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Developing Soil and Water Management Systems for Potato Production on Sandy Soils in Australia

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PIRSA Rural Solutions

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PIRSA Rural Solutions

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This report documents the findings of a three year project into growing potatoes on sandy soils in Australia.

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MEDIA SUMMARY

Potato yields in sandy compacting soils have been significantly boosted following research into new methods of deep tillage. Trials have led to improved water availability in sandy soils and identified potential savings in water use by growers from Polyacrylamide (PAM) soil conditioners and flattened bed structures.

Soil compaction has been shown as a major limiting factor to increasing yields on sandy soils in South Australia. Deep ripping has been trialed to reduce soil strength and increase root growth and yield of tubers. Two deep cultivation tools were used, the Yeoman's Batswing® and the Howard Paraplow®. Separate treatments of ripping with the Batswing®, before and after planting (pre- and post-ripping) were trialed. Trials with the Paraplow® were limited to post-ripping due to their late inclusion in the growing season.

The Batswing® was utilised for pre-ripping using five tines on a two-row toolbar. This ripper was used within a week prior to planting, at a 90° angle to the direction of the rows. The Batswing® was also used in the direction of the potato rows for post-ripping, but with only three tines to avoid disturbing the ridge structure. Pre-ripping was successful on its own, but the highest yield increases (up to 25%) have been achieved by combining pre-ripping with post-ripping. The Paraplow® has decreased soil strength to a greater extent than the Batswing® in post-ripping. This has not translated to any significant effect on yield in the trials.

Surface sealing, low water-infiltration and water-retention in sandy soil are not necessarily limiting yields, but are affecting the industry in terms of water use efficiency. Ripping appears to improve soil water relations considerably, but wide bed structures and a polyacrylamide (PAM) soil conditioner were also trialed.

Ridges flattened into double bed structures improved soil water content by 155%, also giving marginal increases in yield. The PAM used was a liquid claimed to be effective on low-clay soils to improve drainage, aeration, water absorption and retention. Its results have shown a 151% increase in soil water. Ripping after planting with the Batswing gave an increase in soil moisture of 103%. These treatments give the opportunity for growers to decrease the frequency and/or duration of irrigations.

TECHNICAL SUMMARY

Compacting, water repellent sands are now in common use for potato production in Australia. Pressure for larger scales of production have moved growers from more fertile loamy soils to lighter, sand country. Yields from sandy soils are low compared to Europe and the USA. Production methods have scarcely altered from those previously.

Deep ripping treatments were found to be successful in overcoming compaction in soil to 50cm. Ripping with the Yeoman's Batswing® increased root density and yields of saleable tubers by up to 25%, improved drainage to the deeper horizons, and improved water retention to the profile. The size of yield benefits was in proportion to the level of compaction before ripping.

Ripping before planting (pre-ripping) had a high rate of success, but ripping after planting (post-ripping) did not. The density of tines was reduced in post-ripping due to the width of the ridges. Combining pre-ripping with the Batswing® with further post-ripping gained the best results when both cultivations were performed with the same ripper. Use of another ripper for post-ripping, the Howard Paraplow®, resulted in no significant yield increase, as had been the case with the Batswing®. Substantial alleviation of compaction was achieved with the Paraplow®, however in the form used, it loosened a much smaller volume of soil.

Levelling two ridges into one wide bed supporting two rows of plants improved water infiltration and storage. The soil moisture level was raised by 155%. Rolling of beds also provided a small improvement to yield (marginally significant). Treatment with a liquid polyacrylamide also improved water content of soils, but had no significant effect on yield. Each of these treatments could be useful in reducing the frequency and duration of irrigations on sandy soils.

Soil wetter and clay spreading treatments made no significant change in soil water levels or in yield at the properties used for trials. Organic matter and mulch showed good signs of improving soil water and yield in the first year, but could not be adapted to commercial cultivation in their available form.

INTRODUCTION

Background

Potato production in South East South Australia has undergone some major changes in the past 30 years. The number of growers has diminished with the shift to larger-scale production. New methods utilise heavy and expensive machinery for planting and harvesting. Pivot irrigation is employed for its ease of establishment and controlled water application.

In South Australia's South East region, these changes have also meant the need to utilise sandy soils for production, a shift in soil type which has been mirrored across the southern states of Australia. Potato growers for the french-fry market have become the dominant grower group in terms of output. Increased scale of production and preference for a six-year rotation has led the expansion of potato plantings from smaller paddock sizes on loamy soil to broad-acre plantings on larger tracts of sandy soil.

The increased use of sandy soils has bought new problems for growers which were not previously encountered in loamy soils. The sands in the South East are widely subject to compaction, and having low clay and organic matter content, also have low water-holding capacity. Many of the sands are also water-repellent in the surface layers.

This project has targeted these inherent problems of sandy soils to improve production methods for potatoes. Emphasis in the project has been on exposing growers to new technology. The eventual choice of treatments had to be balanced with the costs and time efficiency of incorporating them into the growers' regular growing methods.

Literature Review

Compaction

Compaction refers to the packing effect of a mechanical force on soil. This can be caused by any pressure on the soil surface including vehicles, livestock and (in the longer term) precipitation and irrigation water (Swan et al, 1999).

This packing decreases the volume occupied by pores, and increases the density and strength of the soil mass. As pore sizes decrease, so does the rate of infiltration and drainage from the compacted layer, and roots must exert greater force to penetrate soil. Decreased pore size also reduces aeration and can increase denitrification resulting in reduced nitrogen availability (Swan et al, 1999).

Nutrient availability is reduced by compaction, and in potatoes, limitation of root growth means that additional application of fertiliser will not necessarily improve plant nutrition. Lack of roots and root tips also results in less calcium and oxygen absorption (Fowler et al., 1996).

Studies have shown compaction's ability to decrease potato yields from 15-54% due to the plant's relatively confined growth pattern and sensitivity to interruptions of growth (Swan et al., 1999).

Studies of compaction showed 90% of the damage was caused by the first of five consecutive passes with machinery (Yule, Radford and McGarry, 1998). Soil compaction is often measured as soil strength (kPa) or penetration resistance. The effects of soil strength on potato root growth have been examined in many ways in various papers; that more than 1000kPa has some limit on root growth and 4000kPa stops root growth (Dowling, B., personal comm., 1997); that 3000kPa generally prevents root growth (Cass, A., personal comm., 1997); and that less than 2000kPa constitutes zero compaction (Cass et al., 1999).

Increasing irrigation does not remove the effects of compaction on crop yields, and the anaerobic conditions after rain or irrigation can result in root death and disease prevalence (Brennan and Crabtree, 1989; Fowler et al., 1996)

Ripping

Deep ripping has been very effective in removing compacted layers in sandy soils in south eastern USA and California. Wheel traffic following the deep ripping has also been shown to re-introduce compaction. There are often no measurable benefits of deep ripping in following seasons due to re-compaction (Swan et al., 1999).

Ripping has been shown to be less effective when used on loamy soils with high moisture levels. It often further decreases soil porosity and restricts drainage (Swan et al., 1999). Much information suggests that ripping should not be conducted when soil moisture is too high (Swan et al., 1999; Cass et al., 1999), and that compacted sands maybe able to be ripped all year round (Cass et al., 1999). In marked contrast to the problems caused by compaction, deep ripping can lead to improved water penetration and storage and therefore to more available soil water and softer soil, which increases effective root depth (Cass et al., 1999).

Ripping depth must encompass the compacted soil layer for it to be effective (Swan et al., 1999; Cass et al., 1999). Potato roots are able to reach a depth of 1 metre, but 95% of these roots are found in the top 60cm of soil. Since 70-75% are found in the upper 40cm, taking ripping depth from 40 to 60cm can increase root mass by up to 25%. Due to the bulk of potato roots forming in the top 60cm, ripping below this depth can become an unnecessary cost, as further increases in yield are unlikely. A trial of a 60cm ripper and a 90cm ripper showed no significant difference between their yield increases over the control (Brink, P., pers. Comm. 2000).

Ripping has been shown to improve drought tolerance of potatoes. Farmers in the US were able to reduce irrigation of sandy soil from daily to once every four days through deep ripping. Yield increases associated with deep ripping were more pronounced on sandy compacting soil than on loam (Miller and Martin, 1987)

Design and set-up of the ripper blade are important for maximising the effectiveness of ripping. On compacting sands, a tine with a point at 90° to it should be used (Miller and Martin, 1987; Cass et al., 1999).

Bed Structure

Much of the impetus for inclusion of bed structure treatments in the project has come from the concern of the region's growers. They have been using the same 'ridge' structure for potato rows since commercial production began on loamy volcanic soils in the region. It was seen by many that both infiltration and moisture retention could be hampered on ridged sandy soils.

Data was logged by an automatic soil water station (ASWS) in the UK on potato crops grown in sandy soils which were of a similarly water-repellent nature to many in the South East region (Robinson, 1999).

The data showed that traditional ridge structures allowed most of the water to bypass the plants as it was shed off the steep ridges and infiltrated in the furrows. The structure thereby allowed a soil-water deficit to build up in the core of the ridge as the crops grew and were not replenished by irrigation. Flattened bed structures were trialed, and found to be more successful at capturing water. The flat bed increased water infiltration around the crop (Robinson, 1999).

Clay Spreading

About five million hectares of sand in South East South Australia is non-wetting (Clayton, 1998). Non-wetting light-textured soils are most likely to be water repellent because of fungal metabolites or to hydrophobic waxes condensed onto soil from burning organic matter (Kitsceke, 1997; Savage, 1975).

The application of a fine layer of dispersable sodic clay can overcome water repellency. This approach is viable since clay is usually available in the region within one metre of the soil's surface. Claying water-repellent sands can also increase moisture, organic matter and nutrient retention, as well as correct pH imbalances and control erosion (Clayton, 1998).

Machines have been developed to process and spread clay, which is collected using ripping tines, discs and a collection blade (Clayton, 1998).

Tests show that soils of pH (water)6.6, after being spread with clay, have increased to pH (water)8.0. Benefits such as greater production and a reduction in erosion may be seen within 6 months. Further benefits such as improved organic matter and soil nutrients may take longer to be noticeable but are continuous. Despite its high cost, clay spreading is popular because of these long-term benefits (Kitsceke, 1997).

Mulching

Mulch has been shown to be highly beneficial in reducing runoff by as much as 10% from surface sealing soils. Mulch also reduces disintegration of soil aggregates, caused by raindrop impacts. Barely any breakdown is recorded in mulched soil as opposed to untreated soil with the same rate of infiltration (Stern et al., 1991).

While mulches have been shown to moderate daily and seasonal temperature fluctuations, this can result in an overall reduction in temperature around the plant's roots (Stirzaker and Beckmann, 1997; Ludvigsen, 1995).

A trial of mulching a subterranean clover cover-crop on partially compacted sand before planting an irrigated lettuce crop increased yields of lettuce by 30% in both no-tillage and cultivated crops (Stirzaker et al, 1995). In a second season where soil was artificially compacted, yield of lettuce reduced to 40% in no-tillage treatments compared to cultivated treatments. This 40% doubled to 80% when the soil was mulched with subterranean clover. The mulch was found to increase soil temperature and moisture, reduce soil strength and stimulate the formation of biopores in the compacted sand, leading to significant amelioration. Earthworms and decayed roots formed biopores allowing greater root growth. Yield penalties were associated with growing the mulch *in situ*, as opposed to bringing it in from elsewhere, and this was attributed to phytotoxic breakdown of the clover roots (Stirzaker et al, 1995).

Trials on potatoes in Idaho utilised straw mulch mechanically applied to the bottom of furrows. The mulch was effective in both controlling erosion losses (of a silt-loam soil) and improving infiltration of water under furrow irrigation. The mulch treatment was more effective than treatment with a polyacrylamide (see later section); (Shock and Shock, 1997).

Drawbacks for the grower using this treatment included buying the straw, contracting its application, introducing volunteer wheat and weeds to the field and limiting cultivation after the application of the mulch (Shock and Shock, 1997).

Soil Wetter

Soil wetters or wetting agents are organic compounds called nonionic surfactants. They are closely related in structure to detergents, and similarly lower the surface tension of water. They can also be adsorbed to the surface of soil materials (Letey, 1975).

Soil wetters can be used to increase the infiltration rates of water-repellent soils (see section on Clay Spreading), but are not effective on wettable soils. Depending on the nature of the soil and the rate of use, soil wetters can reduce aggregate stability and pore size of soils (Letey, 1975).

Surfactants can be detrimental to plants in very low concentrations when grown in solution culture, but plants grown in soil require much higher rates of use to produce any detrimental effects (Letey, 1975).

Water repellent sands in south west Western Australia exhibited problems of staggered emergence in barley crops. Application of a soil wetter at seeding in early winter allowed uniform wetting along furrows and improved water infiltration. This was accompanied by a reduction in surface ponding and hence evaporation. Control plots remained dry until harvest and still held viable seed (Crabtree and Gilkes, 1999).

Emergence increased from 110 to 170 plants per m^2 and dry matter production and grain yield also increased significantly. Better soil wetting released applied fertilisers into the soil and increased organic mineralisation of nutrients (Crabtree and Gilkes, 1999).

Problems with weeds were experienced, especially barley, but despite the competition, increases in yield were achieved (Crabtree and Gilkes, 1999).

Previous study in more arid northern regions of Western Australia showed soil wetter decreased grain yield by allowing greater evaporation from sandy soils in dry weather. It was noticed that growth was improved by applying soil wetter during winter, but the result was reduced grain fill during spring and an overall loss of yield. It was also found that a water-absorbing gel polyacrylamide (PAM; see next section) was able to counteract some of the yield losses when used in conjunction with the wetter (Blackwell et al., 1995).

Polyacrylamides

Polyacrylamides (PAMs) are a group of polymer substances with a wide range of morphologies and applications. PAMs are available as solids or liquids. Their molecular size and charge lend them to varying applications, but in agriculture PAMs are generally employed either as erosion control agents or as soil-water relation ameliorants. Their fast rate of development in recent times has lead to much confusion over cost, rate of use and application to production. For this reason this review focuses on a group of PAMs most suited to the project's objectives.

Robert Sojka (personal communication, 1999) explained that two main types of PAMs have been used in agriculture. Firstly in sandy soils, water-absorbing gels in the form of dry powder or crystals, swell to hundreds of times their dry weight in contact with water. These are generally applied to soil in a banded application near to the seed or seedlings and are most commonly used by the nursery industry in potting mixes. These are able to improve water retention properties of soil. Erosion control PAMs are commonly applied as a liquid, and while they have been unable to improve water-retention in studies to date, their ability to increase the infiltration rate, furrow advance time and lateral wetting has been documented (Sojka and Lentz, 1999; Al-Omran and Al-Harbi, 1997).

The line between these two types of PAMs is becoming blurred with the formulation of liquid PAMs with the propensity to improve water-holding capabilities of sandy soils (Andrew McHugh, personal comm., 1999), though much of this technology is still under closely-guarded commercial development.

Since the bulk of research on PAMs is limited to erosion-susceptible soils with high clay or silt content and sandy soils with high infiltration and conductivity levels, there is little published information regarding PAM use in compacting, non-wetting sands with low clay content.

At the point when PAMs were trialed in this project, the PAM best fitting our situation, (Aerotil™, Cytec Industries Inc.) was a liquid. This form was chosen as it appeared to represent good prospects for the future development of more efficient PAMs and allowed simple application to potatoes through the pivot irrigation systems currently in use.

While other studies of Aerotil™ as a soil conditioner are unavailable, Robert Sojka (personal comm.) has said that its chemical characteristics place it more in the erosion-control group of PAMs than the gel-forming group. Many manufacturers' claims tend to support this. Studies of erosion-control PAMs indicate they bind existing soil aggregates together, leading to increased infiltration, reduced runoff and erosion (Shock and Shock, 1997; Stern et al., 1991; Levin et al., 1991)

Claims of the makers of Aerotil™, which are consistent with the properties of regular erosion-control PAMs, include its ability to create a stable granular porous structure which improves drainage and aeration, increases water absorption, controls sheet erosion and improves utilisation of fertilisers. Other claims made by Cytec are more indicative of a water-absorbing gel PAM, such as effectiveness on sandy soils, the ability to overcome surface-sealing problems, and improvement of water-retention. The cost of applying this PAM was (Aust.)$320-$480 per hectare at the time of use (10/1999).

Hypotheses

In the **preliminary field trial** (1996/1997) three main hypotheses were tested.

1. Flattening traditional ridge structures into beds increases volumetric soil moisture and yield of potatoes.
2. Deep tillage with a Yeomans Batswing® combined with flattened bed structures increases volumetric soil moisture, reduces soil strength and increases yield of potatoes.
3. Addition of straw mulch to flattened bed structures deep ripped with the Batswing® increases volumetric soil moisture and yield of potatoes.

In the **first full year** of project trials, treatments were split between two properties to cover the following hypotheses.

1. The addition of straw mulch to ridges improves volumetric soil moisture and yield of potatoes.
2. The growth of an oat cover crop by broadcasting seed alongside potatoes improves volumetric soil moisture and yield of potatoes.
3. Deep ripping with the Batswing® after seeding and bed formation decreases soil strength, which improves volumetric soil moisture and yield of potatoes.
4. Addition of organic matter (pine bark chips) to soil improves volumetric soil moisture and yield of potatoes.
5. Converting ridges (0.85m) supporting a single potato row into beds (1.7m) supporting two potato rows improves volumetric soil moisture and yield of potatoes.
6. Clay spreading into soil at 100t/ha improves volumetric soil moisture and yield of potatoes.

In the **second year** of trials, the following treatments were tested.

1. Clay spreading at 160t/ha improves volumetric soil moisture and potato yield.
2. Converting ridges (0.85m) supporting a single potato row into beds (1.7m) supporting two potato rows improves volumetric soil moisture and yield of potatoes.
3. Deep ripping with the Batswing® after seeding and bed formation decreases soil strength, improving volumetric soil moisture and yield of potatoes.

These hypotheses formed the basis of a replicated trial at one property, while a second property was used to test hypothesis 3. in a larger scale demonstration trial.

For the **third and final year**, results of the previous three sets of trials were assessed and the following hypotheses were formulated and tested across four separate properties in replicated trials.

1. a) Deep ripping with the Yeoman's Batswing® reduces soil strength and increases yields of potatoes grown on sandy compacting soils.
   b) Ripping before planting with the Yeoman's Batswing® decreases the effects of compaction on yield.
   c) Ripping with the Howard Paraplow® decreases the effects of compaction on yield.
2. Polyacrylamides and soil wetters cause surface sealing and compacting sands to absorb and hold more water, and increase yields of potatoes grown under current pivot irrigation practices.
3. Flattening the structure of traditional ridge-shaped beds increases the yield of potatoes grown on sandy soils by allowing greater infiltration of water.

MATERIALS AND METHODS

Preliminary Trial

A preliminary field trial was established in November 1996 on Russet Burbank potatoes to determine the effect of alternative soil management treatments on potato production by improving available water. The four soil management treatments were.

1. Traditional soil management (no deep tillage plus soil ridges).
2. No deep tillage plus soil beds.
3. Deep tillage plus soil beds.
4. Deep tillage plus soil beds plus straw mulch.

The straw mulch was applied at (5 kg m^{-2}), soil ridges consisted of a single row of potatoes on a 0.8m wide soil ridge, and soil beds consisted of a double row of potatoes on a 1.7m wide soil bed.

First Year

Following this preliminary trial two trials were conducted during the 1997-1998 season.

The first of these assessed the potential and effect of soil surface cover treatments and deep ripping on soil strength, available water, and potato yield (Shepody variety). Incorporation of clay was not trialed at this site since claying was already standard treatment on the property.

The following combinations of treatments were applied:

1. Straw mulch (1.75 kg/m2).
2. Oats (broadcast seed, followed by 0.5 kg/m2 of oat straw mulch).
3. Bare soil surface.
4. Not ripped / ripped (deep ripping after seeding and bed formation).
5. No organic matter / organic matter (pine bark chips at a rate of 1.25 kg/m2).

Establishment of oats was unsuccessful due to low soil moisture at the time of broadcasting consequently oat straw was applied to represent this treatment. The field trial was located in a low-lying moist section of the paddock, consequently soil moisture was consistently high.

The second field experiment compared the effect of the following combinations of treatments on potato yield, (Russet Burbank variety);

1. Wide soil beds (1.7 m supporting two potato rows).
2. Traditional ridge (0.85 m supporting a single potato row).
3. No clay / addition of clay (100 t/ha).
4. No ripping / ripping (deep ripping after seeding and bed formation).

Due to the layout of the field trial it was thought that clay incorporation would be performed most accurately post seeding. For this reason, clay incorporation was done by hand and not as deep as would have been by large tillage equipment.

It is important to note that in all field trials deep tillage prior to seeding was undertaken. In these experiments, deep ripping after major operations such as bed formation and seeding was an essential part of minimising soil strength and maximising potato yield.

Addition of mulch and organic matter improved yield, but made harvesting of potatoes difficult due to blockages caused by mulch. Soil-surface cover treatments that reduce evaporative losses such as straw mulch may be more beneficial for late season potatoes than early season.

Addition of clay to wide soil beds maintained volumetric soil moisture at higher levels than no added clay or addition of clay on soil ridges. Addition of clay however did not result in higher yields. This may have been due to poor incorporation of clay, accessibility to available water may not have been improved, or clay may have been too close to the surface, allowing greater evaporation.

Second Year

Trials at two sites were established in September 1998, aiming to confirm findings from the first season and demonstrate links between alternative soil treatments, moisture status and plant growth. The trials examined the effects of deep ripping, clay incorporation and bed structure on soil moisture, compaction and temperature, root growth and size and yield of potatoes.

Mulch and organic matter treatments were not trialed because of the problems experienced in the first season with harvesting blockages, casting doubts over their commercial benefit. New equipment was used for in-situ logging of soil data, mobile measurement of soil moisture (reflectometer) and compaction (penetrometer).

At the first replicated plot trial (Callendale) in a crop of centre pivot irrigated 'Russet Burbank' potatoes, the following combinations of treatments (8 treatments x 4 replicates) were examined.

1. Traditional ridges (single rows) / wide beds (2 rows rolled into a 1.7 m wide bed).
2. No clay / incorporation of clay (160 t/ha).
3. No ripping / ripping (deep ripping between 2 rows).

Clay was incorporated during normal pre-planting cultivation. Deep ripping was carried out two and a half weeks after planting, with a single 30cm wide Yeomans Batswing® tine, at approximately 50cm depth.

A data logger was installed to continuously monitor soil moisture, suction and temperature in the four wide bed treatments. A cone penetrometer was used to measure soil compaction and a hand-held reflectometer (TDR) used to measure moisture content to a depth of 30 centimetres, in all plots throughout the season.

A larger scale trial was established across the width of a centre pivot irrigated 'Shepody' crop. Ripping was the only treatment assessed, because clay incorporation and use of wide soil beds was already standard at this property. Ripping was carried out three weeks after seeding, as described above.

Third Year

The project's emphasis in the final year was on ripping as it had given the best results in the previous trials. The benefits of ripping also required more demonstration to growers, many of who were still appraising the findings.

Clay incorporation was not trialed, as results in 98/99 were inconclusive, probably because of limited incorporation of clay in the soil. The view was that since claying would require at least twelve months to reach its full potential, neither the trials nor the growers would benefit. This was especially pertinent as most growers lease site for only one season every six years. The costs of claying therefore would not be recouped in that one year.

Due to these obstacles to clay incorporation, it was hoped to identify new treatments that could improve soil-water relations in sandy soil, which would give more immediate effects and improved yields. For this reason, polyacrylamide (PAM) and soil wetter conditioners were included in the trials.

Bed structure was included as a treatment on the Mingbool site where traditional (non-rolled) ridge structures were still used. The ridges at this site were rolled by hand using a rake to move the top 10centimetres of soil to either side of the ridge. This site is in a section of the South East where farmers consider drainage a worse problem for potato growth than surface sealing and low infiltration, thus traditional ridge bed structures are more commonly used. Inclusion of rolled ridges was therefore considered a useful test of this theory and an important demonstration to include at this site.

Field trials were conducted on four properties. They were designed to expand on the knowledge gained in 1998/99 in the use of deep ripping to decrease the effects of soil compaction, and to find new treatments to overcome soil surface-sealing and low water retention.

Two designs of ripper were used; the Yeoman's Batswing® and the Howard Paraplow®. Separate treatments of ripping with the Batswing®, before and after planting (pre- and post-ripping) were also trialed. The Batswing® was utilised with five 50centimetre tines for pre-ripping in accordance with the recommendations of the Yeoman company, using five tines on a square toolbar. The ripper was used as close to planting as possible at each property (within a week prior) at right angles to the direction of the rows (see Fig.1a).

For post-ripping, each ripper was used within a week of planting date. The Batswing® was used in the direction of the potato rows, but with only three tines. This allowed one to run between each double row, thus ripping both sides of each ridge (see Figure 1b). The Paraplow® was modified with Howard Australia to better suit the growing conditions of potatoes, since tines already in Australia were designed for other industries. The final design comprised a left and right bent tine running either side of a double bed in the direction of the ridges. These tines were only used for post-ripping for this trial, since their preparation ran into the growing season. The design had been modified to improve ripping in line with the bed structures and reach the required depth for potato roots of 50 centimetres (See Figure 1c).

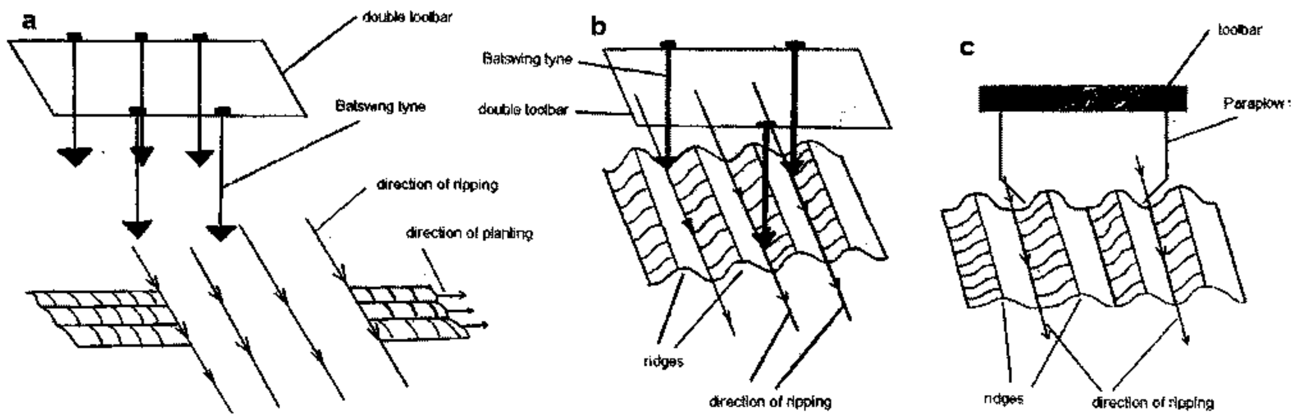
A polyacrylamide (PAM) and a soil wetter were trialed to combat the effects of surface sealing and low water retention. Both liquids were applied at recommended rates, PAM at 45l/ha and wetter at 50l/ha.

Figure 1. Ripping methods used in trials:

a.Pre-ripping with Batswing®,

b.Post-ripping with Batswing®,

c.Post-ripping with Paraplow®.



Trial 1 at Western Flat

The Paraplow was not used on this trial as planting occurred very early in the season, and only the Batswing ripper was available.

A replicated plot trial in a pivot-irrigated crop of 'Shepody' examined the following combinations of treatments (16 treatments x 4 replicates);

1. no pre-planting ripping / pre-planting ripped
2. no post-planting ripping (Batswing®) / post-planting ripping (Batswing®)
3. no polyacrylamide / polyacrylamide (PAM)
4. no soil wetter / soil wetter
5. no PAM and soil wetter / PAM and soil wetter

Trial 2 at Callendale

A replicated plot trial in a pivot-irrigated crop of 'Nooksak' examined the following combinations of treatments (18 treatments x 4 replicates);

1. no pre-planting ripping / pre-planting ripped
2. no post-planting ripping (Batswing®) / post-planting ripping (Batswing®)
3. no post-planting ripping (Paraplow®) / post-planting ripping (Paraplow®)
4. no polyacrylamide / polyacrylamide (PAM)
5. no soil wetter / soil wetter
6. no PAM and soil wetter / PAM and soil wetter

Trial 3 at Kalangadoo

A replicated plot trial in a pivot-irrigated crop of 'Russet Burbank' examined the following combinations of treatments (6 treatments x 4 replicates);

1. no pre-planting ripping / pre-planting ripped
2. no post-planting ripping (Batswing®) / post-planting ripping (Batswing®)
3. no post-planting ripping (Paraplow®) / post-planting ripping (Paraplow®)

Trial 4 at Mingbool

A replicated plot trial in the pivot-irrigated crop of 'Russet Burbank' examined the following combinations of treatments (16 treatments x 4 replicates);

1. traditional ridges / rolled ridges
2. no pre-planting ripping / pre-planting ripped
3. no post-planting ripping (Batswing®) / post-planting ripping (Batswing®)
4. no post-planting ripping (Paraplow®) / post-planting ripping (Paraplow®)

Field trials were harvested where possible using a trial-digger the same width as two ridges. This laid the potatoes on the surface of the ridge where they were collected, separated into tubers over and below 100g (cut-off weight for small tubers) and weighed separately in these categories.

The Enviroscan® logger was employed at Western Flat and the Microscan® logger used at Callendale. The Microscan® logger was altered to give maximum results by providing a larger number of tensiometer and TDR probes to cover the greater number of treatments with ample replication. TDR probes logged soil moisture in the top 30cm of soil, with suction recorded at 25cm and 35cm depths by tensiometers over the growing season. The hand-held TDR unit was also used to provide additional soil moisture data where the soil was not logged.

Penetrometer readings at each of the sites were used to assess the effects of ripping on compaction. The penetrometer logs soil strength in kPa to a depth of 46cm. The penetrometer was used at all properties, primarily to develop a picture of the effects of ripping on soil strength across the ridge structure.

Undisturbed soil core samples to a depth of 0-10cm were collected from each property. These were analysed to determine moisture release curves and field capacity of the four soil types, and their performance when treated with PAM. It was established in 98/99 that these soil characteristics would not differ between ripped and unripped treatments; nor would they provide any contrast in the use of soil wetter, since soil wetter is routinely used to moisten the samples during analysis.

Additionally, samples from thirteen properties across the South East were analysed for particle size distributions and sand fractions to identify possible areas where compacting soils were more or less likely to exist.

RESULTS

Preliminary Trial

Results of a preliminary trial showed increases in soil moisture accompanied by rises in yield after combining ripping, ridge rolling and straw surface-mulching (Table 1).
Yield increases for the two combined treatments were significantly higher than the traditional soil management methods.

Table 1. TDR readings and harvest results from initial trials of ridge-rolling, deep ripping and mulch treatments.

Soil management.	Volumetric soil moisture (24 hours after irrigation)	Marketable Yield (potatoes greater than 100g)
Traditional ridges	11%	26.7 $t.ha^{-1}$
Rolled ridges (beds)	-	-
Beds, deep ripping	15%	35.9 $t.ha^{-1}$
Beds, deep ripping, straw mulch	17%	39.7 $t.ha^{-1}$

- Soil strength, measured by a cone penetrometer, was reduced in deep tillage treatments.
- Wide soil beds and straw mulch reduced soil temperature fluctuations.
- Soil moisture; measured by a portable reflectometer, was maintained at a significantly greater level in wide soil beds, particularly those with straw mulch added.

First Year

Two trials were run during the 1997/8 season. From the first trial, Table 2 shows that only two treatments increased yields to a significant level above the control (bare soil treatment). The deep ripping treatment produced the highest significant increase in yield for this trial, but had no significant effect in combination with organic matter or mulch.

The combination of organic matter and mulch also produced a significant yield increase, without deep ripping. Treatment with mulch on its own was approaching the same level of significance as the combination with organic matter, indicating that the mulch may have been the major contributing factor in the yield increase.

Table 2. The effect of soil management treatments on potato yields (Shepody variety). Those figures with different subscripts are significantly different (0.05 significance level).

Soil management.	Marketable Yield (potatoes greater than 100g, $t.ha^{-1}$)
Bare soil surface	39.9a
Mulch	50.4a
Oats	44.4a
Ripped + bare surface	50.7b
Ripped + mulch	45.9a
Ripped + oats	47.9a
Organic matter + bare surface	47.7a
Organic matter + mulch	50.6b
Organic matter + oats	44.1a

Soil moisture results revealed no significant difference in volumetric soil moisture between soil management treatments. This may have been a result of the early growing season of the potatoes. Harvesting took place in January; consequently potato canopies may have protected the soil surface from evaporative demands prior to demands becoming great.

Harvest from the second trial (Table 3) showed treatment with deep ripping on ridges to increase yield significantly from the control (ridges). No other treatment gave significant results, but the ridge/ripping treatment's superior yields were not significantly higher than those of bed/ripping or bed/clay/ripping treatments.

Table 3. The effect of soil management treatments on Russet Burbank potato yields. Those figures with different subscripts are significantly different (0.01 significance level).

Soil management.	**Marketable Yield (potatoes greater than 100g, $t.ha^{-1}$)**
Ridges	24.1a
Ridges + clay	37.4a
Ridges + deep ripping	42.0b
Ridges, clay + deep ripping	30.6a
Beds	34.2a
Beds + clay	30.4a
Beds + deep ripping	34.7ab
Beds, clay + deep ripping	31.6ab

Volumetric soil moisture results revealed that the combination of wide soil beds with incorporation of clay consistently had the highest soil water content. This did not convert to higher potato yields (Table 3).

Clay incorporation on traditional ridges consistently showed the same soil moisture levels as untreated ridges. Consequently, claying appeared to be more effective when combined with wide soil beds rather than traditional ridges.

Second Year

Trials on two properties were also conducted in the 1998/9 season.

In the first trial at Callendale, soil compaction (penetration resistance) was significantly reduced by deep ripping (Table 4).

- At 25-45cm depths, soil strength was lowered by 500-700 kPa in ripped beds throughout the season.
- In the topsoil (0-25cm) which was less compacted initially (and contained around 80% of roots), ripping also lowered soil strength, but to a lesser extent.
- Measurements across each row showed the greatest effect was closest to the rip line, while the soil on the outer edge of the bed was still marginally affected.
- Ripping enhanced root growth, with analysis of soil cores indicating root density in the A1 horizon (0-25cm) was 45% higher than in non-ripped soil.

Table 4. Changes in soil strength (kPa) through the season, and effects of ripping (average of three penetrometer positions across bed).

Soil Depth	Early, 30 days after planting.		Late, 140 days after planting.	
	Non-ripped	Ripped	Non-ripped	Ripped
0-25cm	400	250	600	450
25-45cm	1650	1100	2100	1350

Table 5 summarises the effects of ripping, and other treatments, on yield at Callendale

In ripped treatments, an increase in total yield, combined with fewer 'smalls' (tubers<100g) caused 'saleable' yield to be approximately 10% higher than in non-ripped treatments. The greatest increase (7.2 $t.ha^{-1}$) was with the ridges and no clay treatment.

Table 5. Effects of soil management treatments on saleable yield (>100g tubers, Russet Burbank variety, $t.ha^{-1}$).

Soil management.	Marketable Yield (potatoes greater than 100g, $t.ha^{-1}$)
Ridges	40.4
Ridges Clay	45.9
Ridges Ripped	51.0
Ridges Clay Ripped	47.6
Beds	47.5
Beds Clay	46.7
Beds Ripped	51.5
Beds Clay Ripped	52.2

Statistical significance:

- The main effect of ripping was highly significant ($P<0.02$) for all clay and bed treatments.
- The main effect of bed structure was marginally significant (P ranging from 0.05 to 0.10 depending on model used) for all clay and tillage treatments.
- The main effect of clay treatment was not significant.
- There were no significant interaction effects.

A sample from each treatment was assessed for specific gravity, a quality indicator of tubers (higher being better). Treatment averages ranged from 19.0 to 19.8% solids. The results suggest each of the wide beds, ripping and clay treatments may increase % solids slightly, but those effects require further investigation.

A weed count in each plot also indicated that in ripped beds weed growth was reduced. TDR measurements taken at Callendale, between half and one day after an irrigation showed moisture content was consistently higher in wide bed treatments compared to single ridges. During the period of peak water use from December to late February, total readily available water (24mm) had been 80% depleted in ridges (4.5mm remaining) compared to only 50% depleted in wide beds (11.5mm remaining), when measurements were taken (see <u>Table 6</u>).

Table 6. Results from soil analysis and moisture content readings during peak water use period (40-120 days after planting) in ridge and wide bed treatments.

- **Readily available water = total mm (30kPa)– wilting point (120kPa)**
- **Amount required to restore to field capacity = field capacity (10kPa)– total mm (30kPa)**
- **Callendale; wilting point = 11.5% = 34.5mm/30cm;**

  field capacity = 19.5% = 58.5mm/30cm

Treatment	Average moisture content (% water/30cm)	Total mm water in 30cm	Readily available (mm in 30cm)	Amount required to restore to field capacity (mm)
Ridges	13.0	39	4.5	19.5
Wide Beds	15.3	46	11.5	12.5

As a result of improved growing conditions, with more available water, wide beds gave rise to higher yields, as shown in Table 5. Saleable yield was on average 7% higher in wide bed treatments. With no clay and no ripping, yield increased by $7 t.ha^{-1}$ (18%) with the use of wide beds. It is likely that a slightly higher percentage of 'smalls' in wide beds was due to higher moisture and more stable temperatures at the time of tuber set.

Incorporation of clay appeared to have a minor effect on yield; the small increase was not statistically significant. Root density was greater in the topsoil of clay treatments. Although continuous TDR data indicates moisture content was actually lower in clay treatments, the effect on moisture retention is still not clear. Soil moisture release curves showed ripping and bed structure had no effect on the water holding properties of the soil itself. These treatments may have affected root density and therefore the percentage of soil water (readily available water) used by the crop. The readily available water may actually drop faster as a result.

In the second trial at Western Flat, penetrometer measurements clearly showed the effect ripping has in reducing soil compaction in both the A1 and A2 horizons for the duration of the season. While compaction gradually increased during the season in both treatments, ripping prevented subsoil (25-45cm) reaching 3000 kPa (where root growth is virtually prevented), and prevented topsoil rising above 1000 kPa (beginning to impede root growth). Most roots would be in the top 25cm, so the effect of ripping could be described as removal of an impediment to root growth.

Moisture Content was measured with the portable TDR on several occasions during the season. Generally there was little difference between ripped and non-ripped treatments, although moisture content appeared to be slightly higher in ripped beds in the later stages of the season.

An EnviroSCAN® system was used to continuously record soil moisture in both treatments, to a depth of 1 metre. Sensors at 20–40cm indicated that following irrigation, water movement into that soil level was more rapid in beds that had been ripped. This may have reduced evaporation of lingering moisture in the topsoil.

Ripping had a positive effect on yield, which was assessed using two methods. Small sample plots were dug by hand and as a check, the distance taken to fill standard harvesting bins was also measured. Both methods gave similar results, indicating ripping increased saleable yield (tubers >100g) by approximately 5% (5.9% and 4.8% for respective methods). This increased saleable yield was concurrent with a 24% reduction in the proportion of un-marketable 'smalls' and a small increase in total yield.

Third Year

Trial 1 at Western Flat

Results of the trial at Western Flat have been the most significant of the four properties.

- A highly significant increase in yield of 16% from ripping with the Batswing® before planting (five tines).
- An interaction between the pre-ripping treatment and post-ripping with the Batswing® (three tines) again gave a highly significant yield increase of 25% (see Table 7).
- Post-ripping on its own gave yield increases of 7%, which were approaching a 5% significance level.

Trial Summary: Control vs Pre-ripped and Post-ripped Treatments (Means of all Treatments)

Significance is stated as Yes, No or Approaching significance (5% l.s.d.).

Control 1	37.2	**Pre-ripped**	43.2	**Signif.**	Y	**% Yield Increase/Decrease**	16%▲
Control 2	38.6	**Post-ripped**	41.8	**Signif.**	A	**% Yield Increase/Decrease**	7%▲

The replicated trial was established in two separate blocks. One Pre-ripped and the other Post-ripped. This was necessary to avoid the wheel tracks of the Centre Pivot. Control 1 & 2 are separate controls that were established in each block.

Table 7 also shows results of treatments with the PAM and wetter soil conditioners, which had no significant affect on yields.

Table 7. Effects of soil management treatments at Western Flat on saleable yield (>100g tubers),

tonnes/ha.

Significance is stated as Yes, No or Approaching significance (5% l.s.d.).

Treatment	Yield (ton/ha)	Signif.	% Yield Increase/Decrease
No pre-rip / No post-rip	36.4	-	-
No pre-rip / Post-rip	38.0	N	5%▲
Pre-rip / No post-rip	40.9	A	12%▲
Pre-rip / Post-rip	45.5	Y	25%▲
Treatment	**Yield (ton/ha)**	**Signif.**	**% Yield Increase/Decrease**
Control	41.3	-	-
PAM	40.5	N	11%▼
Wetter	40.7	N	2%▼
PAM & Wetter	38.3	N	7%▼

Trial 2 at Callendale

Table 8 shows that pre-ripping results again produced a high yield increase of 15%, though this result was only approaching 5% significance. No other result of either ripping or soil conditioners gave a significant result. The combination of post-ripping, PAM and wetter together increased yield by 21%, and this was approaching significance.

Results at this property had a high level of error, possibly contributing to the lack of significant results. This may be attributed to two factors;

1. Part of the trial was waterlogged for the last three weeks of production, due to a low depth to the clay horizons. This factor was considered in the analysis of variance, but may not be fully removed.
2. Harvest of trials at Mingbool and Kalangadoo occurred in the same week as Callendale, and use of the trial harvester could not be arranged under the time constraints. Consequently, samples from the trial plots were reduced from 5 metres of double bed to 1 metre of single bed, greatly increasing the risk of error.

Trial Summary: Control vs Pre-ripping Treatments (Means of all Treatments)

Significance is stated as Yes, No or Approaching significance (5% l.s.d.)

Control	48.0	**Pre-ripped**	55.15	**Signif.**	A	**% Yield Increase/Decrease**	15%▲

Table 8. Effects of soil management treatments at Callendale on saleable yield (>100g tubers), tonnes/ha.

Significance is stated as Yes, No or Approaching significance (5% l.s.d.).

Treatment	Yield (ton/ha)	Signif.	% Yield Increase/Decrease
Control	50.2	-	-
PAM	44.5	N	11%▼
Wetter	49.0	N	2%▼
PAM & Wetter	53.8	N	7%▲
Batswing	53.0	N	6%▲
Batswing, PAM	48.2	N	4%▼
Batswing, Wetter	50.5	N	1%▲
Batswing, PAM & Wetter	60.6	A	21%▲
Paraplow	48.8	N	3%▼

Trial 3 at Kalangadoo

Pre-ripping at Kalangadoo resulted in a yield increase of 7%, which was lower than Western Flat and Callendale. This result was approaching a significant value, as was the yield increase associated with the Batswing® post-ripping of 17%.

Significant yield increase of 21% was achieved by combining ripping with the Batswing® both before and after planting.

A yield increase of 4% with the Paraplow® was not significant (see Table 9).

Trial Summary: Control vs Pre-ripping Treatments (Means of all Treatments)

Control	53.6	**Pre-ripped**	57.2	**Signif.**	A	**% Yield Increase/Decrease**	7% ▲

Table 9. Effects of soil management treatments at Kalangadoo on saleable yield (>100g tubers), tonnes/ha.

Significance is stated as Yes, No or Approaching significance (5% l.s.d.).

Treatment	Control	Treated	Signif.	% Yield Increase/Decrease
Batswing®, post-rip	53.4	62.5	A	17% ▲
Batswing®, pre+post	53.4	64.6	Y	21% ▲
Paraplow®, post-rip	53.4	55.6	N	4% ▲

Trial 4 at Mingbool

Due to heavy hail damage to one side of the trial, pre-ripping results are unavailable.

Yield values were very low, and error values became very large, reducing the overall significance of the results.

Traditional ridges showed yields 19% higher than those of rolled ridges, but none of the results gained in this trial could be considered significant due to the extreme levels of error (see Table 10).

Trail Summary: Ridges vs Rolled (Means of all Treatments)

Significance is stated as Yes, No or Approaching significance (5% l.s.d.).

Ridges	13.9	**Rolled**	11.3	**Signif.**	N	**% Yield Increase/Decrease**	19% ▼

Table 10. Effects of bed structure and ripping treatments at Mingbool on saleable yield (>100g tubers), tonnes/ha.

Significance is stated as Yes, No or Approaching significance (5% l.s.d.).

Treatment	Control	Treated	Signif.	% Yield Increase/Decrease
Batswing®	13.9	13.2	N	5% ▼
Paraplow®	13.9	14.2	N	2% ▲

Additional data collected

Table 11 shows a summarised account of the penetrometer measurements taken across the four properties where the different methods of ripping were trialed.
This data is also summarised for the three positions the penetrometer was used across the ridges.

All styles of ripping achieved some decrease in soil strength.
In the upper 24cm the Batswing® has decreased soil strength the most, by an average of 30%, and by roughly the same figure when combined with pre-ripping.

In the deeper soil, strength has been most decreased by pre-ripping combined with the Batswing® post-ripping (25%), while pre-ripping with no post-ripping achieved a similar average decrease of 22%.

The Paraplow® was also very effective in the deeper soil without pre-ripping (20% decrease in soil strength), especially considering it only operated from one side of each ridge, and penetrometer readings were averaged across the bed.

In the deeper soil, where the Batswing® is combined with pre-ripping, there appears to be an added effect on soil strength, the opposite seems to be true with combining Batswing® pre-ripping with Paraplow® post-ripping. The variation in their respective designs may well tend to cause some compaction when operated on the same soil.

Table 11. Soil strength (kPa) at two depths with ripping treatments (average across four properties/ three penetrometer positions across bed).

Ripping treatments		**Soil Depth**	
		2-24cm	26-46cm
No pre-ripping	No post-ripping	738	2120
	Batswing®	516	1943
	Paraplow®	621	1701
Pre-ripping	No post-ripping	709	1660
	Batswing®	520	1580
	Paraplow®	616	1838

Table 12 shows averages of soil moisture in the top 30cm of soil, as logged by TDR probes over the growing season at Callendale.

Soil moisture in the Batswing® post-ripped plots shows a 103% increase from the results of the control treatment, making the average soil moisture for the season extremely close to the field capacity of the soil.

The soil conditioner results are quite promising from this data, showing a 25% increase in soil moisture from the wetter treatment and a 151% increase in soil water with the use of PAM, which exceeded the soil's field capacity by a large margin.

Table 12. TDR soil moisture readings from Callendale with soil wetter, PAM and Batswing® post-ripping treatments (average of logged readings across the growth season from top 30cm).

Readily available water = total mm – wilting point

- **Amount required to restore to field capacity = field capacity – total mm**
- **Callendale; wilting point = 6.5% = 19.5mm/30cm;**

  field capacity = 34.9% = 104.7mm/30cm

Treatment	Average moisture content (% water/30cm)	Total mm water in 30cm	Readily available (mm in 30cm)	Amount required to restore to field capacity (mm)
Control	16.9%	50.7	31.2	+54
Wetter	21.1%	63.3	43.8	+41.4
PAM	42.4%	127.2	107.7	-22.5
Ripped	34.3%	102.9	83.4	+1.8

Appendix 1 firstly shows penetrometer graphs of the four properties without ripping, at two positions directly under the plants and to the side of the ridge.
These graphs show obvious compaction at Western Flat, with far lower levels at the other three properties, indicating a possible reason why yield increases at the other three properties may have been less significant. A report of particle size distributions done across the South East (Grant, 2000), indicates that there may be some soils which are less prone to compaction, based on different distribution of particle sizes in the sand fraction. It is not certain whether the less compacted properties fit into this category.

Appendix 1 also shows the soil strength results of the three types of ripping tested, alongside the control of no ripping.

Pre-ripping and the paraplow both show significant decrease of soil strength in the outside of the double-row and directly under the row, but this effect is diminished in the centre of the double row. This would reflect the position of the two Paraplow tines on either side of the double bed, and suggest that compaction may have re-occurred at planting in the middle of the double row.

The Batswing tines used after planting appear to have relieved compaction at each of the entry points, but the effect is diminished directly beneath the plants in the centre of the ridge.

Appendices 2 and 3 show the performance of ripping, soil wetter and PAM over the course of the season in terms of their effects on soil moisture.
Enviroscan results from three depths in the profile suggest that PAM has kept more moisture in the top 30cm of soil, while ripping has allowed more to drain from the 10-30cm horizon to the 30-50cm horizon. This work was a small part of the main project. This data is supplied for general interest and discussion.

DISCUSSION

Ripping treatments and Compaction.

This project has identified ripping treatments as a successful method of overcoming compaction in sandy soils used for potato production in the South East region of South Australia. Removal of compaction resulted in increased root density and yield increases of up to 25% with some of the management techniques. Ripping improved drainage and water storage capabilities of subsoils.

Two types of ripper have been used in trials, the Batswing® and Paraplow®, both significantly reducing soil strength in the compacted sands. The Batswing® has produced significant yield increases in many trials over the three years of the project. Trials of ripping with the Batswing® started with ripping parallel to the ridge, with the tine running down the furrow. This was seen to be a desirable method for minimising the risk of re-compaction and ensuring compaction relief directly under the plants. Trials in the third year also tested ripping prior to planting, capable of running a higher density of tines at right angles to the rows, which had yet to be formed.

Yield increases reached 16% with this method using five tines instead of three, improving the increase of yield over ripping after planting (which increased yield by 7% in both the second and third years). An increase of 25% was then achieved by combining the two methods before and after planting. This occurred at the property with the highest compaction, and these results were mirrored by a 21% increase in yield with the same treatment at a less compacted property.

The Paraplow® was adapted for local potato production in the last year of the project, resulting in the greatest reduction of soil strength witnessed in that year. The ripper could only be used in the three properties with least compaction due to its late inclusion in the trials. Two of these properties experienced problems with large degrees of error, and the third had the lowest level of compaction. No significant yield increases were recorded with use of the Paraplow®, but its clear alleviation of compaction shows promise for future work. It is also worth noting that the Batswing® also gave no significant yield increases at these properties when used after planting.

Where ripping with the Batswing® was more beneficial when used both before and after planting, combined ripping with the Batswing® before planting and the Paraplow® after planting resulted in decreases in compaction relief from that attained with each ripper separately.

Yield increases were also insignificant with this treatment. Paraplow® ripping prior to planting could not be tested due to late inclusion in the trials.

Three of the four properties in the final year of trials on ripping exhibited much lower levels of compaction than Western Flat, the first trial to be set up (see penetrometer readings; Appendix 1). This may simply be due to management of the soils. Further investigation of particle sizes from across the South East revealed some soil types to have slightly different size distributions of sand particles (Grant, 2000). It is yet to be seen whether there is any difference between the compacting characteristics of these soil types.

Changes to traditional bed structure.

Higher volumetric water was recorded in rolled bed structures in the first and second years of trials, and in the second year a marginally significant increase in yields was also recorded.

Rolling of two ridges into a bed in sandy soil was considered to be a simple procedure to incorporate into common farming practices. Positive soil moisture results in the first two years backed up the perception many farmers already had that this treatment would allow better infiltration of water into the bed instead of the furrow. The main benefit of rolling ridges together would appear to be the opportunity to apply less water to crops or allow time between irrigations to be lengthened.

This treatment was in common use by the third year of trials. Further investigation of this treatment was considered secondary to studies on ripping methods and alternative ways of improving yields.

Treatments with problems for integration to production.

A number of treatments, initially included in the trials, were deemed to be difficult to integrate with current practices, or had little value for overcoming the problems of sandy soil. These were subsequently not included in trials in following seasons.

Mulch and organic matter were two such treatments. Combining mulch and organic matter achieved significant yield increases in the first year of trials, but were incompatible with the harvest methods used by commercial growers.

In the first and second year, clay spreading was also trialed. While higher soil moisture results were recorded with the use of rolled beds with clay in the first year, further observations in the second year revealed the moisture increase to be due to the bed structure. Neither set of trials showed any significant yield increases. It was observed in both of these seasons that clay incorporation had been low, even by the end of the season, and it was presumed that any impact on soil moisture or yield would require greater periods of time to be effective.

Due to the nature of the potato industry, which often leases land in the region for a single season, clay spreading was considered to be of little benefit to potato producers who did not own and re-use land for potatoes. Information for growers who own land and could spread clay is being sought by other researchers in the region.

In the final year, soil wetters and PAMs were trialed in an effort to reduce the impact of soil surface water repellency and poor water-holding capacity. At Callendale, PAM increased volumetric soil water content at 10cm until the end of November and at 30cm from February onwards. At Western Flat, PAM increased soil water content at 30cm throughout the season.

Soil wetter did not present beneficial characteristics for these soils. In many cases it reduced the volumetric water content of soils and showed some signs of a negative impact on yield (though not significant).

It is conceivable from the data that soil wetter has allowed greater evaporation from soil, without providing significant increase in penetration of water. This resulted in a net loss of available water.

Soil moisture treatments and potato production.

Where compaction has been identified as a factor limiting yields of potatoes in the region, irrigation has probably ensured soil moisture levels remain adequate.

Volumetric water levels were recorded which exceeded the field capacity of soils under soil-water treatments. Such waterlogging may reduce yields. No effect on yields was recorded with any such treatment except where deep ripping was also used. From what is known about compaction, the volumetric water levels measured are probably not the same as water available to plant roots, since much of this water is held in soil too strong for roots to penetrate.

Where ripping alleviated compaction, the soil horizon surrounding potato roots measured a consistent volumetric moisture level roughly equivalent to field capacity, and often higher in the profile below. Where compaction was prevalent, soil moisture generally exceeded field capacity in the root zone and remained dry (and inaccessible) below them. This would suggest that ripping allows drainage of water in the root zone to lower horizons, while allowing the root zone soils to hold a good quantity of water for plant use.

Many of the treatments aimed at increasing soil moisture (such as clay spreading and PAMs) did just that, often allowing soils to exceed their field capacities by a considerable margin in compacted soil. Where these treatments were used without ripping, there was quite often a slight decreases in yield, possibly due to the death of roots by lack of aeration associated with temporary waterlogging.

Where treatments such as clay and PAM were combined with a ripping treatment, the results were quite often a marginal improvement in yield above that of the ripping treatment alone. Our knowledge of compaction is that where it is alleviated, roots are allowed greater room to grow and access to air, due to improvement in soil structure and denser root systems.

Therefore an increase in water supply may allow greater plant growth over and above the improvement from ripping. This extra improvement is unlikely to be significant enough to warrant treatment with soil conditioners such as PAMs where an increase in yield is sought.

Treatment with PAM is likely to be of use where a reduction in irrigation frequency or duration is desired. Increases in volumetric water of soil with the use of PAM are substantial, and may indicate an opportunity to reduce water use without impacting on yields.

The efficiency of this treatment in maintaining soil moisture levels under varied or reduced irrigation regimes has not been tested properly in this project. This would be a promising direction for future research.

TECHNOLOGY TRANSFER

Second Year

A display prepared for the Lucindale Field Days in March, showing preliminary results from the Western Flat trial and the principles behind ripping and wide beds, attracted considerable interest from farmers.

A brief update on the trials was given at a Potato Industry field day in April.

An article summarising the 1998-99 trial results was submitted to the national industry journal Potato Australia in June, and was published in September.

General interest in ripping techniques and clay spreading grew in the South East region. Growers are now "talking about ripped versus non-ripped". A number of growers purchased ripping equipment and some use clay incorporation, ripping and wide bed soil treatments.

At a Field Day for potato growers on August 5, findings from the 98-99 season's trials were presented. The use of ripping equipment, moisture monitoring tools and the penetrometer for assessing soils was explained. Ripping equipment was displayed and discussed at the field day.

Third Year

A number of growers in the South East region have purchased deep ripping equipment for commercial use. Many of these have already benefited from the trial results concerning use of the equipment prior to planting with decreased tine-spacing prior to planting.

An increased interest in the project this year has meant a larger number of growers have become involved as hosts for trials. Paul Frost of Safries Pty Ltd approached a number of growers not involved in the trials to use and assess the ripping equipment in areas under centre pivot. David Brear of Howard Australia has been available for individual advice and to supply the equipment to interested growers.

A poster has been prepared for the Potato 2000 conference in July describing the techniques and benefits of deep ripping.

An article has also been written for the national industry journal Potato Australia giving a summary of results of the 1999/2000 trials, and detail of the benefits of ripping and soil conditioners to growers using sandy soils. This information may also form the basis of fact sheets on deep ripping and polyacrylamide use on sandy soils.

RECOMMENDATIONS

Scientific

This work has raised some doubt about the extent of compacted soils in the region, and to what level of compaction deep ripping is economically beneficial.

More work into the relationship between soil particle size distributions and the potential for compaction would greatly improve the understanding of which soils benefit most from deep ripping. This work could be the key to providing a simple soil test growers could use for determining the profitability of using deep ripping equipment. At this point though, the best measure available is penetration resistance of soil, and it is recommended that penetrometer instruments be made available to interested growers

The packing properties of soils in relation to their particle size distributions and the potential for compaction would also provide clues as to which sands are most susceptible to compaction. Electron microscopy of soil cross sections may be the best method of identifying typical packing structures of these sands and therefore the most vulnerable soil types.

This project has not tested the efficiency of soil amendments such as PAM, widened bed structures and soil wetter in maintaining soil moisture levels under varied or reduced irrigation regimes. Trials where the volume and/or rate of irrigation used could be manipulated and controlled would be very useful in identifying the propensity each treatment holds for reducing irrigation in commercial production.

Such trials should be conducted where deep ripping is standard practice, thereby diminishing the effect of compaction on soil moisture measurements. This may also provide a golden opportunity to improve the techniques of using the Paraplow® for potato production.

Industry

Some analysis of soil strength would be beneficial for producers to assess whether to incorporate deep ripping cultivation into their planting methods.
Soil strength should be recorded to a depth of at least 40cm, and ripping recommended to be of some benefit where penetration resistance exceeds 2000kPa.

Where penetration resistance of soils exceeds 2500kPa, deep ripping is likely to provide a highly profitable return on investment.

Maximum benefits should be achieved with the use of a Batswing ripper before and after planting, combined with treatments described in this paper. While the Paraplow has not been properly tested in this project, impressive reduction of soil strength has been observed, and estimated yield increases from these trials are likely to be a conservative estimate. As with the Batswing, a different configuration of tines allowing more complete coverage of soil is likely to increase yields.

Rolling two ridges into one wide bed supporting two rows of plants can improve water infiltration and storage in the mound in sandy soils, possibly also providing some improvement to yields. Liquid polyacrylamides are also able to improve the water content of sandy soils, but are likely to have no effect on yield. Each of these treatments could be useful in reducing the frequency and duration of irrigations on sandy soils.

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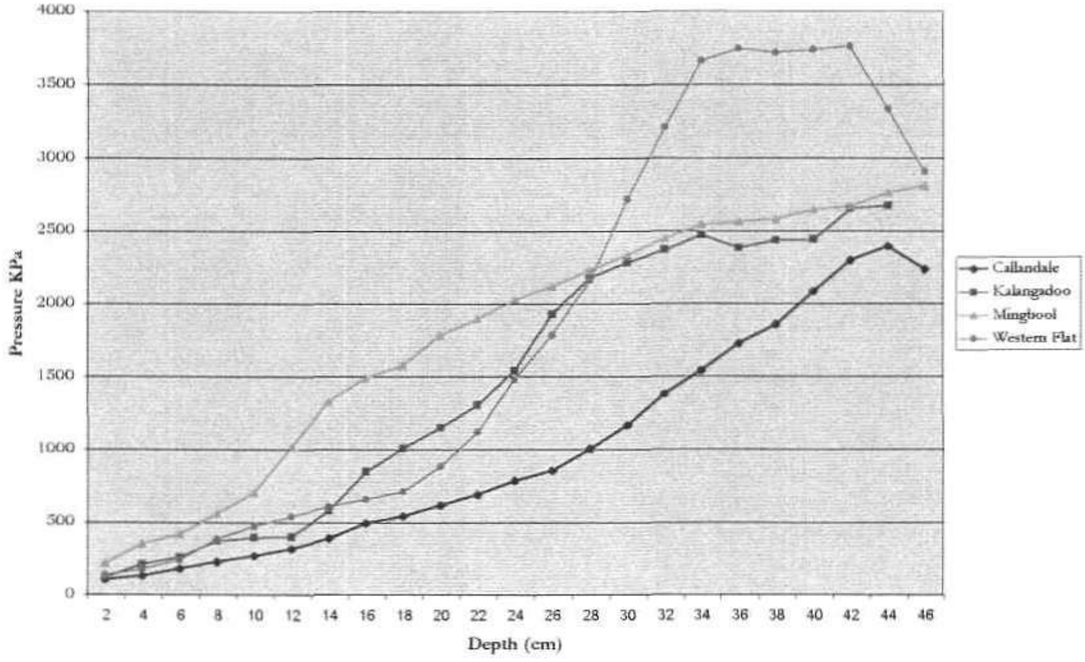
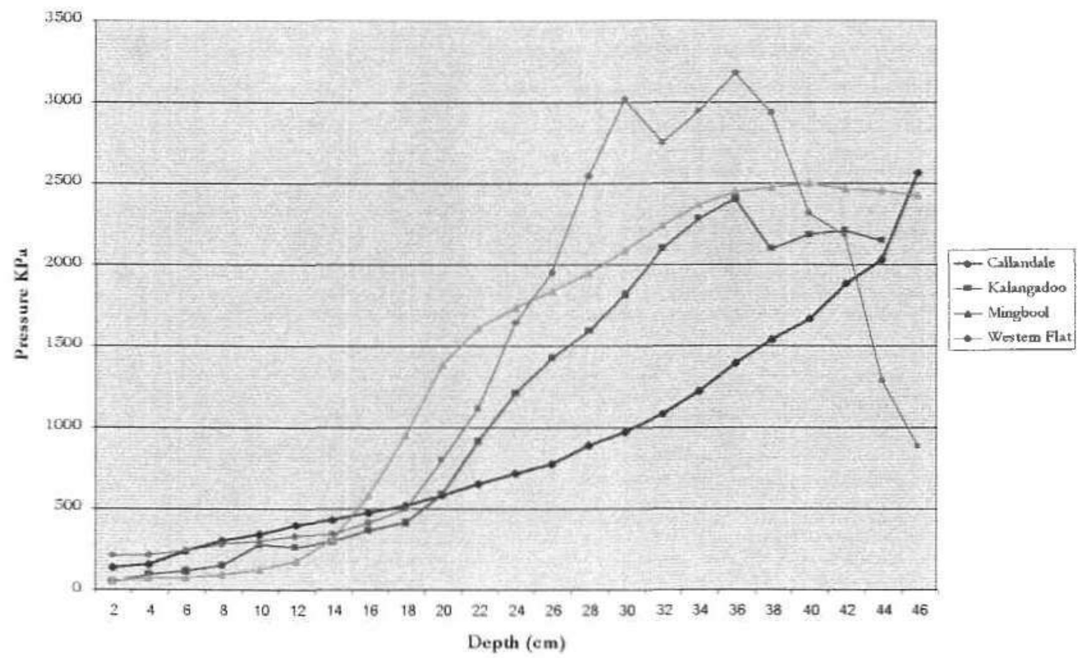
Appendix 1: Penetrometer readings at properties where trials were held in the final year; measurements taken in centre of potato row.

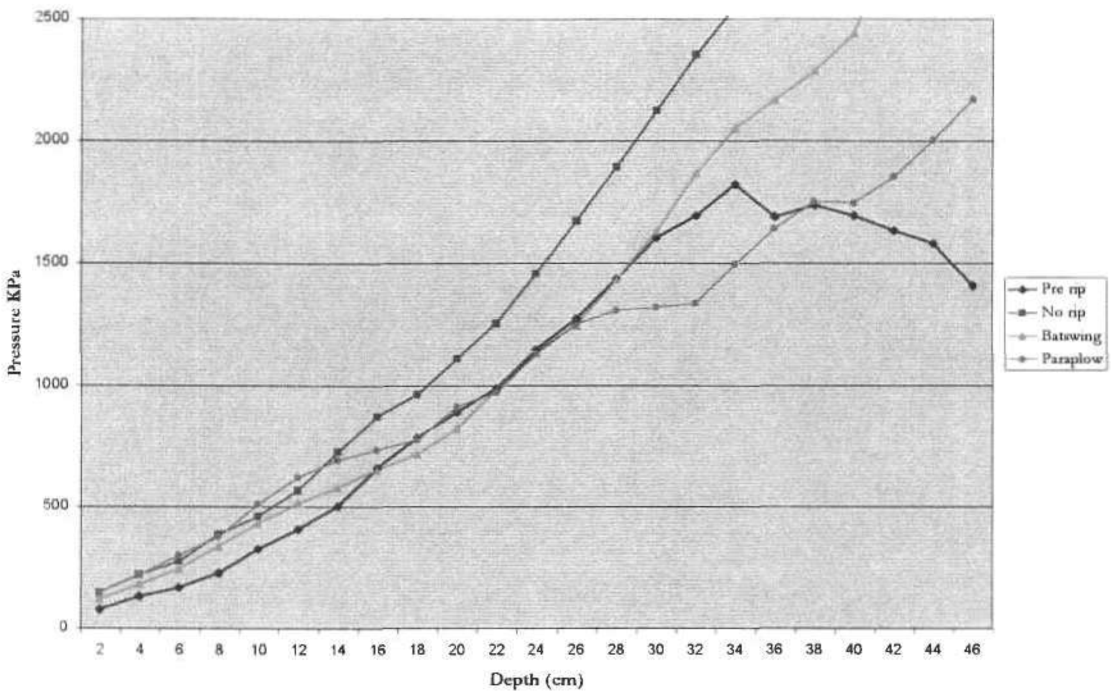
Penetrometer data from control treatments at four subsoiled properties: Outside of potato ridge



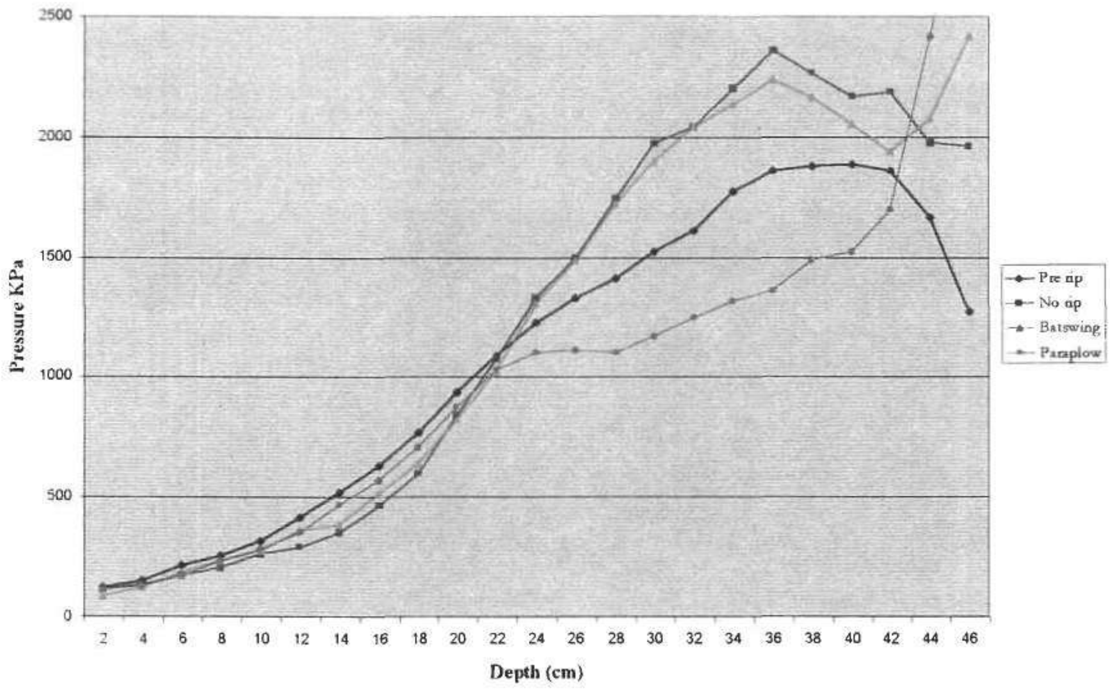
Penetrometer data from control treatments at four subsoiled properties: Centre of potato ridge



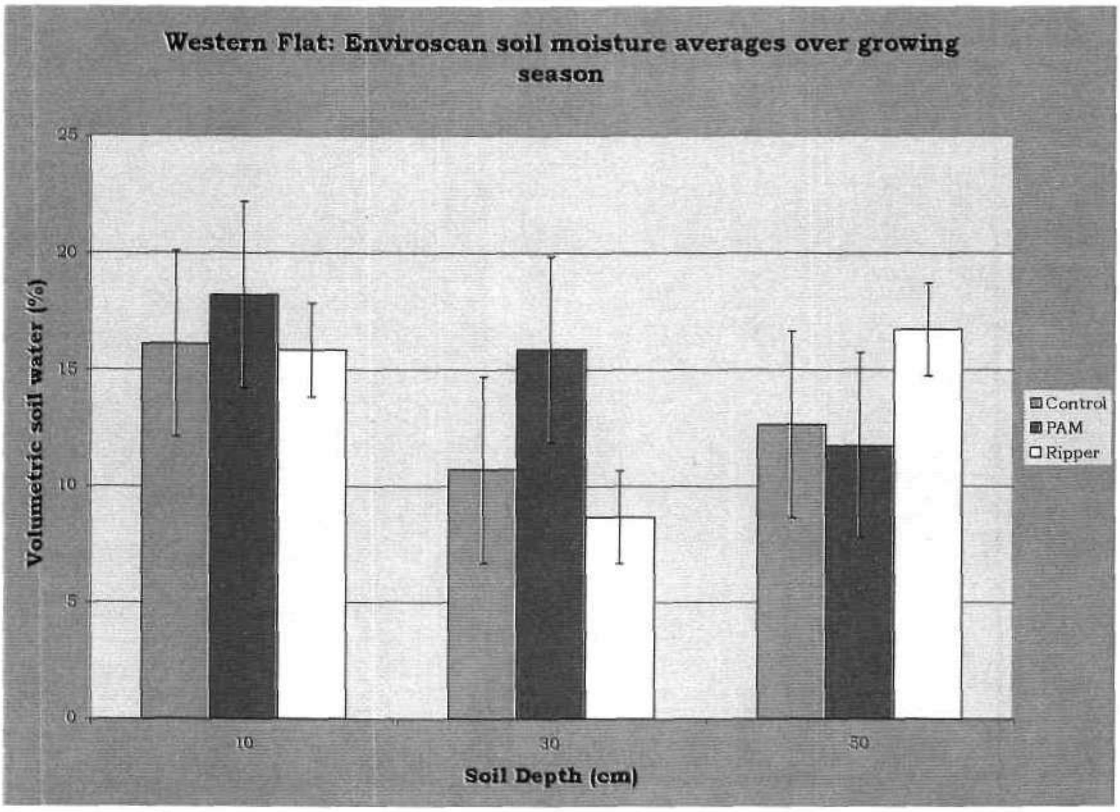
Mean penetrometer data of four subsoiled properties: Outside of potato ridge

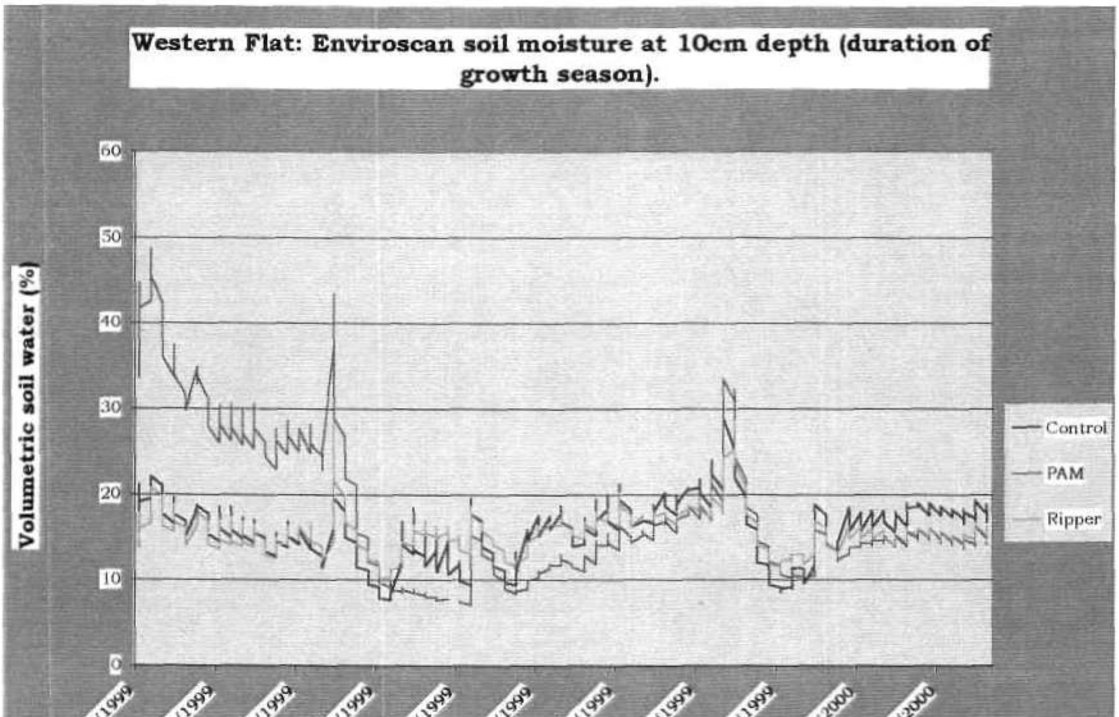


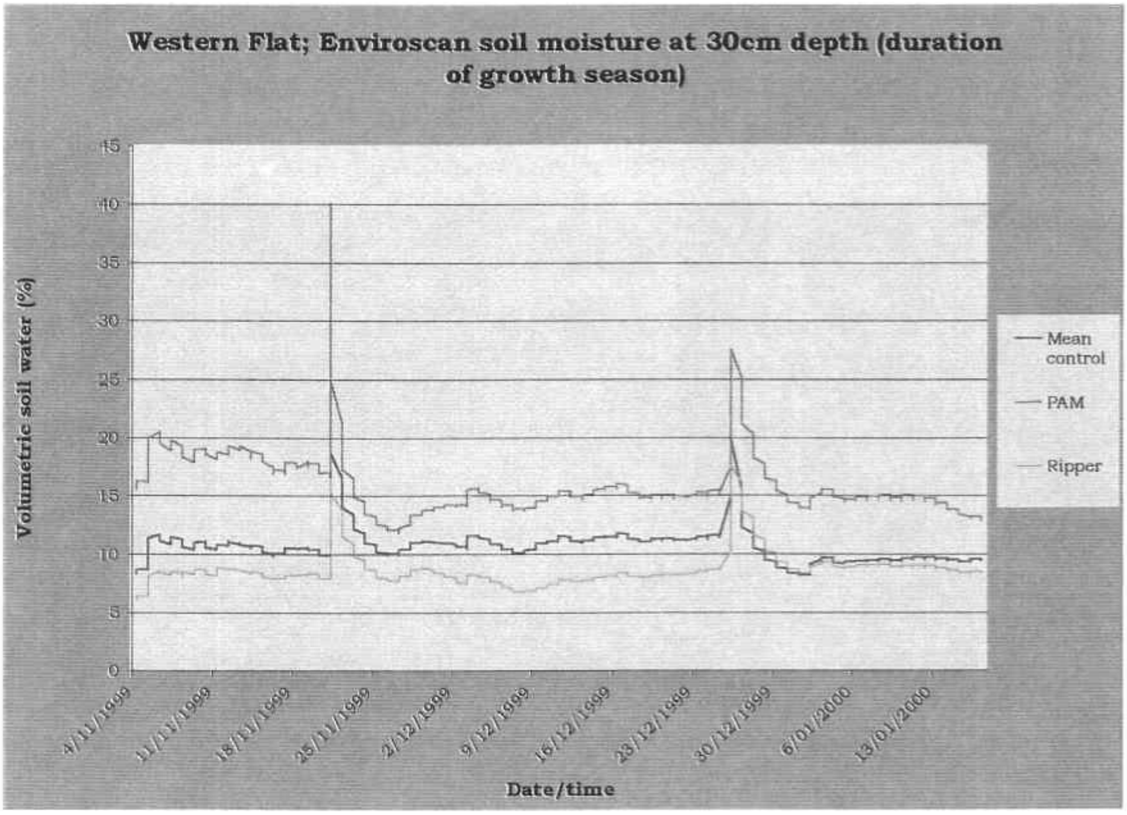
Mean penetrometer data of four subsoiled properties: Centre of potato ridge

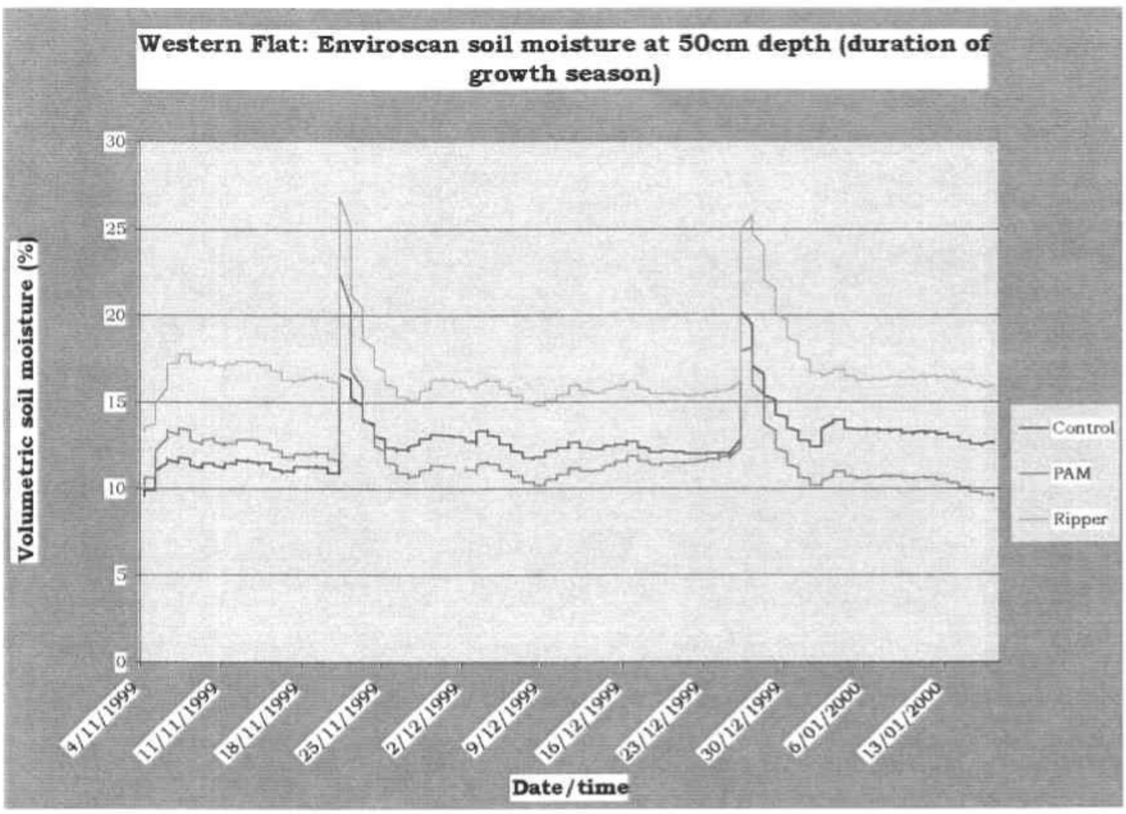


Appendix 2: Enviroscan volumetric soil moisture readings at three depths in the profile with ripping and PAM treatment.






Western Flat; Enviroscan soil moisture at 30cm depth (duration of growth season)
Volumetric soil water (%)
45
40
35
30
25
20
15
10
5
0
Mean control
PAM
Ripper
4/11/1999
11/11/1999
18/11/1999
25/11/1999
2/12/1999
9/12/1999
16/12/1999
23/12/1999
30/12/1999
6/01/2000
13/01/2000
Date/time


Western Flat: Enviroscan soil moisture at 50cm depth (duration of growth season)
Volumetric soil moisture (%)
30
25
20
15
10
5
0
Control
PAM
Ripper
4/11/1999
11/11/1999
18/11/1999
25/11/1999
2/12/1999
9/12/1999
16/12/1999
23/12/1999
30/12/1999
6/01/2000
13/01/2000
Date/time

Appendix 3: Reflectometer (TDR) readings of volumetric water in potato ridgestreated with ripping, soil wetter and PAM during the final year.