SHALLOW LEADING TINES FOR DEEP TILLAGE

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SUMMARY We have conducted a series of experiments at Trangie, Warren, Narrabri and Moree to examine the use of shallow leading tines in conjunction with rippers. Ripper depths of 300, 450 and 600 mm have been investigated. Several leading tine configurations were used at depths of 150 and 300 mm. The leading tine configurations were based on chisel plough tines fitted with chisel points and sweeps. Soil disturbance and the forces on the tines were measured. Soil disturbance was greater when leading tines were used. Some leading tine configurations reduced the total draft in some cases while other configurations increased draft. Ripper depth was the most important factor in determining total draft. The use of shallow leading tines allowed more soil to be loosened with reduced ripper depth and draft.

1 INTRODUCTION

The practice known as shallow leading tines can decrease the cost of deep ripping and can do a better job of loosening the soil. Spoor and Godwin (1978) pioneered the technique in the U.K. There have been limited attempts at its use in Australia. Anthony (1990) at Auscott Narrabri found that the technique allowed crawlers to operate in a higher gear, Cockcroft (1990) found cost savings of about 50% and improved establishment of peach orchards in Victoria and Hogendyk (1992) reports that ploughing before ripping produced a better job at Auscott Warren. Quantitative research results for Australian conditions were non existent.

In 1991, Engineers from N.S.W. Agriculture and scientists from C.S.I.R.O. began a project at Trangie to test this technology (Kirby and Palmer 1992). We equipped a tillage dynamometer (Kruger and Palmer 1985) with a ripper able to dig to 600 mm and positioned commercial chisel plough tines, able to be set 150, 300 and 450 mm above the ripper depth, approximately 1.3 m in front of the ripper tine. The instrumentation in the dynamometer measures the forces on these tines, working depth and forward speed. We also measured soil moisture content and bulk density before each experiment. After the dynamometer runs, we excavated loose soil from a point in each treatment to determine the volume of soil which had been disturbed by the tines.

We tested both 400 mm wide sweeps and 50 mm wide chisel points on the chisel plough tines. In the first experiments, we used a single chisel tine positioned directly in front of the ripper, a configuration referred to as "1 Chisel" or "1 Sweep" depending on the tool fitted to the chisel tine, and two chisel tines positioned in front of and 500 mm to either side of the ripper tine, a configuration referred to as "2 Chisels" or "2 Sweeps". In the later experiments, we replaced the "1 Chisel" configuration with a "3 Chisel" configuration in which three chisel tines were used, one directly in front of the ripper as well as one 500 mm to each side. We used a nominally constant speed of about 3.6 - 4 km/h for all tests.

2 RESULTS

We have conducted experiments at the Agricultural Research Centre, Trangie, Auscott Warren, Togo Station, Narrabri and Telleraga Station, Moree.

We used the Trangie experiment as a preliminary exercise to test the equipment, get some experience of the magnitude of the possible results and determine treatments for the following experiments. It was conducted in February 1992 on the red soil of 'Block 6' at the Agricultural Research Centre. At the time of the experiment, the subsoil was wetter than the plastic limit although the surface layer was dry and set hard. Because this experiment was mainly a test of the instruments, we did not collect soil samples. We did determine, by excavation, the amount of soil disturbed by each treatment. We used only one ripper depth of approx. 500 mm with the leading tines set 200 mm deep. Figures 1 to 5 depict the results of this experiment.

Table I summarises the results from the later trials, in terms of soil disturbance and draft forces.

2.1 Soil Loosening

The data, shown in Table I, for soil disturbed are the results of single measurements for each treatment. We noted, particularly at the Narrabri and Moree sites, that the area of soil disturbed varied considerably over comparatively short distances. These data should therefore be used carefully as they may not be representative of the average disturbance over a long distance.

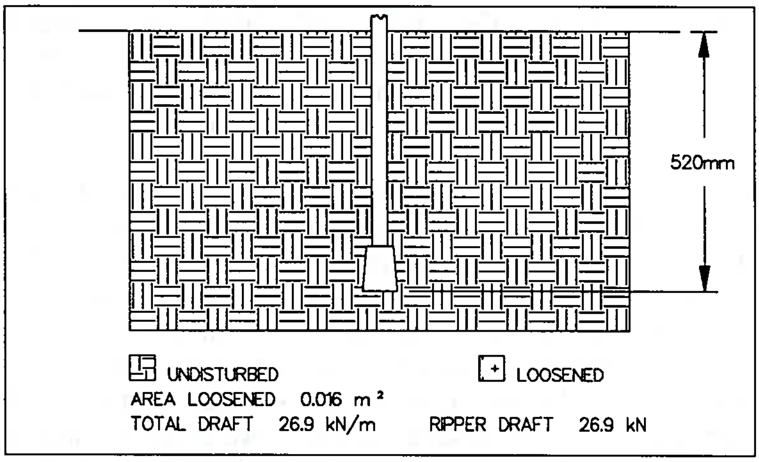

Figure 1 Soil disturbance without leading tines - Trangie site.

At all sites and at all ripper depths, one or more leading tine configurations loosened more soil than was loosened by the ripper alone. The use of shallow leading tines also allowed effective deep tillage under soil conditions which would otherwise have been too wet. The increase in volume of soil loosened varied with the tine configuration, soil type and soil conditions. As might be expected, the effectiveness of the leading tines increased with increasing ripper depth. Where the leading tines were used at both 150 and 300 mm, the latter setting gave the greater volume of loosened soil. In general, leading tine configurations in which the leading tines were laterally offset from the ripper loosened more soil than was loosened by the single leading tine fitted with the same tool. No one configuration consistently outperformed all others however the '2 sweeps', '2 chisels' and '3 chisels' configurations consistently outperformed the ripper alone and the ripper with one leading tine configurations.

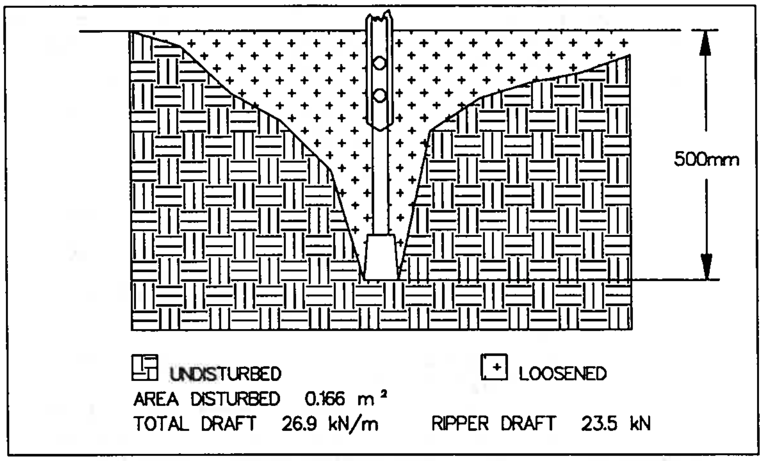

Figure 2 Soil disturbance with 1 leading chisel - Trangie site.

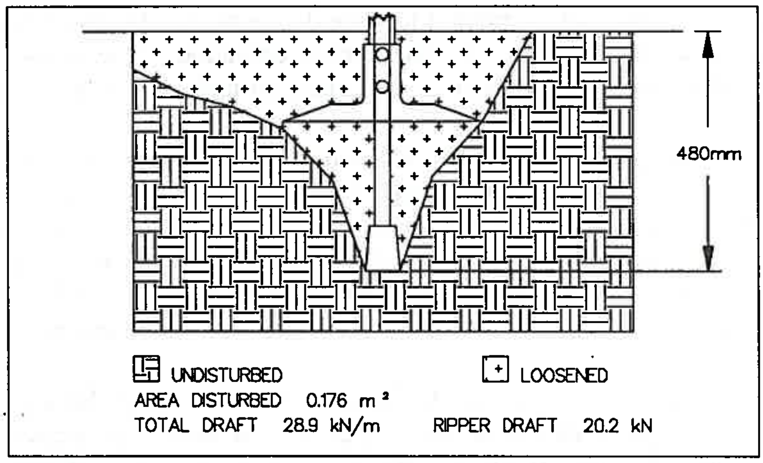

Figure 3 Soil disturbance with 1 leading sweep - Trangie site.

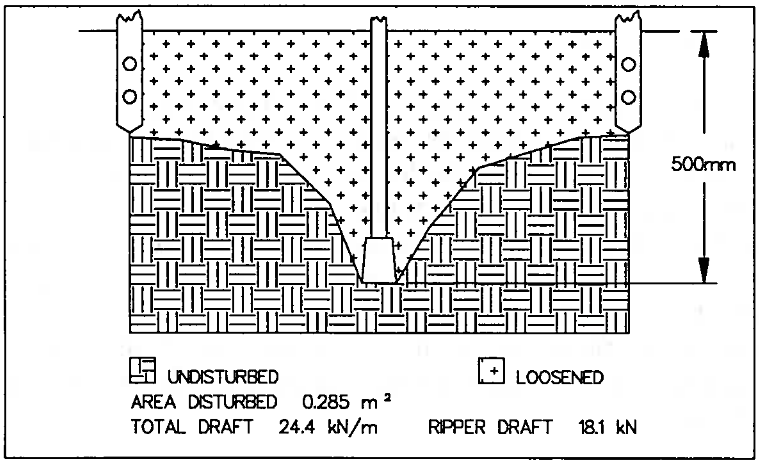

Figure 4 Soil disturbance with 2 leading chisels - Trangie site.

The leading tines had little or no effect when operating within a layer of top soil which was already fairly loose. This might suggest that the leading tines and ripper tines need not be on the one implement but could be separate and used successively as tried by Auscott at Warren. A potential difficulty with this approach is that the surface soil

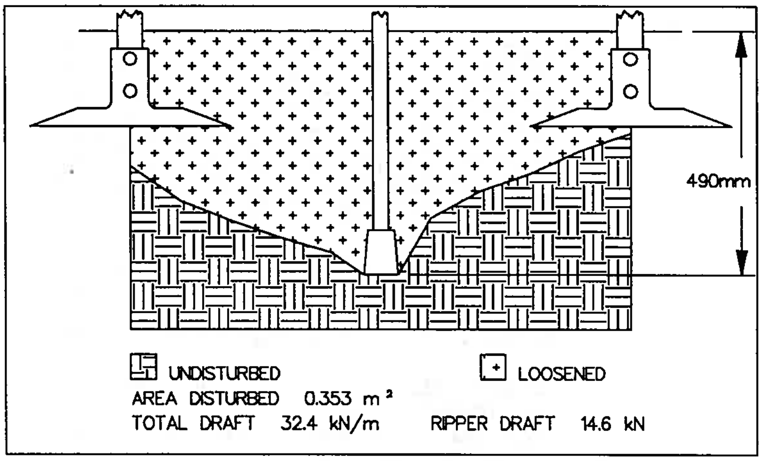

Figure 5 Soil disturbance with 2 leading sweeps - Trangie site.

would be loosened before ripping making it less able to support the high tractive forces and heavy weights imposed by the ripping operation. The results would be reduced tractive efficiency and a danger of recompaction under the wheels/tracks.

At the Narrabri and Moree sites, the soil contained large numbers of natural, vertical shrinkage cracks in the depth range from about 120 mm to about 400 mm. The volume of soil loosened in this depth range appeared to be influenced greatly by the position of these cracks relative to the position of the ripper. In general, the ripper when used alone merely re-arranged some of the natural soil blocks formed by these cracks without breaking the blocks down to any noticeable extent.

We found that it was possible to loosen more soil using the leading tines than was loosened by digging deeper with the ripper *e.g.* at Moree, the ripper at 450 mm with '2 sweeps' at 300 mm loosened 0.39 m^2 of soil while the ripper alone at 600 mm loosened only 0.18 m^2.

2.2 Draft Forces

The total drafts quoted in Figures 1 - 5 and Table I are based on the assumption that the tools used in the experiments represent a section of a wider machine with multiple rippers on 1 m spacing. For no leading tines, the total draft is therefore the draft of the ripper alone, for one leading tine, the total draft is the sum of the ripper and leading tine drafts, for two leading tines, the total draft is the sum of the ripper draft and the draft of one of the leading tines and for three leading tines, the total draft is the sum of the drafts of the ripper and two of the leading tines. This total draft is essentially proportional to the fuel used for the operation, the power required to complete the operation in a given time or the time required for the operation using a given power.

At all sites and ripper depths, one or more leading tine configurations required a lower total draft than the ripper alone however these differences were generally small and not statistically significant as indicated by the superscripts following the drafts given in Table I. Ripper depth was the most significant factor influencing total draft.

Table I Results of the Warren, Narrabri and Moree experiments.

Ripper Depth (mm)	Lead Tine Configuration	Lead Tine Depth (mm)	Warren		Narrabri		Moree	
			Soil Disturbed (m^2)	Total Draft (kN/m)	Soil Disturbed (m^2)	Total Draft (kN/m)	Soil Disturbed (m^2)	Total Draft (kN/m)
600	No Leading Tines		0.252	28.7^{abcde}	0.182	39.6^{a}	0.180	42.7^{cd}
600	1 Chisel	150	0.217	29.7^{abcd}				
600	1 Sweep	150	0.121	30.7^{ab}	0.243	36.0^{a}	0.283	52.3^{ab}
600	2 Chisels	150		27.7^{abcdef}	0.275	37.1^{a}	0.326	52.5^{abcd}
600	3 Chisels	150			0.260	30.4^{ab}	0.221	54.6^{abc}
600	2 Sweeps	150		28.5^{abcde}	0.248	35.1^{a}	0.428	58.6^{a}
600	1 Chisel	300	0.181	29.8^{abc}				
600	1 Sweep	300	0.180	31.7^{a}	0.202	37.0^{a}	0.330	49.5^{abcd}
600	2 Chisels	300	0.286	31.9^{a}	0.446	36.6^{a}	0.276	46.7^{abcd}
600	3 Chisels	300			0.344	38.6^{a}	0.404	40.0^{de}
600	2 Sweeps	300	0.290	31.4^{a}	0.277	36.1^{a}	0.364	43.7^{bcd}
450	No Leading Tines		0.190	22.3^{efghij}	0.157	17.6^{bcde}	0.188	22.7^{fgh}
450	1 Chisel	150	0.129	$22.8^{bcdefgh}$				
450	1 Sweep	150	0.147	21.4^{efghij}	0.244	18.1^{bcd}	0.238	22.3^{fghi}
450	2 Chisels	150	0.178	$22.6^{cdefghi}$	0.194	18.4^{bcd}	0.241	24.9^{fg}
450	3 Chisels	150			0.261	16.5^{bcde}	0.194	24.4^{fg}
450	2 Sweeps	150	0.218	22.5^{defghi}	0.281	19.1^{bc}	0.228	24.8^{fg}
450	1 Chisel	300	0.158	$23.9^{abcdefgh}$				
450	1 Sweep	300	0.146	$25.5^{abcdefg}$	0.181	13.9^{cde}	0.181	24.5^{fg}
450	2 Chisels	300	0.306	$23.0^{abcdefgh}$	0.189	12.7^{cde}	0.342	27.2^{efg}
450	3 Chisels	300			0.278	16.2^{bcde}	0.197	27.6^{efg}
450	2 Sweeps	300	0.270	28.7^{abcde}	0.299	20.1^{bc}	0.390	29.3^{ef}
300	No Leading Tines		0.148	14.0^{j}	0.141	6.4^{e}	0.144	11.9^{hi}
300	1 Chisel	150	0.123	15.6^{ij}				
300	1 Sweep	150	0.090	16.3^{hij}	0.206	6.5^{e}	0.208	10.3^{i}
300	2 Chisels	150	0.136	16.7^{fghij}	0.099	7.3^{de}	0.223	11.7^{i}
300	3 Chisels	150			0.165	8.4^{cde}	0.147	12.3^{ghi}
300	2 Sweeps	150	0.179	16.4^{ghij}	0.168	8.4^{cde}	0.201	11.4^{i}

^{abcdefghij} Forces having superscripts containing the same letter are not significantly different. Valid statistical comparisons between sites are not possible.

Shaded values represent the lowest specific draft (Total Draft per unit area of disturbed soil) for each ripper depth at each site.

A more useful measure may be the specific draft, *i.e.* the total draft divided by the cross sectional area of soil loosened. This quantity provides a method of relating the cost of the operation to the benefit produced. Combinations having the lowest specific draft for each site and ripper depth have been shaded in Table I.

2.3 Tilth

The use of shallow leading tines generally produced a finer tilth than conventional ripper only practice. Analysis of clod sizes from the Auscott, Warren site showed that at ripper depths of 300 and 450 mm, the leading tines had little effect on clod sizes produced but, at a ripper depth of 600 mm, the clods produced by the ripper alone were four times larger than were produced by the ripper in conjunction with leading tines. At the Moree site, all treatments produced larger clods than at the other sites however the staff at the property commented that the "large" clods produced during the experiment were much smaller and fewer in number than they would have expected to see from their ripping operations.

This effect seems to depend on soil moisture content. The size of the clods in drier cracking clay soils also depends on the depth within the profile from which they originate. The smaller clods produced when shallow leading tines are used may eliminate the need for the subsequent operations now needed to breakdown the large clods produced by conventional ripping. The clods produced at Warren by the ripper when used alone were friable and in many cases difficult to pick up without breaking.

The extent to which large blocks from soil containing large shrinkage cracks are broken up depends upon the positioning of the leading tines relative to the layer from which the blocks originated. Best results occurred when the depth of the lead tines fell within this layer. If this layer extends over a large depth range, more than one set of leading tines may be necessary to break up these blocks. It may be better to break the blocks using one or more operations prior to ripping rather than bringing them to the surface as large clods then attempting to break them down as is normal practice.

3 CONCLUSIONS

The use of shallow leading tines improves deep tillage through the increased volume of soil loosened and the finer tilth produced when the ripping operation is performed with the soil wetter than would be feasible when using a ripper alone. This should result in better water infiltration, better root growth and higher yields from subsequent crops. Cost savings by the elimination of subsequent operations to break down large clods are likely to be substantial.

Shallow leading tines did reduce the specific draft for a given ripper depth in most cases and up to 62% at Narrabri at a 600 mm ripper depth. This is comparable with the 55% reduction in specific draft reported by Spoor and Godwin (1978). This was achieved mainly through increases in the volume of loosened soil and small changes in total draft.

Shallow leading tines did not in general have a significant effect on the total draft of the operation and so are unlikely to bring about direct cost increases or savings during the operation unless a reduced ripper depth can be used to produce a similar result. Ripper depth was the most significant factor in determining draft. For example, at

Narrabri, the ripper alone at 600 mm loosened a 0.182 m^2 cross section of soil with a total draft of 39.6 kN/m, *i.e.* a specific draft of 217 kN/m^3, while the ripper at 450 mm preceded by the '3 chisel' configuration at 300 mm loosened a 0.278 m^2 cross section of soil with a total draft of 16.2 kN/m, *i.e.* a specific draft of only 58 kN/m^3: a 52.7% increase in loosened soil with a 59% total draft reduction, *i.e.* a 73% reduction in specific draft. The profile of the loosened soil will however have a different shape. Further research will be required to determine which of the shapes is of greater advantage to the crop.

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