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PERFORMANCE OF A DUAL TINE AND PRESSWHEEL SEEDING MODULE FOR A RANGE OF SPEEDS, PRESSWHEELS AND SOWING TINE ALIGNMENTS

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Abstract

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The performance of a dual tine and presswheel seeding module was compared when using a range of settings and options under soil bin conditions. The parameters measured were the soil furrow profile, the placement of seeds and their effect on germination of triticale (variety Tahara – Xtriticosecale sp.). The tests were undertaken using the soil bin facilities at the University of South Australia using a sandy-loam soil. The seeding module had a deeper working front tine fitted with a winged narrow point followed by a narrow point, seed delivery tube and presswheel which were attached by a parallelogram to provide ground contour following for control of seeding depth. The tests showed that 55 mm wide presswheels with either a flat or wedge profile placed the seeds deeper and gave a reduced mean emergence time of 9.8 days compared to 12.6 days for the 80 and 110 mm wide wedge profile presswheels. The next most important factor affecting mean emergence time was the seeding tine alignment with the seeding tine offset 24 mm to the side of the leading tine giving a faster mean time to emergence of 10.7 days compared to center seeding which had 11.6 days. Increasing the speed of seeding from 8 to 13 km/h had no significant affect on the mean emergence time but the higher speeds were measured to place the seeds with less depth of soil cover, throw more soil from the furrow and throw soil wider from the furrow.

Key words: direct drill; furrow profile, germination, seed placement, soil throw

Introduction

Direct-drill practices that promote soil and water conservation and reduce input costs have become increasingly adopted by farmers. Direct drill practices often undertake the application of fertilizer and seed in the one pass with the aim of placing seed and fertilizer into zones which may be separate or overlapping. The placement of fertilizer segregated from the seed has been found to be desirable for direct drill, so that the fertilizer is not placed too close to seeds as it may have toxic effects that reduce emergence and early plant growth. The minimum recommended distances between seed and fertilizer range from 20 mm (Baker and Afzal, 1986; Choudhary et al., 1985) to 35 mm (Rainbow, 2000 and Baker et al., 2005).

Most types of direct drill implements have been found to provide faster emergence and stronger early growth when the seeding tool is followed by a presswheel that packs soil onto the seed. For example Crabtree and Henderson (1999) concluded that applying presswheels usually improved emergence of lupins and wheat by an additional 6% and 2%, respectively. Hanna et al. (2008) evaluated soil loading effects of planter depth-gauge wheels on early corn growth. They found that emergence rate of corn plants was affected by the loading and soil moisture conditions. With moist soil or in wet conditions, corn emerged more rapidly

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with a low load. In dry soil conditions, corn emerged more rapidly with a heavy load. Chen et al. (2004) conducted trials to determine the affect of different drill configurations on crop performance for no-till seeding. It was found that by using presswheels, faster emergence, increased plant population and increased yield were observed in the normal and dry soil condition, however emergence was reduced in the very wet seeding condition but a comparable yield was still obtained.

There is an optimum seeding depth that is specific to each type of plant and the method of planting. If a seed is planted too shallow it will not germinate and if it is too deep the germinated seed may not emerge to the surface. This was demonstrated by Hadfield (1993) who measured the variations in germination and emergence of wheat and lupine using an inverted-T-shaped no-tillage slot at various depths. He concluded that the variety of wheat used was less sensitive to depth of sowing than lupine in the 20 mm to 50 mm depth range, but both were seriously affected by depths greater than 50 mm under no-tillage.

In order to segregate the placement of seed and fertilizer, some implements use one soil opener with separate seed and fertilizer delivery hoses discharging their products into different levels in the soil profile but they suffer from seed placement being affected by soil conditions, ground contours and travel speed. This experiment evaluates a style of machine which aims to eliminate the issues of depth of seeding varying with ground undulations, speed having a large effect on seed placement and provides separate placement of seed and fertilizer. It uses narrow tines for minimal soil disturbance and has a deeper working leading tine for placing fertilizer below the seed; this is followed by a second narrow seeding tine that is attached to a presswheel that gives control of the seeding depth. The separation in distance between the two tines allows soil to backfill over the fertilizer prior to passage of the seeding tine so that seed placement is less affected by soil condition and travel speed and hence be able to place segregated bands of fertilizer and seed.

Farmers using these dual tine modules to sow their crops have many choices to make on the style of soil engaging tools (widths, rake angle, wings), the style of the presswheel (width, profile and flex), the settings (depth of the seeding tip relative to the presswheel, centered or offset seeding, the discharge heights of the seed and fertilizer tubes) and operating speed. This paper investigates in a soil bin condition the changes in soil furrow profile and placement of seed, and their affect on germination for a range of these parameters with the aim of determining their relative importance when using narrow width ground engaging tools.

Materials and Methods

The combined dual tine and presswheel seeding module

The seeding module used for the experiments is shown in Figure 1 and consisted of a front (fertilizer) tine and boot, a parallelogram linkage, a rear (seed) tine and boot, and a presswheel. The module was manufactured by the company Horwood Bagshaw in Australia.

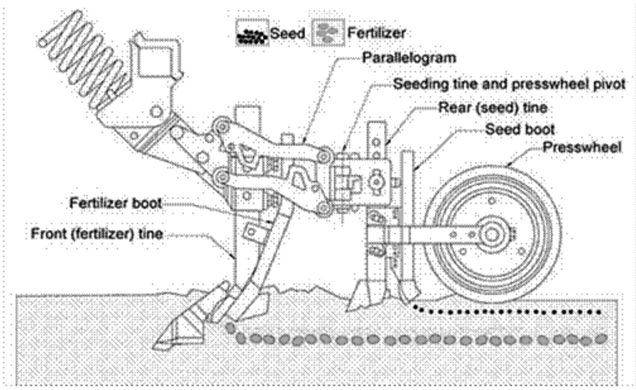

Fig. 1. The combined dual tine and presswheel module

The front tine of the module was designed to place fertilizer deeper than the rear (seed) tine. The fertilizer tine can be fitted with a range of soil openers and for this experiment it was fitted with a 60 mm wide winged opener that had a leading face of 12 mm width with a 55° rake angle. The front tine was set to operate at a depth of 100 mm below the original ground level.

The rear section of the module was mounted on a parallelogram which allowed it to float on the furrow with the depth of operation of the rear tine set by the relative mounting of the seeding tine depth to presswheel position. Hence, as the presswheel follows the soil surface the sowing tine follows a constant sowing depth. The rear sowing tine was fitted with a 12 mm wide (70° rake angle) ground engaging tool. The rear tine and presswheel were fitted to, and pivoted on, the rear of the parallelogram. The purpose of the pivot was to eliminate skidding of the presswheel when cornering. The design of the module allowed the rear tine to trail in-line (centered) with the front tine or be offset on either side of the front tine with distances of 12, 24 and 36 mm to achieve „side banding“ of the seed. In this experiment offsets of zero (centered) and 24 mm were evaluated.

The module allowed fitting of a range of presswheels with various profiles and widths. This experiment evaluated four types of presswheel; Flat 55 mm, Wedge 55 mm, Wedge 80 mm and Wedge 110 mm. The presswheels all had an outside diameter of 380 mm. The presswheels were all used with the same down force of 280 N. The presswheels were of semi-pneumatic construction which provided a small amount of flex of the tyre as it rolled on the soil. The seed tube was set with its base at the same depth as the seeding tine of 40 mm below the presswheel.

The seed placement test facility

This experiment was conducted using the University of South Australia's seed placement test facility. The equipment consisted of four soil bins, each 3 m long and 1.5 m wide which were placed under a set of rails upon which a carriage fitted with the seeding module ran (Figure 2). Each bin was divided down the centre by a metal panel 400 mm high to create eight individual test plots of 3 m length and 0.75 m width. Two conveyor chains were used to pull the carriage back and forth. The facility had a maximum speed of 16 km/h.

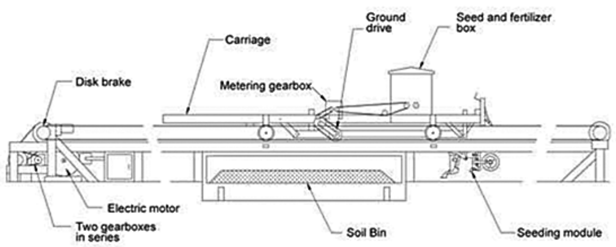

Fig. 2. Soil bin seed placement test rig

The soil used for the experiments was taken from a field at Wanbi, South Australia. It was taken from the top 100 mm and was composed of 16% clay, 12% silt and 72% sand. It was classified as a sandy-loam soil (Klute et al., 1986). The soil was prepared by dry sieving to ensure there were no foreign seeds present, placing the soil in the bins in two 75 mm layers and rolling. The volume of water was added using sprays to achieve the required moisture content and allowed to stand for one week for the moisture to equilibrate. Plastic covers were placed on the bins to reduce evaporation and keep out vermin. The soil moisture for the experiments was 12.5% (d.b.) and the average soil bulk density for the depth of 0 to 100 mm was 1.5 g/cm^3.

The seeds used for the experiment were triticale (variety Tahara - Xtriticosecale sp.). These seeds were chosen as they were a common local feed grain that was relatively large to aid locating after sowing.

Experiment design

The experiment was designed to examine the effect of two speeds (8 and 13 km/h), four styles of presswheels (Flat 55 mm, Wedge 55 mm, Wedge 80 mm and Wedge 110 mm) and with the seeds placed centered with the path of the front tine and 24 mm off to the side of the path of the front tine (i.e. an offset of zero and 24 mm). The working depth of the front tine was 100 mm and the sowing depth of the rear tine was set at 40 mm between the base of the seed boot and the presswheel. The seeding rate along the row was set at 100 seeds/m.

A randomized complete block design was used for the experiment. Each treatment was replicated three times. An analysis of variance was determined using the MSTAT statistical package to examine the effects of treatments (Anonymous, 1988). Least Significant Difference (LSD) tests were used to identify significantly different means within dependent variables at $P < 0.05$ and $P < 0.01$.

Experiment method

Following passage of the seeding module through the soil a 1 m length for sampling was marked and the profile of the soil was measured using a 3D coordinate measuring unit placed on the carriage rails which had a pointer that was manually traversed across the furrow at four locations. The emergence of the seeds was monitored daily for the 1 m sample length until no more seeds emerged for two consecutive days. Following emergence, the soil in the 1 m sample length was manually excavated and the location of each seed was manually measured using the 3D coordinate measuring unit. By allowing the seeds to germinate the seeds were firmly anchored in the soil allowing manual excavation of the soil to expose the location of the seed without disturbing its position. The soil was allowed to dry and the process of sieving the soil and reforming the soil bins was repeated.

The seedling emergence counts were converted to the mean emergence time (MET) using Eq. 1 (Bilbro and Wanjura, 1982).

$$\text{MET} = \frac{N_1.D_1 + N_2.D_2 + \ldots N_n.D_n}{N_1 + N_2 + \ldots N_n}, \quad (1)$$

where N = Number seeds to emerge on days n,
D = Number of days since sowing

The cumulative daily percentage (CE) was fitted using the curve describe by Eq. 2 (France and Thornley, 1984).

$$\text{CE} = \frac{M}{1 + e^{\left(\frac{-K}{t-m}\right)}}, \quad (2)$$

where M = maximum emergence,
K = emergence slope value,
t = days since sowing,
m = shape factor.

The individual seed locations and average furrow profiles for each test were used to calculate a range of seed placement parameters as shown in Figure 3.

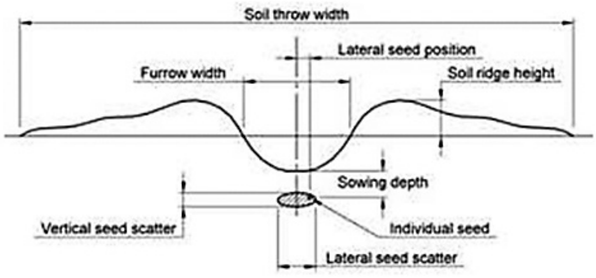

Fig. 3. Definition of parameters for seed location

Results

The average furrow profiles and seed locations are shown in Figure 4 As the operating speed increased from 8 to 13 km/h the results (Table 1) showed that more soil was thrown from the furrow and the soil was thrown further from the furrow, as seen by the furrow width being 12% wider, the furrow depth being 9% deeper and the soil throw being 7% wider but the soil ridge height was 21% lower. Also with increasing speed the average of all results showed the higher speed to place the seeds slightly shallower below the original soil level and combined with a deeper furrow, the higher speed gave a 6 mm less sowing depth. Despite this statistically significant different sowing depth, the emergence results showed no statistically significant difference in emergence between the two speeds.

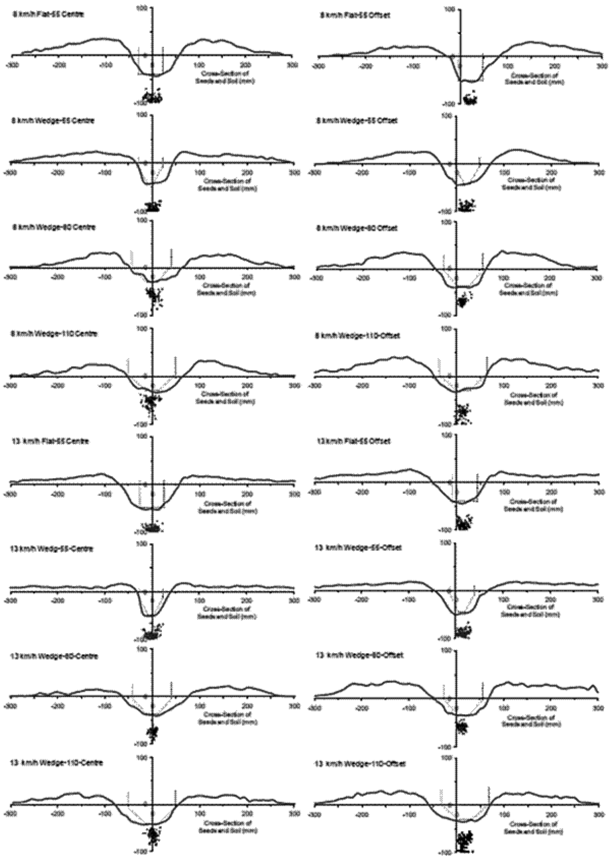

Fig. 4. Seed and soil profiles at 8 km/h and 13 km/h

Table 1. Effect of speed on parameters

	8 km/h	13 km/h	Fcal
Furrow parameters			
Mean furrow width, mm	105.50	117.80	548.74**
Mean furrow depth, mm	41.90	45.60	6.66*
Mean soil ridge height, mm	35.40	27.80	17.17**
Mean soil throw width, mm	595.00	634.00	1158.81**
Seed placement Parameters			
Mean vertical seed position, mm	79.60	78.00	8.79**
Mean lateral seed position, mm	10.70	7.40	63.81**
Mean sowing depth, mm	43.50	37.30	36.99**
Vertical seed scatter, mm	42.15	37.04	89.13**
Lateral seed scatter, mm	40.50	38.0.	22.99**
Emergence parameters			
Mean emergence time, days	11.20	11.10	0.78ns
Maximum emergence, M, %	92.00	92.00	0.03ns
Emergence slope, K	1.02	0.85	64.75**
Emergence shape, m	10.53	11.03	23.35**

* Significant (P < 0.05), ** Highly significant (P < 0.01), and ns = non-significant

Table 2. Effect of seeding tine alignment on parameters

	Centre	Offset	Fcal
Furrow parameters			
Mean furrow width, mm	109.80	113.60	50.73**
Mean furrow depth, mm	43.30	44.20	0.37ns
Mean soil ridge height, mm	30.00	33.30	3.22ns
Mean soil throw width, mm	613.00	615.00	2.56ns
Seed placement parameters			
Mean vertical seed position, mm	77.90	79.70	10.63**
Mean lateral seed position, mm	3.30	14.80	773.26**
Mean sowing depth, mm	39.40	41.30	3.37ns
Vertical seed scatter, mm	41.00	38.20	26.08**
Lateral seed scatter, mm	38.30	40.30	14.71**
Emergence parameters			
Mean emergence time, days	11.60	10.70	76.12**
Maximum emergence, M, %	92.00	92.00	0.19ns
Emergence slope, K	0.89	0.99	22.57**
Emergence shape, m	11.36	10.21	123.34**

* Significant (P < 0.05), ** Highly significant (P < 0.01), and ns = non-significant

Table 3. Effect of presswheel type on parameters

	55 mm Flat	55 mm Wedge	80 mm Wedge	110 mm Wedge	LSD	Fcal
Furrow parameters						
Mean furrow width, mm	113.9b	93.7c	115.4b	124.0a	1.62	595.49**
Mean furrow depth, mm	49.6a	48.7a	38.9b	37.8b	4.52	15.97**
Mean soil ridge height, mm	30.3bc	25.8c	36.4a	34.2ab	5.23	6.67**
Mean soil throw width, mm	607c	608c	619b	623a	3.38	50.46**
Seed placement parameters						
Mean vertical seed position, mm	91.8a	91.8a	62.3c	69.3b	1.62	738.11**
Mean lateral seed position, mm	9.3b	13.6a	7.0c	6.4c	1.19	62.29**
Mean sowing depth, mm	47.1a	47.2a	33.1b	34.1b	2.94	58.82**
Vertical seed scatter, mm	33.8c	36.5b	35.1bc	52.9a	1.56	276.61**
Lateral seed scatter, mm	39.2c	41.0b	32.4d	44.5a	1.51	94.46**
Emergence parameters						
Mean emergence time, days	9.8b	9.8b	12.6a	12.6a	0.28	271.13**
Maximum emergence, M, %	91.0b	93.2a	91.1b	92.8a	1.07	9.13**
Emergence slope, K	1.19a	1.18a	0.75b	0.62b	0.06	185.42**
Emergence shape, m	9.23b	9.25b	12.40a	12.25a	0.29	296.39**

Unlike letters in column denote significant differences ($P < 0.05$), * Significant ($P < 0.05$), ** Highly significant ($P < 0.01$), and ns = non-significant

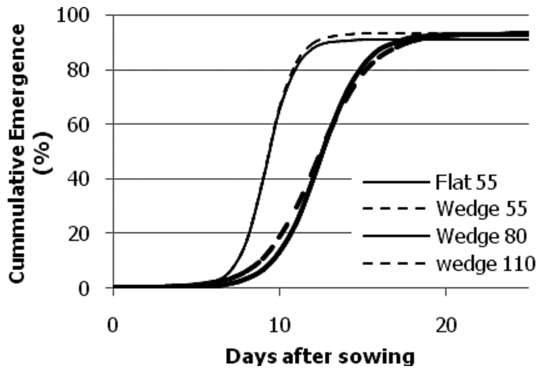

Fig. 5. Effect of presswheel type on emergence

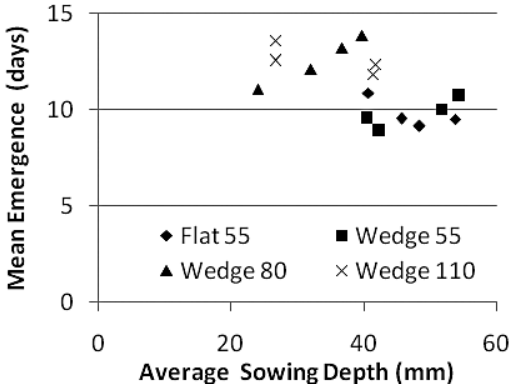

Fig. 6. Effect of sowing depth on mean emergence date

The effect of the seeding tine being centered with the leading tine and then offset to the side by 24 mm (Table 2) was one of the furrow widths being only 4 mm wider for offset sowing but for the other furrow parameters there was no significant difference. With regards to seed placement, the offset sowing resulted in the seed being placed 15 mm to the side (not quite the full 24 mm offset) but the mean sowing depth was not significantly different. The germination of the seeds sown offset from the leading tine was on average nearly 1 day quicker to achieve the mean emergence time.

The presswheel type (Table 3) had a large effect on the furrow depth with the two 55 mm wide presswheels giving a 10 mm deeper furrow than the 80 and 110 mm wide presswheels. Associated with this deeper furrow, the seeds were placed 20 to 30 mm deeper into the soil (below the original soil level). It was observed that the 55 mm wide presswheels gave a time to mean emergence of 2.8 days quicker than the 80 and 110 mm wide wedge presswheels, as shown in Figure 5.

Discussion

The dual tine and presswheel seeding module has a range of options and settings and the results of testing in a 12,5% m.c. sandy-loam soil showed that the furrow profile achieved varied predominantly as a function of speed and presswheel profile.

Whilst the increase in speed from 8 to 13 km/h did not have a significant effect on the emergence for the single module evaluated, if multiple modules would be placed on an implement with a row spacing of less than half the width of soil throw (300 mm for 8 km/h and 317 mm for 13 km/h) additional soil would have been thrown into adjacent furrows above the seed. Typically these modules are used on implements with row spacing of 180 mm and 225 mm and these results show that 10 to 20 mm depth of soil would be expected to be thrown onto the centre of an adjacent row. This is likely to change emergence of seeds in adjacent rows due to both the extra depth of soil and the possibility of herbicides being in that soil if it had been sprayed just prior to seeding.

The results showed that the 24 mm offset sowing gave a mean lateral seed position of 15 mm off-centre. The less than full amount of the offset in the seed position can be explained by the module having a vertical pivot in front of the seeding tine (Figure 1) that allowed the presswheel to steer itself and the sowing tine. Steering down into the furrow explains the reduction in the amount of offset achieved. This steering into the furrow was found to be dependent upon speed for the two 55 mm wide presswheel with the mean lateral seed position being the full 24 mm at 8 km/h but reducing to only 12 mm at 13 km/h. For the 80 and 110 mm wide presswheels the mean lateral position of the seed for offset sowing did not vary with speed and was 13 mm.

Hence, it was found that the 55 mm wide presswheels at 8 km/h were able to track in a straight line, cutting a second furrow on the side of the leading furrow, however as the speed increased to 13 km/h, the furrow was deeper (Table 1) and soil being thrown by the leading tine was seen to still be airborne and not yet backfilling the furrow; these factors would explain the seeding tine tracking more closely in-line wit the front tine at higher speeds. For the wider presswheels they were seen to always track at a slight skew angle due to the influence of the deeper furrow created by the leading tine with their side walls pushing on the furrow and placing the seeds only 13 mm offset (about half the intended offset setting). This shows that the trailing tine does not always cut a dominant furrow in the side of the leading tine‘s furrow. The faster emergence of the seeds sown with the offset seeding tine may be explained by the presswheel packing the soil onto the seed in a different manner as it would be working with one side pressing more firmly on one side of the remains of the leading furrow and tracking with a slight skew angle which would have a different soil packing action.

The presswheel width had a large effect on the furrow, seed placement and emergence. The seed placement setting used was with the base of the seed boot being 40 mm below the presswheel. For both of the 55 mm wide presswheels the average depth was 7 mm deeper (47 mm) indicating extra soil fell into the furrow after passage of the presswheel, but for the 80 and 110 mm wide presswheels the average depth of seeding was 6-7 mm shallower (33–34 mm). Factors affecting the final depth of the seeds would be flex of the tyre, throwing of the soil by the sides of the presswheel, collapse of the side faces of the furrow after passage of the presswheel and the presswheel running on its smaller diameter edges rather than the centre of the tyre. During sowing the presswheels were observed to throw soil as they operated and increasing the presswheel width was measured to increase the soil throw width and increase the soil ridge height indicating that the wider presswheels threw more soil. This can be explained by the edges and inner lip of the wider presswheel tyres picking up and throwing more soil.

The results as shown in Figure 6 did not show a simple trend of mean emergence time being a function of seeding depth. The tines used on the module were narrow and as such they cut a narrow furrow and as shown by the difference in furrow depths, the 55 mm presswheels were able to fit into the furrow and press on the soil above the seeds, hence a deeper furrow. However, the 80 and 110 mm wide presswheels did not fit into the base of the furrow and would have pressed more on the sides of the furrow with their edges, thus giving a shallower depth of seeds below the original soil level and consequently giving less pressing of soil onto the seeds. It was seen that the amount of pressing of soil onto the seeds was a more important factor than the depth of cover of soil over the seed. This finding agrees with the past work of Hinrichsen and Kushwaha (1989) and Fink and Currence (1995) who both concluded that matching the opener configuration and presswheel shape were even more important than vertical force on the presswheel in achieving effective seed to soil contact.

As these tests were only conducted in a sandy-loam soil, the performance in heavier clay soils and with the presence of crop residues cannot be implied, particularly with regards to the effects resulting from soil adhering to the presswheel and incorporation of crop residue into the seed zone. Further work is continuing on the evaluation of the performance of the segregation of seed and fertilizer as a response to various machine settings. With regards to the type of seed used, as the seed is discharging from a seed boot into the soil, it is the author’s opinion that seed placement and pressing of soil onto the seed would be more dependent upon machine set up than seed type or size.

Conclusions

For the combined dual tine and presswheel seeding module and the settings evaluated with the leading tine operating at 100 mm depth and the seeding tine and boot operating 40 mm below the base of the presswheel, the research showed that when operating in a sandy-loam soil the selection of the presswheel width was the most important factor affecting the furrow profile, seed placement and mean time to emergence. The tests showed that the 55 mm wide presswheel with either a flat or wedge profile placed the seeds deeper and gave a mean emergence time of 9.8 days compared to 12.6 days for the 80 and 110 mm wide wedge profile presswheels. Hence, when narrow soil openers are used, matching narrow presswheels must be selected to suit the furrow.

The second most important factor affecting mean emergence time was the seeding tine alignment with the seeds placed and pressed to the side of the front tine giving a mean time to emergence of 10.7 days compared to center seeding which had 11.6 days.

Increasing the speed of seeding from 8 to 13 km/h resulted in the furrow being deeper, the soil throw being wider and the seeds being placed shallower but speed had no significant affect on the mean emergence time when using a single seeding module. This lack of response on mean emergence time is unlikely to be the case though when modules are placed side-by-side on an implement with a spacing of less than 300 mm as increased amounts of soil (up to 20 mm of extra soil cover) will be thrown onto adjacent rows.

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