LATERAL TRANSLOCATION OF SURFACE SOIL BY VARIOUS NO-TILL NARROW POINT OPENERS

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Abstract

Australian no-till farming often uses narrow point openers to open the soil and place seed and fertilizer in a furrow. They are generally used in conjunction with spraying of herbicides for weed control and press-wheels to pack soil over seeds. These openers when operating at speeds beyond 8 km/h can create excessive soil throw which creates problems of increased weed burden and reduced seeding quality, which can also enhance crop establishment risks due to herbicide damage and soil moisture loss. This work uses the results of surface PVC tracer displacement to estimate the likely movement of soil applied pre-emergent herbicide, typically incorporated during the no-till seeding operation, and evaluate the effects of furrow opener geometry.
Three variations to opener design were evaluated; four rake angles of 35, 53, 72 and 90°, three leading edge conditions of blunt, chamfered one side and chamfered both sides, and a range of five bent leg openers. The effect of the various narrow opener geometries on soil movement and furrow profile were evaluated in a soil bin with a sandy loam soil and at a forward speed of 8.2 km/h and a depth of 120 mm.
Results showed that the openers with various rake angles all threw surface soil at least 300 mm from the center and this would land in an adjacent furrow when used at typical row spacings. A low rake angle of 35° had the least lateral surface soil movement and the 53° rake angle gave the widest band of soil, along the tool path, that was cleared of surface tracers. Adding a chamfer to the leading edge reduced lateral soil movement when compared to a blunt opener. The bent leg opener achieved much lower soil movement while loosening a furrow, and when combined with a single sided chamfer was able to virtually eliminate throwing of soil out of the furrow and hence would have no effect on adjacent furrows. The concept of bent leg furrow openers has the potential to change the dynamics of soil disturbance when no-till seeding with tine openers.

Keywords
Soil movement, Face chamfer, Rake angle, Bent leg opener, Pre-emergence herbicide.

Introduction
Australian no-till farming often uses narrow point openers to open the soil and place seed and fertilizer in the furrow. They are generally used in conjunction with spraying pre-emergence herbicides for weed control and are followed by press-wheels to pack soil over the seeds. These openers when used at speeds above 8 km/h can create excessive soil disturbance and soil throw which creates problems such as increasing the depth of soil cover on adjacent furrows(1), stimulating weed seed germination(2) and enhancing seedbed soil moisture loss(3). In Australian farming systems, pre-emergence herbicides are applied onto the soil surface and often mechanically incorporated by the sowing operation to become active on germinating seedlings. Excessive lateral soil throw at seeding can result in herbicide contaminated soil reaching adjacent seed rows(1 and 4) and have an effect on the emerging crop as well as the emerging weeds.

The factors previously identified in the literature affecting soil movement associated with soil loosening include: soil condition such as texture, moisture and structure(5), tool settings such as speed and depth(5 and 6) and geometry of opener(3 and 5). This work investigated the effects of no-till opener geometry on surface soil movement, using both conventional and bent leg furrow openers. The methodology used small aggregate sized cubes placed in a grid pattern in the soil profile and across the path of the opener, acting as tracers to indicate 3D soil movement. The analysis of surface tracer displacements provides a method of estimating likely movement of pre-emergence herbicide sprayed on the soil surface by the mechanical incorporation process. This movement can affect both the efficacy of weed control and the potential risk of crop damage.

Materials and methods

Experiments were undertaken in remolded soil bin conditions using the seed placement test rig at the University of South Australia (UniSA)[7]. Three variations to opener design were evaluated. Firstly, a flat face opener of 16 mm width with four rake angles of 35, 53, 72 and 90°. Secondly, three leading edge conditions of blunt, chamfered one side (single side chamfer) and chamfered symmetrically (double side chamfer), all on a 90° rake angle opener of 16 mm width, as shown in Fig. 1. Thirdly, a range of bent leg openers with 10 mm width, as detailed in Fig. 2 and Table 1. While the concept of bent leg tines is not new, and has been investigated since the 1980s in deep tillage studies, past work (e.g. 8 and 9) has been concerned mostly with soil loosening efficiency and draught force reduction, and did not been examine the implications of a bent leg opener shape on soil movement, particularly when applied to no-till seeding.

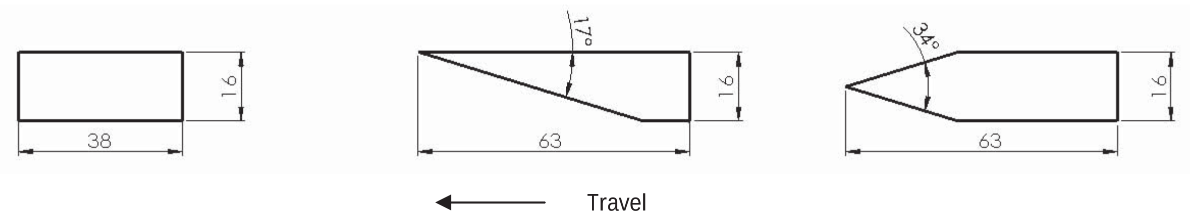

Figure 1. Opener leading edge conditions evaluated on a 90° rake angle opener - blunt (left), single sided chamfer (middle) and double sided chamfer (right) - dimensions are in mm.

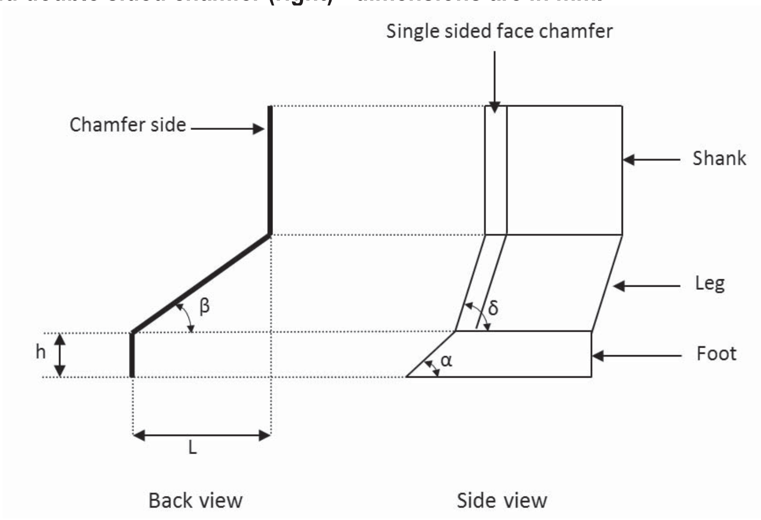

Figure 2. Geometry of bent leg opener (L = shank lateral offset, h = foot height, β = side bend angle, α = foot rake angle and δ = leg forward angle).

All openers were tested using a forward speed of 8.2 km/h and a depth of 120 mm. A randomized complete block design with four replications was used to evaluate the effect of rake angle, leading edge condition and bent leg opener geometry on the soil movement and furrow profile. The equipment used four 3 m long and 1.5 m wide soil bins with a reconstituted red sandy-loam soil (59% sand, 26% silt and 15% clay) with a 10.7% soil moisture content (w/w, dry basis) and 1.37 g/cm^3 soil bulk density (dry basis).

Table 1. Geometry parameters of prototype bent leg openers

Opener	Shank offset-L (mm)	Foot rake angle, α (°)	Side bend angle, β (°)	Foot height, h (mm)	Leg forward angle, δ (°)	Blade face condition
T1	0	45	90	45	70	chamfered*
T2	45	45	45	45	70	chamfered*
T3	95	45	45	45	70	chamfered*
T4	45	45	65	45	70	chamfered*
T5	45	-	45	0	70	chamfered*
T6	45	-	45	0	70	blunt

* single side face chamfer of 17°

Soil movement was measured by placing PVC cubic tracers (1 cm x 1cm x 1cm) in a reference grid within the soil profile prior to tillage and measuring their final position after tillage using a 3 dimensional digitizing frame. The 13 surface tracers were positioned with one on the center of the opener travel path and the others symmetrically set at 10, 20, 30, 60, 90 and 120 mm from the center. These surface tracers were placed at half their height (5 mm) into the soil. The furrow loosening result was assessed over a 0.5 m length of furrow using a scanning laser soil profile meter and included the surface profile of the loosened soil and the furrow soil failure boundaries measured after excavation of the loosened soil.

Results and discussion

Rake Angle

Fig. 3 shows 'whole-of-trial' tracer data for the four rake angle openers, including 4 replications with left and right pseudo-replications obtained by symmetry (for symmetrical tools only), while the furrow profiles shown are the average furrow cross-sections. The variability in the lateral soil throw over the 0.5 m long sample is not displayed by the average profile but is reflected in the position of individual tracers. The results showed that each of the various rake angle openers cleared all of the surface tracers from above the centre of the furrow below which the seeds would commonly be expected to be placed in the seed zone. The opener with the 53° rake angle gave the widest band of soil with no tracers in the region ±90 mm of where the tine passed. Typical row spacing (L_c) in southern Australian no-till farming systems ranges from 225 to 300 mm while a small proportion of farmers may operate at other row spacings, as narrow as 180 mm and as wide as 380 mm. All openers threw a considerable volume of soil beyond the soil furrow boundaries. Their furrow backfill factor, defined using an area basis, as the proportion of furrow cross sectional area backfilled with loose soil, was 93, 92, 97 and 98% for the 35°, 53°, 72° and 90° rake angles, respectively. Results indicate that, at typical no-till row spacings of 225 to 300 mm, these tools would move significant amounts of surface soil contaminated with pre-emergence herbicide onto the adjacent furrow, with the potential for causing crop damage, depending upon herbicide solubility and absorption pathways. The soil bin tests were conducted at 8.2 km/h and at 120 mm depth, and the extent of lateral soil throw and interaction with adjacent furrows has been previously shown to increase even more at higher speeds but reduce at shallower depths [(1)].

Leading Edge Condition

The second opener design parameter evaluated was the leading edge condition (blunt, double side chamfer and single side chamfer). As shown in Fig. 3, the width of the band of soil above the opener path with no surface tracers was maximised by having a blunt leading edge and reduced by having a chamfer on the leading edge. The narrowest band of cleared soil was achieved with the single sided chamfer. Hence, adding a chamfer can be used to reduce surface soil throw away from the path of the opener and thereby allow soil applied pre-emergence herbicide to control weeds closer to the seed row. Also, when considering a typical row spacing (L_c) in Australian no-till farming systems, the results indicate that by using an opener with a face chamfer the movement of surface soil with pre-emergence herbicide onto adjacent furrows can be reduced and thus improve crop safety for adjacent furrows.

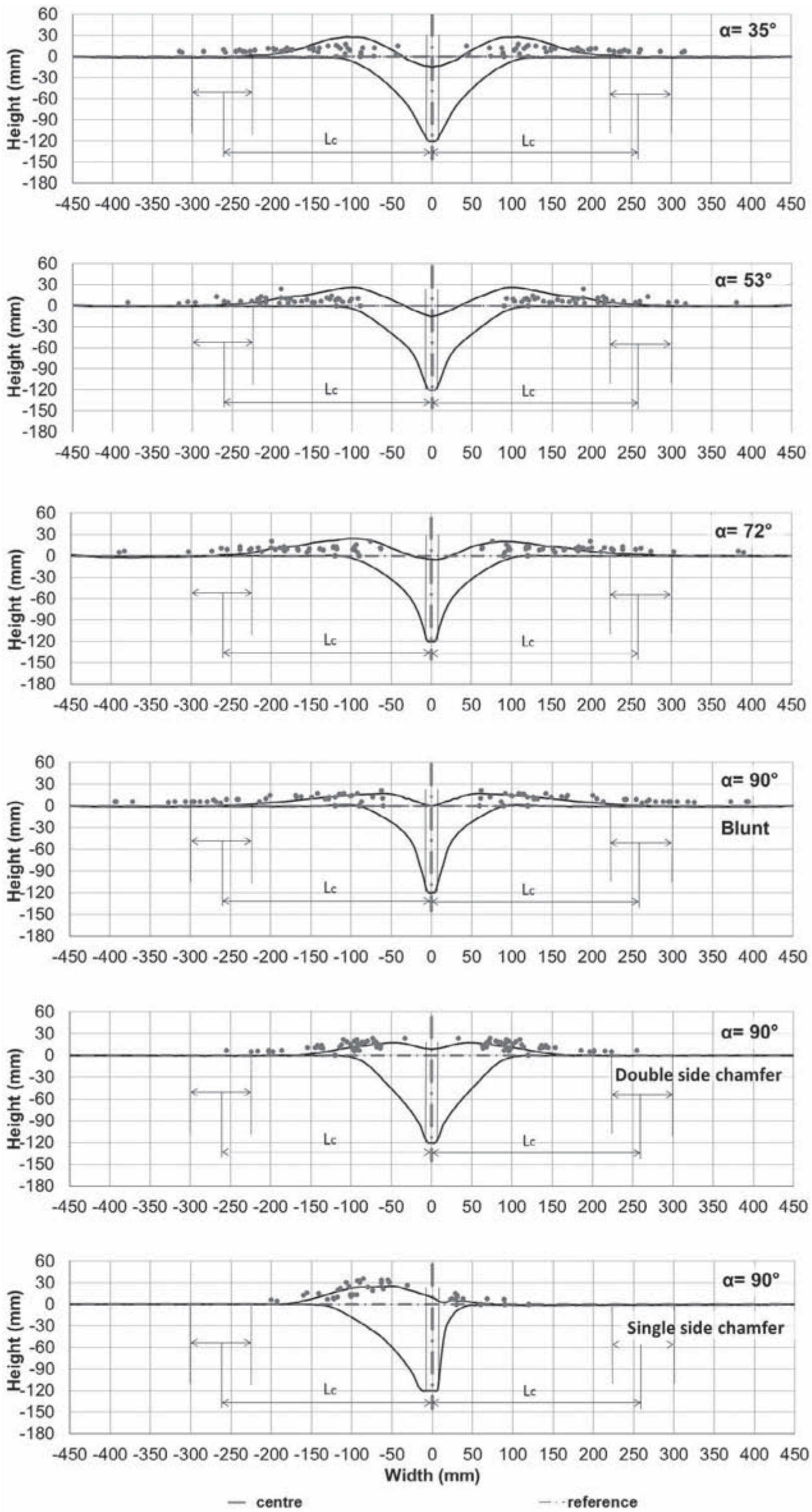

Figure 3. Cross section of soil profiles and tracer locations for various rake angles and different leading edge conditions.

Bent Leg Geometry

The third type of opener design evaluated was a range of bent leg openers. As shown in Fig. 4, the use of a bent leg opener with a single chamfer on the leading edge (openers T2 to T5) results in virtually all of the furrow soil and surface tracers remaining within the furrow width. No furrow soil or surface tracers were thrown as wide as the adjacent furrow for typical Australian no-till seeding row spacings (L_c).

Increasing the shank offset (L) from 0 to 45 and then 95 mm (openers T1, T2 and T3, respectively) decreased the width of the band of soil with no surface tracers. The bent leg opener with a shank offset of L= 95 mm (T3) did not clear a band of surface tracers above a potential seed zone, indicating that pre-emergent herbicides on the soil is likely to remain covering the full width of the surface and potentially affecting crop safety. The above effect of increasing shank offset is associated with the gradual reduction in the vertical shank portion actively engaged in the soil, and influencing the lateral soil movement.

Increasing the side bend angle (β) of the leg from 45° to 65° and then 90° (openers T3, T4 and T1, respectively) resulted in more tracers being moved away from the tine due to a more direct action of the leg chamfer, achieving a wider band of soil without surface tracers over a potential seed zone. This effect would help reduce risks associated with crop safety.

The effect of the presence of the foot with a 45° rake angle is shown for the openers T2 and T5, respectively, operating at equal depth. The addition of a foot (expected to improve the penetration ability of the opener) had virtually no effect on surface tracer movement, reinforcing the primary action which the shank has on soil movement. However, the presence of the foot, by minimising the engagement of the leg portion in the soil, reduced the volume of loosened soil.

The effect of the presence of a single sided chamfer on the leg and shank is shown for the openers T5 and T6. The opener with a blunt leading edge (T6) was observed to throw soil and surface tracers much wider than the furrow, with some tracers thrown as wide as a potential adjacent row (on a typical row spacing) on the side opposite to the bent leg.

This result also reinforces the primary action of the shank portion on lateral soil movement and hence highlights some ability by design to control the extent of lateral soil movement, Hence, if the benefit of a bent leg opener is retaining the loosened soil within the furrow, it must have a chamfered leading edge. A partially blunt edge may assist with also achieving some degree of incorporation for soil applied herbicides.

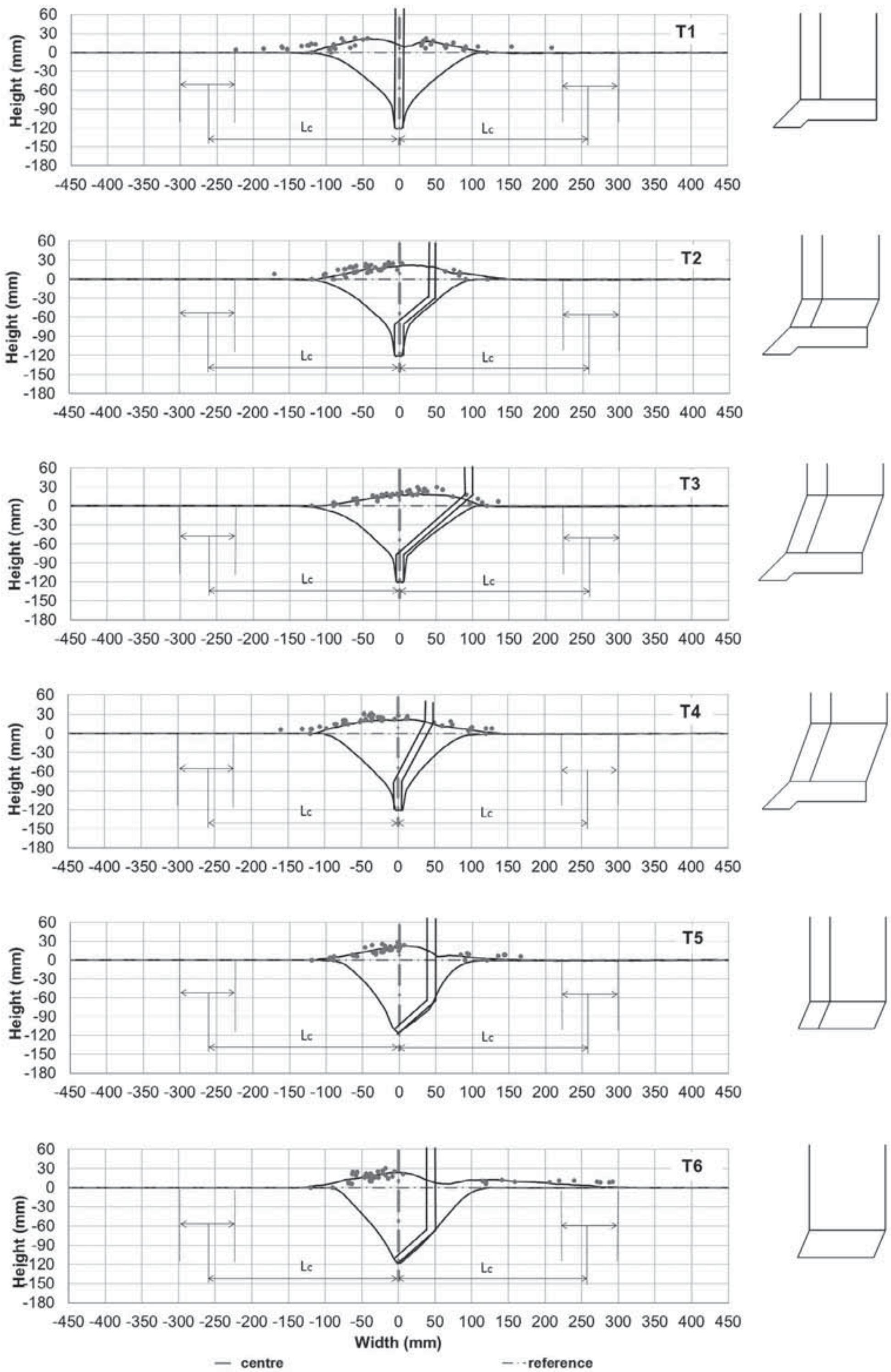

Figure 4. Cross section of soil profiles and surface tracer locations for various bent leg openers (corresponding opener side views are shown on the right hand side)

Conclusions

Concerned with the interactions of furrow opener geometry and soil applied herbicides in Australian no-till farming systems, this study showed differences in action between various narrow opener designs on surface soil movement. The geometry of an opener strongly affects the width of a band of soil with no surface tracers above the tine path, indicating the movement of surface soil sprayed with pre-emergent herbicide away from the potential seed zone. All furrow openers with various rake angles would act to throw surface soil onto adjacent furrows for typical row spacings used in southern Australian no-till seeding which range between 225 and 300 mm. For a straight tine, the 35° rake angle had the minimum lateral surface soil movement and the rake angle of 53° created the widest band (±90 mm about the centre) cleared of surface soil above the seed zone. Adding a leading edge chamfer to a simple vertical opener reduced lateral translocation of surface soil compared to a blunt leading edge and this would also reduce the extent of lateral throw of surface soil into adjacent furrows.

A bent leg opener with a leading edge chamfer was observed to contain the movement of surface soil to within the furrow width and not throw soil onto an adjacent furrow. It can provide a band cleared of surface tracers above a seed zone when the opener lateral offset was 45 mm. With a larger offset of 90 mm, the soil was loosened but not thrown sideways and hence the whole furrow remained covered with surface soil that was sprayed with pre-emergent herbicide. The action of a bent leg opener on surface soil movement was observed to be linked to the action of the vertical shank portion engaging the soil. The work indicates that a suitably designed bent leg opener can overcome the problem of excessive soil throw while maintaining a high furrow loosening capacity and would allow the use of higher operating speeds than currently permissible due to excessive soil disturbance.

Acknowledgements

The authors gratefully acknowledge the Grains Research and Development Corporation and the University of South Australia in co-funding the current PhD research. The initial collaboration with farmer Daniel Rossouw (South Africa) on the “RT Blade” bent leg concept is gratefully acknowledged.

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