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Soil compaction above the seed at sowing to increase crop establishment

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Abstract

Experiments were conducted over the years 1981 to 1984 at 10 conventionally cultivated sites in southern Queensland to determine the effects of three types of press wheel, a seed firming wheel and a rodweeder on crop establishment.

Press wheels generally increased establishment. When this happened, there were no consistent differences due to press wheel design, but all three press wheels gave larger increases than the seed firming wheel or the rodweeder.

Press wheel pressure sometimes reduced establishment, apparently because increased soil strength prevented emergence. When this happened, wheels which pressed the soil directly over the seed row caused greater reductions than wheels which pressed the sides of the row, while the seed firming wheel caused no reduction. The rodweeder was not tested under these conditions.

On the soil types tested, the press wheel vertical loading per unit width of wheel which gave the highest establishment was 8 to 16N/mm for wheat, 4 to 16 N/mm for sorghum and 0 to 4 N/mm for sunflower. Sunflower was more susceptible to excessive soil compaction with press wheels than sorghum. The optimum press wheel force showed little change with soil water content on the soil types tested.

INTRODUCTION

In Queensland, establishment of field crops is highly variable, ranging from 6 to 88% in experimental sowings (Radford 1983). On many heavy clay soils, establishment with conventional sowing machinery is less than 50% of the seeds sown. Higher and more reliable establishment is urgently needed in order to provide more opportunities for crop establishment, reduce seed costs and reduce yield losses due to poor control over plant spacing. In extreme situations, sowing failures occur and replanting is necessary or, if the soil has become too dry to replant, crops are lost. A further penalty for poor establishment is late emergence on post-sowing rain. This results in uneven plant competition, which reduces yield, and uneven plant development, which can increase pest damage and delay harvest.

Compaction of the seedbed soil above the seed with press wheels at sowing has consistently improved the establishment of sorghum (Radford and Nielsen 1985) and wheat (Radford 1986). Press wheel pressure has generally increased, but occasionally reduced, sunflower establishment (Radford and Nielsen 1985). The reductions were apparently due to a level of soil strength which prevented seedling emergence.

Carnes (1934) concluded that soil should be packed below the seed in order to give cotton seedlings a firm footing, but loose soil should be placed on top to ensure low soil strength above the seed. Under simulated field conditions, Stout *et al.* (1961) found that pressures of 35 to 70 kPa improved the emergence of corn, bean and sugarbeet when applied at seed level but decreased emergence when applied 25 mm above the seed. They concluded that planters should be designed to apply high pressure to the soil at seed level but should place relatively loose soil above the seed. This can be achieved with seed firming wheels immediately behind the soil openers. Similarly, side-pressure press wheels firm the soil around the seed but leave relatively uncompacted soil above the seed.

Rodweeders also apply pressure at seed level and leave loose soil above the seed. They could therefore enhance establishment while providing weed control at sowing, a feature actively sought by Australian farmers (Norris and Ward 1983).

Ideally, soil compaction devices should maximise crop establishment by maximising the beneficial effects of compaction at seed level and minimising the adverse effects of compaction above the seed. When press wheels are used for this purpose, they should therefore apply an optimum pressure to the soil — enough to capitalise on the advantages but not enough to cause problems. The optimum press wheel pressure depends on the water content of the seedbed (Pathak *et al.* 1976), crop species (Parker and Taylor 1965), the population of soil insect pests (Radford and Allsopp 1987), and obviously soil type and soil tilth.

The aim of this work was to compare various techniques for compacting the soil around and above the seed at sowing in order to increase crop establishment on some major soil types in Queensland. Crop species tested were grain sorghum (*Sorghum bicolor* (L.) Moench), sunflower (*Helianthus annuus* L.), soybean (*Glycine max* (L.) Merr.) and wheat (*Triticum aestivum* L.).

MATERIALS AND METHODS

We used a single-row cone planter with a narrow (15 mm wide) sowing point on a narrow (15 mm wide) rigid sowing tine for crop establishment experiments at 10 sites (Table 1). At five sites, there were two sowing times (referred to as I and II). At Condamine, Columboola and Dulacca, there was no (or negligible) rainfall between the two sowings, so soil water content was lower for II than I. Sowings were carried out 9 and 32 days after rain at Condamine, 10 and 31 days after rain at Columboola, and 16 and 30 days after rain at Dulacca. We placed the seed at depths (Table 1) considered optimum for the moisture conditions in friable seedbeds which had been cultivated conventionally. Sowing speed was about 5 km/h in all experiments.

Soil compaction treatments

The treatments used to vary the level of soil compaction above the seed were:

Nil: a control treatment which included a chain harrow (a loop of chain dragging behind the soil opener) to ensure adequate coverage of the seed furrow with loose surface soil.

Seed firming wheel (SF) (Plate 1a): a wheel with a hard rubber surface, 180 mm in diameter and 20 mm wide, mounted immediately behind the opener and designed to apply pressure only at seed level. Spring loading applied a force of 2.5 N/mm width of soil-wheel contact (which was 13 mm). The average pressure on the total area of soil-wheel contact (about 325 mm^2) was about 80 kPa. The chain harrow was also used in this treatment behind the firming wheel.

Over-centre press wheel (OP) (Plate 1b): a pneumatic rubber wheel, 510 mm in diameter, convex in cross section, weighted to apply a force of 4 N per mm width of soil-wheel contact (which was 70 mm). The average pressure on the total area of soil-wheel contact (about 3500 mm^2) was about 80 kPa.

Side-pressure press wheel (SP) (Plate 1c): a rubber wheel with zero inflation pressure, 400 mm in diameter and 93 mm wide, with a split rim and concave cross-section, designed to apply more pressure to the sides of the seed row than directly over it. Weight was added to apply a force of 4 N per mm width of wheel. The average pressure on the total area of soil wheel contact (about 4650 mm^2) was about 80 kPa. This pressure would be distributed unevenly across the width of the wheel as well as along its perimeter.

Twin inclined press wheels (TP) (Plate 1d): a pair of wheels each 305 mm in diameter, 25 mm wide and at an angle of 23° to the vertical. These press wheels are designed to apply pressure to the seed zone via the soil surfaces on the sides of the seed row. Weight was added to apply a vertical, static force of 4 N/mm width of coverage across the row (which was 90 mm).

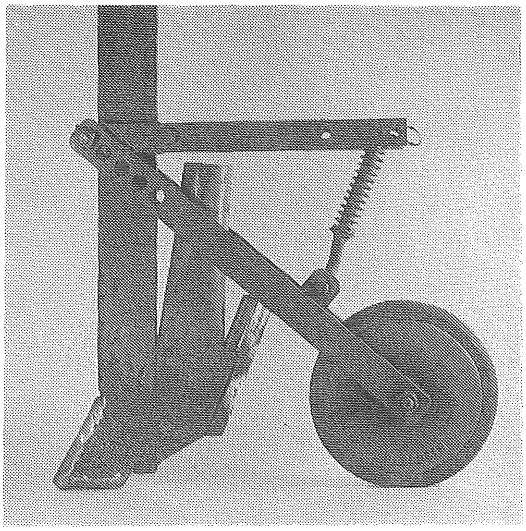
The three press wheel units allowed a comparison of the same static force per unit width with different distributions of that force across the width. The force distribution would further vary in the dynamic situation (while sowing).

Rodweeder: an experimental rodweeder (mounted behind the soil opener) with an induction tine to aid soil penetration and a power-driven 20 mm square rod rotating with a peripheral speed of about 10% of the forward speed of travel. Depth of operation was 20 to 40 mm above the depth of seed placement.

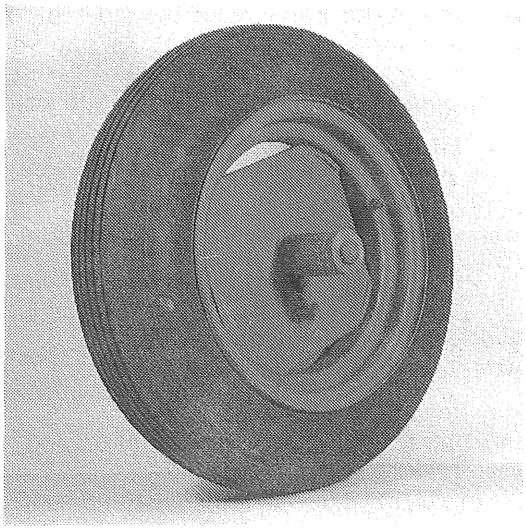
Additional press wheel forces: Forces of 2, 8 and 16 N per mm width of wheel were also tested, using the OP wheel at Dulacca and Drillham and the SP wheel at the other sites. This allowed a comparison of forces of 0, 2, 4, 8 and 16 N/mm. The press wheel linkage mechanism was designed so that the varying draft of different press wheels had no effect on the vertical force applied to the soil.

Table 1. Site and treatment details at the 10 experimental sites

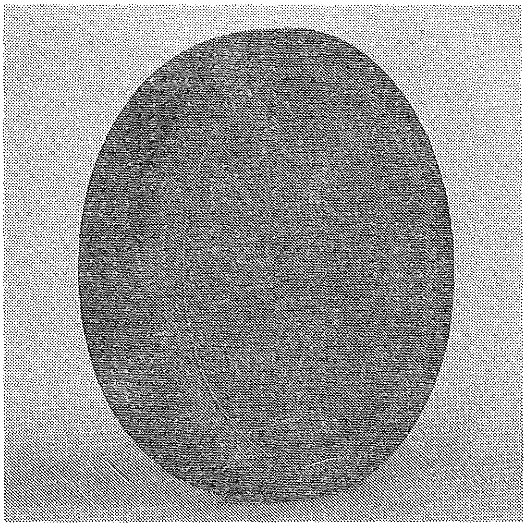
Site	Description of cultivated soil layer	Sowing date	Crop species sown	Cultivars	Laboratory germination (%)	Depth of sowing (mm)	Rain between and emergence (mm)
Toobeah (28°S, 150°E)	Dark reddish brown medium clay	18 Feb. 1981	Sorghum	Dorado	97	85	8
Warwick (28°S, 152°E)	Dark grey to black heavy alluvial cracking clay	6 Mar. 1981	Sorghum Sunflower	Dorado Hysun 21	97 94	80 80	0
Dalby (27°S, 151°E)	Grey to black heavy alluvial cracking clay	11 Dec. 1981	Sorghum Sunflower	Texas 610SR Hysun 31	98 95	85 85	0
Oakey (27°S, 152°E)	Reddish brown clay loam	6 Jan. 1982	Sorghum Sunflower	Goldfinger Hysun 31	86 95	70 70	0
Kingaroy (26°S, 152°E)	Dark brown light clay	I: 28 Jan. 1982 II: 8 Feb. 1982	Soybean Soybean	Davis Davis	92 92	65 65	36 4
Condamine (27°S, 150°E)	Black self-mulching medium cracking clay	I: 12 Jan. 1983 II: 4 Feb. 1983	Sorghum Sunflower Sorghum Sunflower	Dorado 'E' Hysun 31 Dorado 'E' Hysun 31	91 89 91 89	50 50 90 90	0 0
Columboola (27°S, 150°E)	Grey light-medium cracking clay	I: 13 Jan. 1983 II: 3 Jan. 1983	Sorghum Sunflower Sorghum Sunflower	Dorado 'E' Hysun 31 Dorado 'E' Hysun 31	91 89 91 89	60 60 130 13	0 0 0
Cambooya (27°S, 152°E)	Black self-mulching heavy alluvial cracking clay	I: 13 Mar. 1983 II: 15 Apr. 1983	Sorghum Sunflower Sorghum Sunflower	Sundowner Sunking Sundowner Sunking	93 90 93 90	60 60 70 70	44 227
Dulacca (27°S, 150°E)	Greyish brown medium heavy clay	I: 8 May 1984 II: 22 May 1984	Wheat Wheat	Cook Cook	99 99	75 80	1 0
Drillham (27°S, 150°E)	Brownish black light medium clay	9 May 1984	Wheat	Cook	99	65	0



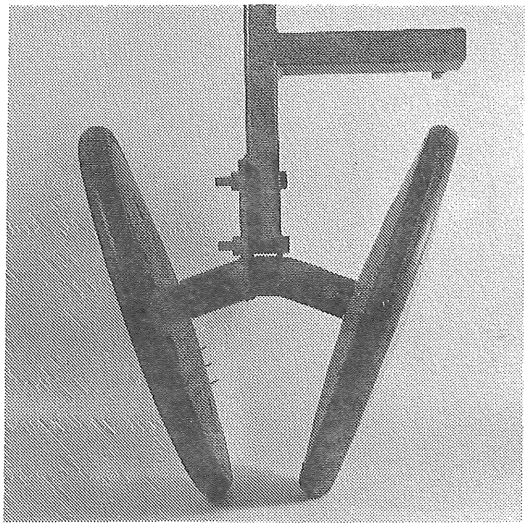
a: Seed firming wheel (SF).



b: Over-centre press wheel (OP).



c: Side-pressure press wheel (SP).



d: Twin inclined press wheels (TP).

Plate 1. Wheels used for compaction treatments.

Design

The experimental units were single 10 m rows sown with 100 to 200 seeds. Where sorghum and sunflower were compared, a mixture of 100 seeds of each species was drilled in the rows.

Randomised block designs were used with three replications. The total number of treatments in each trial always exceeded the number reported here, and because the error variance derived from all treatments was used, there were always at least 18 degrees of freedom for error.

Measurements

Final percentage of all seeds sown that emerged was used to assess treatment performance.

At Condamine, Columboola and Dulacca, soil samples from the seedbed were taken at each sowing in 30 mm increments to a depth of 150 mm, using a 45 mm diameter soil sampling tube. Soil water contents of these samples were determined gravimetrically.

Environmental influences

There was rain between sowing and emergence on 6 of the 15 sowings (Table 1). Surface crusting was not apparent at any site. Subterranean insects affected establishment at Warwick (*Agrypnus variabilis* (Candèze): sugarcane wireworms), Dalby and Oakey (*Nala-lividipes* (Dufour): black field earwigs).

RESULTS

The seed firming wheel (SF) significantly increased sunflower establishment at Oakey and sorghum establishment at Columboola I but usually had no significant effect on crop establishment compared with the control treatment (Figure 1). Because the SF wheel was running on the moist bottom of the furrow, wet soil tended to adhere to its surface and cause sledging (failure to rotate), particularly on heavy clay soils. Furthermore, some of the sown seeds were picked up by the moist soil on the wheel. These problems could be expected to become worse with continuous use of such wheels in commercial sowings.

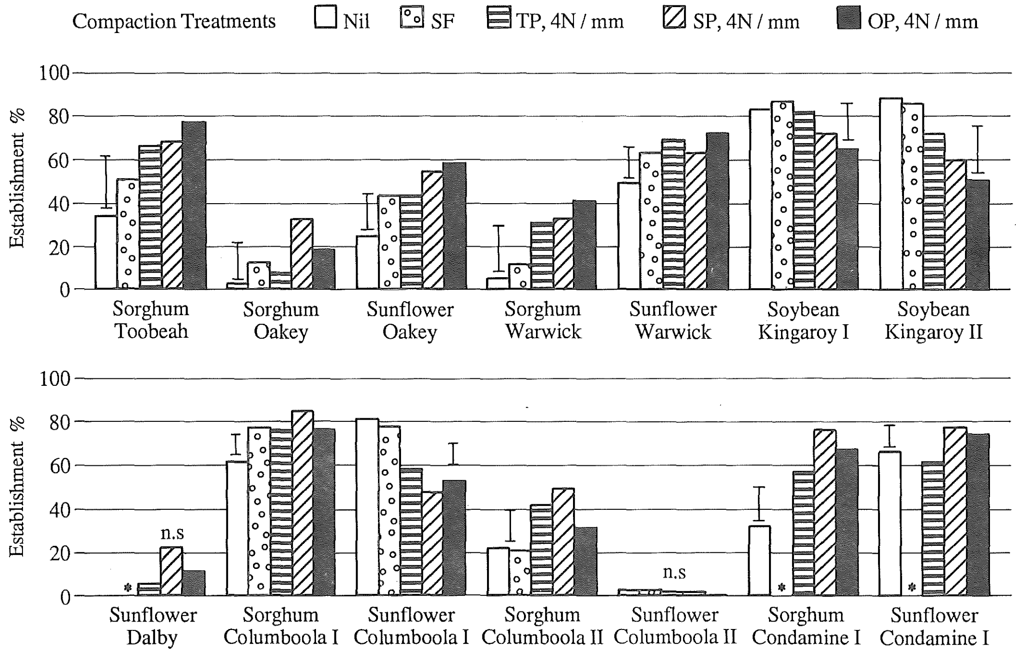


Figure 1. Effect of soil compaction treatments at sowing on the establishment of sorghum, sunflower and soybean at several sites. Vertical lines indicate LSD, $P = 0.05$. n.s.: not significant. *:SF not used. There was no comparison of press wheels in Condamine II.

The three press wheels (TP, SP and OP) at 4 N/mm usually increased establishment compared with the chain harrow (control) (Figure 1). When this happened, establishment was similar with all three press wheels. However, the press wheels failed to increase, and sometimes decreased, establishment of soybean at Kingaroy I and II and sunflower at Columboola I and II. In these experiments, the soybean and sunflower seedlings apparently had insufficient emergence force to penetrate the overlying soil after application of press wheel pressure. Under these circumstances, the more a press wheel treatment compacted the soil directly over the seed the more establishment of soybean and sunflower was reduced. For example, the over-centre press wheel (OP) gave significantly lower soybean establishment at Kingaroy I and II than the twin inclined wheels (TP).

The effects of the rodweeder, SP and nil compaction on establishment are compared in Figure 2. The SP treatment at 4 N/mm significantly increased establishment over the control treatment in all seven sowings, but the rodweeder significantly increased establishment in only two out of seven — sorghum and sunflower at Cambooya II. However, the small but non-significant increases with the rodweeder resulted in no significant differences between the rod and SP at 4 N/mm in six out of seven sowings.

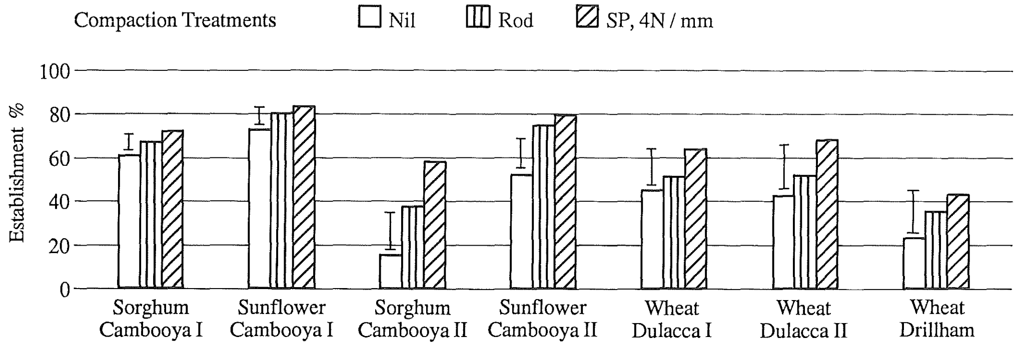


Figure 2. Effect of a rodweeder and a side-pressure press wheel on the establishment of sorghum, sunflower and wheat at several sites. Vertical lines indicate LSD, P = 0.05.

The effect of press wheel force on crop establishment is shown in Figure 3. High press wheel forces (up to 16 N/mm) did not reduce the establishment of sorghum and wheat in any experiment but commonly reduced sunflower and soybean establishment. At Columboola I, a force of only 2 N/mm reduced sunflower establishment significantly, yet 2, 4 and 8 N/mm increased sorghum establishment significantly.

Soil water contents and seeding depths for sowings I and II at Columboola, Condamine and Dulacca are shown in Figure 4. Despite 14 days of soil drying at Dulacca, soil water content, establishment levels and the pattern of response to press wheel pressure were similar in I and II (Figure 3). At Columboola and Condamine, establishment levels were lower in II than I, due to lower soil water content and deeper sowing, but the effect of press wheel force was similar in I and II for both sorghum and sunflower. Depth of sowing was increased for sowing II in accordance with commercial practice (Figure 4).

DISCUSSION

Levels of establishment with the chain harrow ranged from 0 to 89%, reflecting the variability of establishment that occurs in southern Queensland when conventional covering harrows are used. Improvement is obviously needed. Poor establishment at Warwick, Dalby and Oakey was attributed to seed and seedling damage by subterranean insect pests.

Compaction of the soil above the seed (with press wheels) had more influence on establishment, positive or negative, than compaction at seed level (with a seed firming wheel or rodweeder) (Figures 1 and 2).

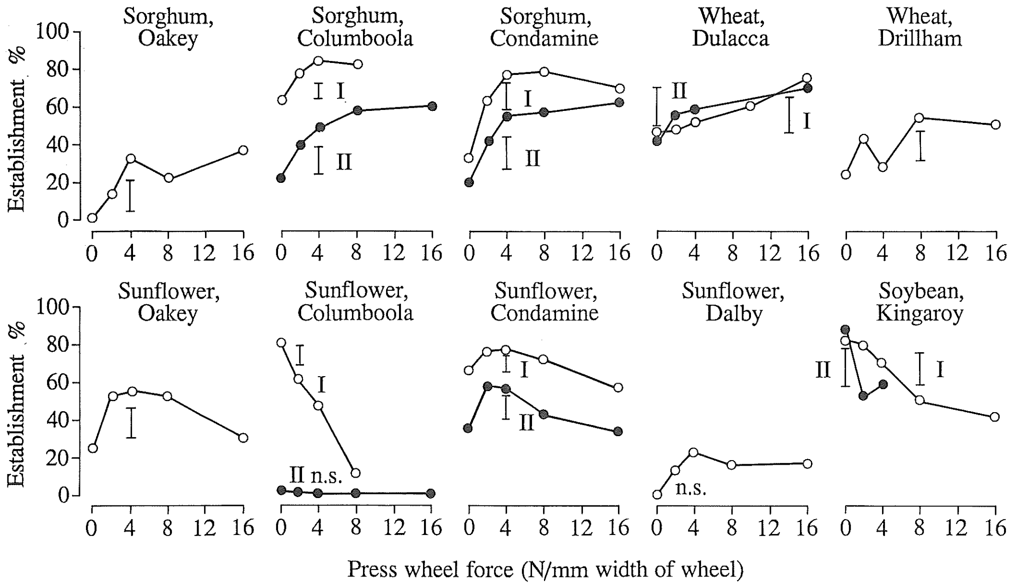


Figure 3. Effect of press wheel force on sorghum, wheat, sunflower and soybean establishment at several sites. An over-centre press wheel (OP) was used for the wheat at Dulacca and Drillham and a side-pressure wheel (SP) at the other sites. Vertical lines indicate LSD, P = 0.05. n.s.: not significant.

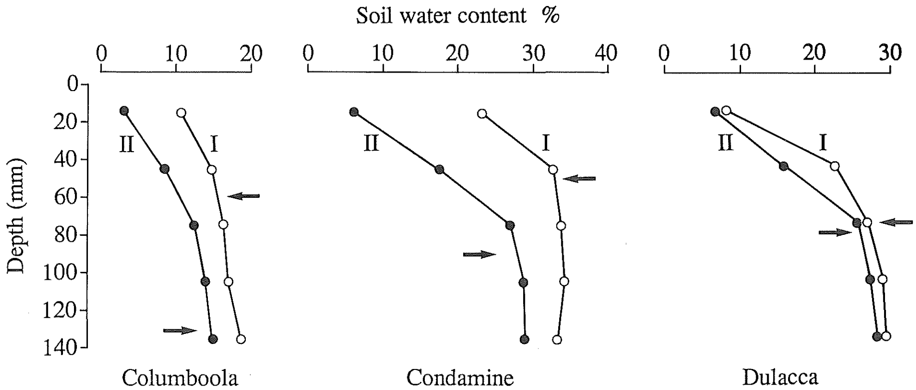


Figure 4. Soil water contents in the seedbed at sowing, and seeding depths (indicated by arrows) for sowings I and II at Columboola, Condamine and Dulacca.

Why did the press wheels sometimes give better establishment than the seed firming wheel when the firming wheel should have improved soil-seed contact and soil water conductivity as much as, if not more than, the press wheels? Evidence in the literature indicates that the additional response with the press wheels can be attributed to reduced evaporation from the compressed soil above the seed, resulting in less desiccation of seed and young seedlings. For example, So (1987) reported increased imbibition by seed at bulk densities of 1.05 to 1.25 g/cm^3 compared with a bulk density of 0.9 g/cm^3. He attributed this increase to increased soil water conductivity and reduced evaporation due to a reduced area of evaporating surface. According to Arnon (1975), the influence of soil compaction on loss of water by evaporation depends on the water content of the soil. At high soil water contents, conduction of water to the soil surface is greater in compacted soil than in loose soil. When the soil surface is dry, however, water moves as vapour through the pore spaces, and evaporation is greater in loose soil than in compacted soil. In our experiments, the press wheels were compacting relatively dry surface soil (Figure 4).

Why did the press wheels sometimes give worse establishment than the seed firming wheel? Compaction of the soil above the seed apparently increased soil strength to a level exceeding the emergence force of the particular crop species (Parker and Taylor 1965; Pathak *et al.* 1976). This negative effect of compaction on seedling emergence can be minimised by using wheels designed to press only the sides of the seed row, and by using optimum press wheel loadings.

The optimum press wheel force per unit width of wheel varied considerably with crop species. At Columboola I, for example, the optimum force was 2 to 8 N/mm for sorghum but 0 N/mm for sunflower (Figure 3). Parker and Taylor (1965) observed that dicotyledonous species are less capable of emerging through high-strength soils than monocotyledonous species. The only negative responses to press wheel pressure occurred for dicotyledonous species (sunflower and soybean) on some soil types. These species have to push two cotyledons to the soil surface whereas sorghum and wheat emerge by means of a narrow, pointed coleoptile.

The optimum press wheel force showed little change with variation in soil water content. At Condamine, for example, the optimum force appeared to be 4 to 16 N/mm for sorghum and 2 to 4 N/mm for sunflower in both sowings (Figure 3), despite a reduction in soil water content in sowing II (Figure 4). The reduced soil water content in II resulted in marked declines in establishment levels, however (Figure 3), partly because it demanded deeper placement of seed (Figure 4). Changes in depth of sowing could also be expected to affect the optimum press wheel force. In contrast, Pathak *et al.* (1976) found that the optimum pressure on the covering soil declined as soil water content increased. On a soil with 90% sand, a pressure of 108 kPa applied to the soil cover for 30 seconds enhanced wheat emergence at a soil water content 'over 6%' but reduced emergence at a water content 'over 9%'. At the higher water content, pressure on the covering soil in excess of 25 kPa reduced emergence. They concluded that high pressures on soil cover at a high initial water content resulted in high soil strength which hindered emergence.

CONCLUSIONS

The use of press wheels gave consistent, positive, crop establishment responses following conventional tillage in southern Queensland, except when dicotyledonous species (sunflower and soybean) were used on some soil types. In these situations, only wheels which apply limited pressure to the sides of the seed row should be tried. Force per unit width of wheel should be 4 to 8 N/mm for wheat and sorghum and 0 to 4 N/mm for sunflower.

Seed firming wheels are not recommended on clay soils. They may have a role on lighter soil types, especially for crop species with low emergence force, but the evidence for this in our data is tenuous.

A power-driven rodweeder behind a seeder may sometimes enhance establishment as well as providing weed control at sowing. Rodweeders could therefore be used to save the cost of the many press wheels required on broadacre seeding machinery. However, the need for deep sowing with rodweeders (to prevent the rod contacting the seed) could make them unsuitable for use with modern cultivars of wheat and barley, which have short coleoptiles (Whan 1976; Radford 1987) and therefore require shallow soil cover.

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References

Arnon, I. (1975), In U.S. Gupta (ed.), *Physiological Aspects of Dryland Farming,* Oxford and IBH Publishing Co.

Carnes, A. (1934), Soil crusts: methods of study, their strength, and a method of overcoming their injury to cotton stand, *Agricultural Engineering* **15**, 167–69, 171.

Norris, C. P. and Ward, L. D. (1983), Machine concepts and design—the effects on field performance, in *Dryland Sowing Technology* Australian Institute of Agricultural Science Occasional Publication No. 7, 49–58.

Parker, J. J. Jr. and Taylor, H. M. (1965), Soil strength and seedling emergence relations, I. Soil type, moisture tension, temperature, and planting depth effects, *Agronomy Journal* **57**, 289–91.

Pathak, B. S., Gupta, P. K. and Mahajan, V. (1976), Effect of soil compaction on seedling emergence, *Journal of Research* **13**, 35–47.

Radford, B. J. (1983), Sowing techniques: effects on crop establishment, in sutton B.G. and deKantzow D.R. (eds) *Dryland Sowing Technology* Australian Institute of Agricultural Science Occasional Publication No.7, 35–47.

Radford, B. J. (1986), Effect of a press wheel and depth of sowing on the establishment of semidwarf and tall wheats, *Australian Journal of Experimental Agriculture* **26**, 697–702.

Radford, B. J. (1987), Effect of cultivar and temperature on the coleoptile length and establishment of barley, *Australian Journal of Experimental Agriculture* **27**, 313–16.

Radford, B. J. and Allsopp, P. G. (1987), Use of insecticides and a press wheel to control soil insects affecting sorghum and sunflower establishment in southern Queensland, *Journal of the Australian Entomological Society* **26**, 161–67.

Radford, B. J. and Nielsen, R. G. H. (1985), Comparison of a press wheel, seed soaking and water injection as aids to sorghum and sunflower establishment in Queensland, *Australian Journal of Experimental Agriculture* **25**, 656–64.

So, H. B. (1987), Soil physical factors limiting crop establishment, in Wood, I.M., Hazard, W.H. and From, F.R. (eds) *Crop Establishment Problems in Queensland: Recognition, Research and Resolution* Australian Institute of Agricultural Science Occasional Publication No. 34, 154–65.

Stout, B. A., Buchele, W. F. and Snyder, F. W. (1961), Effect of soil compaction on seedling emergence under simulated field conditions, *Agricultural Engineering* **42**, 68–71, 87.

Whan, B. R. (1976), The association between coleoptile length and culm length in semidwarf and standard wheats, *Journal of the Australian Institute of Agricultural Science* **42**, 194–96.

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