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Soil disturbance and cutting forces of four different sweeps for mechanical weeding

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ABSTRACT

Sweeps are the most common tools for mechanical weeding for row-crops. However, how their soil disturbance characteristics are associated with the weeding performance has not been well documented in the literature. The main objective of this study was to evaluate the weeding performance of selected inter-row sweeps through laboratory tests. Four different sweeps, namely: Fin, Conventional, ¾-conventional, and Narrow-wing, were tested in an indoor soil bin at a working depth of 40 mm and a travel speed of 8 km h^{-1} in a sandy loam soil. Soil disturbance characteristics (uprooting and cutting width, burial width, and burial depth), soil cutting forces (draft and vertical), and weeding rates were measured. Based on the ANOVA outputs, all these variables were significantly affected by the treatments at $p < 0.05$, except for the draft force. The ¾-conventional and Conventional sweeps had higher vertical forces than the other sweeps. The Conventional and ¾-conventional sweeps produced an uprooting and cutting width of approximately 260 mm, and the Fin and Narrow-wing sweeps resulted in an approximately 7.2% larger uprooting and cutting width. The Fin sweep had the smallest burial width (zero), while the ¾-conventional sweep had the largest burial width (308 mm). This trend was also observed for the burial depth. In general, the burial depth decreased exponentially from the centre of the sweep path over the lateral distance. The Fin and ¾-conventional sweeps had over 70% weed kill and these two sweeps are recommended as the best choices for row-crop weed control.

1. Introduction

Weed control has presented a great challenge for crop production. Most weeds have higher growth rates than crops, which results in competition for nutrients, water, and sunlight. This competitive nature of weeds has adversely affected crop growth (Williams et al., 2007), reduced crop quality (Slaughter et al., 2008; Murphy et al., 2008), increased harvest costs (Swanton et al., 1993), and reduced crop yield (Donald and Khan, 1992; Pike et al., 1990). Weeds also served as hosts to harbor pests (pathogens, nematodes, and insects), which caused diseases and led to low yields and a further decline in crop quality (Boydston et al., 2008; Bastiaans and Kropff, 2003). Therefore, it is critical to keep the weeds under control during the early growth stage. There are several methods for weed control, and the two main ones are chemical and mechanical (Young and Pierce, 2014) methods. Chemical weed control methods have been commonly used in North America due to a higher efficiency as compared to mechanical methods in a large land base (Giles et al., 2004). However, the use of chemicals may harm the environment and public health. Therefore, mechanical weed control methods have received a lot of attention, as they reflect more environment-friendly practices (Dedousis and Godwin, 2008).

Mechanical weeding kills weeds by three modes: burying, cutting, and uprooting (Young and Pierce, 2014). Burying refers to putting a layer of soil on top of weeds to restrict their growth. Cutting involves physically shearing off part of weed plants. Uprooting is breaking the contact between soil and plant roots. Burying typically occurs during seedbed preparations, and cutting and uprooting occurs during cultivation and after crop emergence. Terpstra and Kouwenhoven (1981) used a hoe-ridge for inter-row and intra-row weed control and found that 57% of the weeds were killed by uprooting, 45% by burying, and 33% by desiccation on the surface.

Soil-engaging tools used for mechanical weeding include rotary hoes, brushes, basket weeders, tine harrows, and sweeps (Young and Pierce, 2014). Some of them, for examples, brushes and tine harrows, were effective for intra-row weeding, and some of the

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others, for examples, sweeps and hoes, were suitable for inter-row weeding (Kouwenhoven, 1997). Harrow-type weeders relied on uprooting and hoe-type weeders relied on burying for weed kills (Cirujeda et al., 2003). In a field study, a tine harrow and a powered brush hoe were used for intra-row weeding, and sweeps were used for inter-row weeding for peanut production (Johnson et al., 2012). The combination of these operations together with preharvest mowing gave the best result, in terms of the peanut yield. Pullen and Cowell (1997) tested six different mechanical weeding mechanisms, including duckfoot, powered rotary hoe, ground-driven rotary hoe, sweep, brush weeder, and harrow comb weeder. The results showed that the harrow comb weeder was least effective and the sweep was the most effective for inter-row weed control. The reported weed kills for the sweep was about 90%. The high effectiveness of sweeps in controlling weeds is attributable to the fact that sweeps cut large areas of the soil between crop rows.

There are several factors which affect the effectiveness of mechanical weeding. Increasing working depth did not significantly increase the weed kill, but disturbed more soil (Terpstra and Kouwenhoven, 1981). Increasing travel speed resulted in a reduced weed cover (Paarlberg et al., 1998). In another study, Cirujeda et al. (2003) found that higher speed harrowing and hoeing did not have a higher weed control efficacy, but caused higher soil movement. Paarlberg et al. (1998) reported that the travel speed of the sweeps did not affect weed control. They found that different types of sweeps performed differently in weeding effectiveness, studying a fin-type sweep, a low-crown sweep, and a point-and–share sweep. Based on these literature results, this study focused on comparisons of four types of sweeps in their inter-row weeding performance.

Besides the effectiveness of weed kill, soil disturbance is one of the important performance indicators. Most researchers who studied weed kill rates also studied soil disturbance (Pullen and Cowell, 1997; Paarlberg et al., 1998). Soil disturbance determined the burying and uprooting kills of weeds. A hoe weeder was more effective in a loamy soil than in a sandy soil, due to the larger influence zone of the hoe in the loamy soil. Soil disturbance is also related to crop damage. Pullen and Cowell (1997) studied different weeding tools for eliminating rape plants and found that sweep had a kill rate of 89% and could work for narrow-row crops due to its low soil disturbance. A duckfoot weeder also resulted in relatively high killing rates (65–99%); however, it had a higher soil throw that may damage the crops. Generally, a weeding tool has the best performance when it cultivates most of the inter-row area without damaging the crop.

There are lacks of soil disturbance characteristics of weeding tools in the literature and discussion on how soil characteristics are associated with the weeding performance. Little research has been done on comparisons of different inter-row sweeps. The objective of this study was to evaluate the weeding performance of four selected inter-row sweeps. The specific objectives were (1) to characterise the soil disturbance of the sweeps, including

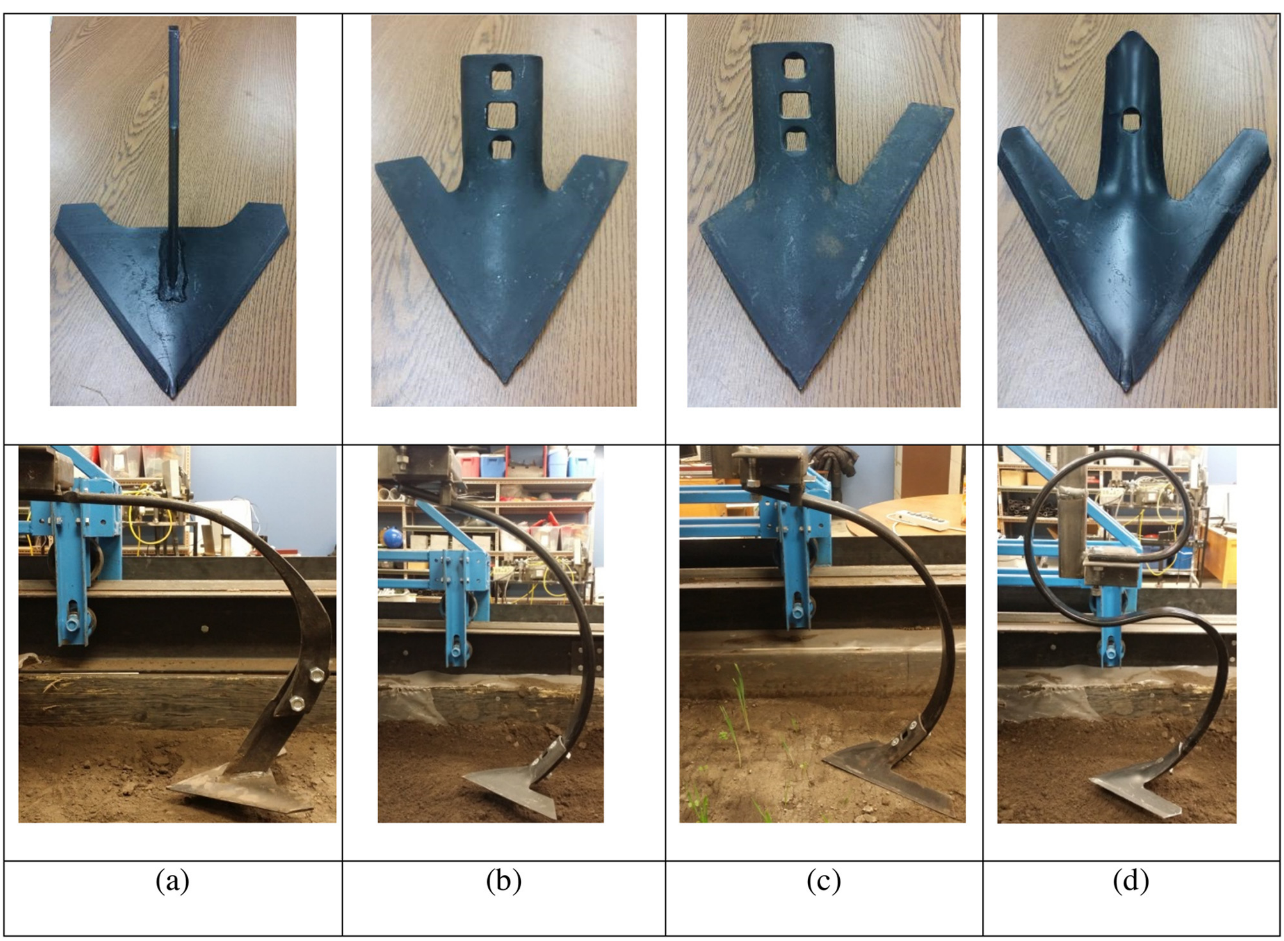

Fig. 1. Sweeps and shanks used in the experiment: (a) Fin; (b) Conventional; (c) $^{3}/_{4}$-conventional; (d) Narrow-wing.