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Research Paper

Soil translocation by narrow openers with various bent leg geometries

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No-till farmers in Australia often use narrow point openers to place seed and fertiliser in furrows in conjunction with the spraying of pre-emergence herbicides. These openers can produce excessive soil throw which creates problems such as increasing the depth of soil cover on adjacent furrows, herbicide contamination above seed in adjacent furrows, increased stimulation of weed seed germination and furrow moisture loss. This study evaluated the effect of a range of bent leg narrow opener geometries on soil movement when operating at 120 mm depth and 8.2 kmh^{-1}. Results showed that a bent leg opener geometry combined with a chamfered face could loosen a furrow without throwing soil laterally out of the furrow due to the shank being offset (bent) away from the central up-heaval of soil. The bent leg openers were also able to loosen soil with minimal mixing of soil layers. Increasing the shank offset from the furrow centre reduced the surface soil interaction with the vertical shank section operating in the furrow. Decreasing the side bend angle from 65° to 45° reduced surface tracer lateral movement. Adding a leading foot to a bent leg opener reduced the loosened cross sectional area by 13% due to the shallower engagement of the side-leg portion. These findings have implications for optimising no-till seeding practises through better control of soil throw, aiming to: reduce weed seed germination and soil moisture loss, enable narrower row spacing options, the safer use of pre-emergence herbicides incorporated when seeding and higher operating speeds.

1. Introduction

No-till farmers in Australia often use narrow point openers to open the soil and place seeds and fertiliser in the furrow. These openers when used at forward speeds above 8 km h^{-1} can exhibit excessive soil disturbance and soil throw that create problems such as increasing the depth of soil cover over seeds in adjacent furrows (Desbiolles & Saunders, 2006; Solhjou, Fielke, & Desbiolles, 2012), stimulating weed seed

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germination (Chauhan, Gill, & Preston, 2006) and increasing soil moisture loss (Chaudhuri, 2001). To control weeds, farmers in Australia often use pre-emergent herbicides sprayed onto the soil surface that are mechanically incorporated into the soil by the seeding operation and become active on germinating seedlings. Moderate levels of lateral soil throw at seeding can have the desired effect of moving surface soil sprayed with pre-emergent herbicide away from above the seed row and improving crop safety (Solhjou et al., 2012). However, at excessive levels this can have the undesired effect of moving the soil onto adjacent seed rows and inducing crop damage (Desbiolles & Saunders, 2006).

One emerging problem in Australian no-till farming where there is widespread reliance on herbicides for weed control is that weeds are developing resistance to an increasing range of herbicides (Boutsalis, Preston, & Gill, 2008; Goddard et al., 2008, p. 544; Walsh & Powles, 2007). Hence, farmers in spite of using herbicides, are faced with increasing amounts of weeds establishing and competing with their crops for nutrients, moisture and light. Soil tillage is well known to affect the dynamics of weed seed germination (Buhler, 1991; Chauhan et al., 2006; Mohler, 1993; Mohler, Frisch, & McCulloch, 2006; Yenish, Fry, Durgan, & Wyse, 1996), such as by exposing seeds to light, altering seed distribution in the soil profile and burying surface seeds in the inter-row. This research follows a series of studies (Solhjou, Desbiolles, & Fielke, 2013; Solhjou et al., 2012) that was concerned with understanding how soil layers translocate during a no-till seeding operation, as influenced by furrow opener geometry, with the aim of controlling soil disturbance to a desired level.

The factors influencing soil movement identified in literature include: soil condition such as texture, moisture and structure, tool setting such as forward speed and depth of work and geometry of the tool. The geometry of an opener includes factors such as rake angle, width and opener face geometry and these can significantly influence soil movement, especially lateral soil throw as well as soil mixing (Godwin, 2007; Sharifat, 1999; Solhjou et al. 2012, 2013). In previous related work, Solhjou et al. (2012) found that the geometry of an opener strongly affects the characteristics of the loosened furrow and patterns of soil movement. At 8.2 km h^{-1} and 120 mm depth,16 mm wide simple openers with a flat face and square edges, set at rake angles of 35, 53, 72 and 90°, all threw surface soil laterally a maximum distance of at least 300 mm from the centre. When used with typical Australian no-till farming seed row spacings of 180–300 mm this would result in soil landing in adjacent furrows. A 35° (low) rake angle opener was seen to move tracers placed deep in the soil up to the surface and was found to throw more soil from depth out onto the furrow ridge. A larger 90° rake angle opener created a significantly narrower furrow and slightly improved furrow backfill. Observation of the soil flow showed that soil impacting the shank created much of the vertical, lateral and forward soil movement. In order to reduce this soil throw, Solhjou et al. (2013) showed that adding a chamfer to the face of a vertical narrow opener reduced this impact effect and thus significantly decreased the lateral, forward and vertical translocation of soil.

Bent leg tine designs (Fig. 1) have the shank portion offset to the side of the soil upheaval zone created during furrow loosening. While the concept of bent leg tines is not new, and in deep tillage studies has been investigated since the 1980s, past work was mainly concerned with soil loosening efficiency and draft force reduction (e.g. Harrison, 1989; Jafari, Raoufat, & Hashjin, 2008; Majidi & Raoufat, 1997; Raper, 2005). An appropriate low disturbance tined opener would also allow an increase in working speed without affecting the quality of the seeding operation, thus providing gains in productivity. Related development work in South Africa on the *RT Blade* bent leg opener prototype, seeking to improve no-till seeding performance, led to a short pilot evaluation of its soil throw benefits conducted at the University of South Australia (Desbiolles & Leonard, 2008) which highlighted significant improvements in furrow backfill and reductions in lateral throw of soil.

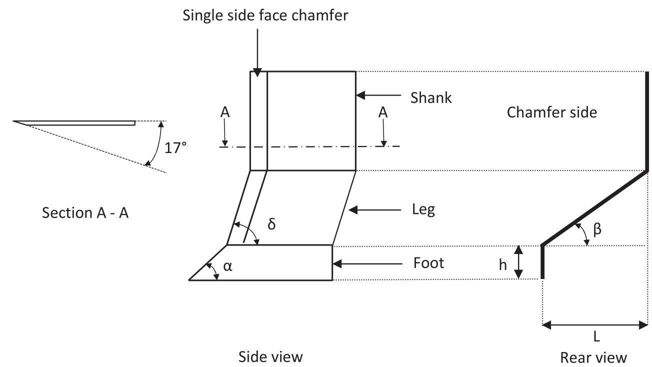

Fig. 1 – Geometry of bent leg opener. L = shank lateral offset, h = foot height, β = side bend angle, α = foot rake angle and δ = leg forward angle.

In this study, the effect of a range of bent leg opener geometries was investigated to understand how key design parameters drive specific aspects of vertical, lateral and forward soil movement, with the aim of minimising soil throw out of the furrow and soil layer mixing. Whilst this study was undertaken in a soil bin using a structureless remoulded soil without crop residues, these fundamental findings will help develop techniques for optimising no-till seeding practises including aspects that control weed seed germination, soil moisture loss, seed row spacing, pre-emergent herbicide incorporation and associated crop safety. Further work will be needed to continue these studies in field conditions and address any possible interactions with the presence of roots, stones and crop residue, as well as soil stickiness related issues.

2. Material and methods

The experiments were undertaken in remoulded indoor soil bin conditions with a red sandy-loam soil (59% sand, 26% silt and 15% clay) with cohesive-frictional properties, which is a typical soil of South Australian fields. As with past research (e.g. Liu, Chen, Lobb, & Kushwaha, 2007; Rahman, Chen, & Lobb, 2005; Sharifat, 1999; Spokas, Forcella, Archer, & Reicosky, 2007), this work used cubic tracers placed at different locations across and down the profile prior to tillage