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Performance of a No-tillage Seeder with Different Cover Crop Species and Residue Management for Sweet Sorghum for Sustainable Biofuel Production

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Abstract

The strategy for sustainable biofuel production should be compatible with increasing SOM (soil organic matter) to improve soil quality for biomass productivity and reducing purchased inputs for production. Combining cover crops with no-tillage offers many benefits for improving soil quality, but requires a higher level of management to achieve maximum benefit. This study evaluated the performance of a no-tillage seeder for sweet sorghum production and identified appropriate ways of using the no-tillage seeder with various amounts of cover crop residue. Previous field research revealed that using a medium (360 rpm) PTO rotational speed and mixed-seeding of rye and hairy vetch with a no-tillage seeder is effective for increasing sweet sorghum germination under cover crop residue mulch.

[Keywords] no-tillage, cover crop, residue management, PTO, power consumption, sweet sorghum, germination percentage

I Introduction

Sustainable biofuel production systems are desirable for building sustainable societies, and will have an important role for producing biofuel feedstock in this century. However, there are several obstacles that need to be overcome for producing biofuel, including the energy required for production of the biofuel feedstock. In general, tillage consumes 30 % of total energy required for crop production and no-tillage significantly reduces energy consumption (Sakai *et al*., 1998). Developing successful no-tillage systems is thus important for reducing energy consumption and maintaining soil organic matter in sustainable biofuel production.

Conventional tillage systems in Japan start with plowing to a depth of 30 cm with a moldboard plow or cultivating to a depth of 15 cm for rotary tillage in the fall or spring. Soils are then disked or cultivated in the spring once or twice to further break down aggregates and smooth the soil surface before planting (Gu *et al*., 2002). These treatments ensure the germination of crop seeds and enhance the mineralization of soil organic matter (SOM); however, many scientists and farmers have recently recognized that the conventional tillage system stimulates decomposition of SOM and increases the potential for soil erosion by wind and water (Magdoff, 1998).

Conservation tillage systems, including no-till, leave more surface residue because the soil is not turned over. These systems create less potential for soil erosion and therefore conserve SOM. Many studies on ecosystems under long-term management involving conventional tillage (CT) and no-tillage (NT) practices have demonstrated that tillage causes a substantial decrease of SOM content and mineralization of carbon (Elliott *et al*., 1994; McCarty *et al*., 1995; Six *et al*., 1999).

Japanese soils, especially Andisols, usually show great soil organic carbon (SOC) stock which ranges from 30 to 60 g kg^{-1} (Kusaba, 2001); therefore it is often difficult to increase SOC by adopting NT. Sakai *et al*. (1988) reported that there was no significant difference in SOC content between NT and CT for upland field production in a 7-year experiment. On the other hand, SOC accumulation in paddy fields occurred earlier and increased to a greater extent compared with upland fields after adoption of the NT system. Ito (2002), for example, reported a 63 % increase in SOC at 0 to 2 cm in the top soil layer 4 years after adopting the no-till system for paddy fields compared with the conventional tillage system in Furukawa, Japan. These results suggest that paddy fields have greater potential to conserve SOM because the decomposition of organic matter occurs more slowly under flooded conditions.

Cover crops are grown in addition to primary cash crops for the purpose of erosion control, organic N enrichment, conservation of soil organic matter, scavenging soil residual

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N, and nematode control (Komatsuzaki, 2004). Ismail *et al.* (1994) evaluated the long-term effects of tillage in continuous corn cropping with a rye (*Secale cereale* L.) cover crop in Kentucky, USA. SOC in the top 30 cm did not change from 1975 to 1980, but increased substantially from 1980 to 1989. Komatsuzaki and Mu (2005) evaluated the effects of tillage in continuous field rice cropping with rye and hairy vetch (*Vicia villosa* Roth) cover crops in the Kanto region of Japan. SOC in the top 0 to 2.5 cm increased compared with winter fallow 2 years after adopting cover cropping; however, other soil layers did not change.

On the other hand, in recent years, bio-ethanol production derived from biomass (corn, sugarcane, etc.) has increased remarkably, especially in North and South America. By 2010, approximately 19,500 mega gallons of bio-ethanol had been produced in the world (Renewable Fuels Association 2010).

In Japan, "on-site models" (small scale/dispersion types) for biofuel crop cultivation in various areas are recommended. One of the most promising biofuel crops is sweet sorghum (*Sorghum bicolor* Moench), which has been used as a forage crop. Its many advantages include considerable sugar production in its stem, a short growing period, wide cultivation area (from the tropics to throughout the temperate zone), and no adverse effects on local food crop production and economies (Kamiyama *et al*., 2008; Nitta *et al*., 2011). In addition, sweet sorghum has a high ability to absorb nutrients from surrounding soil, including excess nitrogen and phosphorus. Sweet sorghum cultivation has therefore attracted much attention not only as a forage and bio-remediation crop, but also for its potential for biofuel production.

The strategy for sustainable biofuel production should be compatible with increasing SOM to improve soil quality for sustaining biomass productivity and to reduce purchased inputs for production. These techniques will usually reduce chemical or organic nutrient inputs. In addition, cultivation of cover crops is a more attractive alternative because they have been shown to add organic matter to the soil (Wagger and Mengel, 1988; Shipley *et al*., 1992; McCrancken *et al*., 1994; Gu *et al*., 2004). These technologies should be used for biofuel production, but proper management techniques for no-tillage with cover crop are still not well understood for biofuel production.

In previous research (Zhao *et al*., 2009; 2012), the power consumption and performance of the no-tillage seeder was examined when seeding soybeans with various types of mulch of cover crop species and residue management. The performance of the no-tillage seeder was influenced by not only the cover crop species and management but also cover crop termination. To develop the sustainable biofuel production, appropriate cover crop residue management and no tillage seeder performance will be necessary. Especially, the difference of PTO speed may affect the performance of no tillage seeder and sweet sorghum germination under various cover crop residue managements.

The objectives of this study were: 1) to evaluate the performance of the no-tillage seeder for sweet sorghum production and 2) to identify appropriate ways of using the no-tillage seeder with cover crop residue mulch.

II Materials and Methods

1. Study site and field management

Study sites were established at the Field Science Research and Education Center, Ibaraki University College of Agriculture, in the Kanto region of Japan. The soil at each site was a clay loam humic Allophane (haplic Andosols). Experimental design was split-split plot with 3 replications, main treatment was cover crop species, and sub factor was cover crop residue amount and sub-sub factor was PTO speed. Each plot size was 4 m × 25 m. Cover crops of rye (*Secale cereale* L.), hairy vetch (*Vicia villosa* Roth.) and mixed seeding of rye and hairy vetch were used in the experiment, fallow plots were also added in the experiment. Cover crops were sowed on October 11, 2009 after rotary tillage at the seeding density of 50 kg/ha seeds in the hairy vetch plot, 100 kg/ha seeds in the rye plot, and 50 kg/ha hairy vetch seeds and 50 kg/ha rye seeds in the mixed-seeding plot. The cover crop was terminated on April 30, 2010 and planting using the no-tillage seeder was done on May 1.

Three types of cover crop residue management were adopted in the field: residue-free, standard amount and double residue amount. The residue-free treatment was established by mowing the cover crop with a flail mower (FNC1601, Matsumoto) and then removing residue but the stubble (stubble: less than 10 cm). For standard amount management, the cover crop was mowed and the residue was laid on the soil surface. For the double residue amount treatment, the cover crop was also mowed, and then the cover crop residue from the residue-free plot was evenly laid on the surface. Three PTO rotational speeds were used in the experiment by adjusting the engine of the tractor: low speed (PTO speed: 230 rpm), medium speed (PTO speed: 360 rpm) and high speed (PTO speed: 480 rpm).

Sweet sorghum (*Sorghum bicolor* Moench cv.*Big Sugar*) seed was used in the experiment. The sprouting percentage was 97 % tested in the laboratory and the sowing rate was also tested for calculating the germination percentage. Germination of sweet sorghum was investigated on May 18. The number of germinated plants was determined by counting and averaging plants in the 3rd and 4th rows.