Research article

Effects of Crimping by Oggun Tractor-mounted Roller/crimper on Cover Crop Termination, Soil Strength, and Soil Moisture in Upland Cambodia

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Abstract Rolling/crimping technology for terminating cover crops is essential to ensure that the rolled plant residue benefits both soil and succeeding cash crops. Cambodia has also adopted this technology, but it is still at the initial stage due to limited rolling services. The objectives of this study were to compare different roller-crimpers with the Oggun-mounted USDA roller-crimper in terminating sunn hemp (*Crotalaria juncea L.)* and to determine their effects on soil strength and soil moisture. The experiment was conducted in Rattanak Mondul, Battambang province in the wet season of 2019, using a randomized complete block design with three treatments having four replicates, each of which was 14 m x 34 m and spaced 5 m. The treatments consisted of (i) a USDA roller-crimper, mounted on 19-hp Oggun tractor, (ii) a Cambodian made roller-crimper with elliptic bars, and (iii) a disc-plow, both pulled by a 75-hp tractor. Plant height and biomass before rolling; soil strength at 0-10 and 10-20 cm depths before and after rolling; field operations; and soil volumetric moisture content (VMC) evaluated on the day of rolling, and then one, two, and three weeks after rolling, along with termination rate were analyzed. The results show that the height and biomass of sunn hemp were not significantly different among the treatments, being 164 cm and 2.57 t ha^{-1}. In Oggun crimping, speed and field efficiency were lowest, being 3.5 km h^{-1} and 0.8 ha h^{-1}, but fuel use was highest. Under plow-based management, soil compaction was slightly higher and termination rate was more efficient, when compared to other treatments. Significant difference was not observed for VMC between the equipment used. However, crimping can be beneficial for cover crop termination, compared with disking that may have long-term effects on the soil.

Keywords conservation agriculture, plant biomass, sunn hemp, termination rate

INTRODUCTION

Cover crops are an integral part of conservation agriculture (CA) and are planted to benefit the soil in numerous ways (Clark, 2012). Unlike CA, conventional tillage (CT) modifies the soil, adversely affecting soil physical, chemical, and biological properties (Acar et al., 2018). Technically, CT involves plow-based practices, leaving less than 30% of crop residue on the soil surface (Vian et al., 2009). In contrast, CA is defined as a farming system whose key principles are minimal soil disturbance, permanent plant cover, and crop diversification (FAO, 2016). It helps reduce soil erosion, run-off, soil temperature, and soil compaction, retain soil moistures, increase nitrogen in the soil, and

suppress weed (Balkcom et al., 2018; Mitchell et al., 2019). Because of its benefits, CA has been adopted in Cambodia since 2004 to improve soil fertility for upland crops; nevertheless, it is still considered an early stage at which rolling services remain inadequate.

There are many kinds of cover crop available in Cambodia, and sunn hemp is highly preferred. Sunn hemp (*Crotalaria juncea L.*) is a tropical leguminous crop native to India and Pakistan. It is a drought-tolerant crop that can reach 183 cm and grow on soil pH 5 to 7.5 (USDA, 2012). It produces 1 to 9 tons ha^{-1} of biomass and 122 kg ha^{-1} N in 45 to 90 days (Price et al., 2012). Seeding rates vary from 17 to 34 kg ha^{-1} (Balkcom et al., 2011). Mature sunn hemp is manageable by crimping, or herbicide, but herbicide is harmful to soil and human health (Kornecki et al., 2012).

Kornecki (2015) defined a roller-crimper as functioning to flatten cover crops on the soil surface, to kill or injure them, to create mulch through which cash crops are seeded and grow. Crimping is effective when legumes are at flowering stage, or when grass cover crops reach anthesis stages (Frasconi et. al, 2019). Cover crop termination should be done no more than three weeks before planting cash crops (Kornecki, 2009, 2012 and 2015). Crimpers consist of one or two rollers. Crimpers with one roller may have elliptic or straight bars, and the roller itself can be solid or hollow. Crimpers with one smooth roller are also common but need spontaneous operation with herbicide spray to kill the cover crop (Kornecki et al., 2012). Besides that, crimpers with two rollers use the front roller, which is usually smooth, to flatten cover crops and the rear one to crush them. Recent crimping technology is trapping and applying tractor engine heat to kill the cover crop, so the crimping mechanism is not roller-based, but like an iron (Fasconi et al., 2019).

OBJECTIVE

The objectives of this study were (1) to compare different roller-crimpers with Oggun-mounted USDA roller-crimper in terminating sunn hemp (*Crotalaria juncea* L.) and (2) to determine their effects on soil strength and soil moisture.

METHODOLOGY

In the wet season of 2019, the experiment was conducted on clayey soil, called *Mollisol*, with pH 7 to 7.13 in Rattanak Mondul District, Battambang Province, Cambodia. The average day-time temperature and monthly rainfall were 29°C and 148.6 mm (Climate.data.org, 2019). Sunn hemp was planted on May 12, 2019 at equal rate of 22 kg h^{-1} and terminated at the blossom stage.

Materials

The roller-crimpers tested in this experiment were a patented two-stage roller-crimper developed at the National Soil Dynamics Laboratory (NSDL), the United State Department of Agriculture (USDA), and a Cambodian made roller-crimper with elliptic bars. The USDA roller-crimper (Kornecki, 2011) had two drums with a width of 1.35 m. The first drum was smooth and the second drum had six straight crimping bars used. The Cambodian made roller-crimper had one roller a width of 2.0 m. designed its elliptic crimping bars. A disc-plow had six discs and was 2.0 m. long, functioning to cut and incorporate the cover crop into the soil, and turn over the soil. In addition, the tractors utilized to pull these implements were different. The USDA roller-crimper was mounted on the Oggun tractor; the Cambodian made roller-crimper and the disc-plow on a Ford 6600 tractor. Oggun is manufactured as an open-system tractor by the Cleber LLC located in Alabama, USA. It is hydraulically operated, weighs 0.8 ton, and has a 19-hp gasoline engine. The Ford 6600 tractor is powered by a 75-hp diesel engine, weighing 2.56 tons.

Design and Sampling Methods

Research design was based on the studies by Kornecki (2009, 2012 and 2015), but slightly modified to suit the Cambodian condition. A randomized complete block design (RCBD) was used comprising

three treatments, each with four replications. Each plot was 34 m long and 14 m wide to accommodate at least five times the roller-crimper's widths and spaced 5 m for tractor turning. The three implements were evaluated on the same day. Before rolling, sunn hemp height was measured at 9 randomly chosen locations in each plot. Sunn hemp biomass was collected from three locations within each plot area using a 1.0-m^2 area wire frame (1.0 x 1.0 m). The biomass samples were dried for 15 days at 50 to 65℃ using a solar dryer parabola dome. Before and after rolling, bulk density and soil penetration resistance were evaluated at 0-10 and 10-20 cm depths from three locations within each plot. The soil samples were dried for 24 hours at 105℃ using an oven (Universal Oven UN55 Memmert). Soil penetration resistance was evaluated using a cone penetrometer with 0-100 reading scales (model S086 proving ring penetrometer). Termination rate was evaluated 7, 14, and 21 days after rolling, using a visual method. Each rolled, or disked plot was split into five and evaluated based on 0-100% scales for mortality rate. However, the rolled residue was sprayed with glyphosate two weeks after rolling, to plant corn. Due to herbicide effects, data were collected only two weeks and then averaged. Volumetric soil moisture content (VMC) was measured using a portable TDR moisture meter with 12 cm long rods (Spectrum Technologies, Plainfield, IL) on the rolling day and then 7, 14, and 21 days after rolling in each plot.

The data were analyzed performing analysis of variance (ANOVA) by using the R-software 6.3.1 available online. Fisher's protected LSD test at $\alpha = 0.05$ probability level was used to show significant difference and to determine interactions between treatment means, periods before and after rolling, and soil depths.

Fig. 1 (a) USDA roller-crimper, mounted on Oggun; (b) Cambodian made roller-crimper, pulled by 75-hp diesel tractor; (c) disc-plow with six discs

RESULTS AND DISCUSSION

Sunn Hemp Height and Biomass

Significant differences in the plant height (*P-value = 0.462*) and biomass (*P-value = 0.823*) were not observed among the treatments, being 164 cm and 2.57 t ha^{-1}. The reason was that sunn hemp was planted using the same method, but crimping/disking was applied afterwards at blossom. The plant height of sunn hemp in this study was acceptable, compared to the data by USDA (2012) and Balkcom and Reeves (2004), indicating it within the range of 120 to 180 cm. However, the plant biomass was slightly low, compared to the average value of 5.6 Mg ha^{-1}, due to prolonged drought. Balkcom et al. (2011) recognized the weather as the main factor. His findings showed that the plant biomass was even lower than 2.0 Mg ha^{-1} despite different planting dates and seed rates applied.

Field Operations

There were significant differences in speed, fuel consumption, and field efficiency (*P-value < 0.001*) among the treatments. Disking speed was the fastest, operated at 5.21 km h^{-1}, followed by the Cambodian made roller-crimper at 4.5 km h^{-1} and the USDA roller-crimper at 3.5 km h^{-1}. The Oggun consumed 21.35 liter ha^{-1}, greater than the 75-hp tractor that used 11.13 liter ha^{-1} for disking and 12.44 liter ha^{-1} for crimping. Oggun crimping achieved low field efficiency at 0.79 ha h^{-1}, while