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*Cotton Research and Development Corporation*

Project CSO 3C

**SHALLOW LEADING TINES FOR DEEP  
TILLAGE**

**FINAL REPORT**

**A.L. Palmer and J.M. Kirby**

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# *Cotton Research and Development Corporation*

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## PROJECT FINAL REPORT - PROJECT CSO 3C

### SHALLOW LEADING TINES FOR DEEP TILLAGE

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## PROJECT FINAL REPORT - PROJECT CSO 3C

**PROJECT TITLE:           SHALLOW LEADING TINES FOR  
DEEP TILLAGE**

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**PROJECT COMMENCED:** 1 November 1991 (Funds received and work commenced)

**PROJECT COMPLETED:** 30 June 1992

**AIMS:** To test and demonstrate the use of shallow leading tines for deep tillage.

### **SUMMARY OF RESULTS:**

The use of shallow leading tines for deep tillage was pioneered in the U.K. about 15 years ago. It has not been widely adopted in Australia despite considerable potential advantages. This project aimed to test the technology under Australian conditions incorporating soil and operating parameters relevant to Australian cotton growers.

Experiments were conducted on the Agricultural Research Centre at Trangie and on cotton farms at Warren, Narrabri and Moree on red, grey and black soils under conditions ranging from wet to dry.

The results of these experiments confirmed the potential of shallow leading tines to loosen more soil for similar energy inputs thereby substantially reducing the specific draft. Specific draft is the total draft of the tines per unit volume of loosened soil. In most cases, the total draft of deep tillage and leading tines at each site depended only upon the working depth of the deep tillage tine. When leading tines were used, the draft reduction on the deep tillage tine was offset by the draft of the leading tines. In approximately two thirds of the leading tine configuration/deep tillage tine depth/site combinations, the specific draft was up to 95% less than that of a deep tillage tine alone at the same depth. In the other combinations, the specific draft was up to 124% greater than that of a deep tillage tine alone. No one leading tine configuration was consistently better than the others and the efficacy of all varied from site to site. The results prove the potential of the technology. However, the significant number of cases in which the leading tines

increased specific draft, indicate that there is a substantial risk in using this technology commercially before the variables which determine success or failure have been identified and appropriate values quantified.

The tilth produced when leading tines were used was found to be finer than produced by a deep tillage tine used alone. This was an unexpected finding not previously reported in the literature. In one experiment, the clods produced by the deep tillage tine alone were four times the size produced when leading tines were used. This reduction in clod size has the potential to save the cotton industry an average of \$25/ha p.a. by eliminating the need for subsequent operations to break large clods left after conventional deep tillage operations such as ripping and direct listing.

The use of leading tines was found to loosen soil under much wetter conditions than a deep tillage tine alone. This has significant implications for soil management strategies, timing and frequency of irrigation and other operations and the use or otherwise of rotation crops to dry compacted soil.

The potential of leading tines to produce a finer tilth and allow operations at moisture contents higher than previously possible without producing smearing could possibly be exploited in implements for the renovation of permanent beds or retained hills and mechanical weed control. The leading tine concept could be adapted to the maintenance of permanent beds. Several operations, not necessarily including 'deep tillage', can possibly be performed in a single pass with similar power and fuel consumption to only one of the operations. One pass with such a machine could perhaps replace several mechanical operations and the growing of one or more rotation crops for the repair of soil damage.

#### RECOMMENDATIONS:

1. The development of a commercial deep tillage implement and/or further research to provide guidelines for growers wishing to modify their own machines should be given a high priority. Such development work must recognise that considerable time and effort in the testing and modification of prototypes will be required to produce a machine of acceptable quality and having reliable performance.
2. The use of shallow leading tines, or other tools, in a multi-depth implement for the single pass renovation of permanent beds or retained hills without deep tillage should be investigated.
3. The implement development work in 1 and 2 above should not end with a working prototype. Further research should be conducted to determine the best management strategies to take advantage of the ability of shallow leading tines to loosen more soil and produce a finer tilth. This research should examine the effects of moisture profile at the time of tillage, tine configuration, speed of operation, volume of soil loosened and the number of operations needed following deep tillage in order to produce an acceptable seed bed on lint yield and irrigation management and needs to be conducted on a representative range of soil types. This research should include full economic analysis of the effect of leading tines on deep tillage, bed renovation operations and subsequent operations and management strategies including the use of rotation crops.

# DETAILED FINAL REPORT

## BACKGROUND:

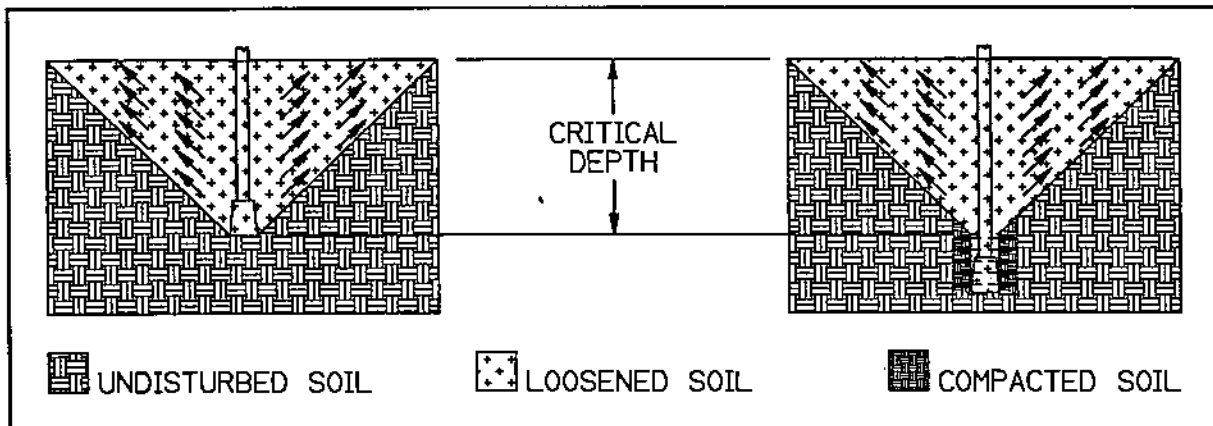


Figure 1 Effect on soil movement of using a ripper above and below critical depth.

There is a limit, called the 'critical depth', to the useful range of working depths at which a tined implement, such as a ripper, will loosen soil. The action of a tine is to push the soil immediately in front of it upwards and forwards. If the soil adjacent to the tine is strong enough, it will then push the surrounding soil up and loosen it. If the depth is too great, the soil around the tine will not be strong enough to overcome the strength and weight of the overlying soil. This soil will flow sideways or down and around the tine instead, creating a smeared or compacted layer around the foot of the tine. This effect is shown in figure 1.

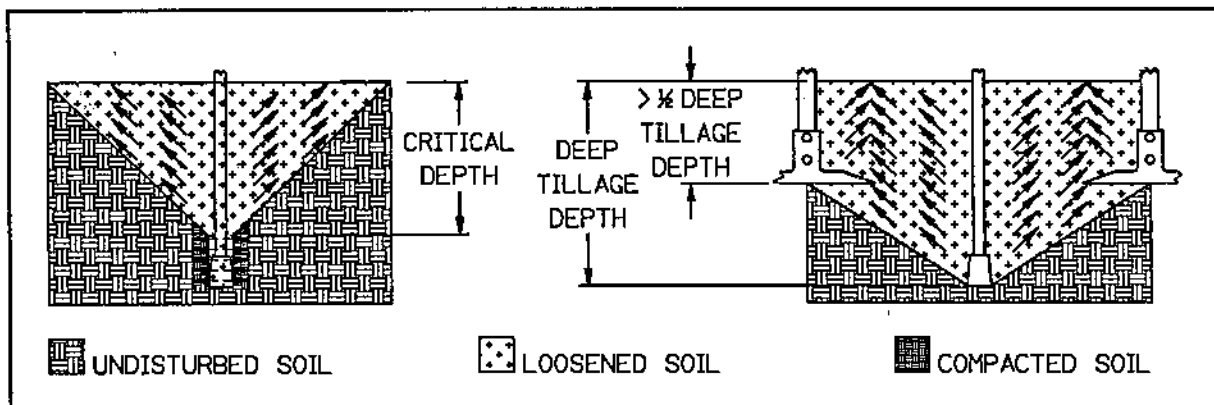


Figure 2 Effect on soil movement of using a ripper below its critical depth with shallow leading tines.

The critical depth can be extended downwards by using shallow working tines in front of the deep tine to loosen some of the overlying soil. Although the amount of overlying soil is the same, it is now weakened by the leading tines which allows more of it to be loosened before it exceeds the strength of the soil at the foot of the deep tine. This effect is shown in Figure 2. The use of shallow leading tines for deep tillage was pioneered in the U.K. by Spoor and Godwin (Spoor and Godwin, 1978). Their research showed that the technique could roughly double the volume of soil loosened by a deep tillage tine used alone and slightly reduce the total draft of the implement resulting in a saving of up to 55% in specific draft. Both Spoor and Godwin have visited Australia

and advocated adoption of the technique here. Despite adoption overseas no Australian implement manufacturers have developed machinery for Australian farmers. Limited Australian experience tended to confirm the U.K. results but did not produce quantitative data or lead to widespread adoption. The cost of deep tillage to the cotton industry has been estimated as being of the order of \$2.4 million per year (Kirby and Palmer 1992). The potential for savings indicated a need for testing and promoting the technique.

## EQUIPMENT DEVELOPMENT AND SETTINGS:

### Tines:

Since the lack of commercially available implements was one of the reasons for the project, we had to develop our own 'implement' before experiments could begin. Even before the original research by Spoor and Godwin, (1978) who used conventional straight shank subsoiler tines, considerable effort had been devoted to deep tillage tines leading to the development of the parabolic tine. U.S. research at the National Tillage Machinery Laboratory in the 1950's, (Nichols and Reaves 1958), indicated a reduction in draft for a subsoiler with a curved shank. Tupper (1974 and 1977) defined the 'parabolic' subsoiler design and reported a reduction in power required. Williford *et al.* (1974) described the 'Triplex' subsoiler for wide-bed controlled traffic cotton production and Williford (1980) showed higher cotton seed yield from plots subsoiled with one 'Triplex' subsoiler compared with two conventional subsoilers 102 cm apart. Smith and Williford (1988) found that a parabolic subsoiler tine had a lower draft and generated greater soil lifting forces than conventional or triplex subsoilers. We selected a tine from the Grizzly Deep Digger, which is similar in shape to the parabolic tines, as the deep working tine for our experiments. For the shallow leading tines, we originally chose some heavy duty commercial chisel plough tines, which we had on hand. The major reasons for the selection of chisel plough tines as the leading tines were the number of chisel ploughs already in use in the industry and the wide range of readily available points which could be fitted to them. We chose to use both 50 mm wide chisel points, with the aim of minimising draft based on previous work, (Palmer, Albert and Smith 1988 and 1989, Palmer and Kruger, 1982 and Palmer, Kruger and Humphries, 1982 and 1983) and 400 mm wide sweeps with the aim of increasing soil disturbance.

These tines were mounted on specially built frames attached to NSW Agriculture's Tillage Dynamometer (Kruger and Palmer, 1985) so that all the forces on the tines could be measured.

Unfortunately, the 'heavy duty' chisel plough tines failed during the first experiment and had to be replaced. The reasons for choosing chisel plough tines were still valid and so Mr Palmer designed still heavier duty chisel plough tines, which were used in all subsequent experiments.

### Working Depths and Speed:

Local inquiries indicated that 450 mm was a typical ripping depth with some growers ripping to 600 mm. Spoor and Godwin's original research included working depths to 400 mm. We chose to use nominal working depths for the deep tillage tine of 300 mm, which was shallower than Spoor and Godwin, 450 mm, which is typical practice in the Macquarie Valley, and 600 mm which seemed to be the extreme used by cotton growers. We chose to use nominal leading tine depths of 150 mm and 300 mm. Although the design of the frames under our dynamometer would have permitted a leading tine depth of 450 mm when the deep tillage tine was set at 600 mm, we did not consider this a practical combination. Because we expected variation from the nominal settings, we used a 'fifth wheel' to monitor actual depths. In the first experiment, for which the

'fifth wheel' was not ready, we used a single working depth with the deep tillage tine set at 500 mm and the leading tines set at 200 mm.

Working speed was arbitrarily chosen at about 4 km/h (1.1 m/s) because this speed was felt to be fairly typical of that used for deep tillage operations, it was achievable fairly reliably with the tractors available for the experiments and we believed that at such a low speed, any speed variation would have a minimal effect on draft and soil disturbance. Actual average speeds were monitored using the same 'fifth wheel' as was used to monitor depth.

#### **Tine Spacing:**

Within the space limitations of the dynamometer and the time constraints for the experiments, it was not possible to vary the longitudinal (*i.e.* parallel to the direction of travel) distance between the leading tines and the deep tillage tine. This remained fixed at approximately 1.3 m.

Several configurations were used for the leading tines. In the first three experiments, the configurations used were a leading tine, fitted with a chisel point, directly in front of the deep tillage tine, a leading tine, fitted with a sweep, directly in front of the deep tillage tine, two leading tines, fitted with chisel points, ahead of but 500 mm to either side of the deep tillage tine and two leading tines, fitted with sweeps, ahead of but 500 mm to either side of the deep tillage tine.

In the last two experiments, the leading tine configurations were a leading tine, fitted with a sweep, directly in front of the deep tillage tine, two leading tines, fitted with chisel points, ahead of but 500 mm to either side of the deep tillage tine, two leading tines, fitted with sweeps, ahead of but 500 mm to either side of the deep tillage tine and three leading tines fitted, with chisel points, one of which was directly in front of the deep tillage tines and the other two of which were located 500 mm to either side. Figure 3 shows the relative positions of the tines.

#### **EXPERIMENTS:**

##### **Experiment 1 - Agricultural Research Centre, Trangie:**

The first experiment was conducted on red/brown soil at the Trangie Research Centre in February 1992. This experiment was designed mainly to test our equipment and determine the range of forces which the tines were likely to have to withstand. A single nominal depth setting with the leading tines at 200 mm and the deep tillage tine at 500 mm was used in this experiment. The soil was wetter than desirable for deep tillage but drier soil was not available due to general rain. The lack of drier soil for this experiment showed the ability of shallow leading tines to work successfully in soil wetter than we would otherwise have tried. Deep tillage with leading tines produced a finer tilth, than would have been expected had the soil been ripped when dry, and indicated the possibility of extending the range of conditions under which deep tillage could be performed. Unfortunately, the commercial leading tines failed due to excessive draft loads necessitating the design and manufacture of stronger tines for the remaining experiments. The new tines were designed to withstand the forces encountered in the first experiment with a safety margin. Dr A.J. Koppi from University of Sydney extracted soil monoliths showing the undisturbed soil structure and the passage of a deep tillage tine at a working depth of 500 mm.

##### **Experiment 2 - Agricultural Research Centre, Trangie:**

The second experiment was planned as a repeat of experiment 1 but using the new tines. It was conducted in May 1992 by which time the soil was much drier and harder. This experiment was

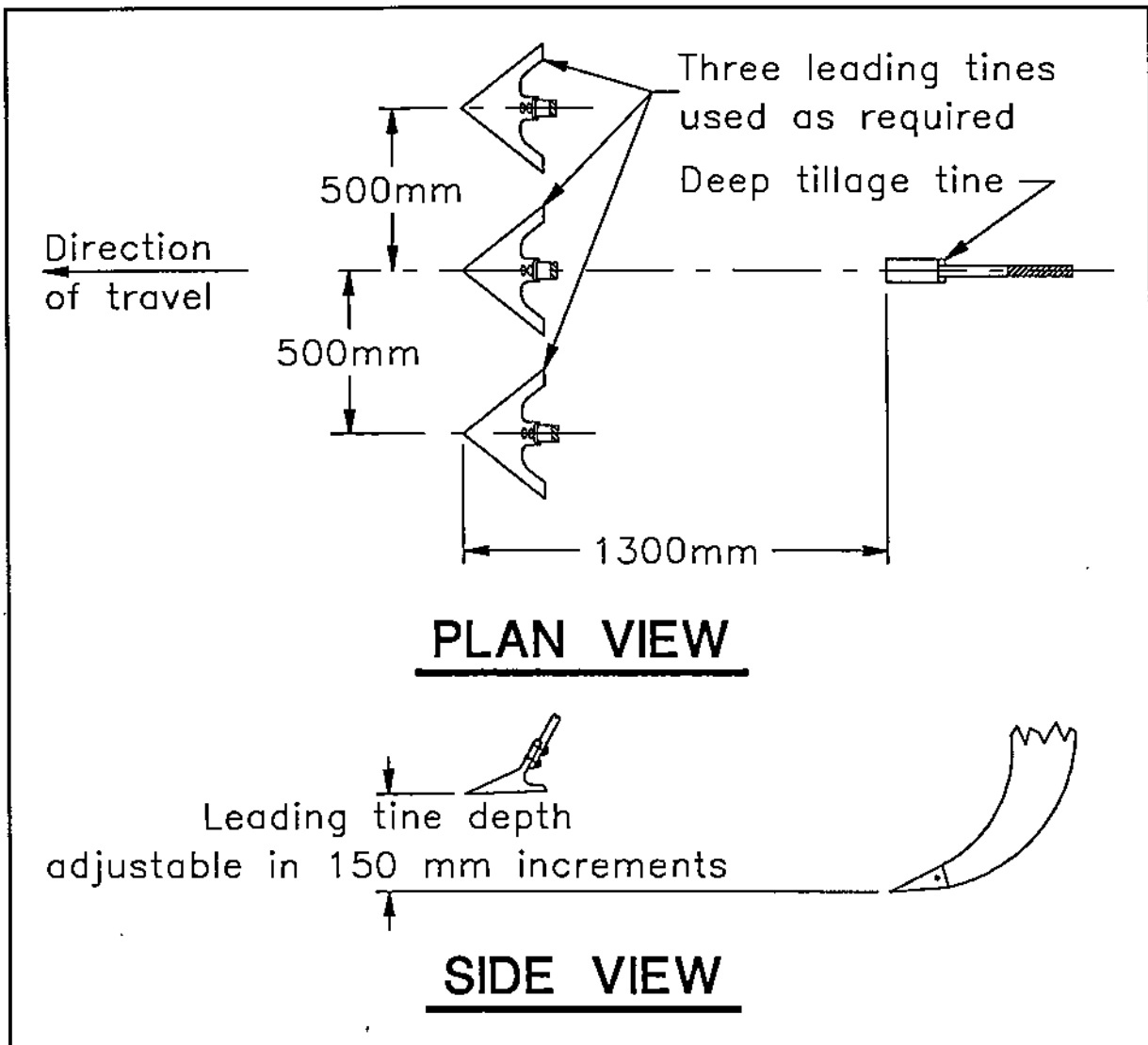


Figure 3 Arrangement of leading and deep tillage tines used in experiments.

abandoned when the point broke off one of the new tines and forces above the nominal capacity of the deep tillage tine were measured. The broken leading tine was repaired and all were further upgraded during the course of experiment 3.

### Experiment 3 - Auscott Warren:

This experiment was conducted on a grey clay at Auscott Warren. The block was unirrigated, had never been ripped and was being prepared for a wheat crop. The top 100 mm or so of soil was loose, as a result of tillage, with the profile below that being compacted. The soil moisture content was relatively high, although still below the plastic limit, near the surface. The stickiness of the soil below the top layer precluded the collection of samples for bulk density measurement below 150 mm. Samples of clods were collected from this site for measurement of clod sizes and soil samples were collected for moisture content determination at depths of 150 - 300, 300 - 450 and 450 - 600 mm. Soil monoliths were extracted and examined using the 'Solicon' system to show the effect of using a deep tillage tine at depths of 300, 450 and 600 mm.

#### **Experiment 4 - Togo Station, Narrabri:**

The treatment using a single leading tine fitted with a chisel point was deleted from this experiment and replaced with one using three leading tines fitted with chisel points. The experiment was conducted on a cracking clay soil which had been chisel ploughed to about 100 - 150 mm. This top layer was relatively dry and cloddy. The soil below contained some cracks but was otherwise compacted. Soil samples were collected for bulk density and moisture content at depths of 0 - 150, 150 - 300, 300 - 450 and 450 - 600 mm.

#### **Experiment 5 - Telleraga Station, Moree:**

The treatments used in Experiment 4 were repeated at this site on a black clay soil. The top 100 mm of soil was dry, loose and crumbly as a result of preparation for a failed wheat crop which had been planted into the stalks of the previous cotton crop. There was a band of soil, approximately 10 - 20 mm thick, at a moisture content fairly close to the plastic limit just below this surface layer. The soil from there down to about 400 mm was drier, compacted and contained many large shrinkage cracks separating large hard clods. From 400 mm to 600 mm the soil was relatively uncracked. This site had never been ripped. Soil samples were collected for bulk density and moisture content at depths of 0 - 150, 150 - 300, 300 - 450 and 450 - 600 mm.

### **RESULTS AND DISCUSSION:**

#### **Mechanical Parameters Recorded:**

Draft forces of leading and deep tillage tines were recorded using a P.C. based data acquisition system in the tillage dynamometer. This system was devised by Mr Palmer for use with a three-point-linkage dynamometer (Palmer, 1992) and augmented with a 'fifth wheel' for the measurement of speed and depth in this project. The collected data from each dynamometer run was graphed, as shown in Figure 4, prior to analysis.

#### **Soil Disturbance Measurements:**

At each site, soil profiles were excavated to determine the volume of soil disturbed. As well as the volume disturbed, these excavated profiles also provided data on the shape of the disturbed area and the actual ripping depth achieved. The mean depths, as recorded by the 'fifth wheel' were then adjusted, by adding or subtracting an offset, to best match the actual depths determined by excavation. This allowed for effects such as the fifth wheel's running in a furrow or on a hill. At the Auscott Warren site, the Solicon image was compared with the disturbed profile determined by excavation with good agreement between the two techniques. Figure 5 shows the solicon image of the furrow left by the deep tillage tine working at 300 mm without leading tines and Figure 6 shows the corresponding profile obtained by excavation.

Particularly at the Telleraga Station site, but also to a lesser extent at the Togo Station site, we observed that the volume of soil loosened was influenced by the presence of vertical shrinkage cracks in the soil. A crack close to the line of travel of the deep tillage tine inhibited the loosening of soil beyond the crack's position whereas a crack situated outside of what would otherwise have been the expected zone of loosened soil allowed loosening all the way out to the crack's position. This suggests that there may be scope in the future to fine tune the tine spacing of deep tillage implements to somehow match the crack spacing in cracking clay soils. Because of the limitations imposed by row spacing, this may mean initiating cracks at the edges of beds by drying or the use of narrow tines or the use of more than one deep tillage tine per bed/hill.

AUSCOTT - WARREN  
 NOMINAL RIPPER DEPTH 600mm  
 TWO LEADING SWEEPS AT 300 mm

REP 2

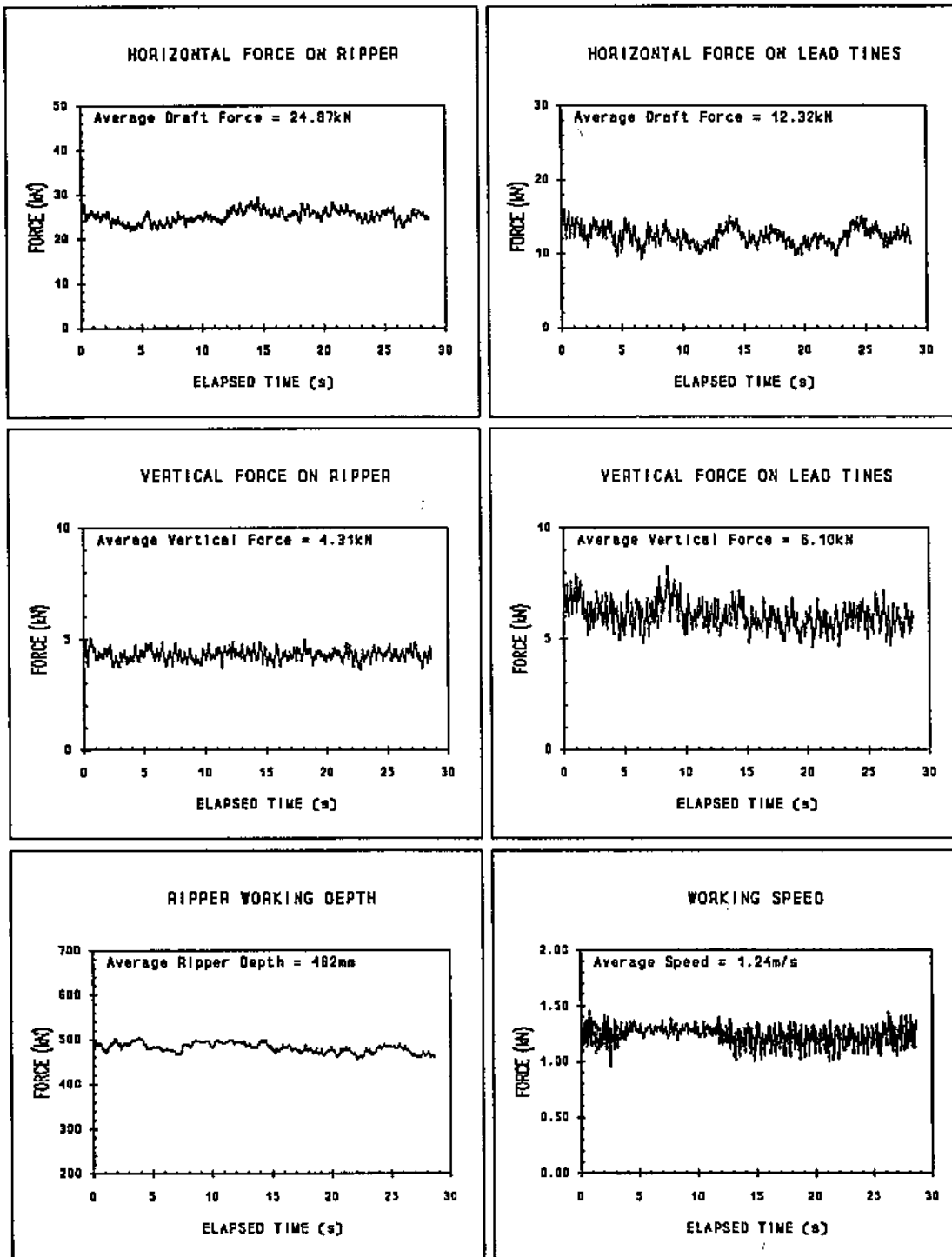


Figure 4 Typical force, depth, and speed data from a dynamometer run.

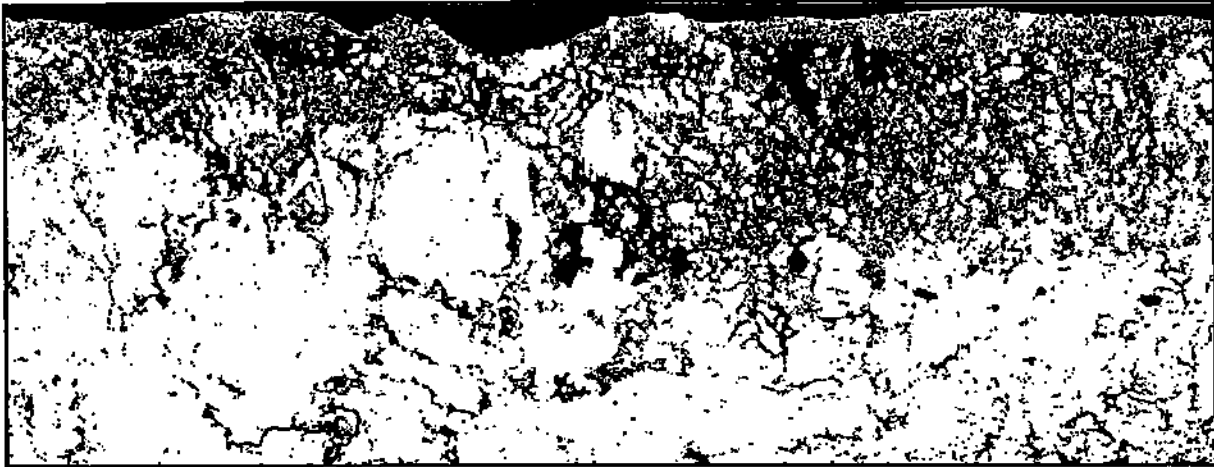


Figure 5 Solicon image of a 1000 mm wide vertical section of soil ripped to 300 mm at Auscott Warren.

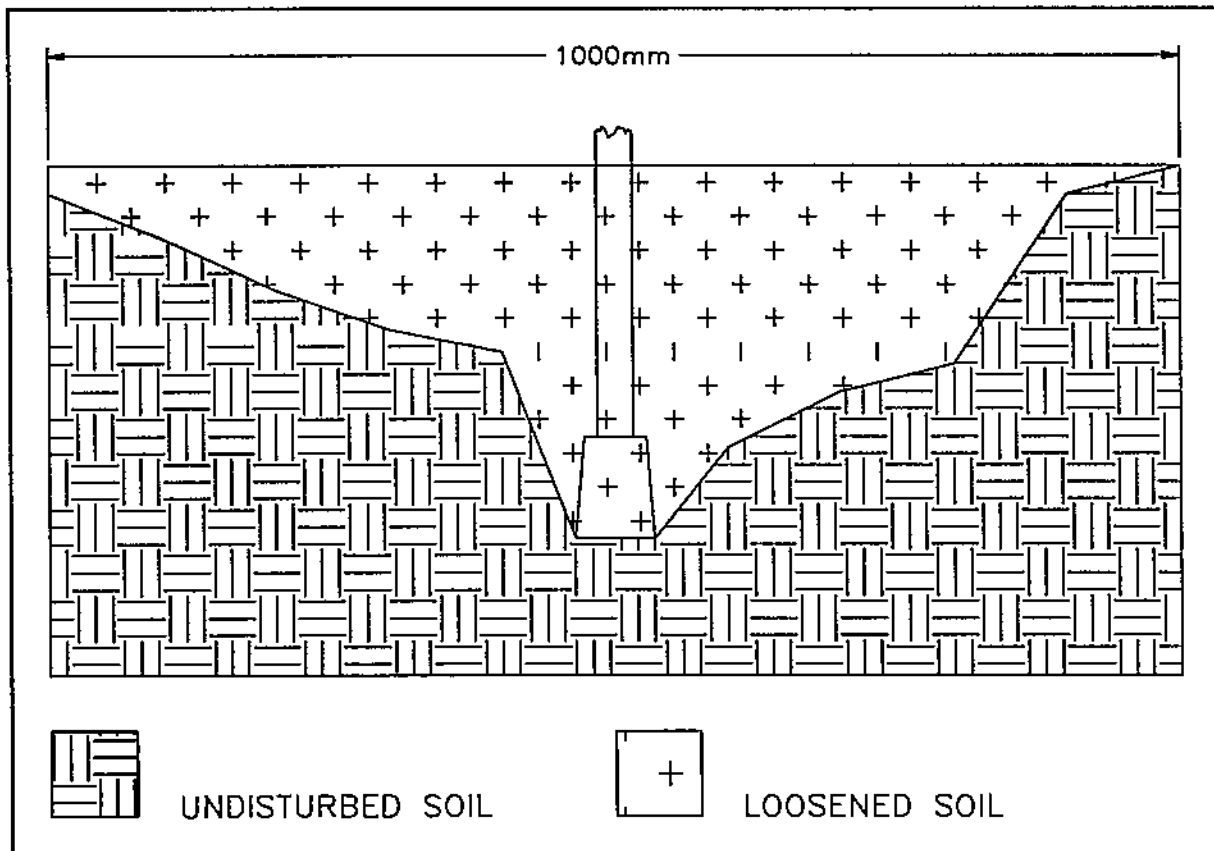


Figure 6 Loosened soil profile obtained by excavation for ripper at 300 mm without leading tines at Auscott Warren.

**Effect of Leading Tines on Draft and Soil Disturbance:**

In most cases, the leading tine configuration made no significant difference to the total draft of the combination of tines. It did, however, make a significant difference to the draft of the deep tillage tine. In general, the draft reduction on the deep tillage tine was offset by the added draft of the

leading tines resulting in little total change. The greatest reduction in total draft was 28% and the greatest increase in total draft was 37%. The generally insignificant change in total draft has no effect on the energy or tractor power required for deep tillage, but it does have some important implications for machinery design. In particular, the strength of the deep tillage tine does not need to be as great which leads to a potential weight and cost saving. Some of the weight and cost saving in the deep tillage tine and its supporting framework will be offset by the weight and cost of the shallow tines.

The only factor to consistently affect total draft was the working depth of the deep tillage tine.

Table I Results of the Trangie experiment.

Nom. Deep Tillage Tine Depth (mm)	Lead Tine Configuration	Lead Tine Depth (mm)	Soil Disturbed (m <sup>2</sup> )	Total Draft (kN/m)
500	No Leading Tines		0.016	26.9
500	1 Chisel	200	0.166	26.9
500	1 Sweep	200	0.176	28.9
500	2 Chisels	200	0.285	24.4
500	2 Sweeps	200	0.353	32.4

In almost all cases, the presence of leading tines increased the volume of soil disturbed. The results of Experiment 1 are summarised in Table I and the results of Experiments 3, 4 and 5 are summarised in Table II.

These results show that leading tines loosen more soil than a deep tillage tine used alone for similar effort when operated under the same conditions. Specific draft, *i.e.* draft force divided by the cross sectional area of soil loosened, is a measure of the efficiency of the soil loosening operation. Table III lists the best and worst specific draft figures for each site and deep tillage tine depth. In approximately two thirds of the site/nominal deep tillage tine depth/leading tine configuration combinations, the specific draft of deep tillage tine plus leading tines was up to 95% less than the specific draft of the deep tillage tine used alone. In the remaining cases, the specific draft of the deep tillage tine plus leading tines was up to 124% greater than the specific draft of the deep tillage tine used alone. There is clearly potential for significant savings as well as potential for spectacular failures. Most of the failures, *i.e.* cases when the specific draft with leading tines was greater than the specific draft of the deep tillage tine used alone, occurred when the leading tines were operated at insufficient depth to effectively loosen any compacted soil. There is therefore a need for care in choosing the working depth of the shallow leading tines in relation to the soil strength profile to ensure that the leading tines do in fact contribute to the soil loosening process.

#### Tilth and Soil Moisture Range:

The results of the dry bulk density and moisture content measurements at each site are summarised in Table IV. The low bulk density in the 0 - 150 mm range at the Moree site is due to the extremely loose crumbly mulch layer while the high moisture content is due to the thin wet layer immediately below the mulch layer. A similar effect, although not so pronounced can be seen in the results from the Narrabri site. Bulk density was not measured below 150 mm at the Warren

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

Nom. Deep Tillage Tine Depth (mm)	Lead Tine Configuration	Lead Tine Depth (mm)	Warren			Narrabri			Moree		
			Adjusted Average Deep Tillage Tine Depth (mm)	Soil Disturbed (m <sup>2</sup> )	Total Draft (kN/m)	Adjusted Average Deep Tillage Tine Depth (mm)	Soil Disturbed (m <sup>2</sup> )	Total Draft (kN/m)	Adjusted Average Deep Tillage Tine Depth (mm)	Soil Disturbed (m <sup>2</sup> )	Total Draft (kN/m)
600	No Leading Tines		483	0.252	28.7 <sup>abcd</sup>	551	0.182	39.6 <sup>a</sup>	542	0.180	42.7 <sup>ad</sup>
600	1 Chisel	150	486	0.217	29.7 <sup>abcd</sup>						
600	1 Sweep	150	498	0.121	30.7 <sup>ab</sup>	522	0.243	36.0 <sup>a</sup>	597	0.283	52.3 <sup>ab</sup>
600	2 Chisels	150	452		27.7 <sup>abcd</sup>	513	0.275	37.1 <sup>a</sup>	581	0.326	52.5 <sup>abcd</sup>
600	3 Chisels	150				473	0.260	30.4 <sup>ab</sup>	594	0.221	54.6 <sup>abc</sup>
600	2 Sweeps	150	488		28.5 <sup>abcd</sup>	514	0.248	35.1 <sup>a</sup>	601	0.428	58.6 <sup>a</sup>
600	1 Chisel	300	487	0.181	29.8 <sup>abc</sup>						
600	1 Sweep	300	441	0.180	31.7 <sup>a</sup>	520	0.202	37.0 <sup>a</sup>	544	0.330	49.5 <sup>abcd</sup>
600	2 Chisels	300	490	0.286	31.9 <sup>a</sup>	542	0.446	36.6 <sup>a</sup>	553	0.276	46.7 <sup>abcd</sup>
600	3 Chisels	300				545	0.344	38.6 <sup>a</sup>	526	0.404	40.0 <sup>ab</sup>
600	2 Sweeps	300	493	0.290	31.4 <sup>a</sup>	544	0.277	36.1 <sup>a</sup>	550	0.364	43.7 <sup>bcd</sup>
450	No Leading Tines		426	0.190	22.3 <sup>abcd</sup>	427	0.157	17.6 <sup>bcde</sup>	428	0.188	22.7 <sup>fb</sup>
450	1 Chisel	150	417	0.129	22.8 <sup>bcdefgh</sup>						
450	1 Sweep	150	400	0.147	21.4 <sup>abcd</sup>	415	0.244	18.1 <sup>bcd</sup>	422	0.238	22.3 <sup>fbh</sup>
450	2 Chisels	150	415	0.178	22.6 <sup>cdgh</sup>	424	0.194	18.4 <sup>bcd</sup>	435	0.241	24.9 <sup>g</sup>
450	3 Chisels	150				420	0.261	16.5 <sup>bcde</sup>	432	0.194	24.4 <sup>g</sup>
450	2 Sweeps	150	400	0.218	22.5 <sup>cdgh</sup>	419	0.281	19.1 <sup>bc</sup>	426	0.228	24.8 <sup>g</sup>
450	1 Chisel	300	408	0.158	23.9 <sup>abcdgh</sup>						
450	1 Sweep	300	417	0.146	25.5 <sup>abcdgh</sup>	349	0.181	13.9 <sup>cd</sup>	428	0.181	24.5 <sup>g</sup>
450	2 Chisels	300	417	0.306	23.0 <sup>abcdgh</sup>	414	0.189	12.7 <sup>cd</sup>	437	0.342	27.2 <sup>gh</sup>
450	3 Chisels	300				434	0.278	16.2 <sup>bcde</sup>	420	0.197	27.6 <sup>gh</sup>
450	2 Sweeps	300	416	0.270	28.7 <sup>abcd</sup>	421	0.299	20.1 <sup>bc</sup>	423	0.390	29.3 <sup>g</sup>
300	No Leading Tines		271	0.148	14.0 <sup>i</sup>	291	0.141	6.4 <sup>a</sup>	315	0.144	11.9 <sup>h</sup>
300	1 Chisel	150	279	0.123	15.6 <sup>ij</sup>						
300	1 Sweep	150	283	0.090	16.3 <sup>ij</sup>	296	0.206	6.5 <sup>a</sup>	309	0.208	10.3 <sup>i</sup>
300	2 Chisels	150	280	0.136	16.7 <sup>ghij</sup>	284	0.099	7.3 <sup>ab</sup>	315	0.223	11.7 <sup>i</sup>
300	3 Chisels	150				297	0.165	8.4 <sup>cd</sup>	311	0.147	12.3 <sup>gh</sup>
300	2 Sweeps	150	271	0.179	16.4 <sup>ghij</sup>	281	0.168	8.4 <sup>cd</sup>	315	0.201	11.4 <sup>i</sup>

<sup>abcdghij</sup> 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 deep tillage tine depth at each site.

site because the wetter soil adhered too strongly to the sampling tubes thus preventing the extraction of uncompressed samples.

The clod size measurements at the Warren site indicated that the clods produced by the deep tillage tine used alone were four times the size of the clods produced by the combinations of deep tillage

**Table III** Greatest and least reductions in specific draft with leading tines at each site.

Site	Nominal Deep Tillage Tine Depth (mm)	Actual Average Deep Tillage Tine Depth (mm)	Actual Average Lead Tine Depth (mm)	Leading Tine Configuration	Area of Soil Loosened (m <sup>2</sup> )	Total Draft (kN/m)	Specific Draft (kN/m <sup>2</sup> )	Specific Draft Reduction (%)
Trangie	500	N.A.	N.A.	No Leading Tines	0.016	26.9	1681	
		N.A.	N.A.	2 Sweeps at 200 mm	0.353	32.4	92	95
		N.A.	N.A.	2 Chisels at 200 mm	0.285	24.4	86	95
		N.A.	N.A.	1 Chisel at 200 mm	0.166	26.9	162	90
		N.A.	N.A.	1 Sweep at 200 mm	0.176	28.9	164	90
Warren	600	483		No Leading Tines	0.252	28.7	114	
		493	193	2 Sweeps at 300 mm	0.290	31.4	108	5
		498	48	1 Sweep at 150 mm	0.121	30.7	255	-124
	450	426		No Leading Tines	0.190	22.3	118	
		417	267	2 Chisels at 300 mm	0.306	23.0	75	36
		417	117	1 Chisel at 150 mm	0.129	22.8	177	-50
	300	271		No Leading Tines	0.148	14.7	99	
		271	121	2 Sweeps at 150 mm	0.179	16.4	92	8
		283	133	1 Sweep at 150 mm	0.090	16.3	182	-83
Narrabri	600	551		No Leading Tines	0.182	39.6	217	
		542	242	2 Chisels at 300 mm	0.446	36.6	82	62
		520	220	1 Sweep at 300 mm	0.202	37.0	183	16
	450	427		No Leading Tines	0.157	17.6	112	
		434	284	3 Chisels at 300 mm	0.278	16.2	58	48
		424	124	2 Chisels at 150 mm	0.194	18.4	95	15
	300	291		No Leading Tines	0.141	6.4	45	
		291	146	1 Sweep at 150 mm	0.206	6.5	32	30
		284	134	2 Chisels at 150 mm	0.099	7.3	74	-63
Moree	600	542		No Leading Tines	0.180	42.7	237	
		526	226	3 Chisels at 300 mm	0.404	40.0	99	58
		594	294	3 Chisels at 150 mm	0.221	54.6	248	-5
	450	428		No Leading Tines	0.188	22.7	121	
		423	273	2 Sweeps at 300 mm	0.390	29.3	75	38
		428	278	1 Sweep at 300 mm	0.181	24.5	135	-12
	300	315		No Leading Tines	0.144	11.9	83	
		309	159	1 Sweep at 150 mm	0.208	10.3	50	40
		311	161	3 Chisels at 150 mm	0.147	12.3	84	-1
Maximum Specific Draft Reduction 95%      Minimum Specific Draft Reduction -124% Average Specific Draft Reduction 15% There were 43 specific draft reductions in 62 site X deep tillage tine depth X leading tine treatment combinations								

Table IV Average dry bulk densities and gravimetric soil moisture contents at each site.

Site	Depth Range (mm)	Average Dry Bulk Density ( $t/m^3$ )	Average Gravimetric Moisture Content (%)
Warren	0 - 150	1.16	18.1
	150 - 300	-	23.8
	300 - 450	-	24.4
	450 - 600	-	22.8
Narrabri	0 - 150	1.05	29.5
	150 - 300	1.30	26.5
	300 - 450	1.25	26.6
	450 - 600	1.29	26.3
Moree	0 - 150	0.79	20.8
	150 - 300	1.52	16.5
	300 - 450	1.49	18.8
	450 - 600	1.32	21.8

tine and leading tines. In the Trangie experiment the deep tillage tine used alone was a spectacular failure due to the wet conditions and merely created a cavity surrounded by compacted soil. Figure 7 shows Solicon images of undisturbed soil and the cavity surrounded by compacted soil produced by the deep tillage tine used alone. The removal of pores around the cavity is noticeable from about half the working depth downward while the 'V' of loosened soil at the top is small. The combinations of deep tillage tine and leading tines produced acceptable soil loosening and fine tilth almost to the bottom of the deep tillage tine. This experiment demonstrated the potential for deep loosening using leading tines when the soil is too wet for effective loosening by a deep tillage tine alone. Two benefits may flow from this. Firstly, the opportunity to loosen the soil mechanically without having to resort to rotation crops to first dry the soil is enhanced and secondly, the ability to produce a finer tilth may eliminate the need for post ripping tillage to break up the large clods produced by dry ripping.

In all the experiments conducted within this project, all treatments at each site were applied within a 24 hour period at essentially the same soil moisture content which may have biased the draft results against the use of leading tines. It is likely that, if each treatment was applied at its optimum moisture content, the specific draft of the deep tillage tine alone, used in drier/harder soil, would be higher while the draft of the deep tillage tine/leading tine combinations, used in moister/weaker soil would be lower.

The finer tilth produced when leading tines are used has the potential to eliminate one or two subsequent operations. A rough economic analysis, based on contract rates for the operations which may be eliminated and an average frequency of ripping, suggests that this could save the cotton industry an average of \$25/ha p.a.

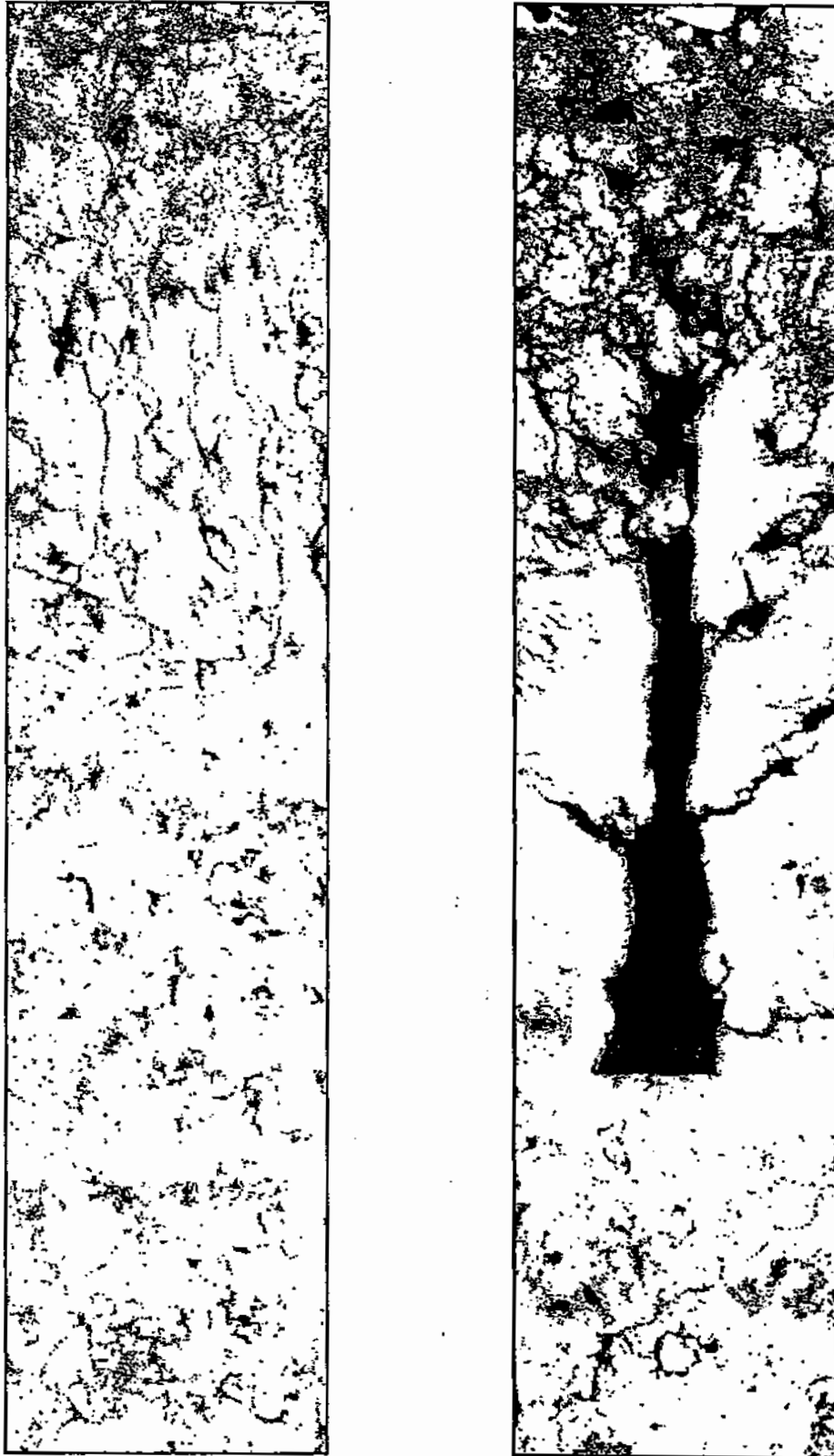


Figure 7 Solicon images from Experiment 1 at Trangie showing undisturbed soil and the deep tillage tine cavity.

## **PUBLICATIONS TO DATE:**

Details of publications arising from this project are shown in bold face in the reference list at the end of this report.

Some of the results of this project were presented in a paper to the 1992 Australian Cotton conference (Palmer and Kirby 1992).

Articles on this project have been written for *The Australian Cotton Grower*, (Kirby and Palmer 1992), *Australian Grain*, (Palmer and Kirby 1992) and *NSW Agriculture Today* (Palmer 1992).

Work is proceeding on an item for a future edition of 'The Seeding Edge' published by the Kondinin Group.

A news segment on the project, which was prepared by Mr Palmer and NSW Agriculture's regional media unit, was broadcast on Prime Television.

Mr Palmer has given presentations on the project at the 1992 Macquarie Cotton Field Day and to five groups of farmers visiting the Trangie Research Centre as well as conducting a demonstration and giving a presentation at the NSW State Ploughing Championships, Narromine, 1992.

Posters describing the project were featured at the official opening of the Macquarie Landcare project.

Dr A.J. Koppi, from University of Sydney, used Solicon images, shown in Figure 7, of soil sections from this project to illustrate a presentation to the 1992 Soils Conference.

## **CONCLUSIONS and RECOMMENDATIONS:**

This project has produced sufficient evidence of the potential worth of shallow leading tines to justify the development of a commercial machine and the adoption of the technology by cotton growers. Assistance to implement manufacturers in the production of a commercial implement or firm guidelines for individual growers to adopt the technology by modifying existing implements should therefore be given a high priority. The need for such assistance is indicated by a significant proportion of unsuccessful treatments in our experiments. Although the working depth of the leading tines appears to be a major factor in determining the effectiveness of leading tines, other factors, such as soil condition or tool shape, which rendered some treatments unsuccessful some of the time need to be identified. This knowledge is required in order to produce an implement which will work reliably under the widest possible range of conditions. Without it, the risk of failure is high.

The most obvious benefit from the use of shallow leading tines is in the increased volume of soil loosened but, to date, we do not know how that increased volume will affect lint yield, irrigation frequency or water use, all of which have important economic consequences. For example, Hulme *et al.* (1986) reported that irrigation strategies need to change with seedbed preparation methods and that cotton plants did not appear to exploit the more favourable conditions which they had created by ripping.

This project has demonstrated that the total draft of an implement fitted with leading tines is likely to be similar to that of an implement without leading tines. Deep tillage operations using leading tines are therefore unlikely to be cheaper than conventional deep tillage but should produce better

results. The potential to use mechanical soil loosening at a wider range of soil moisture contents and possibly in lieu of the use of rotation crops has some significant economic and management strategy implications. The collection of sufficient data for a full economic analysis should also be given a high priority following the development of a full size implement. This work should take into account the relationship between soil moisture content at the time of tillage, tine configuration, volume of soil loosened, the need for subsequent operations and the effects on lint yield and irrigation management. This data will show where additional improvements to crop management or tillage machinery will give the highest returns to growers as well as informing growers how best to take advantage of the technology.

The possibility of using leading tines to extend the moisture range for deep tillage, as revealed in the first experiment, and produce a finer tilth may be exploited in implements for the renovation of permanent beds or retained hills. Smearing, which occurs because the critical depth is small when the soil is wet, could sometimes be prevented by the use of leading tines, or other shallow working tools, allowing the renovation of beds without the need for excessive soil drying. This could be applied to comparatively shallow tillage operations, e.g. weed control or the removal of bed shoulder compaction, which would otherwise be impossible or damaging to the soil under moist-to-wet conditions. An investigation of the application of leading tines to shallow or medium depth tillage machinery for the maintenance of permanent beds or hills should also be given a high priority.

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