will contribute to the productivity of established switchgrass stands in the semiarid Loess Plateau.

1. Introduction

Switchgrass (*Panicum virgatum* L.) is a warm-season perennial grass which is indigenous to North America tallgrass prairie (Muir et al., 2001). Switchgrass is proposed one of the most valuable energy crops for a high biomass yield because it adapts to a wide range of climates (Parrish and Fike, 2005; Wright and Turhollow, 2010). Along with the high yield potential and cost-effective growth characteristics, some switchgrass cultivars have recently been cultivated as a forage grass for ecological restoration because of its tolerance to water and nutrient limitations on China's Loess Plateau (Ma et al., 2011). Among the introduced cultivars, the upland ecotypes are proposed adapted cultivars with high photosynthetic rate and water use efficiency, and thus produce greater biomass yields (Ma et al., 2011; An et al., 2013). Focusing on the use of switchgrass for biomass production has raised questions about optimal management practices for this use (Muir et al., 2001).

Nitrogen (N) fertilization is considered one of the principal management practice for switchgrass biomass production and feedstock quality (Sanderson and Adler, 2008; Wang et al., 2010). To date, there is a large body of works have investigated biomass production of switchgrass responses to N fertilizer addition (Muir et al., 2001; Heaton et al., 2004; Parrish and Fike, 2005; Tulbure et al., 2012; Pedroso et al., 2013). Previous studies suggest that switchgrass cultivation for feedstock use without N fertilization would be impracticable (Sanderson and Adler, 2008; Wang et al., 2010; Vogel et al., 2002). The sustainable switchgrass yields may be achievable with as little as 50 kg N ha^{-1} yr^{-1} (Parrish and Fike, 2005). Research carried out in the southern American indicates that 168 kg N ha^{-1} is an optimum N level for switchgrass biomass production on low fertility soils (Muir et al., 2001). Mulkey et al. (2006) demonstrate that N fertilization at the rate of no more than

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112 kg ha^{-1} is recommended when once annually is used to optimize biomass production in South Dakota. N fertilizer rates ranging from 0 to 300 kg N ha^{-1} yr^{-1} result in a linear increase in switchgrass yields in warmer locations in the second and third years (Pedroso et al., 2013). It is most likely that N fertilization plays a central role in contributing to high biomass production. However, a study finds no response to N supply, suggesting that N fertilization may not be required for switchgrass growth (Christian et al., 2002). Therefore, N fertilization requirements for switchgrass still remain uncertainty (Nikièma et al., 2011). Limited information is available concerning the effects of N fertilization on switchgrass growth and production in the semiarid environments with nutrients and water deficiency.

In addition to production improvement, fertilizer management may create the regulation for crop-weed interference, which is largely depending on the availability of essential nutrients (Teyker et al., 1991; Di Tomaso, 1995). N supply is reported to noticeably influence the critical period for weed control in corn (Evans et al., 2002). In wheat fields, weed competition and competitive ability are directly correlated with N supplement (Iqbal and Wright, 1997). Increasing N rates supplied to winter wheat decreases annual weed populations and production (Valenti and Wicks, 1992). Applying N fertilizer in spring improves initial growth of winter rye and winter barley more than that of the weeds, and gives them competitive advantages over weeds in the fields (Melander et al., 2005). In particular, N fertilizer application can increase the leaf area index and light interception of crops, resulting in the better weed control and higher yields (Olasantan et al., 1994). Otherwise, optimal placement of N fertilizer also improves early N uptake and growth of crop, and then the crop's competitiveness with weeds is enhanced (Petersen and Mortensen, 2002). Managing for increased competitive ability of crops against weeds is considered an important component of integrated weed management systems (Gill et al., 1997). Such culture practices will provide a more stable and long-term management of weeds, and integrated weed management systems have the potential to reduce external inputs and production costs (Sheibani and Ghadiri, 2012).

Existing studies have mainly focused on improvement in switchgrass stand establishment through certain weed management (Miesel et al., 2012; Sadeghpour et al., 2014), whereas the research on N supply on switchgrass-weed inferences after switchgrass establishment is lacking. In the semiarid Loess Plateau, cultivar characteristics and production practices for maximum biomass yields and integrated weed managements are likely to be different from those in more humid areas. Therefore, the field study was initiated to determine the response of some switchgrass cultivars and its associated weeds to various rates of N fertilizer when grown in a lowly productive soil. Our objectives were to address four applied questions: (1) how did N supply affect growth and production of 5-year and 8-year switchgrass in semiarid environment, (2) how did three switchgrass cultivars response to N supply, (3) how did N supply shift the weed control effect of switchgrass, and (4) were there relationships between switchgrass and weed growth in terms of N supply?

2. Materials and methods

2.1. Switchgrass cultivars

Switchgrass seeds were provided by Professor Nobumasa Ichizen, Utsunomiya University, Japan. The switchgrass cultivars in the study are Blackwell, Cave-in-Rock and Pathfinder. Ecotypes, ploidy levels and origins of the switchgrass cultivars are given in Table 1.

Table 1
Ecotypes, ploidy levels and origins of the switchgrass cultivars in this study.

Switchgrass cultivars	Ecotype	Ploidy	Origin
Blackwell	Upland	Octoploid (8n)	Northern Oklahoma 37°
Cave-in-Rock	Upland	Octoploid (8n)	Southern Illinois 38°
Pathfinder	Upland	Octoploid (8n)	Nebraska/Kansas 40°

2.2. Experimental sites

The experimental sites were selected in Dingbian County, Shaanxi Province, and Guyuan City, the Ningxia Hui Autonomous Region, China. Both experimental sites were located in the semiarid Loess Plateau. The Dingbian site has a continental, semiarid climate with mean altitude of about 1331 m. The soil type of this site is loessial soil. The weed species within switchgrass plots are *Pennisetum centrasiaticum* Tzvel., *Leymus secalinus* (Georgi) Tzvel., *Setaria viridis* (Linn.) Beauv., *Phragmites australis* (Cav.) Trin. ex Steud., *Artemisia scoparia* Waldst. et Kit., *Ixeridium chinense* (Thunb.) Tzvel., *Mulgedium tataricum* Linn. DC., *Gueldenstaedtia harmsii* Ulbr., *Lespedeza daurica* (Laxm.) Schindl., *Heteropappus altaicus* (Willd.) Novopokr., *Polygonum sibiricum* Laxm., *Polygonum sibiricum* Laxm., *Chenopodium glaucum* Linn., etc. The Guyuan site is located in the loess hilly and ridges region with the mean altitude of about 1597 m. Here the vegetation is typical grassy prairie steppe. The soil type of this site is the loessial soil transitions from common dark loessial type to lighter loesse. The weed species in this site include *Poa sphondylodes* Trin., *Leymus secalinus* (Georgi) Tzvel., *Artemisia scoparia* Waldst. et Kit., *Phragmites australis* (Cav.) Trin. ex Steud., *Stipa grandis* P. Smirn., *Medicago sativa* L., *Gueldenstaedtia harmsii* Ulbr., *Melilotus officinalis* (L.) Lam., *Trifolium pratense* Linn., *Ixeris chinensis* (Thunb. ex Thunb.) Nakai, *Plantago asiatica* Ledeb., *Aster altaicus* Willd., *Convolvulus arvensis* Linn., *Potentilla multifida* Linn., *Limonium bicolor* (Bunge) O. Kuntze, *Incarvillea sinensis* Lam., etc. The locations, climatic conditions and soil properties at two sites were given in Table 2.

To obtain the basic meteorological information during the growing season of 2013, the meteorological stations (HOBO weather station, Onset Computer Corporation, MA, USA) had been established at two experimental sites. The air temperature and precipitation during the growing season at the experimental sites were shown in Table 3. The mean monthly temperature during growing season was 16.7 °C at Dingbian site and 14.0 °C at Guyuan site. The total amount of precipitation during growing season was 291.8 mm at Dingbian site and 551.3 mm at Guyuan site, respectively. Precipitation of the middle growing stage (July) was much higher than that of other stages at two experimental sites, accounting for 37.5% and 42.8% of total precipitation of growing season in Dingbian and Guyuan, respectively. In general, the mean monthly temperature during growing season was higher at Dingbian site than that at Guyuan site, whereas the precipitation was much lower at Dingbian compared with that at Guyuan.

2.3. Experimental design and samples collection

Seeds of switchgrass were sown in separate 6 m × 5 m plots, with a depth of 3–4 cm and a row spacing of 40 cm, in the spring of 2006 at Guyuan, and in the spring of 2009 at Dingbian. Each cultivar has three replicate plots. The seeding rate was 10 kg of pure live seed ha^{-1} (Vogel, 1987). All the plots were mulched with wheat straw to conserve soil moisture until seedlings emerged. The plots were unfertilized during 2006–2012 growing seasons at Guyuan and 2009–2012 growing seasons at Dingbian, and irrigated only during the first growing season to help with stand establishment. All the switchgrass were removed at the ground level at the end of growing season.

Field evaluation of switchgrass and weed growth performance were conducted in the growing season of 2013. The experimental design was split-plot design with three replications. Cultivars were assigned to the main plots and N rates to the subplots. Each main plot consisted of three N rates (0, 120 and 240 kg N ha^{-1}). At 5th May 2013, N fertilizer (ammonium nitrate) was applied broadcast on the soil surface before raining.

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