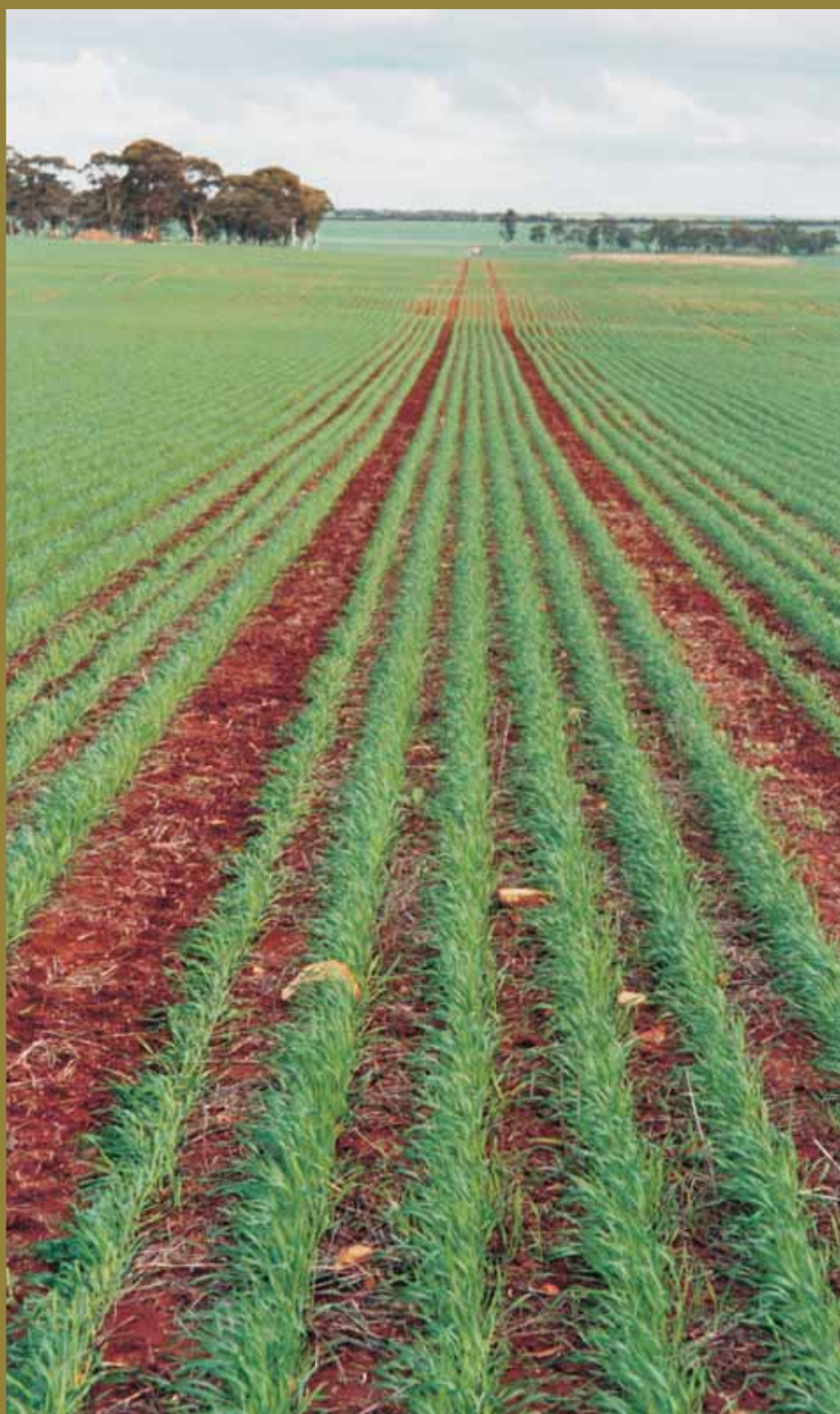


Tramline Farming Systems

Technical manual



Department of Agriculture
Government of Western Australia



GRDC

Grains Research & Development Corporation

Tramline Farming Systems: Technical Manual

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Department of Agriculture Western Australia, GRDC Project DAW 718.*

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Acknowledgements

We would like to acknowledge all the farmers and others who have participated in this research including Dan and Tony Critch, Miles Obst, Kevin Thomas, Rohan Ford, Nigel and Don Moffat, Paddy Barber, Glenn and Tony Fretwell and the Liebe Group for the provision of trial sites. Thank you to Mike Collins, Peter Newman, Greg Hamilton, Peter Walsh, Bill Crabtree, Wayne Chapman, Don Yule, Stewart Cannon and Jeff Tullberg for your valued

input. Thanks to Rudi Bartels of BEELINE Technologies for guidance system terminology. Thank you to the Grains Research and Development Corporation and the Department of Agriculture for funding this project DAW 718 'The development of tramline farming for Western Australian cropping' and the Sustainable Energy Development Office (SEDO) of the Department of Energy of Western Australia for funding C359M SEDO.



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Section 1,2,3 and 4



Introduction

**Tramline farming
decision tree**

**Summary of Tramline
Farming-definitions,
benefits and costs**

Setting priorities

1.0 Introduction

Tramline farming improves farm production and efficiency by controlling traffic and confining compaction to permanent tramlines and reducing overlap. This manual will help you develop your farming system to get the tramline farming benefits. The manual contains information on the principles and techniques of implementing a tramline farming system. There are many options available, so you can tailor the system to suit your own farm.

In eastern Australia, controlled traffic farming (CTF) is another term used for permanent wheel track farming. The system is based on bare, straight tramlines. The term tramline farming is more commonly used in Western Australia where the system is closer to the original European concept of using bare tramlines for spraying only to avoid weed and soil erosion problems. Although most tramline farmers work in straight lines, some Australian growers, mostly from Western Australia, have shown that tramline farming can be worked successfully round and round. The terms tramline farming and controlled traffic farming can be used interchangeably. For the purpose of this manual we will refer to tramline farming.

The tramline farming decision tree on page 2 is an overall summary of the decisions you need to make in designing your system and the options available. You can then refer to each section as required.

There are five main choices to make:

1. What are your farm priorities?
2. What direction do you want to work your paddock?
3. What guidance system would you like?
4. What machinery widths and tracks do you want to base the system on?
5. What tramline type is suitable?

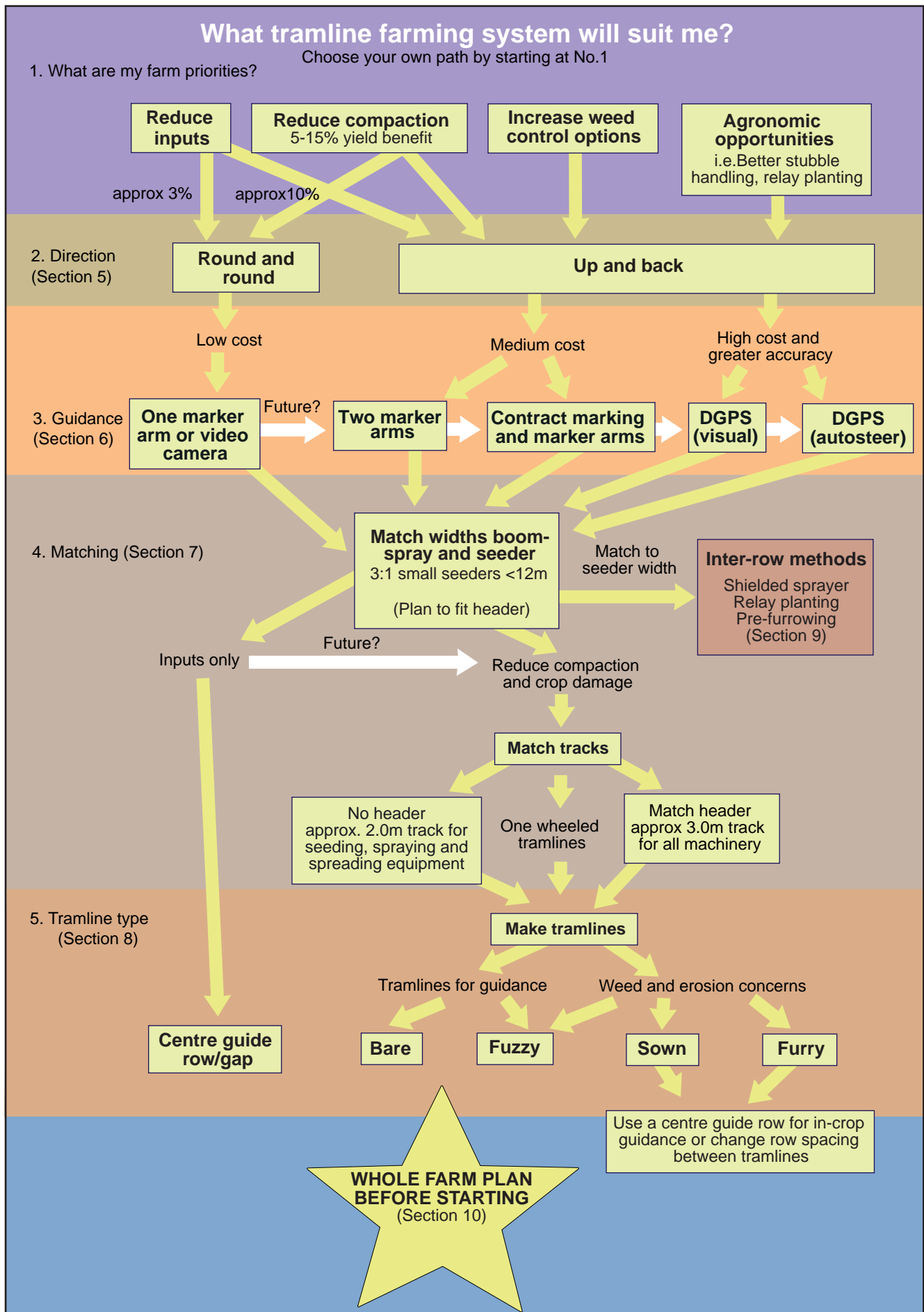
When answering these questions keep in mind your own farm situation, including things like budget, farm layout, and climate. A tramline farming system can be developed over a number of years according to your circumstances.

Please read this manual in conjunction with other published material on tramline-based systems, for example, *Controlled Traffic Farming*, Kondinin Group July 2000 Farming Ahead, No. 103 p28-42, and February 2003, No. 134 p18-31; *Controlled Traffic Farming Guide*, Conservation Farmers 2003; and technical information about raised bed farming. For example Hamilton, G., Bakker, D. (in press) *Raised Bed Farming Manual*, Department of Agriculture Western Australia.

This manual contains information on the principles and techniques of implementing a tramline farming system.

The terms tramline farming and controlled traffic farming can be used interchangeably.

2.0 Tramline farming decision tree



3.0 Summary of tramline farming definitions, benefits and costs

3.1 Definitions

Tramline farming or controlled traffic farming is a crop and fodder production system which confines tyre and track induced soil compaction to permanent tramlines by controlling traffic. This produces softer crop zones and allows easy access into the crop for row cropping, relay planting or raised bed techniques. An ideal system has all equipment matched for compatibility of width and tracks.

Tramline farming uses a guidance system which may be mechanical, such as marker arms, or electronic, such as video or global positioning systems (GPS) for more accurate driving to minimise overlap and to set up and maintain tramlines. Tramline farming can work round and round or up and back.

Accurate driving and matching machinery operational widths are very complementary to precision farming methods for zone farming and for variable rate applications of fertilisers and herbicides.

increases over time;

- grain quality: for example, fewer screenings in cereals and more oil in canola by improved soil characteristics and plant root access to water.

More agronomic opportunities

The use of high accuracy technology provides new agronomic opportunities such as:

- relay of summer crops before grain legume is harvested, using relay planting;
- better fertiliser use by placement near row, deep ripping and placement on alternate inter-rows;
- banding of post-emergent fungicides and inter-row shielded spraying;
- better stubble handling by running tines between rows of the previous crop;
- sowing back into old furrows or pre-made furrows after early rains or wet harvests.

The tramline farming benefits of reduced inputs and increases in yield have been shown to translate into improved gross margins of

Benefits of tramline farming include 3 to 10 per cent reduction in inputs and 5 to 15 per cent increase in crop yields.

A tramline farming system is estimated to reduce fuel use by up to 25 per cent.

Table 3.1. Relative value of major benefits (efficiency and yield based on conservative figures).

Benefit	Amount	Value
Less over lap	5%	\$7.50 (\$150/ha of inputs)
More yield	10%	\$30 (2 t/ha yield and \$150/t on-farm)

3.2 Benefits

Better efficiency

Crop production efficiency is increased with tramline farming by:

- reduced input costs of 3 to 10 per cent from less overlap through more accurate driving;
- easier driving from using a guidance system, which reduces fatigue;
- earlier access for operations such as seeding, spreading and spraying on the compacted tramlines in wet conditions.

A tramline farming system is estimated to reduce fuel use by up to 25 per cent. Fuel and fertiliser savings could translate to 200 tonnes of greenhouse gas abated for each tonne of improved grain production.

Better yield and value

Less crop damage and soil compaction by confining wheels to permanent tramlines can improve:

- crop yield by 5–15 per cent, depending on soil type, the degree of track matching and the duration of the system. Yield benefit

\$45/ha (Table 3.1). The yield benefit from reducing compaction and crop damage is greater when compared to the overlap savings.

See Appendix 1 for more details on research results studying the benefits of tramline farming.

3.3 Estimated costs

The cost of tramline farming varies depending on the guidance system you choose and your current on-farm machinery setup. The wide range of guidance systems and machinery available means that changes can generally be made within any farm budget and may be made over a period of time. Guidance systems can range from low cost marker arms to more expensive and accurate Differential Global Positioning System (DGPS) auto-steer systems (Table 3.2).

Costs to modify machinery widths may vary from a few dollars to change a boomspray width to the changeover costs to buy another harvester front or an alternative seeder.

The most important recommendation is that tramline farming is seen as a farming system and implemented in a planned manner within the long-term goals for your enterprise.

Table 3.2. Approximate guidance system costs (2003) (Only a rough guide; manufacturers will provide more detail)

System	Camera	Marker arms	DGPS visual	DGPS auto-steer		
Home made/ Commercial		second-hand	+/- 1m	+/- 20 cm	+/- 2 cm	
Approx. cost (\$)	600	1000—2000	3500—6000	4000—40,000	50—60,000	80—100,000

The costs to modify machinery tracks vary greatly, but are generally within the range of \$1000 to \$5000 per item of machinery. New equipment is now being manufactured with adjustable tracks, for example adjustable boomspray axles and tracked tractors.

Other costs that may be associated with developing and improving a tramline farming system include:

- the cost of designing and modifying paddock layouts to improve efficiency;
- new specialized equipment such as inter-row shielded sprayers (\$20,000 to 50,000).

Simple estimate of costs and benefits from Tramline\$Calculator

There is a simple spreadsheet available to calculate the benefits for your situation and compare to the possible costs for your machinery. Contact the Department of Agriculture Western Australia, ph (08) 9956 8555.

4.0 Setting priorities

Capturing the most effective benefits for an individual farming enterprise needs a clear decision on the most important priorities to aim for. Each property has its own agronomic situation and unique set of equipment, as well as the unique skills of the grower. This diversity between enterprises makes a single recommended recipe for adapting to tramline farming impossible. The most important recommendation is that tramline farming is seen as a farming system and implemented in a planned manner within the long-term goals for your enterprise.

It is important to consider your own farm priorities. Almost all farmers wish to reduce their input costs and improve the soil. For some, controlling compaction, or new weed control options, or agronomic opportunities may be important. Your priorities will determine the tramline farming system you develop. The savings gained from reducing overlap could be then used to finance matching machinery. If you are unsure, try one paddock in a trial.

Section 5



Direction of working

5.0 Direction of working

5.1 Up and back (parallel) working

Traditionally, tramline farming is done with working up and back in straight lines. This is the most efficient method of working a paddock because:

- driving to a straight line is easier than following a curved path;
- double worked corners of round and round operations are eliminated;
- precise inter-row or close to row operations work more easily in straight lines.

However, every paddock on the farm may not be suitable for up and back farming because of complications with paddock shape and

obstructions such as trees and rocky outcrops. In such situations it is possible to sow along the contour. (See Section 9 Layout)

Challenges implementing up and back working

As with all new systems there are challenges. The following are some challenges and potential solutions noted by growers changing to working up and back:

Challenge: tight turns and overlap at the end of the run for the seeding equipment.

Up and back is the most efficient method of working a paddock.

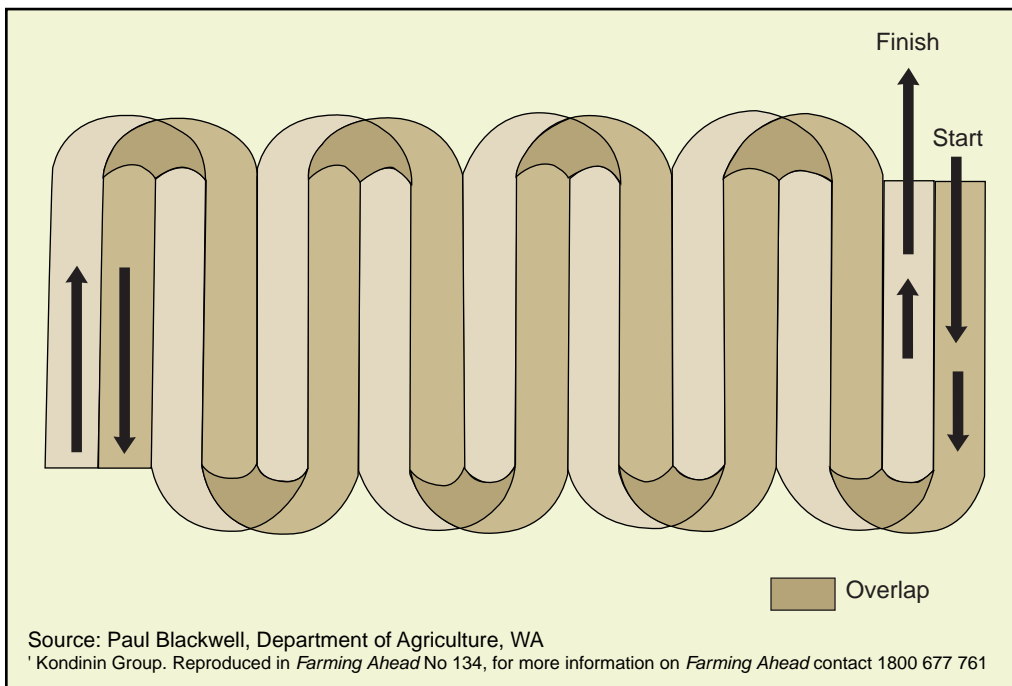


Figure 5.1. 'Clapper corners'



Photo 5.1: 'Rip skip' is illustrated very well in this paddock as two varieties of wheat were briefly mixed up when the seed of one variety finished before the skips had been filled in.

Tramline farming round and round can be used as a cheap introduction to the system before moving to up and back working.

Solution: 'rip skip': this is where every second seeding run is seeded then the seeder comes back and fills in the gaps as seen in the photo below. This method can be done easily with electronic DGPS guidance.

Challenge: lots of switches to flick at the end of the run to lift the bar out of the ground and turn the air seeder off and back on again.

Solution: the 'clapper corner' was developed by Lindsay Chappel who uses the rip skipping method and leaves his bar in the ground throughout the operation, creating curved headlands on the edge of the paddock (Figure 5.1). This will be a compromise when compared to lifting the bar out of the ground on the ends and then seeding the end separately, as there will be more overlap and some parts of the headland not sown. On the other hand, the risk of errors, such as forgetting to turn the air seeder back on, is reduced.

Challenge: swath falls over or crop lodges. Growers working up and back have noted some problems with swathing crops down the tramlines as the swath tends to fall down the tracks and is too low to pick up. Another problem is lodging crops that can be picked up in one direction but not in the other.

Solution: in these cases consider aligning the layout at right angles to your prevailing wind. If this is not convenient then it may be one situation where you don't work on the tramlines at harvest.

Challenge: unloading at harvest.

Solution: the placement of field bins requires some planning. Work out the distance you can travel in an average crop before the harvester bin fills and put in an access road or a turn around point. Or if working with a chaser bin on the tramlines you need to think about what side the unloading auger is on. Harvesting alternate rows as a 'rip skip' can help.

Challenge: avoiding double sowing on the ends.

Solution: if seeding up and back there are a few options to avoid double sowing on the ends. Seed around the paddock the width of the boomspray before starting to work up and back. When turning on the ends lift your bar out when you get to the edge. The laps sown on the outside act as a guide for when to lift the bar and turn the air seeder off. Alternatively, you could seed the ends of the paddocks when you finish, or if you have a wide access road, use that as your turning point, or when using auto-steer, seed a clapper corner.

Challenge: rough paddocks changing from working round and round.

Solution: seed the tramlines for the first few years to smooth out the paddock. Once smooth, lift the tines behind the tractor wheels. Alternatively, use a tractor with very good suspension and a comfortable seat!

5.2 Round and round (racetrack)

Anti-clockwise round and round sowing is the most familiar method of operating in Western Australia and a tramline farming system can be worked this way. Only one marker arm and one modified row width for tracking is needed. Corner problems can be reduced where possible by not double sowing corners and keeping seeding runs in groups of two or three to match the sprayer width. Tramline farming round and round can be used as a cheap introduction to the system before moving to up and back working.

If corners are not double sown, all cropping operations can be quicker but the application rates of fertilisers and pesticides are still compromised on corners if the application continues as the machine turns, overdosing the inside of the turn and underdosing the outside. Consider why you sow corners in the first place. If it is for weed or erosion control then ensure other control measures are taken.

Section 6



Guidance systems

6.0 Guidance systems

There is a range of different guidance systems available to suit individual farm budgets and priorities, ranging from cheap mechanical guidance to more precise and costly electronic guidance systems. Generally the bigger the cropping area, the greater the savings from preventing overlap by using electronic guidance. Farmers with programs greater than 1500 ha and input costs of around \$100/ha have made savings of about 10 per cent by using an accurate electronic guidance system. This goes a long way towards rapidly recovering the cost of the system. Refer to Table 6.2 for a summary of guidance systems.

6.1 Marker arms

Marker arms provide mechanical guidance. These can be as simple as a length of steel pipe supported by cables and dragging a section of anchor chain. The more advanced marker arms are fully hydraulic, double fold systems. The cost of building your own marker will vary depending on what materials you have available and the complexity of the design. The cost of a fully hydraulic arm marker arm ranges from \$3500 to \$6000 (2003 prices).

The disadvantages of using mechanical marker arms are obstructions such as trees, and regular repairs. Some suggestions to overcome problems are:

Difficulty finding marks in stubble: the use of chains and 'mad rabbits' on marker arms is a very old method, but has advantages over a disc because of lower maintenance, a clearer mark and less dependence on the height of the arm.

Following a mark or line: this can be more accurate if a mark on the front of the bonnet is lined up with a mark on the cab screen to form a 'gun sight'. Bonnets with a central crease or line are better for this. Putting a front wheel on the mark is also reliable, but this method reduces the ability to straighten out 'wobbles'.

Difficulty finding tramlines after stock damage: there is little known about the effect of stock on tramlines. Some farmers are reporting difficulty finding the tramlines the following year from stock damage. Placing a peg or selecting a landmark to mark the centre of the first run may provide guidance for future years. Contract GPS tramline marking is another option if the system used is accurate enough to return to the same place the following year.

6.2 Video camera guidance

A video camera located on the edge of a seeder bar and linked to a monitor mounted in the cab of the tractor can be used to steer to the outside row of the previous run. The cost of this system was approximately \$600 in 2003. As the camera is located on the bar there is less risk of damaging it on obstacles.

6.3 DGPS guidance

Electronic systems are based on differential global positioning systems (DGPS) satellite signals. These systems offer more reliability and practicality than marker arms. They range in complexity from a differential system

Farmers with programs greater than 1500 ha and input costs of around \$100/ha have made savings of about 10 per cent by using an accurate electronic guidance system.



Photo 6.1 One marker arm seeding round and round



Photo 6.2 A video camera located on the wing of the air seeder bar (a) is used to record an image displayed in the tractor cab (b) on the left.

steering accuracy of about +/- 10–90 cm (sub meter) with drift from day to day. High quality base station systems are accurate to about +/- 1-2 cm with little drift but they have shorter range because the base station must be stationary on-farm.

Automatic steering can be applied to any electronic guidance system for most current types of tractors. Automatic steering uses a steering kit fitted to each tractor and takes over from the steering wheel. The guidance system can be easily transferred between tractors, although not the steering kit. The most accurate auto-steer comes from a base station system.

Visual guidance systems can operate up and back or round and round. Auto-steer systems generally have been designed work up and back (parallel), although a few manufacturers have developed a system to steer round and round (race track).

The cost of electronic guidance systems can range from \$11,000 for DGPS visual guidance to \$90,000 for DGPS with auto-steer (2003 prices).

Satellite reception can sometimes deteriorate or drop out. The presence of on-ground marks (such as tramlines or central marker rows) will provide some guidance when these technical difficulties occur. This is a sensible 'belt and braces' strategy. Software is being developed to predict when satellites are likely to be down. During these times you could undertake maintenance or other jobs, change shifts or fill up.

(L-band or high precision-dual frequency) that uses a series of satellites (up to 12 satellites), with a differential correction provided by a network of accurately surveyed reference points via a geostationary satellite, to a real time kinematic (RTK) system with differential correction from a local on-farm base station. L-band or high precision systems have a

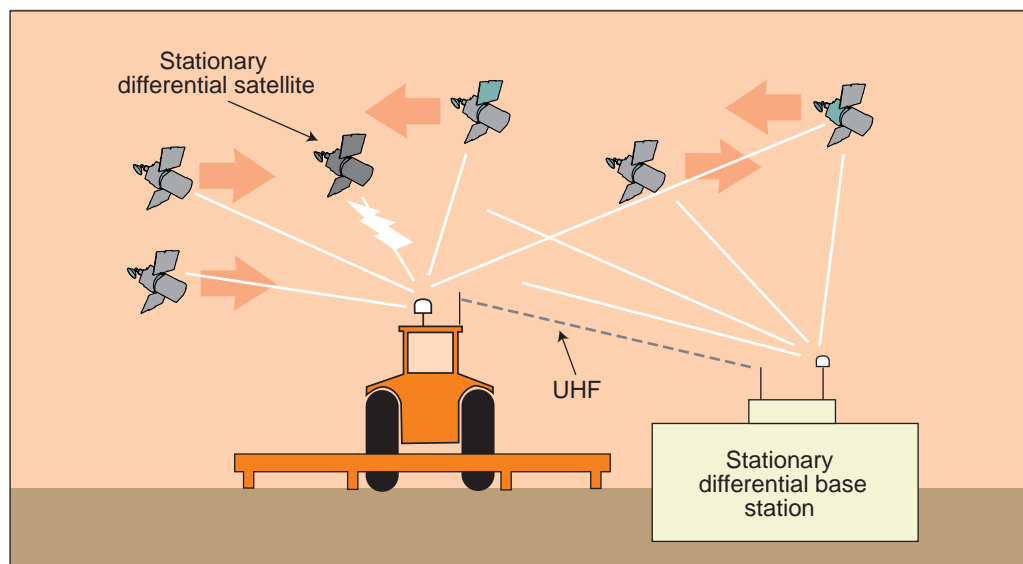


Figure 6.1. Tractor receiving signals from satellites for DGPS guidance.

6.4 Contract marking

Employing a contract marker who has an auto-steer DGPS system to mark every spraying run up and back maybe a feasible option for growers who crop less than 1500 hectares. Two marker arms can then be used at seeding to fill in the adjacent seeding runs. Alternatively, every run could be marked by the contractor.

6.5 Post-seeding guidance

Most of the guidance systems mentioned above are for guiding the seeding tractor, although GPS-based systems can be used for any paddock operation. Marks on the ground or in the crop can be left for the driver to follow, for example the tyre marks of a tow-behind air seeder box. Centre guide rows can be made by widening the two middle rows or leaving a broad row. Visible tramlines are another form of post-seeding guidance (see Section 8 Tramline design). All post-seeding guidance relies on accurate seeder positioning with its own suitable guidance system.

6.7 Guidance terminology

This is some of the terminology used to evaluate electronic guidance systems.

Absolute positioning —Positioning with respect to a well-defined coordinate system (for instance, WGS84). An example of this is post-processing of logged data to precisely



Photo 6.3 Base station located on-farm to achieve +/- 1-2cm accuracy with a DGPS auto-steer guidance system. Check the manufacturer's recommendations for the ideal position relative to the working area.



Photo 6.4 Every boomspray run has been marked in this paddock by a contractor.



Photo 6.5 A central guide row made in the center of the bar by pushing two rows close together is visible after harvest (38 cm broad rows).

determine the true position of a base station (see <http://www.auslig.gov.au/geodesy/sgc/wwwgps/>).

Accuracy — Accuracy is a statistical measurement of freedom from error or how close a measurement is to the true but unknown value. It is generally defined as an interval, confidence level or probability within which the true value is likely to occur. For example, 1 m circular probability error (CEP) means that 50 per cent of the measurements are within one metre of the true position.

Cross-track error — The distance from the current way line measured at right angles to the way line.

Precision — Precision refers to how small a unit the instrument can measure. A centimetre level receiver is more precise than a metre level receiver, for example A poor base fix with a DGPS product can result in very precise measurements that are offset from the true position, for instance very precise but inaccurate.

Relative positioning

— The determination of relative positions between two or more receivers which are simultaneously tracking the same GPS signals, where one receiver is static and the others are mobile.

Repeatability — Repeatability or repeatable accuracy is a statistical measurement of the accuracy with which a user can return to a previous position. The main confusion with the term repeatability is the time frame within which it is used. To reduce confusion, the term ‘Absolute repeatability’ is used by some manufacturers to refer to repeatability that can be used from season to season.

Way line — Line between two points, A and B, that sets the initial direction of travel and subsequent path of travel parallel to this line.

Table 6.1. Benefits and problems of guidance systems.		
System	Benefits	Problems
Marker arms or video camera	<ul style="list-style-type: none"> • Low cost • Mechanical guidance (mark on the ground) • No technical support required 	<ul style="list-style-type: none"> • Can be difficult to see mark in stubble • Only for ripper and seeder • Maintenance cost, low precision • No auto steer • Turns can be tight in up and back working
Contract marking by DGPS auto-steer	<ul style="list-style-type: none"> • No capital cost • Possible to obtain digital elevation maps at the same time 	<ul style="list-style-type: none"> • May lose marks before seeding if grazing stock in the paddock • Marking costs need to be less than saving from overlap achieved by owning a DGPS guidance system
Marine beacon	<ul style="list-style-type: none"> • Independence from stationary satellite (no annual lease cost) • Free correction signal • One-off capital cost for receiver • Around same price and accuracy as differential satellite 	<ul style="list-style-type: none"> • Limited to areas with reception mainly near the coast but can have inland reception depending on land relief • Radio reception may be poor during stormy weather or at dawn and dusk • Electrical noise (fans in cabs) may affect the signal
Differential base station	<ul style="list-style-type: none"> • Independence from stationary satellite (no annual cost) • More accuracy • Very little drift from day to day 	<ul style="list-style-type: none"> • 10 km range for each base station position • Higher cost electronic system. Refer to section 6.3 • Base station service cost may be high depending on distance from service centre
Differential base station with auto-steer	<ul style="list-style-type: none"> • Better driving accuracy than visual • Easier driving and freedom to monitor paddock and seeding equipment • Can't 'rip skip' * to reduce tight turns at the end of seeding runs 	<ul style="list-style-type: none"> • Most expensive system • Needs a steering kit for each tractor • May require regular stops to zero gyro • 10 km range and 'line of sight' for each base station position for some models • Small areas not cost effective for auto-steer purchase (less than 1500 ha)

* 'Rip skip' refers to seeding every second run before filling in the alternate runs.

Section 7



Matching machinery widths and tracks

7.0 Matching machinery widths and tracks

If matching the harvester initially requires substantial modifications it is possible to start with matching the seeding and spraying equipment and include the harvester later.

Ideally, all machinery tracks and widths should match but large grain harvesters with wide wheel tracks, offset harvester fronts and large air seeder bars greater than 12 metres can make matching difficult. As soil is compacted most in moist conditions, spraying and seeding equipment is the most important machinery to match. If you have lots of easily compacted sandplain soil or tend to have wet harvests then seriously consider fitting in the grain harvester.

7.1 Why match in the grain harvester?

There are several reasons why matching the harvester into a tramline system is a good idea.

- Harvesters and chaser bins are the heaviest equipment on most farms and cause soil compaction during wet harvests or where soil is moist from shallow watertables. This compaction can be severe enough to carry over many seasons.
- Harvesters will thresh and separate grain more efficiently when large amounts of power are not being used for traction, especially when harvesting on recently deep ripped sand.
- On-ground guidance from spraying tramlines can be confused by wheel tracks from harvest that do not match the tramlines for the other operations.
- There may be integrated weed control options (weed seeds and chaff from harvesters dumped on tramlines), which could be more efficient than chaff carts.

If you are planning to fit the harvester in then it is best to base the widths and tracks of the whole system on the harvester because the harvester can be the most expensive piece of

equipment to modify. Harvesters with 11 metre fronts are commonly offset and cause difficulties for matching in up and back operations (not such a problem for round and round operations). There are now centred belt harvester fronts available up to 14 metres.

If matching the harvester initially requires substantial modifications it is possible to start with matching the seeding and spraying equipment and include the harvester later. Controlled traffic farmers in Queensland who have been tramline farming for up to five years are finding that after initially matching only the spraying and seeding equipment they now wish to include the harvester. To accommodate this they are modifying their equipment to three metre tracks.

7.2 Matching boomspray and air seeder bar widths

The easiest machinery width ratio to operate in the paddock is a 3:1 boomspray:air seeder bar width ratio as it fits neatly to the edge of the paddock (Figure 7.1). This ratio works well for systems using small air seeder bars and combine seeders less than 12 metres wide. The harvester can be easily matched to the system at 1:1 harvester:air seeder bar ratio, for example:

- 9.1 m air seeder bar, 27.3 m boomspray, 9 or 18.2 m spreading, 9.1 m harvester front;
- 12 m air seeder bar, 36 m boomspray, 12 m spreading and 12 m harvester front.

Some growers found that making the air seeder bars 10 to 30 centimetres smaller than their cutter bars on the harvester front created too much gap at harvest time. This occurs because the point guards are wider than the cutter bar and can draw more crop into the harvester front. Setting the bar width to match the cutter bar is the best option. Having the air seeder bar wider than the cutter bar could pose a problem in sparse crops such as lupins.

Other odd number ratios have been used with small combine seeders such as a 5:1 boomspray: seeder bar ratio, for example, a 4 m combine seeder and 20 m boomspray.

Larger air seeders (greater than 12 metres wide) are better suited to a 2: 1 boomspray:air seeder bar ratio, for example:

- 12 m air seeder bar, 24 m boomspray, 12 m spreader;
- 13.5 m air seeder bar, 27 m boomspray, 13.5 m spreader;
- 15 m air seeder bar, 30 m boomspray and 15 m spreader;
- 18 m air seed bar, 36 m boomspray, 18 m spreader.

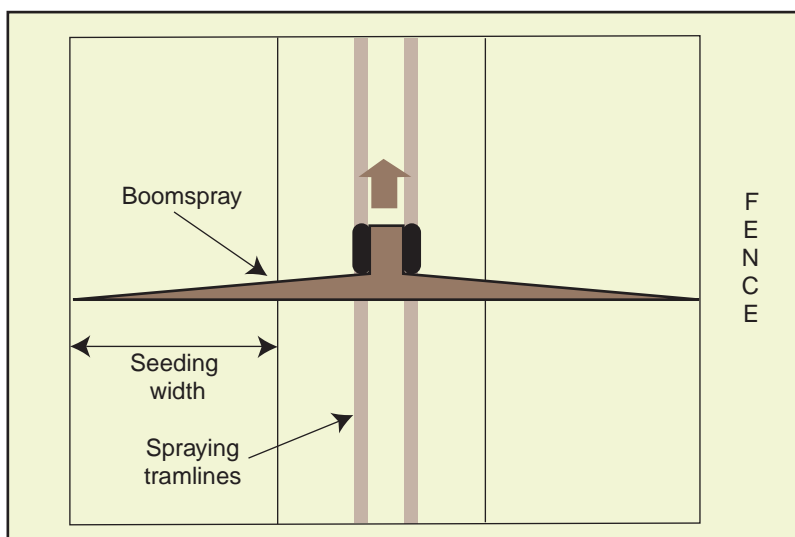


Figure 7.1. 3:1 boomspray to air seeder bar ratio.

The 2:1 boomspray:air seeder bar ratio can be tricky on the edge of the paddock but can be done by shutting off sections of the boomspray

(Figure 7.2a). Consider how many sections would be ideal when upgrading your boomspray.

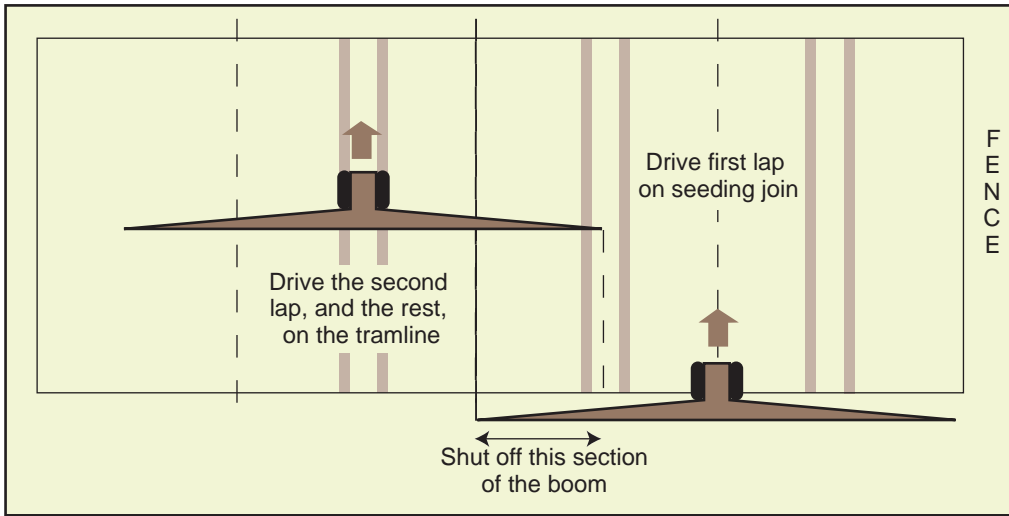


Figure 7.2 a). Drive the first lap on the seeding join with the outside quarter of the boom shut off, then continue on the tramlines.

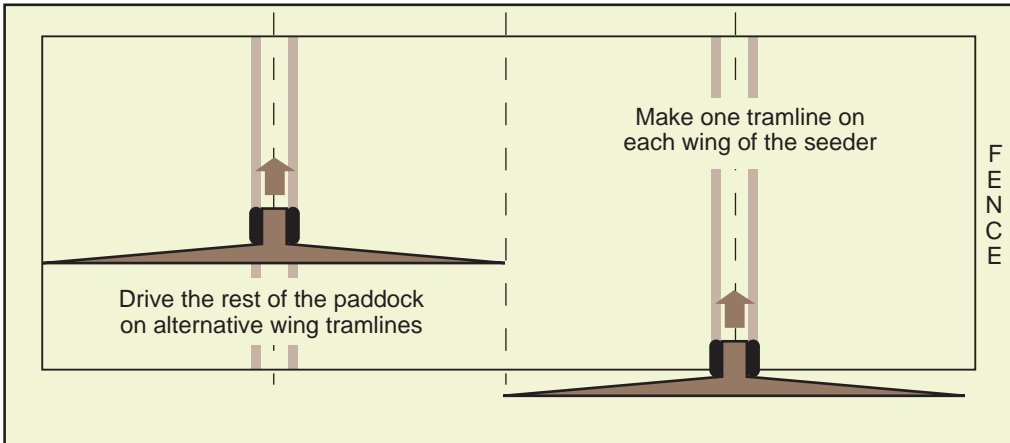


Figure 7.2 b). Make wing tramlines and drive down the seeding join. A wing tramline can be made by lifting a tine on the wing of the seeder that is half your wheel axle width from the edge of the bar.

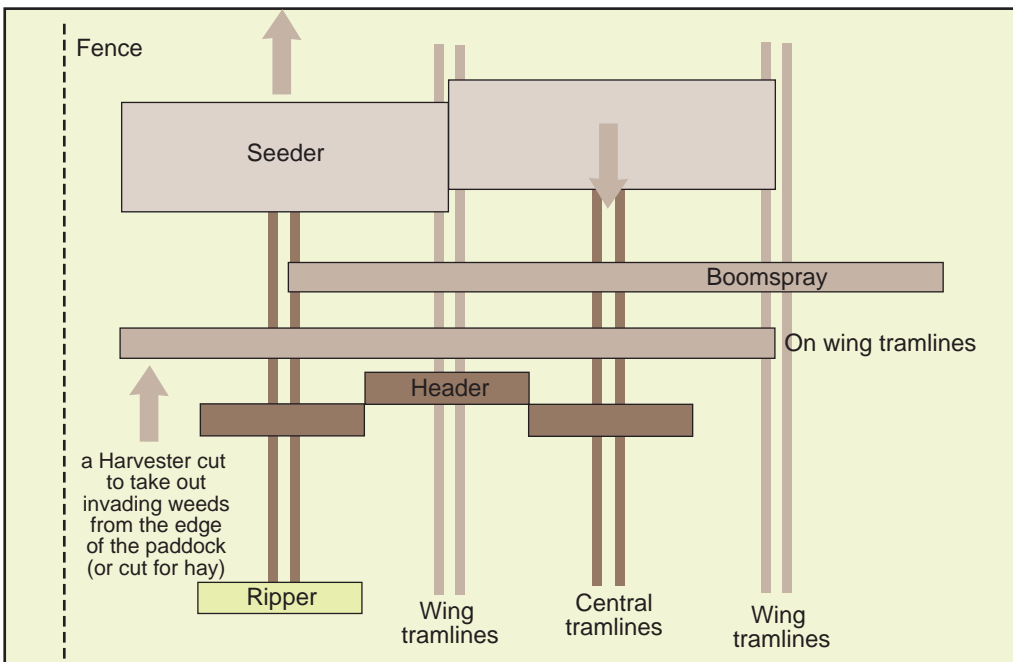


Figure 7.3. 2:1 air seeder bar:boomspray ratio including the harvester and deep ripper in the system

To get the most from a tramline farming system it is essential to match wheel track width.

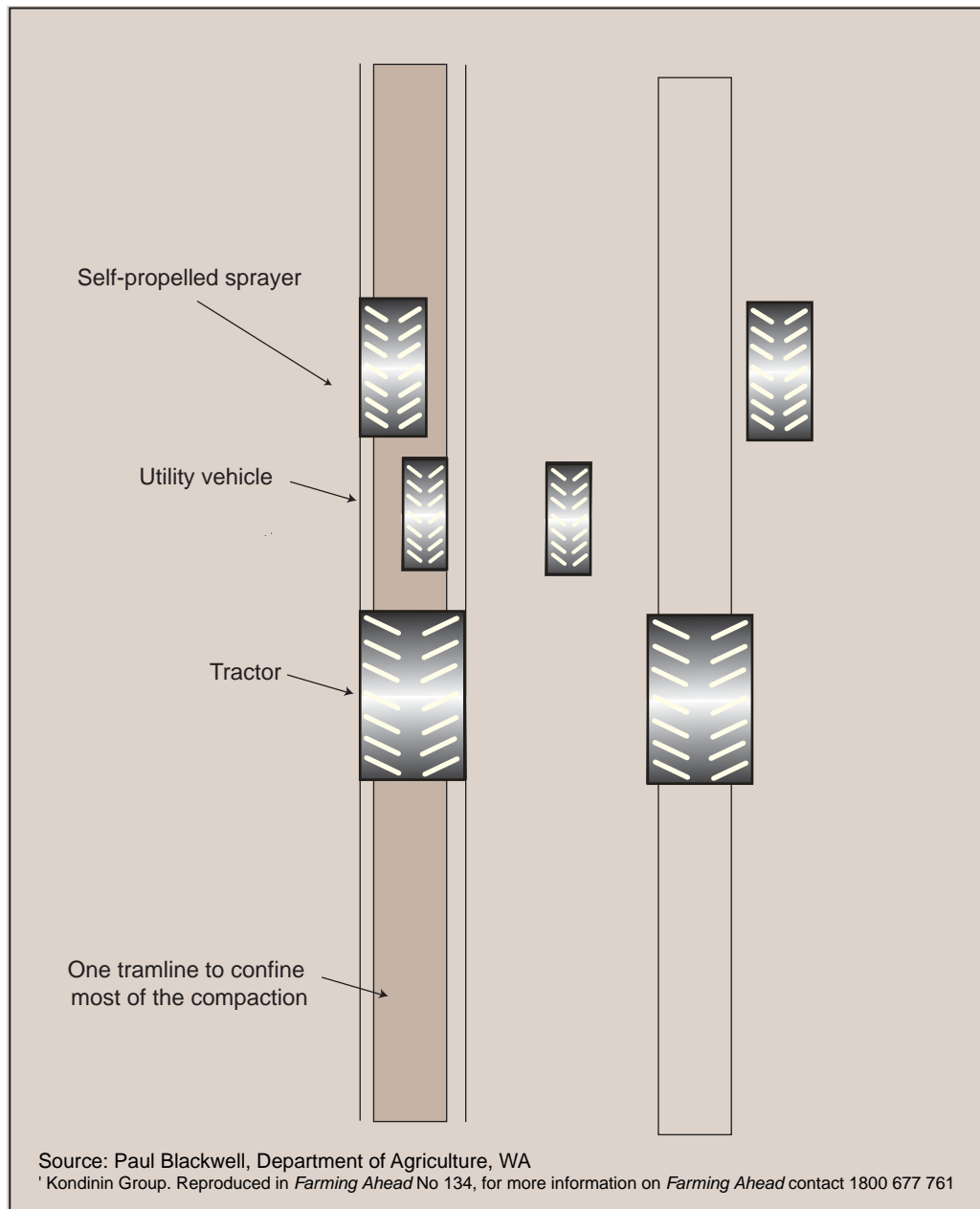


Figure 7.4. The 'one-wheel' tramline to accommodate many track widths.

An alternative to shutting off sections of the boom is to make spraying tramlines in the wings of the air seeder bar and drive down the seeding joints. This can be effective if you have a 17.6 m bar, 35 m boomspray and a 9.1 m harvester. This approach is illustrated in Figure 7.2b while 7.2a shows a compromise at the edge of the paddock to allow normal use of tramlines after the first pass with the boomspray.

Wider air seeders can be modified to fit two widths of the harvester front as shown in Figure 7.3.

7.3 Machinery wheel track matching for tramlines

To get the most from a tramline farming system it is essential to match wheel track

width. This may involve some modifications to axles (see Section 7.4 Modification options). Generally farm machinery fits tracks of 2.2 to 2.7 m but some later model harvesters have track widths slightly greater than 3 m. Therefore 3 m is the preferred width for matching in the harvester.

Multiple width tramlines

When machinery models or finances hamper using a common track it is possible to use two or more pairs of tramlines: for example, one track for the ute-pulled sprayer (about 1.8 m), one for the spreaders and seeding tractor (about 2 m), and one for the air seeder cart and the harvester (about 3 m). However, a tyre width of about 300–600 mm can result in continuous wheelings between 1.5 m (the inside edge of the ute tyre) and 3.6 m from

Farm	Seeding tractor	Spraying tractor	Air seeder box	Boomspray	Spreader	TOTAL (\$ in 2002)
Ford				4500	4500	11000*
Moffat	100	800		3000		4000
Lewis		1330	1900	1710		5000
Chappel			1900			2000
Fretwell		4500		3500		8000

* With \$2000 to modify the air seeder bar wheels.

the centre line, giving 2.1 m of compacted soil. A better solution is to use a 'one-wheeled' tramline for multiple track widths (Figure 7.4), or a 'three-wheeled tramline' for a combination of 3 m and 2 m track widths.

For example, if you have 3 m tracks left by the tow-behind air seeder cart and a 2 m track for spraying and spreading, you could work up and back with the left or right hand spraying or spreading wheel on the left air seeder cart mark of each seeding run. This confines half of the compaction to one common tramline and leaves two other tramlines, one for the 3 m tracks and one for the 2 m tracks. This is 50 per cent less compaction than you would have had from two pairs of separate tramlines. Keeping to the north side of the 3 m tramlines ensures that the offset between seeding and spraying or spreading is consistent in the paddock. Using a one-wheel or three-wheel tramline is easier in round and round operations than up and back; the common track is always on the same side (left or right)

in the whole paddock. This can be used as a stepping stone to matching all machinery track widths.

7.4 Machinery modification options

Most existing machinery does not have matching widths or wheel tracks so changing cropping machinery and wheel track width is essential to win the most benefit from tramline farming systems. The purchase of all new equipment is not necessary to begin tramline farming as many machines already on-farm can be modified to match widths and tracks. On-farm costs of modifications have been about \$2000 to \$10,000 for many Western Australian farms (Table 7.1). But before making modifications, consult manufacturers' warranty specifications and occupational health and safety standards.

If modifications are not practical for your machinery, plan to update your machinery to more suitable widths and tracks during your usual machinery changeover periods. New

The purchase of all new equipment is not necessary to begin tramline farming as many machines already on-farm can be modified to match widths and tracks.

If modifications are not practical for your machinery, plan to update your machinery to more suitable widths and tracks during your usual machinery changeover periods.



Photo 7.1 Cotton reels have been used to take the John Deere JD4250 MFWD tractor axle out to 3 m



Photo 7.2 This John Deere tractor has had the front axle extended to 3 m centres

machinery is being designed to have easily adjustable track widths and more common matching widths.

Options for modifying machinery width

Boomspray — Changing the width of a boomspray may be as simple as adding a tap or clamp to reduce the spraying width or small extensions to increase it.

Air seeder bar — It may be possible to remove tines or discs to reduce the width or extend the frame to add more tines or discs.

Spreader — Adjust the throwing distance of the spinners, which is often difficult beyond 18 m. Otherwise change to an air spreader system with suitable ease of loading.

Harvester front — Wider harvester fronts are normally offset to assist unloading. Centred fronts are required for the best tramline layouts. Some engineering companies are offering modification of offset fronts. Otherwise change the front of the harvester. There are now centred belt front harvester fronts available up to 14 m. However, to unload into a chaser bin on the run the auger may need to be lengthened or extensions added to the chaser bin. Prices vary depending on width, platform type and options required. For example, a 12.2 m centred draper front with a bat reel begins at approximately \$65,000 plus GST (2003 price).

Deep ripper — Some increase of deep ripping width, for the same tractor power, may be possible when tines are lifted or removed from where the tramlines are needed. Matching the ripper to a wider air seeder may also be possible by using guidance to rip with two lifted tines where the tramlines go (in the central part of the air seeder width), then modifying the width of the ripper and dropping the two lifted tines to rip the miss between. For example, for a 12 m seeder and a 9 m ripper, the ripper first runs on guidance at 12 m spacing with the two tines lifted for the unripped tramlines, then the two tines are lowered, the ripper folded to rip 3 m and the gaps between the first runs are ripped out.

Options for modifying machinery tracks

In most instances the reason for changing machinery wheel tracks is to include the harvester on an approximately 3 m track.

Boomspray — It may be possible to move and strengthen the axles. Hydraulically adjustable axles (2–3 m) are commercially available that will extend or retract the axle for more convenient road travel. Alternatively, change the sprayer, especially to a self-propelled model if moving to 3 m tramlines.

Tractor (spraying, seeding and spreading) — use manufacturer's adjustments; extend and strengthen axles; use 'cotton reels' to extend front wheel assist axles; change to a tracked



Photo 7.3 The spreader has been mounted on an old truck axle modified to a 3 m track. Modifications to vehicle axles may require risk assessment on-farm and re-certification for road use.

tractor with row-crop settings for a 3 m tramline. It is better to extend the axles because farmers who have used cotton reels to extend their front axles have reported increased wear on the bearings. However, if the tractor is needed for other purposes such as mowing, the ease of removing the cotton reels to narrow the track is an advantage.

Seeding tractor — Duals can be removed within manufacturer's specifications to allow singles on 3 m centres. In some cases duals or triple tyres may still be required in the early stages of establishing tramlines to help provide

enough traction for deep ripping through the existing compaction. The additional wheels may also be needed for flotation in other parts of the seeding program. To confine most of the compaction to the main tramlines increase the pressure in the inner dual tyres and reduce it in the outer tyres. The outer tyres then cause less compaction outside the tramline and can improve flotation when off the tramline, such as on end workings, like trainer wheels on a child's bicycle. Be careful not to reduce the pressure in the outer tyres too much and cause tyre damage. Minimum tyre pressure



Photo 7.4 Chaser bin with a side hopper used to unload on tramlines with a 9.1 m harvester front.



Photo 7.5 Unloading on adjacent tramlines with a 9.1 m harvester front.



Photo 7.6 Extended auger on a John Deere harvester with a 9.1 m front to enable unloading into a chaser bin on adjacent tramlines

specifications must be observed and the combined pressures must be sufficient to carry the total load.

It may be possible to rotate the wheels. Tracked tractors and self-propelled sprayers can sometimes be run on row-crop settings (3 m) and can thus match the track width of the harvester.

Spreader— the axles of the spreader could be modified using cotton reels or old truck rims or by extending the axles for 3 m tracks.

Harvester— It is difficult to change the axle of a harvester so most other machines must be modified to match it. The front wheels could be rotated on some older model harvesters. Access to grease points behind the wheels may be reduced on some models. The general rule to modifying harvester tracks is that the front wheels are set at their minimum track and the rear wheels follow within the wheel marks of the front wheels.

Chaser bins — Axles can be widened to fit wider tramlines, but the main difficulty is unloading the harvester while both are on adjoining tramlines. Rob Taylor of Dalby, Queensland has a catching hopper on the side of his chaser bin and a cross auger to distribute the load evenly (Photo 7.4). Old PTO harvesters can be converted into chaser bins which fit a 3 m track (Photo 7.5). The harvester auger must then be long enough to reach. For example, a 9.1 m harvester front can unload into a chaser bin on adjacent tramlines with a 6.7 m auger. It is possible to extend the augers to unload into a chaser bin. (See Photo 7.6).

Setting up the bar and tine spacing

Tine spacing will vary depending on the type of crops you grow and your climatic conditions. As wider row spacing is becoming more common for pulse crops than cereals it is important to consider the guess row. The guess row is the gap between two neighbouring seeding runs, for example one

row spacing. If the guess row is not considered when setting up the bar the gap between two neighbouring seeding runs can be too small or rows may overlap.

Tine spacing does not have to be evenly spaced across the bar. A variation in tine spacing, such as rows between the wheel tracks closer together, can provide some extra in-crop guidance. Some farmers start by:

1. setting up the tines for a centre row or central gap in the middle of the seeder bar;
2. setting the tines in place around the tramlines and;
3. on the edges on the bar;
4. then fill in the gaps.

If you are going to change the row spacing between cereal and pulse crop or summer crops you may wish to keep tines more evenly spaced. If you are planning to include an inter-row shielded sprayer in the system, ideally the tine spacing needs to be the same on both sides of the bar.

The following row spacings work well if alternating between wide and narrow row spacings using 3 m centre wheel tracks:

- 38 cm/76 cm
- 25 cm/ 76 cm
- 25 cm/50 cm
- 19 cm/76 cm

If using 2 m wheel track centres try:

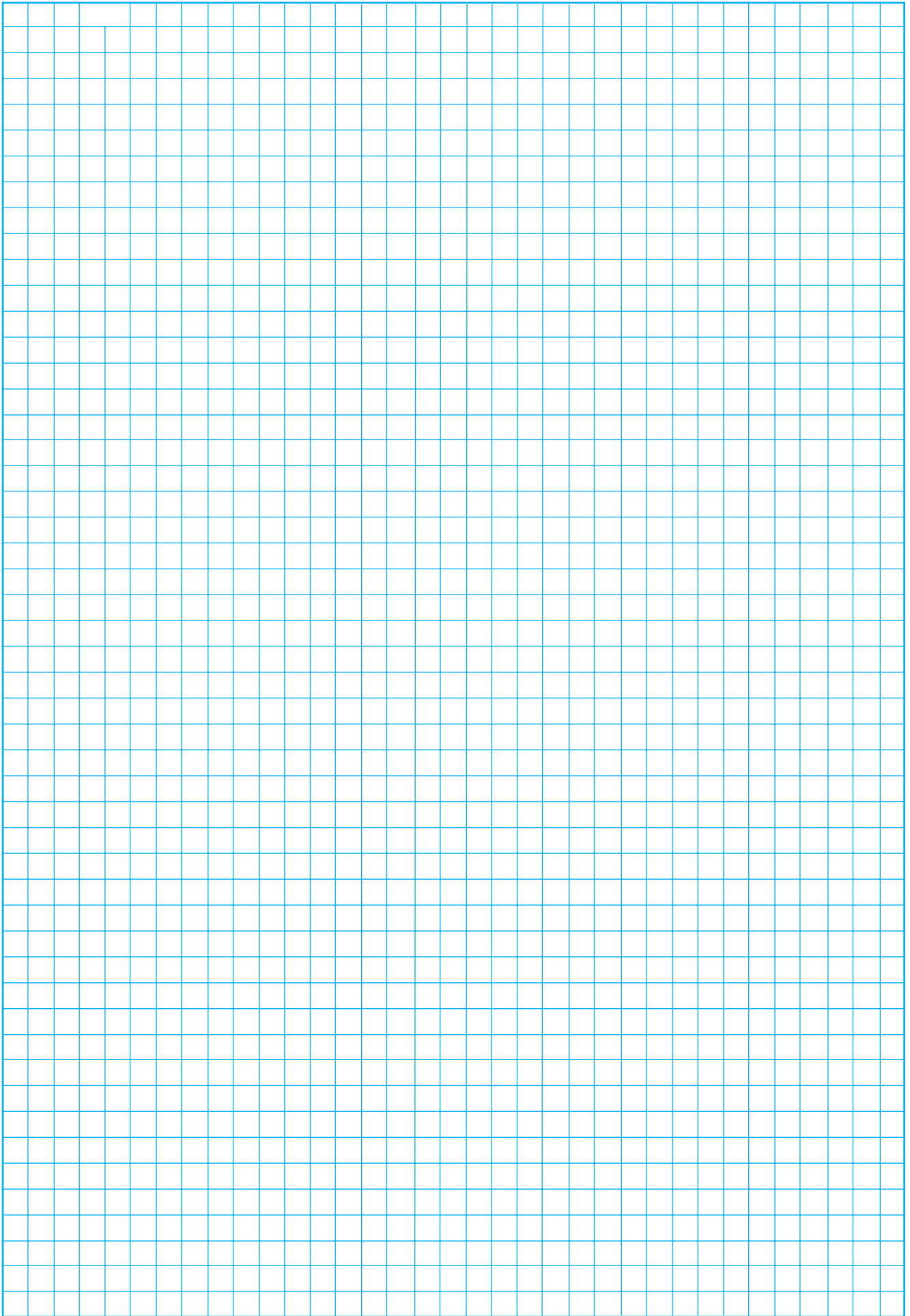
- 34 cm/101 cm
- 45 cm/101 cm

Exercise

Take a tape measure over to the shed and measure the operating widths and tracks of all your machinery used for cropping. Using the page provided, draw sketches of your machinery.

Note:

1. *Remember when measuring the bar tine to tine add one row spacing to get the operating width. Many people have been caught out by this.*
2. *Try to use either imperial or metric when measuring equipment as there can be small differences. This is a common problem when using US built tractors and harvesters and Australian built air seeder bars and boomsprays.*



Section 8



Tramline design

8.0 Tramline design



Photo 8.1 Bare tramline



Photo 8.2 Fuzzy tramline



Photo 8.3 Sown tramline

Traditionally tramlines have been left bare. However, due to concerns with herbicide resistance, gaps in the crop and potential erosion on non-wetting sands, particularly in Western Australia, there are other options available. The suitability for in-crop guidance of the other designs varies.

8.1 Bare tramlines

Bare tramlines provide a firm compacted zone for running machinery and no crop is damaged during post-seeding operations. Bare tramlines are very visible for in-crop guidance.

Bare tramlines can be left by lifting the tine or blocking the seed and fertiliser, behind the wheel of the seeding tractor. Ideally, the width of a bare tramline should fit all the machinery wheels to avoid crop damage but this may mean the gap is too wide in cereals, creating weed control problems. The width of the bare tramline commonly varies from one missing 18 cm row to two missing 30 cm rows. Narrow bare tramlines seem to be a good compromise to provide visual guidance and weed control, while reducing wheel-induced crop damage.

A common concern raised by growers when contemplating bare tramlines is that by removing a tine for the tramline production will be reduced as there are two less rows of crop per seeding run. However, yield compensation is often reported from the edge rows of bare tramlines, where the seed from the unused tubes on the tramline have been diverted into the edge rows. The plants on the edge row have better access to water and

sunlight. Such yield compensation from edge rows on sandy soils in Western Australia is being supported by trial work (See Appendix 1 Research results). Research trials also show that the overall yield benefits more than compensate for the area lost to bare wheel tracks.

8.2 Fuzzy tramlines

Fuzzy tramlines can be used in situations where some in-crop guidance is desirable but weed competition is a concern.

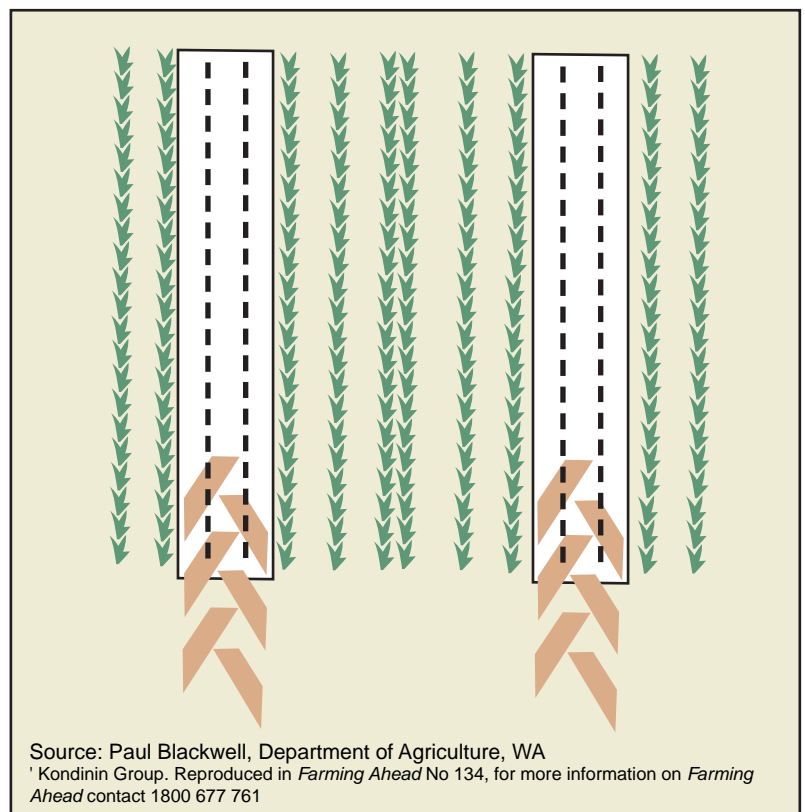


Figure 8.2. Sown tramline with central guide row.

Leaving the tines down for the first few years may help smooth out rough paddocks when changing from working round and round the paddock to up and back.

Fuzzy tramlines are made by rolling top-dressed seed into the tramline with one of the following wheels of the seeder. The seed and fertiliser is sprayed from hoses taken out of the seeding boot in the tramline zone and strapped to the frame about 800 mm above the ground. The wheel rolls them in and a broad green band of crop is formed. This can be distinguished from the sown rows next to it and followed for spraying and spreading on the appropriate seeder laps. (See Photo 8.3.) Lugged tyres are better for 'planting' this top-dressed seed. Trifluralin and drought can be a problem with this method. Fuzzy tramlines do provide clear in-crop guidance in cereals but can be difficult to see in advanced canola.

8.3 Sown tramlines

Sown tramlines together with a central guide row are a useful substitute for bare tramlines when soil throw is needed for herbicide incorporation (such as Trifluralin) in a cereal phase (Figure 8.2). The rows in the tramlines are sown with shallow points or disc openers to retain as much firmness as possible in the tramline and assist traction. The soil throw between the points mixes in the herbicide. Leaving the tines down for the first few years may help smooth out rough paddocks when changing from working round and round the paddock to up and back.

A sown tramline is often difficult to distinguish

from the rest of the crop, so the central row of the air seeder can be modified to make it different to the other rows. Try using a twin central row and perhaps moving the neighbouring rows further from the centre. For spraying, spreading and even harvesting the centre row can be followed. If you have DGPS guidance, the central guide row can provide insurance if the electronic system fails. The wheel marks from a tow-behind air cart (not a trike!) will also help to identify the tramline in a young crop when sown tramlines are used. A central guide row is not very useful in crops with a dispersed canopy such as canola or lupins. Different row spacing between the tramlines to the rest of the bar has helped some growers for guidance.

8.4 Furry (chaff) tramlines

A few growers who have matched the harvester into the system are diverting chaff from harvesters onto bare tramlines. The chaff on the tramlines may have a few different effects:

- 1) provide a mulch effect which reduces weed germination;
- 2) weeds may germinate in the tramlines but can then be targeted specifically for weed management such as drop nozzles over the tramline;
- 3) encourage early weed germination in a dry autumn to improve knockdown herbicide efficiency.

The extra cover may also reduce the risk of



Photo 8.4. Chaff diverters



Photo 8.5. Chaff diverted into the tramline from a three tonne crop.

erosion. The effect of this technique on weed burden is being assessed. Three tramline farmers in Western Australia developed chaff diverters for their harvesters in 2002.

8.5 Tramline maintenance

Good tramline maintenance to avoid long-term problems relies on setting up the system well by:

- choosing the most efficient direction for the in- paddock operations and water movement;
- deciding on the most convenient access for loading and unloading;
- taking care with areas prone to being wet;
- setting up the whole system well with unripped tramlines where an initial deep ripping is employed.

Once the system has been designed it is important to maintain the tramlines to prevent problems such as weedy or deeply rutted tramlines. Following are some tips on tramline establishment and maintenance:

Making tramlines in wet conditions — Making tramlines on soil too wet and loose has sometimes caused excessive sinkage in tracks. Not cultivating or deep ripping the tramline, cutting shallow or using disc seeding units where the tramline is planned can help. This ensures a firmer track and less sinkage. The best approach is to avoid conditions that are too wet but, if necessary, running some tracks at slightly wider widths than others can also help to spread the sinkage. Rutted tramlines can be filled by a grading chain or a smudge bar mounted on the cultivator or seeder to pull dry surface soil back into the rut and firm it with a following wheel, such as from the tow-behind bin. Alternating tramlines for each operation is another option. Tyres could also be rotated to pull in soil with the tread pattern.

Losing depth control at seeding — If the main seeding bar wheels are in depressed tramlines, and the seeder has no independent depth control for each sown row, the rows near the tramline can be sown too deeply. Independent depth control on each row, using, for instance,

Once the system has been designed it is important to maintain the tramlines to prevent problems such as weedy or deeply rutted tramlines.

Table 8.1. A comparison between different tramline types.

Design	Visual guidance	Dust raised during spraying	Firm running	Weed control by competition	Production
Bare Sown	Very good Fair*	Some Further testing required	Yes No	Poor Good	Nil@ Moderate
Fuzzy Furry	Fair# Good	Least Yes	Yes Further testing required	Good*** Further testing required	Poor## Nil@

* Visible early with tow-behind box wheel marks or using a central guide row. # Poor in non-cereal crops. @ Some compensation possible from edge rows. ***Trifluralin problems (poor incorporation). ## Poor emergence in dry seasons and when rolled in with smooth tyres.

parallelogram seeder units from Janke, Gyal and Ausplow or 'U' boot designs, can help overcome this problem.

Spray-only tramlines with tramline controllers — Too many bare tramlines can create confusion with the boomspray operator when it comes to choosing spraying tramlines. A solution to this is to set up the bar to seed tramlines very shallowly, compared to other rows (this digs up less tramline and conserves some firm running), then use a tramline controller to turn off the seed only on the runs needed for spraying.

Tramline controllers can be bought from Europe or North America. These automatic controllers just need to be told how many laps of the seeder fit into one width of the sprayer. They will use electronic signals and solenoids to automatically close off the correct number of rows to fit the sprayer and spreader wheels in the paddock and match the seeder. The controller may also be able to change over the marker arms at the end of each run. The current designs are for up and back seeding.

If using DGPS guidance another option may be to seed every spraying run first with the tramline tines up then come back and fill in with the tines down.

Controlling weeds in bare tramlines — If more weeds develop in bare tramlines than the rest of the paddock some options are:

- use a narrow bare tramline. This means the wheels may run on the edge row

causing the head in the rows of the tramline to stay greener for longer than the rest of the crop or reduce grain quality. If the harvester fits, the system guards could be put on the knife in the tramline zone to prevent green heads from going through the harvester;

- alternate tramlines for spraying so that unwheeled tramlines are sprayed resulting in low dust and no herbicide blunting wheel impact on the weeds in the non-wheeled tramlines;
- on some soil types, the use of alternate tramlines for spraying may also produce beneficial wheel damage to weeds in the tramline;
- some UK farmers spray knockdown herbicide onto the tyres of the sprayer to clean up the tramlines;
- put extra nozzles, higher rate nozzles or drop down nozzles on the sprayer in the tramline position. Crop deflectors could be used to minimise crop damage;
- shielded spray hoods on bare tramlines could be used while spraying (slowly) or as a separate operation if some tramlines are worse than others;
- reduce dust when spraying. Dust from bare tramlines can be a problem when spraying. To reduce the dust and counter its effect on herbicide uptake, try using double nozzles as shown in Figure 8.3.

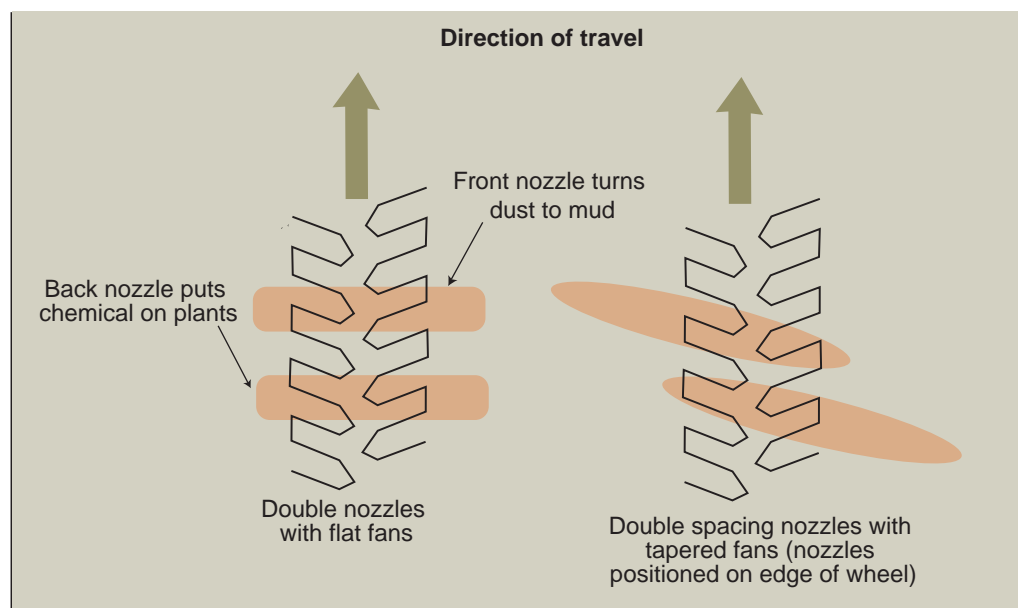


Figure 8.3. Extra spray nozzles installed behind the wheels can overcome the effect of dust. This figure was supplied by Conservation Farmers Inc. and the Department of Natural Resources and Mines, Queensland from (2003) *Controlled Traffic Farming Guide*, Conservation Farmers Inc., Toowoomba, Queensland.

Section 9



Layout planning

9.0 Layout planning

Whole farm planning is very important when introducing new technologies such as tramline farming into your system, as often a change in paddock layout is required to get the most effectiveness from the new technology.

Useful tools for planning layouts include aerial photographs, farm maps, topographic and soil type maps, even yield maps and, of course, your own knowledge of the farm. Tramline farming is very compatible with precision agriculture technologies such as variable rate technology. Some changes may take more than one season to put into practice but it is helpful to have a plan for the future. If in doubt about layout contact a professional consultant, as layout mistakes may cause severe erosion damage and are often expensive to remedy.

To design the most efficient layout consider:

- length of run;
- access roads;
- tramline orientation;
- surface water control.

9.1 Length of run

For maximum efficiency of cropping operations generally, the longer the run the better, as the numbers of corners and turnings are reduced. In some cases it may be practical to join paddocks (see Figure 9.1).

At the same time, consider how practical long runs are and surface water control issues. Some growers are choosing to plant trees to straighten up the edges of paddocks or keep

paddocks with too many obstacles as dedicated stock paddocks.

9.2 Access roads

Long runs are the most efficient for loading and unloading machinery during seeding and harvesting. Think about where your access roads need to go. Calculate how far you can travel at seeding before you need to refill and at harvesting before you need to unload. Access roads can be used to turn around on and be designed to control surface water.

9.3 Tramline orientation

Tramline orientation may vary depending on the characteristics of the paddock, soil type and slope. If the paddock is fairly uniform, select the longest run. Some people choose to run tramlines north-south to avoid driving into the sun early in the morning or late in the evening.

The other issue to consider when laying out tramlines is whether you go up and down slope or across slope. There are both positives and negatives for each situation, so you will need to assess each situation on an individual basis.

Working up and down allows the slope to drain uniformly and reduces the risk of rill formation from furrow overflows when the paddock is sown on the contour. However, without careful design and some remediation, the run-off may be directed by the furrows to areas that would not normally receive the flows, causing erosion, flooding and waterlogging. In heavy rainfall episodes, run-

If in doubt about layout contact a professional consultant, as layout mistakes may cause severe erosion damage and are often expensive to remedy.

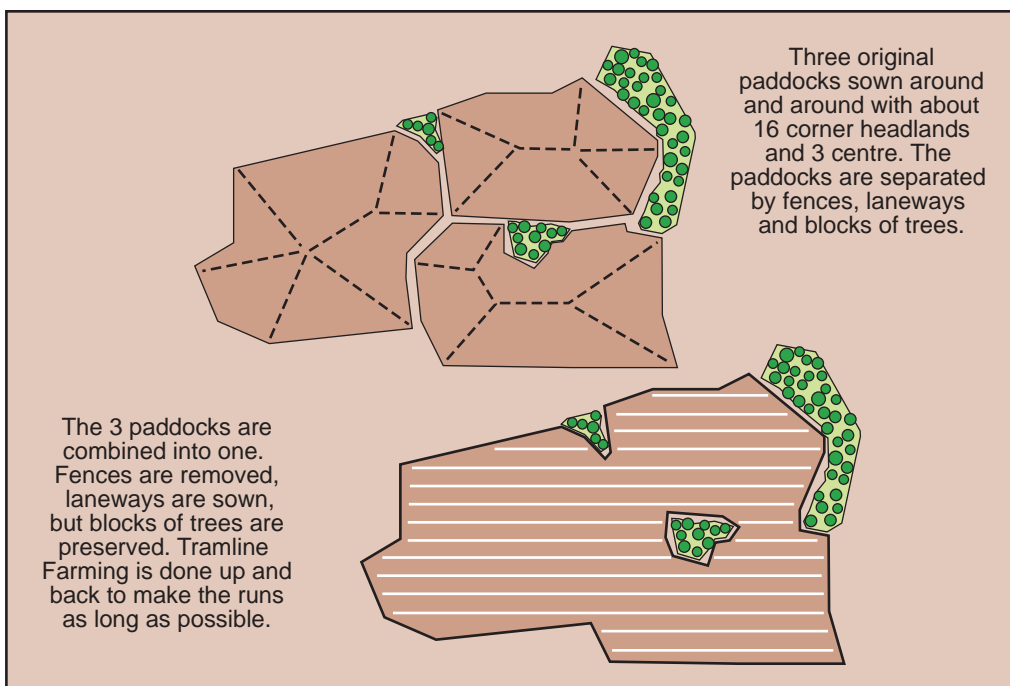


Figure 9.1. A hypothetical example of improved efficiency from longer runs.

After a long period of no-till seeding and no stock, soil structure between the rows can be much more permeable because the macro-pores and bio-pores are protected from annual disturbance.

off from tramlines, up and down the hill, may cause massive erosion in the tramlines if the volume of water is too large and the run is too long. This must be balanced against the problems of contour layouts where heavy rainfall leads to flow concentration and the formation of deep gullies in the paddock.

In light rainfalls, seeding along the contour can trap moisture in the furrows. Across slope working can also distribute water evenly across the paddock. Waterlogging or erosion could occur if the water is channelled into old gully lines or low points in the paddock.

In both cases erosion may occur if water collected from elsewhere enters the furrows or tramlines.

9.4 Surface water control

In developing your tramline farming system it is important to make sure the layout of your tramlines is compatible with the control and safe disposal of run-off. Consulting contour maps and understanding the water movement on your property is a good background for determining your tramline layout and the appropriate control measures. Important things to consider include:

- good stubble cover;
- degree of slope;
- length of slope;
- soil infiltration properties;
- rainfall intensity;
- preventing run-on from areas that shed water, such as roads or rocky outcrops; and
- water control and disposal options.

Soil infiltration — As a general rule, the better the soil structure the higher the infiltration rate. After a long period of no-till seeding and no stock, soil structure between the rows can be much more permeable because the macro-pores and bio-pores are protected from annual disturbance. The best evidence of this happening is the lack of increased drain or dam filling, even in wet years. This seems to be occurring on many soil types, with the exception of non-wetting sands. Infiltration is expected to improve even more when tramlines are used as restricting compaction conserves the soil structure between tramlines. Infiltration also decreases as the soil profile fills up with water. If the soil pores are already full and rain falls, run-off can occur.

Stubble cover — Maintaining good stubble cover levels is important to reduce the risk of erosion. Organic matter from plant roots helps to improve the soil structure by binding soil particles together and providing channels for rapid water penetration. Good stubble cover levels can be maintained by practising no-till and managing grazing. This means not over-grazing during the summer months.

Preventing run on — Tramlines should be protected from any run-on water; for example, some headlands, corners, adjacent bush or rocky outcrops can shed water into tramlines and cause the beginning of rills or gullies. Tramlines should run over a hilltop and not stop at the top to reduce the hilltop run-off being fed down a tramline.

Options for surface water control

Where there is a likelihood of erosion, flooding or waterlogging, conservation earthworks should be installed. A few possible options follow.

Strategic broad grade banks located at the base of the slope and appropriate positions up-slope may help to reduce these problems when most of the seeding is up and down slope. Broad based channels can be used on two to six per cent slopes. A common practice in eastern Australia is to drive over the banks with machinery at right angles where possible and at no less than 45 degrees to avoid machinery damage and erosion. This needs to be proven for Western Australia as climatic conditions and soil types are very different to eastern Australia. The broad banks in eastern Australia are seeded all the way over or along to reduce the potential for erosion and reduce weed invasion. This may be a challenge in Western Australia as we have very shallow topsoil.

On long runs, access tracks could be made into catch drains and mounds that the seeding and spraying equipment can pass over safely during cropping operations.

It is possible to work tramlines between existing contour banks.

Long runs may be shortened by adding strip breaks. Strip cropping is a practice of breaking up an easily degradable area into bays by including strips of vegetation (often grasses or pasture) to reduce the run-off and erosion potential. These strips are alternately cropped each year.

Run-off from all drains and broad banks should be disposed of safely into grassed waterways, existing waterways or dams.

There has been limited research in Western Australia into this issue. Please keep a look out for new information and consult your local surface water control expert.

Further reading:

Keen, M. (1998) *Common Conservation Works Used in Western Australia*, Resource, Management Technical report 185, Department of Agriculture Western Australia, Geraldton.

Agricultural Resource Management Surface Water Management Structures Design and Specifications for a Broad Based Channel (Terrace) Code 10.

Section 10



**Agronomic opportunities
of tramline farming**

10.0 Agronomic opportunities of tramline farming

The establishment of permanent tramlines provides many opportunities for agronomy as tramlines can provide good in-crop access without damaging the crop through mechanical means or compaction by the wheels of machinery. Some of these opportunities are:

- easier stubble handling;
- sowing into old furrows;
- inter-row shielded spraying including band spraying;
- relay planting.

10.1 Easier stubble handling

Tramlines provide opportunities for easier stubble handling through improved precision by using a guidance system. The seeder bar can be guided to allow tines or discs to run between the existing crop rows or stubble lines. The potential benefits from retaining stubble include soil moisture retention and reduced erosion risk.

One method of seeding between old rows is to pull the seeder by an offset hitch, to the left or right by half a row spacing. If the seeder is moved to the left, the left-most tine is removed and put on the right-hand side to balance the pull. Other tines may need moving to ensure

the frame wheels have a tine in front of them to form a fresh furrow and guide the frame. For large air seeder bars this approach may not work as the tines may slip back into the old furrows as this is the path of least resistance.

Tramlines may allow the easier use of disc seeders to reduce soil disturbance as disc openers are more effective when the soil is less compacted. If seeding between old rows, the disc encounters less stubble and hair pinning problems are lessened.

10.2 Old furrow sowing

While sowing into old rows may be a disadvantage in some instances, sowing into the old furrow can be an advantage. Sowing back into old furrows takes advantage of the water harvesting capabilities of furrows. DGPS auto-steer guidance with a base station would be very useful in this situation. Trials conducted at Pindar in Western Australia indicate that pre-furrowing a pasture paddock dry in summer (if cover is good enough to minimise erosion risk) improves water entry and crop establishment when the crop is seeded into the furrows after early autumn rains. (See Photo 10.2.)

Sowing back into old furrows may also be an advantage for using any residual fertiliser from the previous year. Potential problems with root disease or nutrient toxicity need to be considered.

10.3 Inter-row shielded spraying

Inter-row shields enable the use of non-selective herbicides between crop rows to improve weed control. The concept was



Photo 10.1. Seeding into pre-made furrows.



Photo 10.2. Seeding into pre-made furrows with precise DGPS guidance system.



Photo 10.3. 'Redball' type shields.

The idea of inter-row shield spraying is to capitalize on the use of lower cost, knockdown herbicide between the rows and reduce higher cost selective herbicides and fungicides in the crop row.

initially developed in North America as a substitute for inter-row cultivation in row cropping. Shield models such as 'red ball' were imported to Australia for row cropping in Queensland and New South Wales. The red ball shield is named for the red ball in the flow meter that indicates that the nozzles inside the hood are clear. Recently, growers in Victoria and Western Australia have been acquiring less expensive designs to fit narrower row spacing than the typical one metre spacing in eastern Australia.

The idea of this is to capitalize on the use of lower cost, knockdown herbicide between the rows and reduce higher cost selective herbicides and fungicides in the crop row. This can at least halve the cost of herbicides in grain legumes and helps to reduce the development of resistance to selective herbicides. Other advantages of shielded sprayers include,

reduced spray drift and the possibility of spraying in weather conditions that may be too windy for broadacre spraying.

On a shielded sprayer there are three possible spray circuits: one in the shield, between the rows; one into the row from the side of the shields (lay-by nozzles); and one over the top of the row for band spraying (Figure 10.1). It is possible to set up the system to run several different chemicals at once.

When setting up for using row crop shielded sprayers consider the following:

- guidance system (if any) — 2 cm DGPS preferred as manual steering is very dependent on operator ability and accuracy tends to drop off during a shift;
- seeder bar setup, row spacing;
- banding residual herbicide in-row at seeding;

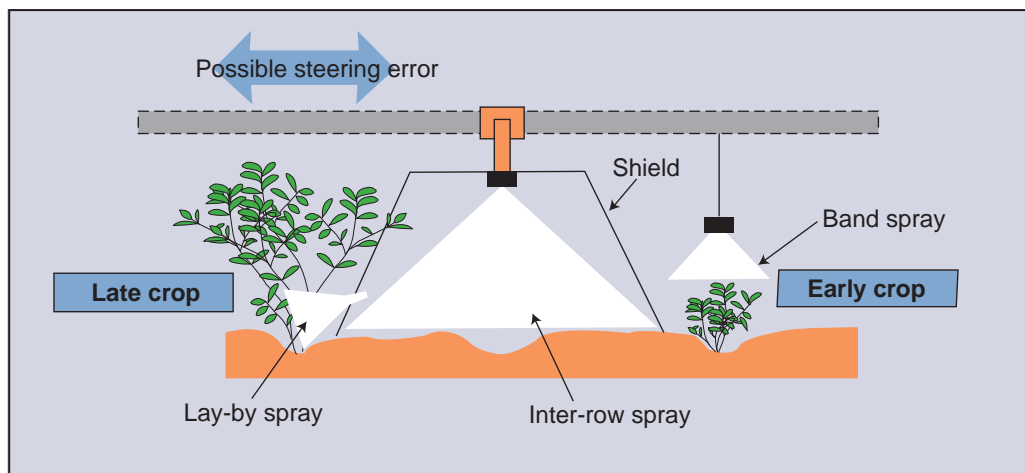


Figure 10.1. Shield spraying design principles.



Photo 10.4. The setup used for the Rowcrop Rocket designed by Mike Collins mounted on a spray ute in 2002. The shields are set up the same distance behind the hitch point as the ute axle is in front. As a consequence, when the ute turned to the left, the ute rear swings to the right, helping to compensate for the tendency for the shields to cut the corner.

- direction of working;
- shield design;
- mount for shield (boom, mounting arm or bracket);
- nozzle mount, size, and so on;
- flaps and brush to keep spray in the shield;
- lift system;
- anti-drip system.

Shield design

There are several different designs for shields available.

Fixed shield (red ball type): red ball type shields are normally mounted on a three point

linkage boom. Their lateral position in relation to the tractor is determined by the position of the tractor relative to the row, so that any steering error with the tractor affects the weed control effectiveness and crop damage. The row zone must be wide enough so that the shield can be far enough away from the row to not damage the crop when at its closest position to the row, and does not leave unsprayed ground when at its furthest distance from the row. This leads to the overlap being determined by the precision of the steering system. (See figure 10.1.)



Photo 10.5. The setup for Rowcrop Rockets mounted on a spray ute on a 40m radius curve. This is about the maximum angle for this setup.

A self steering shield has been designed to reduce the reliance of shield spraying accuracy on the steering system.



Photo 10.6. Self-steering shields made by Harold and Glenn Millington, Burracoppin, from on-farm materials.

Self-steering shields:

A self steering shield has been designed by Mike Collins, Department of Agriculture Western Australia, to reduce the reliance of shield spraying accuracy on the steering system. The development of the 'Rowcrop Rocket' design follows the principle of a trailed shield on wheels that keeps the spray nozzle at the correct height and reduces steering errors. The wheels also reduce spray splash into the crop row. The wheels are angled to the vertical to be parallel with the spray, to allow closer treatment to the base of the crop plant. Trials have shown that the wheels help guide the shield. They either run in the furrows of unseeded rows (with central wheel,

Millington's system, Photo 10.6), or hug the walls of press wheel grooves (Rowcrop Rocket, Photo 10.5) when the crop plants are small, or run along the base of crop stems when the plants are bigger. The greater the precision, the narrower the in-row zone can be.

Further reading

Collins, M. and Holmes, J. (2003).

Lupin Row Cropping: Herbicides to Band, Shield Design and Economics. Crop Updates 2003, Department of Agriculture Perth.



Photo 10.7. The Diamond's precision planter on tramlines in 2001 lupin crop before relay planting.



Photo 10.8. Ten week old maize after lupin harvest.

Nozzle selection

Mike Collins, WANTFA, Northam.

Nozzles used for row crop spraying should have an even distribution across their width. The manufacturer normally designates them as 'even' or 'E' nozzles. Normal boomspray nozzles are therefore not suitable, as they have an elliptical pattern and are designed to be used with each adjacent nozzle overlapping by 50 per cent, to result in an even overall pattern.

The variables to consider when selecting nozzles are, operating pressure, bandwidth (with inter-row spraying this is the inside width of the shield, not the row spacing), and operating speed. From the calculation results, the nozzle size can be chosen to fit within the desired water rate per hectare range. Nozzle angle is of concern to achieve the right bandwidth to suit the height and width of the shield.

In some shield designs, it is possible to turn the nozzles around so that the fan is at less than right angles to the direction of travel, resulting in a narrower band. This is necessary with band spraying in order to place the nozzle at a reasonable height to reduce bandwidth variations due to ground undulations (yet not too high to get excessive band distortion due to crosswinds).

With band spraying using a pre-emergent herbicide at seeding and intra-row banding (where a selective herbicide is sprayed into the

crop row when the inter-row zone is sprayed with shields), there is difficulty in finding small enough nozzles. Trials by the Department of Agriculture Western Australia have used an 8001E nozzle for band spraying at seeding. At 8 km/hr, for a 12.5 cm band the water rate: $= \frac{0.32 \times 600}{125.125 \times 8} = 192 \text{ L/ha}$

Another problem relating to small nozzles is the likelihood of blockages with banded herbicides such as propyzamide (or Kerb) that are a wettable powder. Later formulations of propyzamide appear to be more finely ground, and have performed better.

10.4 Relay planting

When rising watertables in low-lying areas or hillside seeps are fresh enough to support summer crops or pastures, relay planting is a useful method of planting the summer species. The summer crop species is planted between the rows of a winter crop when the winter crop is close to maturity, such as at leaf drop in lupins or anthesis in cereals. Summer crops require a minimum ground temperature at which they germinate and grow so there may be some instances where this method is not useful. The soil may also be wetter before harvest to help establish the crop, because the winter crop shades the soil surface.

Relay planting overlaps the winter and summer growing seasons. The summer species is at a young stage, but lower than

The summer crop species is planted between the rows of a winter crop when the winter crop is close to maturity, such as at leaf drop in lupins or anthesis in cereals.

cutter bar height when the winter species is harvested, which should allow more time for more water use before the summer species matures. The extra water use by the summer species can help reduce the rate of watertable rise or reverse it.

Experience with relay cropping in Western Australia is limited. Lupins are a recommended crop for relay planting as when the ground temperature is generally warm enough the lupins are dropping their leaves, which opens the canopy providing light for the establishment of the summer crop as well as

some protection from the wind. Summer crop species suitable for relay cropping in lupins will vary depending on your climatic conditions.

Relay planting of deep-rooted perennials and pastures, for instance lucerne, may also be an option to consider if summer cropping is not feasible. There is current research being undertaken on establishing lucerne in July to August on 1 m rows in a cereal crop to increase water usage.

Section 11



**Tramline farming
case studies**

11.0 Tramline farming case studies

The following case studies outline the tramline farming systems being developed by 15 farmers in Western Australia to suit their own farming systems. Each farm is at a different stage of development from getting started, to consolidating the system, to fully matched.

11.1 Getting started

Case study 1: Darren Baum

Reason for tramline farming

Wellstead farmer Darren Baum was a participant of the Tramline Tour 2001 to Queensland and New South Wales. Seeing the systems working in the east encouraged Darren to have a go on his property. He believes tramline farming will be very complementary to his no-till system. 'Our experiences this year have proved the system is worthwhile and we would like to move to the next level' (2003).

Guidance system

Darren Baum has seeded their cropping program for two years round and round using one marker arm as an introduction to tramline farming. The tractor is driven down the mark left by the marker arm by lining up with the badge in the centre of the tractor bonnet.

Machinery

All the machinery widths are matched to include the harvester:

- 9.1 m Ausplough DBS air seeder bar pulled with a JD 8450 tractor;

- 27.3 m boomspray with a JD7810 front wheel assist tractor;
- 9.1 m JD STS 9650 harvester.

Tramlines

As the wheels don't match at this stage they leave a bare central guide row for the sprayer to follow. The mark has been left by removing one tine from the middle. In 2002 they moved two tines in the centre of the bar out 8 cm either side. Darren has decided this gap is not wide enough for clear guidance throughout the season, although in the early stages of crop growth the mark is still easy to follow for spraying. Weeds are an issue in the centre row so next year he might try putting two nozzles down the central row to spray more selective herbicide and hopefully achieve better weed control.

Observed benefits

Darren estimates they saved 4–12 per cent input costs working round and round with one marker this season, depending on the shape of the paddock. He was able to save enough fertiliser for his lucerne sowing. Spraying has been much easier following a mark.

Driving at night has become less tiring at seeding because the driver has a mark left by a disc on the end of the marker arm to follow. The marker arm has helped inexperienced drivers reduce overlap. They put a foam marker on the end of the marker arm to make the mark more visible at night. This has worked very well.

KEY FEATURES:

- one marker arm
- round and round
- harvester width matched

Farm location:

Wellstead

Area cropped 2003:

2800 ha

Annual rainfall:

380–450 mm

Main soil types:

loam

Enterprises:

- cropping
- occasional agistment of stock



Photo 11.1. Darren's seeding and spraying equipment are almost matching.

KEY FEATURES:

- round and round marker arm
- up and back two markers

Farm location:

Ajana

Area cropped 2002:

7290 ha

Annual rainfall:

308 mm

Main soil types:

sand, loam

Enterprises:

cropping: wheat, canola, lupins, barley

Future plans

Next year, Darren would like to purchase a second marker arm and work up and back. Plans for next year also include modifying wheel tracks. The airseeder will be easy to modify and his seeding tractor (JD 8450) currently has duals that could be removed and run on singles at three metres. He is a little concerned about removing the duals as the bar was hard to pull given the hard ground and dry conditions this season.

Case Study 2: The Logues and Porters

'Riverside', owned by the Porters, was shared cropped with John and Phil Logue to tramlines for the second year in 2003.

Reason for tramline farming

Tramlining is being undertaken to avoid soil compaction and lengthen the interval between deep ripping operations. It should also make summer weed spraying a lot less stressful (less time spent looking for foam!) and should enable more night spraying in the summer.

Guidance system

1997–2001: one marker arm (Flexicoil) round and round;

2002: two marker arms (one was Flexicoil marker arm and the other was homemade). The seeding tractor is driven to a mark on the edge of the bonnet;

2003: DGPS visual guidance plus or minus 10 cm accuracy was used at seeding. DGPS visual submeter accuracy was used in the self propelled sprayer.

Machinery

Their seeding and spraying machinery widths match at a 2:1 ratio:

- 17.37 m air seeder bar;
- 34.7 m self-propelled boomspray;
- 2x 11 m harvesters.

Tramlines

- 2.7 m track for seeding and tractor and boomspray wheels;
- sown and fuzzy or bare central guide row.

In 2002, the Logues did not modify any equipment except for lifting two tines in line with air seeder wheels to make a fuzzy tramline. To make the fuzzy tramline the outlet of the seed tube was lifted 300 mm above the ground. The Logues found the fuzzy tramlines difficult to see. In 2003 the Logues left no fuzzy tramlines as they had a GPS guidance system in the sprayer. The tyre marks from the air seeder box also provided guidance as they were visible in the early stages of crop growth.

Only the tractor wheels and boomspray wheels line up at this stage. The back wheels of the airseeder box are outside the preferred tack width and the front wheels and seeder bar wheels are inside it, making a wheeled zone of three metres. At this stage no modifications have been made as they are not convinced that compaction at seeding is a problem. For the last two years the zones with the most wheels and compaction have yielded most on the sandy soil. This effect is being investigated, as observations of poor crop growth in the wheeltracks of the harvester from previous seasons indicate compaction may still be a issue.



Photo 11.2. Bob, Phil and John attaching a marker arm before beginning to seed a new paddock.

Layout

Bob Porter has been using one marker arm working round and round since 1997. He has been very impressed with the results on his property. Bob has reduced the height of his contour banks to allow seeding over the banks with a Flexicoil air seeder bar. This has made seeding less complicated and faster. Rock heaps and lone trees have been progressively removed to reduce obstacles in the paddock. The Porters have a regular tree planting program that compensates for the removal of lone trees.

Since 2002 the tramlines have been worked mainly up and back although some odd-shaped paddocks were sown round and round with one marker arm.

The Porters have found navigating the seeder and marker arms around lone trees and small clumps challenging. They are experts at repairing marker arms. The marker arm problems resulted from the homemade arm, which could not be retracted, and which cut deep grooves at the end of paddocks when turning around — it would cut up the soil and bury the seed too deep.

Future plans

In 2004 DGPS auto-steer will be fitted to the seeding tractor.

KEY FEATURES:

- simple guidance arm following the edge of previous the combine run
- up and back

Farm location:

Kojonup

Area cropped 2003:

400 ha

Annual rainfall:

530 mm

Main soil types:

gravelly sand over clay,
loamy sand over clay

Enterprises:

- cropping: wheat, canola, barley, faba beans
- sheep

11.2 Consolidating the system

Case Study 3: John and Caroline Young

Kojonup farmers John and Caroline Young have been tramline farming for five years. The Youngs run a mixed crop and sheep enterprise on 1100 hectares.

Benefits

John estimates his fertiliser and herbicide costs have been reduced by up to 10 per cent working up and back using tramlines.

The firm tramlines provide a definite advantage for in-crop spraying. John does not need to use duals and is able to spray when many of his neighbours cannot because it is too wet. When John first started tramline farming his neighbours gave him a hard time about all the missing rows in the paddock.

Guidance system

John uses a very simple guidance system that cost about \$100. The system consists of a metal rod mounted under the engine of his tractor reaching the width of his combine. At each end of the rod, a trailing plastic strip is placed to run in the last row from the previous pass of the combine. As the rod is no wider than the combine and the driver can see it from the cab there is no risk of breaking it off on trees.

John leaves two bare tramlines on each seeding run by removing a tine from behind the tractor wheels. Bare tramlines provide guidance for the sprayer. The tracks are 500 mm wide. Finding the previous year's tracks can sometimes be a challenge after summer grazing the stubble.

Machinery

- 4 m Shearer TCD combine;
- 20 m boomspray;
- harvester front width varies depending on contractor.

Tramlines

- bare;
- 1.8 m track seeding tractor Deutz DX110 and spraying tractor Deutz DX430.

Layout issues

In Kojonup the Youngs have many trees, rock heaps and hills to negotiate. During seeding John tries to keep diversions around trees in multiples of five to fit his boomspray width. John believes he has no more erosion working up and down slopes than when he seeded round and round. He does practice no-till and retains good stubble cover.



Photo 11.3. John's simple guidance rod to help follow the last row of the previous seeding run.

Case Study 4: Tom and Denise, David and Joanna Lewis

In 2002 Tom and David Lewis with wives Denise and Joanna of Bruce Rock implemented a tramline farming system on their property for as little as \$7900.

Reason for tramline farming

The Lewises' reasons for beginning a tramline system include:

- a need to limit compaction after 22 years of continuous cropping (tramlines make compaction work for you not against you);
- the use of all inputs becomes much more accurate;
- spraying is a lot easier and less tiring by being able to follow tramlines and not having to look for foam.

Guidance system

The guidance system consists of video cameras and a Garmin 182 DGPS. See section 6.2, page 19. The Garmin 182 DGPS picks up an AMSA marine correctional signal from Fremantle or Albany. It is a free service and gives accuracy to around a metre. It has proven very worthwhile for seeding to date.

The cameras are set up on each extremity of the seeder with a small sight made of light angle steel about 80 mm from the lens to line up on the previous run. A monitor is positioned in the tractor aligned with the centre of the bonnet. The black and white cameras pick up plenty of light, even at night, and give a clear view and focus. The cameras don't appear to suffer from vibration although the system has not been run for long periods of time yet (one season). Dust on the lens was considered a potential problem. Practically, all that is required is an occasional wipe with a clean cloth, usually while filling up.

The system of cameras and DGPS give a reasonably accurate and economical entry into tramlining, avoiding the need to purchase and maintain more expensive marker arm equipment. Some experience and skill is needed to obtain the maximum potential from using this system. If the video screen is watched too closely it can be tiring.

Machinery

To match their seeding and spraying machinery some modifications were required.

At this stage the harvester (11 m front) has been left out of the system. Seeding is up and back with bare tramlines on 2.25 m centres. The bare tramlines are left by lifting one tine on each side of the seeding machine behind the wheels of the seeding tractor.

Layout issues

Establishing tramlines required a review of the existing layout of paddocks and rethinking some areas to end up with a more efficient design. Some areas of the farm considered unsuited to tramlining initially will be included after a study of the farm map and some relocation of tracks. Early consideration of the system suggested about 60–70 per cent of the farm was suited to an up and back tramline layout; this has now been raised to at least 80 per cent.

Plans for the future

Plans for the near future involve establishing permanent tramlines through some 'straightening up' of initial runs, possibly a year or two to settle on the most efficient layouts and inter-row shield spraying. A few new access gates will be needed onto roads due to tracks being altered. Some individual trees will be removed over time; these are well compensated for through planting new trees in a planned program.

KEY FEATURES:

- low cost video guidance
- up and back

Farm location:

Bruce Rock

Area cropped 2002:

2446 ha

Annual rainfall:

350 mm

Enterprises:

cropping: wheat, barley, triticale, lupins, canola

Operation	Equipment	Modifications	Cost (\$)
Seeding	Seeder bar Ausplow DBS 12.2 m wide		
	Air seeder Bourgault 3225	Track altered to 2250 mm	1900
	Liquid cart custom built - 3 tanks		
Spraying	Tractor John Deere 9300 4wd radial duals	Not altered at this stage	
	Sprayer custom - 25m wide	Modified track	1710
	Tractor John Deere 6600 front	Modified track using spacers wheel assist	1330
Modification cost			4940
Guidance	Garmin 182 DGPS with 2 video cameras	2 cameras, monitor and cable \$600	3000
Total			7940

KEY FEATURES:

- two marker arms and DGPS guidance
- up and back
- no tracks match but it is a future plan

Farm location:

Ongerup

Area cropped 2003:

3000 ha

Annual rainfall:

450 mm

Enterprises:

cropping: wheat, barley, canola, lupins, sheep, lucerne, pasture.

Case Study 5: Colin and Fiona Pither

Colin and Fiona Pither began the first stage of implementing a tramline system on their property at Ongerup in 2002. Colin returned from the tramline farming tour to the Eastern States in 2001 very enthusiastic about the benefits controlled traffic could provide to his no-till farming system. Due to budget restrictions Colin has begun a plan for the next five or so years to obtain guidance and modify his machinery to get the full benefits of the system.

Reasons for tramline farming

- accuracy of working;
- easier for less skilled labour;
- reduced compaction;
- eliminate missed weed control;
- easier stubble handling;
- potential to spray between rows.

Guidance system

In 2002 Colin worked up and back with two marker arms on his seeder bar and JD visual DGPS guidance in his spraying tractor. In 2003 he sold the marker arms because they were too difficult to operate on uneven country and used DGPS guidance in his seeding tractor as well. Drift was an issue, particularly if they stopped for three to four hours, but in that case they simply reset the system to the required mark. At this stage Colin believes it is accurate enough for what they want to do until they can afford to go to auto-steer.

Machinery

In 2002 his machinery width and tracks were not matched. He has now matched the widths and some of the tracks that will eventually include the harvester:

- 10.9 m Ausplow DBS air seeder bar;
- air seeder bin 3 m wheel track centres;
- 32.7 m Burando Hill boomspray with adjustable axle to 3 m pulled by a JD7810 spraying tractor. Rear tractor wheels are 3 m track;
- 11 m harvester (the harvester front is currently offset).

Colin is changing over his John Deere 8400 model tractor to a tracked tractor that will easily allow the tracks to be moved out to three metres.

Tramlines

- two bare tramlines;
- track width 3 m centred.

Benefits

Colin has found working up and back along straight lines much easier for spraying. Where possible they work north and south, side-on to the wind, which is good for spraying and spreading. He has been removing some grade banks to work up and down slopes. This season they have had above 500 mm rainfall and there has been no soil erosion or water logging where there used to be. Colin thinks this may be a combination of working up and down slope to drain the water away and working deep to remove compaction with the DBS tines. He believes they will need to observe what happens over the next few seasons before making any definite conclusions. In the future some fences may need to be changed to make paddocks simpler to work.

Case Study 6: Paddy and Sharon Barber

Paddy and Sharon Barber have been tramline farming for two years.

Reason for tramline farming

Paddy was a participant on the Tramline Tour 2001 to New South Wales and Queensland. He found this tour very valuable and it helped him to further appreciate the benefits a controlled traffic system can provide. Paddy believes tramline farming 'is a simple concept with great benefits particularly in terms of reducing inputs'. In the future he would like to invest in auto-steer to overcome driver lapse in concentration causing wiggly seeding lines.

Guidance system

In 2001 Paddy used one marker arm and sowed one fuzzy tramline round and round. In 2002 he seeded his 4400 ha program up and back using DGPS visual (John Deere) guidance, and in 2003 used auto-steer.

Machinery

- 10.8 m air seeder bar;
- 32.5 m boomspray;
- 16.25 m multi-spreader;
- 10.8 m harvester front.

Tramlines

- 2 m track;
- two bare tramlines in lupins and canola;
- two fuzzy tramlines in cereals.



Photo 11.4. Paddy seeding in 2002 up and back with dGPS auto-steer.

Layout issues

Paddy seeds three laps around the paddock before commencing up and back seeding and sprays two full laps when spraying, otherwise the turns are too tight. The seeder bar is lifted out of the ground to avoid double seeding. Paddy has used fuzzy tramlines in his cereals as a precaution on his water-repellent sandy soils. Last year he found the fuzzy tramlines easy to follow while spraying. These were easiest to follow in cereals throughout the growing season but they were a little difficult to follow at times in the canola and lupin crops. Therefore, this season bare tramlines have been left in lupins and canola.

Observed benefits

Paddy has found working up and back better than round and round as his overlap was further reduced because no headlands were seeded. Spraying has been much easier. During 2001 Paddy estimates that crop inputs were reduced by around five per cent and this has further increased to seven per cent with electronic guidance.

Future plans

While the long-term aim is to match harvester width to the tramlines there is a difficulty with an offset harvester front and how to fit a chaser bin on the tramlines. As machinery is changed over Paddy will select machines to match and enhance his tramline farming system.

KEY FEATURES:

- 2001 round and round marker arm
- 2002 DGPS guidance up and back

Farm location:

Gibson

Area cropped 2003:

3350 ha

Annual rainfall:

450 mm

Main soil types:

shallow to medium depth sand over gravel over clay at 30–50 cm

Enterprise:

cropping: wheat, malt barley, canola and lupins

KEY FEATURES:

- up and back DGPS auto-steer
- removal of contour banks
- no-till and annual chemical fallow
- curve sown headlands

Farm location:

Perenjori, Morawa

Property size:

6720 ha

Area cropped 2003:

4800 ha

Annual rainfall:

324 mm

Enterprises:

Cropping only: wheat, barley, canola

Case Study 7: Lindsay and Karen Chappel

Lindsay and Karen Chappel from Perenjori have been using tramlines for two years since Lindsay returned from the Tramline Tour 2001 to New South Wales and Queensland in 2001.

Guidance system

A DGPS auto-steer (Beeline) with a base station is used in the seeding tractor to seed up and back. Bare tramlines are used as guidance for spraying.

Machinery

- 17.6 air seeder bar
- 35m boomspray
- 17.6m spreader

- 11m harvester front

Some modifications were required to bring Lindsay's air seeder box track to 2.2 m (costing about \$1900) and 15 minutes labour was all it took to shut down some nozzles on the boomspray to bring it to 35 metres in width.

Bare tramlines were left by lifting two tines behind the tractor wheels making spraying very simple. 'No foam marker or bent neck!'

When turning at the end of the run the bar is left in the ground while sowing alternate runs to form 'curve sown' headlands in some paddocks to save time. Sowing is completed by filling in the unsown runs while still sowing as the seeder turns on the headlands. This is now known as the 'clapper corner'. Lindsay developed this system to avoid confusing the tractor driver by having too many switches to flick on and off at the ends of the run. This reduces the risk of making mistakes such as forgetting to turn the air seeder back on after turning. The DGPS system allowed rip skipping (sowing alternate runs) to make the turns wider.

Layout issues

In order to have longer and more efficient runs the Chappels have been removing contour banks. After many years of no-till the soil structure and water infiltration rate has improved such that contour banks have not been filling with water. This has been quite an expensive exercise but Lindsay is confident the savings could be made up in one year with reduced overlap. Lindsay is also seeding up and down slopes as he saw done on the Tramline Tour to Queensland in 2001. This is to keep any run-off evenly distributed, but it has raised a few neighbours' eyebrows.

Observed benefits

An immediate benefit for Lindsay of implementing his tramline system was the cost saving from reduced overlap. Lindsay has reduced his overlap from 19 per cent to one per cent in paddocks. 'One paddock in previous years was always sprayed 130 hectares but using tramlines the paddock was only 109 hectares: that is a reduction in overlap by 19 per cent. Tell that to the non-believers — a saving that big is hard to imagine'.



Photo 11.5. Lindsay chappel standing on his bare tramlines 2002.

Case Study 8: Geoffrey and Vivienne Marshall

Reason for tramline farming

Geoffrey and Vivienne Marshall have undertaken the challenge to capture the benefits of tramline farming on their property at Hyden. Geoffrey sees 'tramlining and precision farming as natural progressions for cropping systems,' particularly for his no-till system.

'Agronomy driven logic is my main reason for seeking high accuracy auto-steer capacity. Having a tined (Conserva-Pak) seeding system with 300 millimetre spacings and continuous crop, many possibilities arise. The strength of the rotation is logically the success of the pulse, legume or alternative crop such as canola, et cetera. The cash driver is still cereals. We need to change this'.

The potential agronomic benefits that Geoffrey sees tramline farming and no-till can offer are: Soil benefits — precise fertiliser rates and placement, less soil disturbance leading to many subtle improvements, recycling of nutrients, maintaining an even layer of crop residue over the whole paddock, wider row spacings for some crops, less soil compaction. Spraying possibilities — substantially reducing reliance on chemical inputs and costs, use a shielded sprayer to allow more selective use of residual and knockdown herbicides, reduce selective herbicide resistance, optimising spraying opportunities, less cultivation leading to fewer weeds, the desire to use discs for crop establishment. Cost efficiencies — no overlap means real cost savings on each operation. 'Depending on how accurate we were previously, savings of 3 to 10 per cent can be achieved. Fertiliser is a single large item where big dollars can be saved.'

Guidance system

Geoffrey works up and back using a base station DGPS auto-steer (Farmscan) guidance system in both his seeding and spraying tractors.

Machinery

- 15.2 m air seeder bar;
- 30.4 m boomspray;
- 11 m harvester.

Tramlines

- 2 m centres;
- sown.

Future plans

Next season Geoffrey is upgrading his machinery to a 12 m air seeder bar and 36 m boomspray all on 3 m wheel track centres. The tracks and widths are being modified to fit the harvester into the system which, when the budget permits, will be a 12 m platform.

KEY FEATURES:

- up and back
- DGPS auto-steer guidance

Farm location:

Hyden

Area cropped 2003:

2400 ha

Annual rainfall:

320 mm

Enterprises:

cropping only: wheat, barley, lupins, canola

KEY FEATURES:

- up and back dGPS auto-steer
- shield spraying
- three wheeled tramline

Farm location:

Mingenew

Area cropped 2002:

3800 ha

Annual rainfall:

400 mm

Main soil types:

sand plain

Enterprises:

- cropping: wheat, lupins, canola,
- sheep, cattle

Case Study 9: Miles and Aiden Obst

Mingenew farmers Miles and Aiden have been seeding up and back with tramlines since 2001.

Reason for tramline farming and benefits

The Obsts first considered tramline farming to get the benefits of reduced overlap and input costs (saving on pesticides and fertilisers) and increased yields. The use of a DGPS auto-steer system together with tramline farming has provided the Obsts with many agronomic opportunities to improve their farming system. Miles believes 'the development of a shield sprayer and the opportunity to sow inter-row lupins into wide rows is a new tool to use in the fight against herbicide resistance'. The auto-steer DGPS system in the seeding tractor has reduced driver fatigue. The harvester may also be auto-steer this season.

Guidance system

The Obsts use DGPS auto-steer (Beeline) system in their seeding tractor and a base station located on farm.

Machinery

- 12 m air seeder bar;
- 36 m boomspray;
- 11 m harvester;
- 12 m inter-row shielded sprayer.

Tramlines

- 2 m track for seeding tractor and sprayer;
- 3 m track for air seeder box;
- three wheel tramline, sown.

The Obsts' seeding and spraying equipment operate on three tramlines, as the wheel tracks are different widths (3 m tracks for the tow-behind air cart and a 2 m track for spraying and spreading). When spraying or spreading Miles works up and back with his left or right hand spraying or spreading wheel on the northern air cart mark of each seeding run. This confines half of the compaction to one common tramline and leaves two other tramlines, one for the 3 m tracks and one for the 2 m tracks. This is 50 per cent less compaction than he would have had from two pairs of separate tramlines. Keeping to the north side of the 3 m tramlines ensures that the offset between seeding and spraying or spreading is consistent in the paddock.

Future plans

Challenges for next year include maintaining the accuracy of the guidance system to sow into old furrows, to gain benefits of water harvesting and residual fertiliser. In the future Miles would like to convert his seeder bar to three-point linkage to enable better control of the bar and shorter turns at the end of each up and back run.



Photo 11.6. Obst's inter-row shielded sprayer.

11.3 Fully matched systems

Case Study 10: Harold and Jo, Glen and Narelle Millington

Burracoppin farmers Harold and Jo Millington and their son and daughter-in-law Glen and Narelle have been using no-till for about six years and tramline farming round and round for two years since 2002.

Guidance system

The Millingtons use one marker arm to work round and round. The first track around the paddock is made very accurately, by marking out with a disc marker mounted on their ute.

The ute maintains a constant distance from the fence by a 'feeler' gauge mounted on the opposite side of the ute from the marker arm (Figure 11.1). The feeler gauge has a strip of plastic on the end, which clicks on the fence to tell the driver that the ute is in the correct position. The seeding tractor later follows the marked line to help layout the seeding laps very precisely.

Machinery

- 17.9 m air seeder bar;
- 35.8 m boomspray;
- 17.9 m spreader;
- 9.1 m harvester.

KEY FEATURES:

- round and round, one marker arm
- machinery matched

Farm location:

Burracoppin

Area cropped 2003:

1860 ha

Annual rainfall:

250–300 mm

Main soil types:

sand, loam clay

Enterprises

Cropping only: wheat, barley, lupins, canola
Cropping only

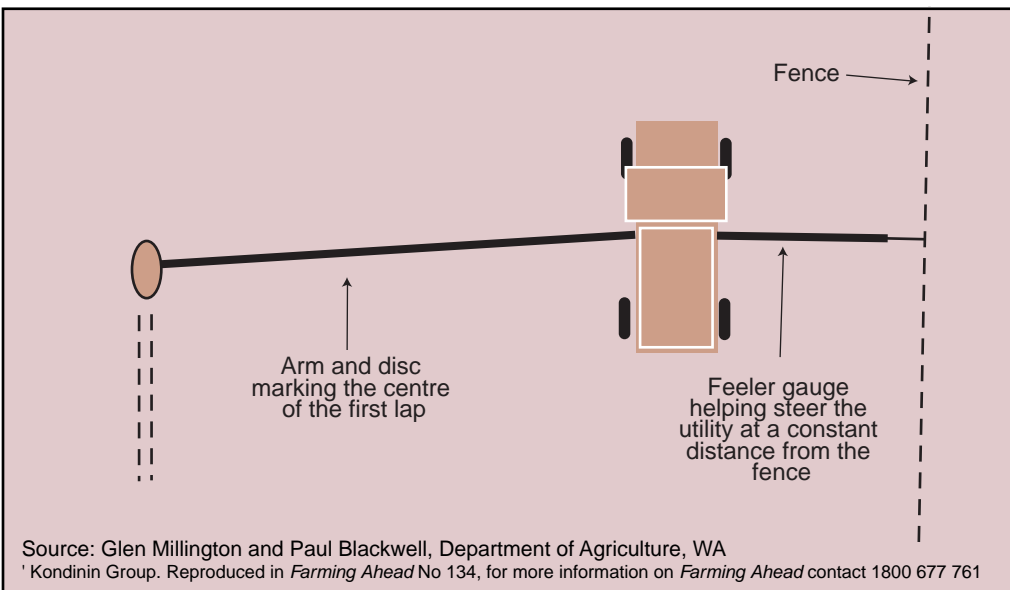


Figure 11.1. Marking out the first run using a plastic feeler gauge.



Photo 11.7. Millington's spreader and sprayer on bare tramlines.

The Millingtons' main expense to start tramline farming was \$2000 for the purchase of a marker arm.

Tramlines

- 2.4 m track;
- bare for canola and lupins and fuzzy for cereals.

All machinery runs on the same track width. The seeding tractor, air seeder, spreader and harvester use a pair of bare tramlines in the centre of the air seeder bar. Each wing has bare tramline (one from each pass of the bar) for spraying and harvesting from. Very accurate and precise marking with marker arms allows the spraying tramline to fit the tramlines for each wing. The Millingtons sow their cereal crops on 38 cm wide rows with legumes having a single skip row between pairs of 38 cm rows making 76 cm rows.

Future plans

Future plans include the use of inter-row shield spraying. Harold and Glen have developed and tested an 18 m self-steer inter-row shield spray hood. Most of the materials have been collected from around the farm; an old scarifier bar has been modified as the frame and the shields have been made from empty 200 L herbicide drums. Their Flexi-N tank used at seeding doubles as the tank for shield spraying. To make the shields track between the crop rows a small wheel has been attached in the centre at the back of the shield that runs in a furrow left at seeding. The shields are used on 76 cm spacings which have been made by blocking off every second tube at seeding. The tine is left down to form a furrow which the spray hood wheels follow. Harold also has some innovative ideas for improved weed control based on harvester modifications to put the harvester chaff on the tramlines.

Case Study 11: Don and Anne, Nigel and Tanya Moffat

Moonyoonooka and Tenindewa farmers Don and Anne Moffat with their son and daughter-in-law Nigel and Tanya have accepted the challenge to tramline in some very hilly and rocky country.

Reason for tramline farming

The Moffats' main motivation for moving to a tramline system was to reduce compaction and inputs, although at this stage they have seen no evidence of a reduction in inputs. 'A 55 hectare paddock sprayed last year sown normally is still 55 hectares this year with controlled traffic'. However, they will not give up hope of reducing inputs and next year plan to sow a bigger area to tramlines.

Guidance system

In their first season of tramline farming in 2002, spraying tramlines were marked in summer using a borrowed DGPS auto-steer system. These tramlines were conveniently used for spraying and spreading before seeding.

When seeding this year, the seeder followed pre-made marks every third seeder run width and put down both marker arms to mark out the adjacent runs. This works well with a 3:1 fit between bar and boom. Both arms were then retracted and the disc marks were used as a guide to seed adjacent runs. The pre-made

marks were often difficult to follow due to stock damage during autumn and burnt harvester rows.

In 2003 they again used a contractor with a DGPS auto-steer guidance system to mark new paddocks for tramlines. Every second run was marked to enable rip skipping and wider turning. In the future, to avoid stock damage pre-seeding, marking will be done as close to seeding as possible. In paddocks that were cropped the previous season the tramlines were used for guidance at seeding. No marker arms were used as the tramlines were still quite visible.

Machinery

In 2002 the Moffats modified their machinery widths and tracks to fit the harvester on 3 m tracks.

Costs of modifications and machinery are show in Table 11.2. In 2003 modifications included rebuilding the multi-spreader axle and changing the air seeder box to tow-behind with 3 m wheel track centres to help recognise the tramlines in crops, especially in lupins sown with double row spacings.

Layout issues

All controlled traffic (1035 ha) working was up and back. Very tricky paddocks were sown as normal round and round. The Moffats have left bare tramlines for the harvester to follow during harvest and hope to be able to use these

KEY FEATURES:

- up and back
- two marker arms
- all matching machinery
- hilly and rocky country

Farm location:

Moonyoonooka and North Tenindewa

Area cropped 2002:

1600 ha

Annual rainfall:

Moonyoonooka 450 mm

Tenindewa 325 mm

Enterprises:

- cropping: wheat, barley, lupins, canola
- sheep, cattle



Photo 11.8. Moffat's using the tramlines from the previous season for guidance at seeding.

Table 11.2. Moffats' machinery modifications and costs 2002.			
Operation	Equipment	Modifications	Cost (\$)
Seeding	Seeder bar 29 tine John Shearer Trashworker	Brought back to 8.9 m 2002 and back to 9 m 2003	No cost
	Air seeder 3 t John Shearer tow between Tractor		No cost
	JD8640 4WD	Removed duals and wound out to 3 m	100
Spraying	27 m boomspray	Extended axle to 3 m track. Rebuilt boom to parallel lift to enable boom to fold inside the wheels for road transport	3000
	Tractor JD4250 MFW	Track spread to 3 m using cotton reel spacers	800
Spreading	18 m Multi-spreader	Track widened to 3 m using cotton reels but was not very successful. (more detail)	
Modification cost			3900
Guidance	2 marker arms		5290
Total			9190

for seeding for next year. Tramlines were run up and down slope where possible. To make runs more efficient the Moffats have removed some contour banks and fences. Since moving to no-till farming in 1995 it has become evident that the contour banks weren't running water due to better soil structure and water infiltration.

Observed benefits

Spraying has become very easy with tramlines to follow instead of foam markers. Nigel was a participant of the Tramline Farming Tour 2001 to Queensland and New South Wales. After seeing the benefits of controlled traffic in the east, Nigel realised their machinery was quite well matched and could be simply modified to implement a tramline farming system of their own.

Case Study 12: Rohan and Carol Ford

Reason for tramline farming

Rohan and Carol Ford from Balla began tramline farming in 2002, motivated by the need to alleviate soil compaction, improve soil health and an increasing concern that the chemical farming system is not sustainable. Rohan was also searching for a new challenge.

Ninety-five per cent of their farm is yellow sands and deep wheel ruts from the harvester are still evident 10 years after harvest. Working from the tramlines, including deep ripping, will confine compaction from machinery movement in the paddock to help conserve the benefits of deep ripping.

Guidance system

In 2002 Rohan seeded their 2700 ha program to tramlines using two marker arms and DGPS (John Deere) guidance system. The combination was used to improve driving accuracy because using marker arms on undulating soil was difficult. To avoid problems with the marker arm and tight turns on the ends in 2003, Rohan upgraded his seeding tractor to a JD tracked tractor with auto-steer using the Greenstar DGPS system. This enabled him to rip skip, sowing every second seeder run in one pass across a paddock and filling in the missed runs on the return pass.

Machinery

Rohan has matched his machinery width and tracks to the harvester to reduce compaction at harvest and because nine metres was the most economical width. His bar was about 10.67 m so to match his machinery widths he

would have needed to widen his boomspray and buy a new 10.97 m harvester front, which would cost \$20,000 alone compared to \$22,000 to modify most of his equipment.

Some modifications were required to move the wheels on the seeder bar, air seeder box, sprayer and spreader to 3 m (Table 11.3). Their seeding tractor has now been traded for a tracked tractor (8320T) with an adjustable track to 3 m to be used for spraying and seeding operations.

The harvester (JD9600) will be just off the tramline on 3.4 m centres, but the chaser bin will be modified to fit the tramline track and allow grain to be transferred from the harvester on an adjacent tramline. The harvester wheels will fit when the harvester is traded in the future.

Tramlines

Tramlines were sown in the first year because Rohan was concerned about erosion of bare tramlines on his in water-repellent sands. In some paddocks the Fords found the crop in the rows on the tramlines emerged first and was easy to see for post-emergent spraying. They used DGPS guidance (Greenstar) to guide them to the correct row. Rohan experimented with fuzzy tramlines but they did not work very well on the non-wetting soil, as the smooth tyre on the air seeder box did not press the seed into the sand.

Rohan now uses bare tramlines to make them more visible for spraying late in the season and reduce crop damage. One tine was lifted behind the tracks to leave a 40 cm gap for the tramline (20 cm row spacing is used for cereals). The tractor tracks are a bit wider than

KEY FEATURES

- up and back 2 markers and DGPS guidance
- all machinery fits the harvester
- deep ripping from tramlines

Farm location:

Balla

Area cropped 2003:

2980 ha

Annual rainfall:

250–300 mm

Main soil types:

yellow sand

Enterprises:

- cropping: lupins, barley, wheat
- sheep, cattle

Operation	Equipment	Modifications	Cost (\$)
Seeding	9m seeder bar germinator disc opener	Change to 3 m track	2000
	Air seeder Morris air tank	Change to 3 m track	No cost
	Tractor JD8870 4WD	Remove duals to run single tyres (710/70R-38 radial)	
Spraying	27 m boomspray Beverley hydroboom	Change to 3 m track	3500
Spreading	18 m multi-spreader	Was truck mounted now tow behind	4500
Deep ripper	9 m	Removed 2 tines to not rip tramlines	No cost
Modification costs			10,000
Guidance	Greenstar	Upgrade and guidance program	5500
	2 marker arms		6500
Total			22,000



Photo 11.9. Deep ripping between lupin rows during flowering

this 40 cm gap, but Rohan has decided this is a good compromise to leaving a wider bare tramline that may become weedy and have greater potential for erosion. Rohan has noticed the spraying tramlines are deeper than the unused tramlines. The challenge for next year will be to maintain an even seeding depth.

Layout issues

Tramlines were seeded up and back, north and south except for one paddock that had very short runs north to south, so that one was seeded east to west. Before beginning to sow a paddock the seeder was run up and back on the ends to provide a guide for when to turn and when to lift the bar. Turning was very tight on the ends of the runs because as they were unable to rip skip using two marker arms.

Benefits and observations

Rohan highlights the importance of precise driving. 'Educating drivers is important so they understand the reason to drive straight and what you are trying to achieve. Tramlines have given us a step in the right direction to control weeds, chemical use (resistant weeds) and a more effective use of fertiliser in our non-wetting soils'.

The easy in-crop access tramlines provide is enabling Rohan to trial deep ripping between established rows of barley or lupin crops during the growing season. In 2003, together with Dr Paul Blackwell, Department of Agriculture, he has experimented with deep ripping in between lupins on 50 cm wide rows. If there is no resulting yield penalty in the lupins, this may be a better time for deep ripping as it is a relatively quiet time of year and the soil is still moist. Deep ripping is usually done after the first rains in April when there is pressure to start seeding.

Case Study 13: Anthony and Daphne, Glenn and Lisa Fretwell

North-east Newdegate farmers Tony and Glen Fretwell have been tramlining since 2001.

Initial tramline farming system

The Fretwells introduced controlled traffic to their 4000 ha cropping program with the purchase of one marker arm and a 36.57 m boomspray. Most paddocks were sown round and round leaving one bare row as a guidance line for the sprayer and contract spreader. This guidance line was used for night spraying and contract spreading before the purchase of any GPS based equipment. Up and back working was tried in two paddocks. During 2001 the Fretwells learned a great deal about the cost savings from overlap reduction and the simplicity of navigation for all paddock operations by following a guidance line in the stubble.

Guidance system since 2002

A Beeline Navigator Broadacre (maximum error 20 cm) is swapped between the 4WD JD 8960 sowing tractor and the spray tractor. The Fretwells fitted auto-steer on their JD 9600 harvester in 2002. Tines are removed and fuzzy or bare tramlines are left at 3 m wheel centres on every 18 m run.

Machinery

The progression to full tramline farming in 2002 seemed natural as the machinery owned was close to matching in widths.

- 18 m air seeder bar;
- 36 m boomspray;
- 18 m multi-spreader;
- 9.1 m harvester front;
- 18 m inter-row shielded sprayer.

Tramlines

- 3 m tracks;
- fuzzy and bare.

By matching all wheel spacing to the 3 m of the harvester any advantages from controlled soil compaction will also be won. Both tractors have been converted to single tyres at 3 m wheel spacing. The track width of Fretwell's front wheel assist tractor is being converted to 3 m by extending the differential and drive axles. Glenn purchased a kit from Tasweld Engineering, Toowoomba for \$4500. and the extensions are covered by John Deere warranty. In time, the air seeder box will be changed to a four wheeled style rather than the current trike style. The boomspray has been fitted with a hydraulically adjustable axle that is about 2 m for road transport and can be adjusted to 3 m in the paddock to match the tramlines. The chaser bin poses a problem in the system since it is the greatest single contributor to soil compaction on the farm and the harvester auger will not reach into it while on tramlines.

Layout

All paddocks are worked up and back from the side of the paddock, giving the longest straight run, while going north to south where possible and up and down slopes rather than across slopes. In 2002 all contour banks, more fences, all single trees and more rock heaps were removed from paddocks to simplify operations.

Inter-row shield sprayer

The Fretwells are also developing an 18.23 m shielded sprayer. 'We have observed the shielded spraying concept working in other industries and are excited by the preliminary research in the Western Australian broad acre



Photo 11.10. Fretwell's harvester on auto-steer.

KEY FEATURES:

- up and back dGPS auto-steer guidance
- shielded spraying
- harvester fits the system

Farm location:

North-east Newdegate

Area cropped 2003:

5350 ha

Annual rainfall:

356 mm

Main soil types:

sand, loam, clay

Enterprises:

cropping only: wheat
barley, lupins, canola



Photo 11.11. Fretwell's seeding tractor pulling the chaser bin with a matching 3m wheel track.

environment. There seems room for progress of this concept for our style of farming. It fits well with straight line farming system, auto-steering, herbicide resistance management, and herbicide cost reductions. With further experimentation of shield design and wide row spacing, we foresee this practice effective for canola, faba beans and field peas as well as the lupin crops'.

Case Study 14: Kim and Dianne, Neil and Jo Diamond

Buntine farmers Kim and Dianne together with Neil and Jo Diamond started tramline farming in 2002. They have now been using the system for two years.

Reason for tramline farming and benefits

Kim and Neil's observations of successful tramline farming systems on the Tramline Farming tour to New South Wales and Queensland in 2001 inspired them to implement the system on their own property.

Neil Diamond believes 'the input cost savings achievable with controlled traffic are too great to ignore. The system has allowed us better opportunities for relay planting summer crops and perennials (lucerne) and the use of shield spraying in lupins. Once the driver has learnt how to use the navigator, driving has become easier and less fatiguing'.

Guidance system

The Diamonds use a DGPS auto-steer (Beeline) system with a base station to guide their seeding and spraying tractors. Neil pre-marked paddocks before seeding as insurance if auto-steer was not available. This was done two ways in combination with other paddock

operations for greater efficiency:

- while fertiliser was spread on auto-steer way lines a pair of marker arms mounted on a three-point linkage frame were used to mark runs;
- while burning, auto-steer way lines were used to rake stubble into windrows on 9 m spacings for guides during spraying and seeding.

Machinery

The Diamonds have matched their machinery width to fit the harvester in the system and have two track widths for different machinery.

- 9.1 m Flexicoil 820 air seeder bar at 18 cm row spacing for cereals and three-point linkage toolbar for lupins on 76 cm row spacings for lupins;
- 27 m Hardi hydraulic lift-fold boomspray;
- 9.1 m harvester;
- 9.1 m inter-row shielded sprayer.

The Diamonds have designed and built a 9 m shield sprayer, mounted on three-point linkage with Holtfreeters in Northam. The sprayer has 19 shrouds set at 450 mm row spacings. Two 800 L tanks are mounted on the bar and one 800 L tank is mounted on the front of the tractor. The sprayer will be used for inter-row shield spraying between 45 cm lupin rows. Early spraying runs of the shield sprayer have gone well.

KEY FEATURES:

- up and back dGPS auto-steer
- Pre-marking
- Relay planting Shield spraying

Farm location:

Buntine

Area cropped 2002:

2660 ha

Annual rainfall:

325 mm

Main soil types:

Loam, gravel

Enterprises:

cropping wheat, barley, oats, lupins, lucerne, sheep, pigs, cattle



Table 11.12. The Diamond shielded sprayer.

Tramlines

- 2.2 m track for seeding tractor Stieger ST310 III, spraying tractor John Deere 7600 MFWD, boomspray, air seeder box Flexicoil 1330 and FlexiN cart;
- 3 m track harvester;
- bare tramlines on 2.2 m.

Relay planting

Tramlining has provided another option of relay planting maize into lupins. In 2001, the Diamonds used a precision summer crop planter to sow maize on 1 m spacings between rows of lupins when the lupins were filling pods about 10 weeks before harvest. At harvest

the tallest maize was 300 mm high — the same height as the lowest lupins pods. The maize was pushed under the cutter bar as the lupins were harvested. Relay planting gave at least a 10-week period of sowing advantage, compared to normal sowing after harvest. The maize was also sown into wetter soil. Because the lupins were dropping their leaves when the maize was planted, more light was able to reach the emerging maize crop. As well as summer crops, lucerne will also be planted into barley at 1 m spacings after post-emergent spraying.

Case Study 15: Owen and Terri Brownley

Lake King farmers Owen and Terri Brownley started tramline farming in 2002.

Reason for tramline farming

- agronomic gains. Inter-row shielded spraying, sowing between last year's crop rows for better stubble handling with a no stock system;
- help prevent harvest compaction with wet harvests;
- try to concentrate weed seeds from harvest into wheel tracks for better control;
- help prevent compacted subsoil all over paddocks;
- band spray residual chemicals and fungicides to prevent full soil contamination.

Guidance system

Owen uses DGPS auto-steer (John Deere) in his seeding tractor and visual DGPS guidance (Farmscan and John Deere DGPS) in his spraying tractors to work up and back.

Machinery

The Brownleys have designed their system to include the harvester on 3 m wheel tracks.

- 12.3 m Flexicoil air seeder bar;
- 12.3 m triple disc air seeder bar;
- 36.9 m boomspray;
- 12.3 m spreader;
- 12.3 m and 11 m harvesters;
- 12.3 m inter-row shielded sprayer.

A 12.3 m custom built harvester front by Midwest Fabrications is centre mounted on one of Owen's harvesters. Residue spreading and chaff control systems are being designed to divert chaff onto the tramlines. The other harvester has an offset 11 m harvester front that is currently used for harvesting peas and beans separate from the centre feed machine. It will be a challenge to fit this into the system.

Some modifications of axles were required to take the wheel tracks out to 3 m centres. The boomspray is towed by a JCB fast track, the axles of which have been extended to three metres. The axle modification was done by Tasweld Engineering in Toowoomba. The axle extensions used have been warranted by JCB. The boomspray wheels slide out hydraulically to 3 m after the booms have been folded out.

The seeding tractor is a JD tracked tractor set on 3 m track spacing. The tracks are 400 mm wide to fit in the 600 mm tramlines and give plenty of grip for the tractor's 300 horsepower.

The chaser bin axle has been widened to 3 m. It travels 90 per cent of the time on tramlines except when emptying the harvester, when it moves off the tramlines. This will hopefully be overcome next harvest.

Tramlines

- 3 m track;
- bare. To be covered with weed seeds then straw.

KEY FEATURES

- Up and back
- DGPS guidance
- All machinery matched including the harvester

Farm location:

Lake King

Area cropped 2003:

3000 ha

Annual rainfall:

365 mm

Main soil types:

Shallow sand and gravelly sand, neutral loams

Enterprises:

Cropping only: wheat, barley, canola, faba beans, summer crops
Cropping only



Photo 11.13. Owen's JCB with modified axles to 3m towing a boomspray with adjustable axles.

Owen left bare tramlines by blocking off the seed tubes behind the wheels and lifting the tines. The seeder bars have a centre tine on 300 mm row spacing and every second row for wide row work or every third row for summer crops.

Benefits

The potential for on-farm trials with matching harvester and seeder width is enormous. The plots are harvested as part of the normal paddock operations and yield mapped data are interpreted after harvest. There are no delays with weigh trailers and cleaning up missed areas after the trial is harvested.

The inter-row shielded sprayer has improved the efficiency of spraying fungicides on pulse crops. The over row nozzles are used to band spray fungicide on the 600 mm crop row early in the growing season. Precise placement of fungicides in pulse crops by spraying young plants with the over row nozzles has reduced the amount of fungicides required for crop

protection. Bare tramlines have reduced crop damage from traffic when multiple applications have been required.

Inter-row spraying is used to control weeds in wide row winter crops and warm season's crops.

Future plans

A strategy to reduce the weeds in the bare tramlines is required. Owen plans to try diverting chaff onto the tramlines at harvest. Another issue to be addressed is the tramlines becoming slushy during winter and developing ruts. This makes a bumpy ride for later traffic and the ruts holds water that causes even more bogginess.

Owen recommends thinking about paddock layout before starting a tramline farming system particularly if you are planning to remove fences in the future. If you have the same way lines in two paddocks that will eventually be combined there is no need to reset the tramlines.

Appendix 1



Appendix

1.1 Improved efficiency

Tramline farming improves cropping efficiency by reducing overlap as a guidance system is used to set up the tramlines on an even spacing across the paddock. The input savings of seed, fertiliser, herbicide and fuel will vary depending on the accuracy of the guidance system, paddock layout and driver accuracy. For example, when operating round and round, using one marker arm, an estimate of five per cent less inputs is reasonable based on trials and farmer experience. When the paddock is seeded up and back using DGPS auto-steer (2 cm accuracy), without corner sowing, farm experience shows that a 10 per cent reduction of inputs is reasonable.

Fuel use efficiency in machinery running on tramlines has been reported to increase because wheels are running on firm, compact tramlines that cause less rolling resistance and wheel slip compared to running on the rest of the paddock. Queensland research showed up

to 50 per cent reduction in fuel use when the tramlines were not tilled compared to tilled soil in clay soils (Tullberg and Wylie, 1994).

Tramlines can be a great benefit for seeding and spraying operations after deep ripping sandy soil if the tramlines are not ripped. Measurements at Mullewa, Western Australia, found a 10 per cent reduction in fuel use when unripped tramlines were used for seeding and spraying operations compared to machinery running on deep ripped soil. Recent research is measuring the benefits of tramlines for fuel use more accurately. Opportunities for applying critical spray applications from firm tramlines in wet conditions, without losing traction or getting bogged, provide other benefits.

The relative economic benefits of compaction control are much larger than the benefits from reduced costs due to less overlap. Figure 1.1 shows that the gross margin benefits from compaction control are even greater in later

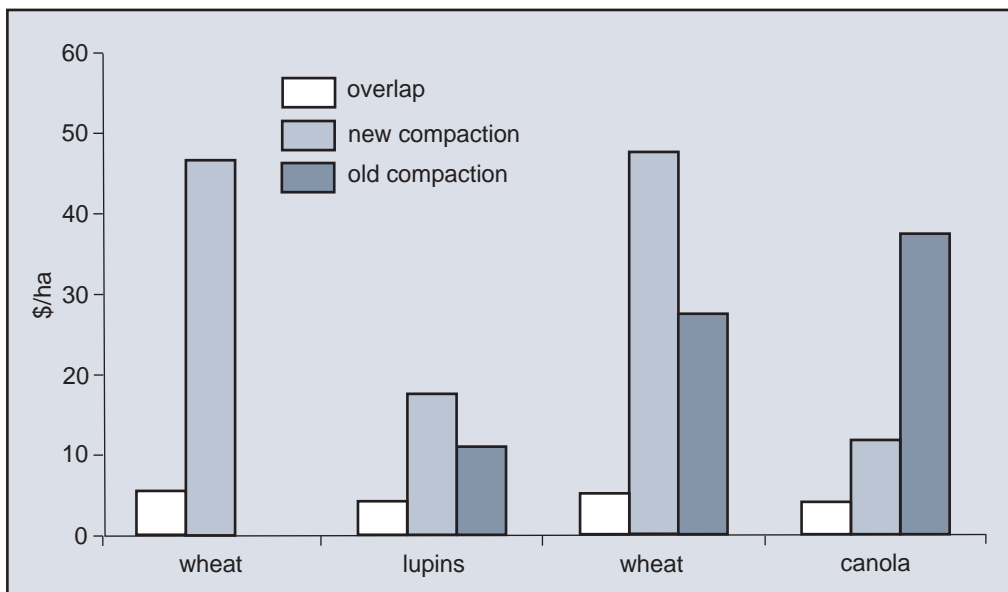


Figure 1.1. Annual growth margin benefits of tramline farming at Mullewa over four seasons from either reduced inputs from less overlap (3 to 4 per cent), new compaction in the season, or old compaction accumulated from previous seasons. The overlap of successive wheelings is 80 per cent and the yield loss from the tramlines is not included in the calculations.

Year	1997	1998	1999	2000
Crop	Wheat	Lupin	Wheat	Canola
Yield of normal system, t/ha	2.41	1.10	2.45	0.945
Yield of tramline farming system, t/ha	2.6	1.21	2.77	1.055
Benefit over normal traffic	8%	10%	13%	12%
LSD (5%)			0.11	0.127
Grain quality benefit	-	-	Less screenings	More oil

seasons when the residual effect of old compaction from previous seasons is included.

More recent analysis (Blackwell *et al.*, 2003) has shown that a net gross margin benefit of more than \$50/ha can be expected from a sandplain farm adopting tramline farming in Western Australia, based on benefits from overlap and compaction control, as well as use of shielded sprayers in lupins and reduced fuel use.

1.2 Compaction control

Soil compaction and wheel damage to growing crops can reduce yield in many situations. Compaction restricts plant root access to soil water and nutrients because soil structure is damaged.

Trials at the University of Queensland, Gatton indicate controlled traffic improves infiltration, reduces run-off and improves crop yield on self-mulching black earth (Tullberg *et al.* 2001; Yuxia *et al.* 2001). Crop yield was increased by up to 16 per cent.

Crop yield of barley, wheat and beans increased with the absence of wheels by 12–17 per cent on red brown earth at Roseworthy, South Australia (Ellis *et al.* 1992). As 10 per cent of the paddock was lost to wheels from bare tramlines left every seeding run, this translates to a two to seven per cent yield increase from practicing tramline farming.

Similarly, results from trials at Mullewa indicated there was approximately a 10 per

cent yield benefit of tramline farming sandy soil over normal traffic for a wheat-lupin-wheat-canola rotation, after deep ripping before the first wheat (Table 1.1). The tramline system was based on 9.1 m with bare tramlines left every third run for spraying.

Further increases in yield benefit come from later seasons as the soil between the tramlines is compacted less and improvement in paddock soil structure can be maintained. The upper limit of benefits to date in Western Australian trials is about 14 per cent. Limited data has been collected on the response of different crops, however, the response of barley and canola appears similar to wheat, but effects on lupins seem less.

Compaction effects from wheel marks can often be seen by delayed flowering of the crop and greener lines where the wheels have run. Research at Mullewa on sandy soil showed that the yield loss within a wheel mark, compared to uncompacted soil, from a tyre or track loaded by more than 1 t can be up to 100 per cent for late post-emergence operations and up to about 40 per cent for seeding, wet harvests and for wheel marks from previous seasons, compared to deep ripped conditions (Figure 1.2).

Post-crop emergence operations have a greater effect on crop yield as soil compaction is further compounded and the plant is also mechanically damaged (such as stems broken).

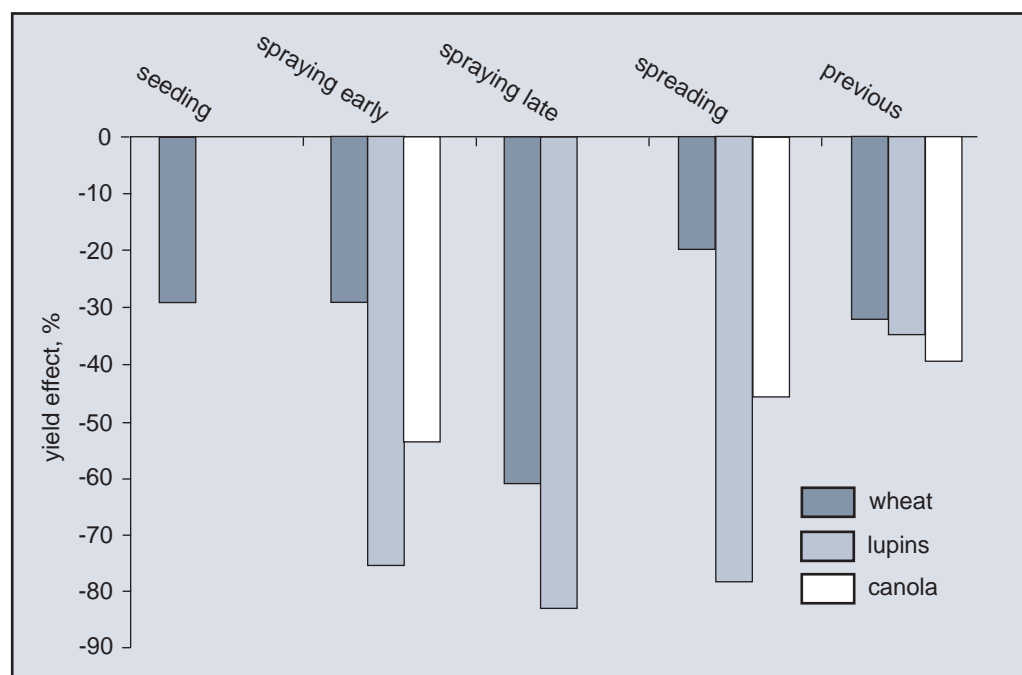


Figure 1.2. Yield loss within wheel marks on yellow sand at Mullewa 1997-2000.

Table 1.2. Plant establishment, growth and yield; * significantly more or less than normal agronomy.

Treatment	Yield (t/ha)		Plants (/m ²)		Dry matter (g/m ²)		Gross income (\$/ha)	
	lupin	grass	blue lupin	grass	blue lupin	grass		
1. Normal agronomy	1.07	44	2.3	4	184	29	6.4	181
2. Green manuring	0	53	3	16*	237	48	38*	0
3. Brown manuring	0	55	3.8	4	273*	64	16*	0
4. Crop topping	1.04	37	1.5	2	287*	25	0.2	177
5. Hoods and topping	1.19*	42	0.5*	3	255	0.5*	7.5	202
LSD(5%)	0.08	17	1.9	10	69	30	22	(\$170/ t)

The quality of grain is also affected by wheeling. Cereal grain from wheel marks had higher screenings and canola had less oil than from zones with no wheel marks (Blackwell, 2000).

The first pass of a wheel has been found to cause the most compaction (Tullberg, 2001). Little compaction may occur if the soil is dry and sets hard in summer, for example yellow sand. Subsoil compaction may not be reduced using rubber-tracked vehicles, compared with vehicles with tyres. Blunden *et al* (1994) showed that in wet conditions compaction in sandy soils from track machines was greater than for tyres at 30 cm depth.

1.3 Improved weed control (shielded spraying)

Tramline farming assists inter-row shielded spraying by providing well-marked seeder rows with little overlap and a firm tramline for easy access to the crop for the vehicle operating the shielded sprayer.

A trial in 2000 at Miles Obst's farm at Mingenew on pale sand over gravel was planted with Wonga lupins on 56 cm rows and a 91 cm row space for the tramline. The crop was either grown with normal agronomy (simazine and selective herbicides applied by a boomspray), shield sprayed with Roundup[®] between the rows at main stem flowering, green manured, brown manured or crop topped. Green and brown manuring were included as alternative weed management strategies. Details of the crop results and weed control are shown in Table 1.2. In the growing season, 192 mm of rain fell; less than half the annual average rainfall.

The shield treatment gave the largest yield and had the lowest growth of blue lupin weeds. Presumably the large blue lupin weeds competed for soil moisture in this dry season and contributed to a reduction of yield in the other treatments. There must have also been some compensation in the shielded crop for

the lack of crop in the tramlines, compared to the other treatments.

The economic benefits of shielded spraying over a lupin-wheat phase were made with the Ryegrass Integrated Management model (RIM). For the model run we used a lupin yield of 1.2 t/ha and a wheat yield of 2.34 t/ha (\$170 and \$180/t respectively). No grass selectives could be used in the lupins and there was 25 per cent carry-over of the initial 500 seeds/m² of ryegrass into the wheat phase. The wheat was grown with delayed sowing and high seeding rates to maximise weed control. The shield treatments tested were:

- the worst case scenario with only 80 per cent control by inter-row shields; or
- the best case scenario with additional KerbÆ for in-row control (only used in the non-cereal phases and paid for by saving the cost of simazine) for 98 per cent weed control (Table 1.3).

The inter-row shield treatment, including in-row weed control, gave the best gross margin in the lupin year and averaged over the two years, and ryegrass numbers were also kept relatively stable. This should encourage the development of low cost shields for use on normal farm spraying equipment. Unlike green manuring, the shielded spraying treatment provides some income in the first year as well as weed control.

1.4 Tramline design

The type of tramline used can vary depending on whether weed control is an issue or some in-crop guidance is required. Ultimately, bare tramlines are the best for visible guidance, minimising crop damage and grain quality concerns from damaged crop, and they are firm for running machinery. However, some growers are concerned that taking a crop row out for the tramline will reduce potential crop yield. There is evidence to suggest that the edge rows of a bare tramline will compensate to some degree for the missing row.

Ryegrass (seeds or plants/m ²)	% control	Lupin year		Wheat year	
		Seeds; April	Plants; Nov	Seeds; April	Plants; Nov
Res.RG no G.selective, normal agronomy	70	500	151	5195	1173
Green manure with simazine	99	500	3	155	35
Inter-row shields on 80% width, no in-row control	80	500	38	1487	336
Inter-row shields +in-row control; 98% grass control	98	500	17	591	134
Gross margin \$/ha				2 years	Average over 2 years
Res.RG no G.selective, normal agronomy	21		110	131	65.5
Green manure with simazine	-130		275	145	72.5
Inter-row shields on 80% width, no in-row control	29		172	201	100.5
Inter-row shields +in-row control; 98% grass control	59		212	271	135.5

A trial at Mullewa on sand and red loam in 2003 studied the yield response of four wheat varieties Camamah, Wyalkatchem, Westonia and Calingiri in the tramline zone (rows in the tramline and the two edge rows) of bare, fuzzy or sown tramlines that were not used for spraying tramlines. The extra seed from the bare tramline was diverted into the edge rows.

The bare tramline zone had less yield than the sown tramline zone, except for the longer season variety, Calingiri, which grew 25 per cent more grain (350 kg/ha) in the tramline zone with 50 per cent less screenings than the crop outside the tramline zone (Figure 1.3). This indicates varieties may respond to compaction and competition in different ways.

Wyalkatchem notably showed less compensation than the other varieties. More research is needed to clarify the effect of extra seed in the edge rows, the width of the bare tramline, and the soil density under the tramline.

Fuzzy tramlines had the poorest yield in the tramline zone, especially Wyalkatchem with a 900 kg/ha penalty. Camamah and Calingiri seemed best adapted to fuzzy tramline design. However, fuzzy tramlines still provide some in-crop guidance and weed control through competition.

Shallow sown tramlines had the most consistent yield benefit in the tramline zone,

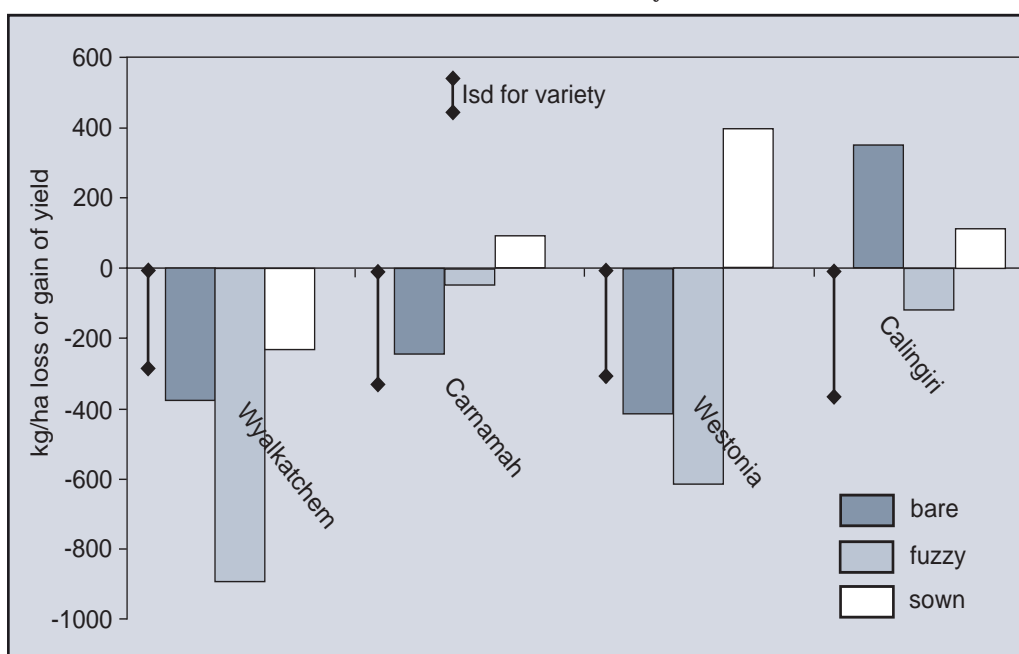


Figure 1.3. Grain yield loss or gain in the tramline zone (tramline width and both edge rows) for bare, fuzzy and sown tramlines and four varieties of wheat at Mullewa in 2003.

Conditions	Trial estimated increase %	Conservative on-farm effect %
No matching tracks	0	0
Matching tracks, only mechanical guidance	7	3.5 (50% of trial results)
Matching tracks, with electronic guidance for all operations	7	5 (closer to trial results due to more precision in driving)

especially about 400 kg/ha in Westonia. Rows of crop in the tramline offer no on-ground guidance. This could come from auto-steer options or central broad rows and wheel marks from tow-behind air seeders. Further benefits of sown instead of fuzzy tramlines are the levelling of rough running when the seeding direction is changed from racetrack to parallel. The tramlines studied were not used for spraying, so late crop damage was not measured. It would be expected the yield in the fuzzy and sown tramlines would be lower if used for spraying tramlines.

1.5 Economics of tramline farming

Some growers are concerned that tramline farming is too expensive. A calculator was developed by the Western Australian Department of Agriculture to predict the economic benefits gained on farms by comparing the yield and input benefits according to the area cropped and the degree of precision available (Blackwell *et al.* 2002).

Four different cases were simulated using the calculator, ranging from a low cost investment in one marker arm and retaining a racetrack (round and round) pattern, to the most expensive option of DGPS auto-steer and a tramline controller. These results assume that the seeder bar and boomspray already match two or three to one, yields are 2 t/ha, on-farm price for wheat is \$150/t and costs are \$60/ha for fertiliser and \$40/ha for herbicides. Guidance costs may vary depending on suppliers and developments in technology.

The figures used for yield benefits shown in Table 1.4 are based on trial results and on-farm measurements in Western Australia. The trial estimations have been reduced by 50 per cent to conservatively estimate what a farm cropping operation can achieve, due to less precision than in the trial work.

In addition, when a tramline controller is used to enable tramlines not used for spraying or spreading to be sown, an extra 0.5 per cent

yield increase is estimated for the extra yield from plants in the tramlines.

Overlap savings of five per cent for round and round operations and 10 per cent for up and back are assumed.

Results

Case 1. One marker arm, one fuzzy tramline and operating round and round

As little as 500 ha of wheat crop grown with tramline farming could pay for the cost of one marker arm (\$2500) to work round and round and leave fuzzy tramlines (Figure 1.4). This is a good introduction to the concept of tramline farming and enables an easier transition into up and back operations, where there are much better and longer term benefits from straight tramlines.

Case 2. Two marker arms and working up and back in straight lines

Two marker arms and working up and back are the most common arrangement used by farmers in Queensland and New South Wales who adopted controlled traffic farming in the nineties. Some of these early users still feel little need for electronic guidance, apart from when establishing new tramlines. Once the tramlines are marked they can be visually followed during crop operations and in subsequent years.

One thousand hectares of wheat crop grown with tramline farming will easily pay for the cost of two marker arms (\$5000). Another pair to mount on the deep ripper would also be justified (Figure 1.5).

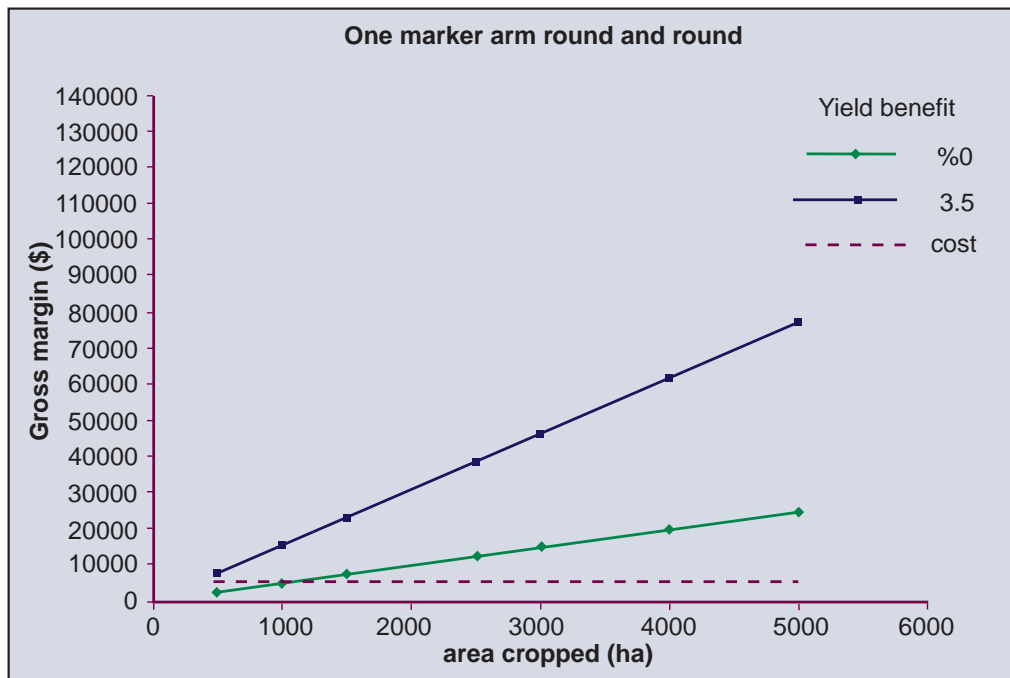


Figure 1.4. Estimated economic benefits of one marker arm, one fuzzy tramline working round and round. Gross margins are based on 2 t/ha yield, \$150/t on-farm price, \$60/ha fertiliser cost and \$40/ha herbicide cost. Ten per cent input reduction. Yield benefit zero per cent equals overlap savings only; 3.5 per cent equals matching tracks and mechanical guidance.



Figure 1.5. Estimated economic benefits of two marker arms working up and back. Gross margins are based on 2 t/ha yield, \$150/t on-farm price, \$60/ha fertiliser cost and \$40/ha herbicide cost. Ten per cent input reduction. Yield benefit zero per cent equals overlap savings only; 3.5 per cent equals matching tracks and mechanical guidance.

Case 3. Two marker arms and a tramline controller working up and back

The cost of the marker arms and controller can be paid for in about 1000 ha of cropping from overlap savings and yield benefits (Figure 1.6). The controller also makes the spraying and spreading operations more efficient because there is less possible confusion about which tramlines to use.

Case 4. DGPS auto-steer and two steering kits working up and back in straight lines

It would be difficult to pay for DGPS auto-steer (plus or minus 20 cm accuracy) and two steering kits (\$65,000) in one year from only overlap savings. At least about 3000 ha of sandplain cropping would be needed to pay off the cost when there is good track matching

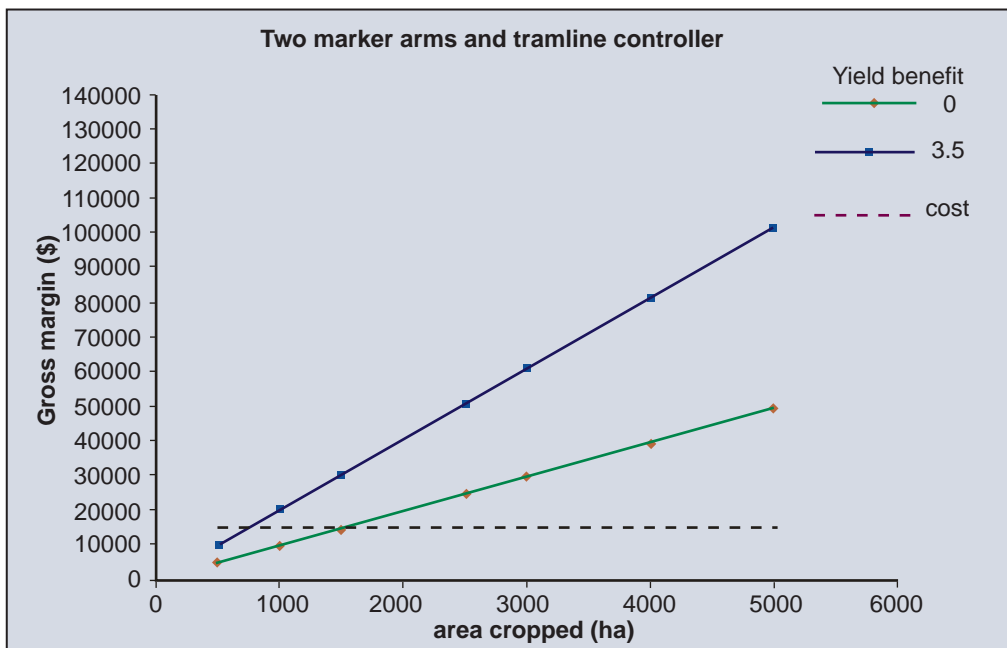


Figure 1.6. Estimated economic benefits of two marker arms and a tramline controller working up and back. Gross margins are based on 2 t/ha yield, \$150/t on-farm price, \$60/ha fertiliser cost and \$40/ha herbicide cost. Ten per cent input reduction. Yield benefit zero per cent equals overlap savings only; 3.5 per cent equals matching tracks and mechanical guidance.

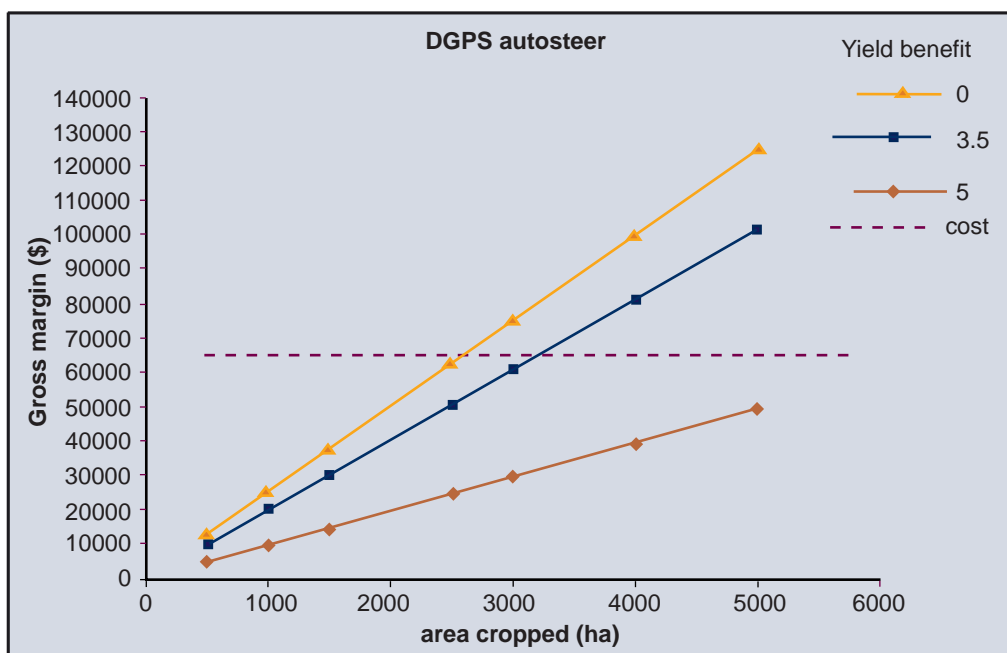


Figure 1.7. Estimated economic benefits of DGPS auto-steer guidance working up and back. Gross margins are based on 2 t/ha yield, \$150/t on-farm price, \$60/ha fertiliser cost and \$40/ha herbicide cost. Ten per cent input reduction. Yield benefit zero per cent equals overlap savings only; 3.5 per cent equals matching tracks and mechanical guidance, 5 per cent equals DGPS, matching tracks and electronic guidance.

and auto-steer is used for seeding and spraying operations to obtain the full benefit of the system (Figure 1.7). A second steering kit may not be required in the spraying tractor if bare tramlines or some form of in-crop guidance is used.

Conclusions

This is a conservative estimate of benefits because it is only calculated for the first year of a tramline system. More realistic estimates

come from benefits calculated over a period of years and are paid for by loans at an appropriate interest rate. The dollar values of crops and yield used in these calculations are on the low side of average to ensure a conservative analysis. This analysis does not include the benefits from other agronomic opportunities that are possible using tramlines, for example shielded spraying, relay planting and sowing into previous furrows.

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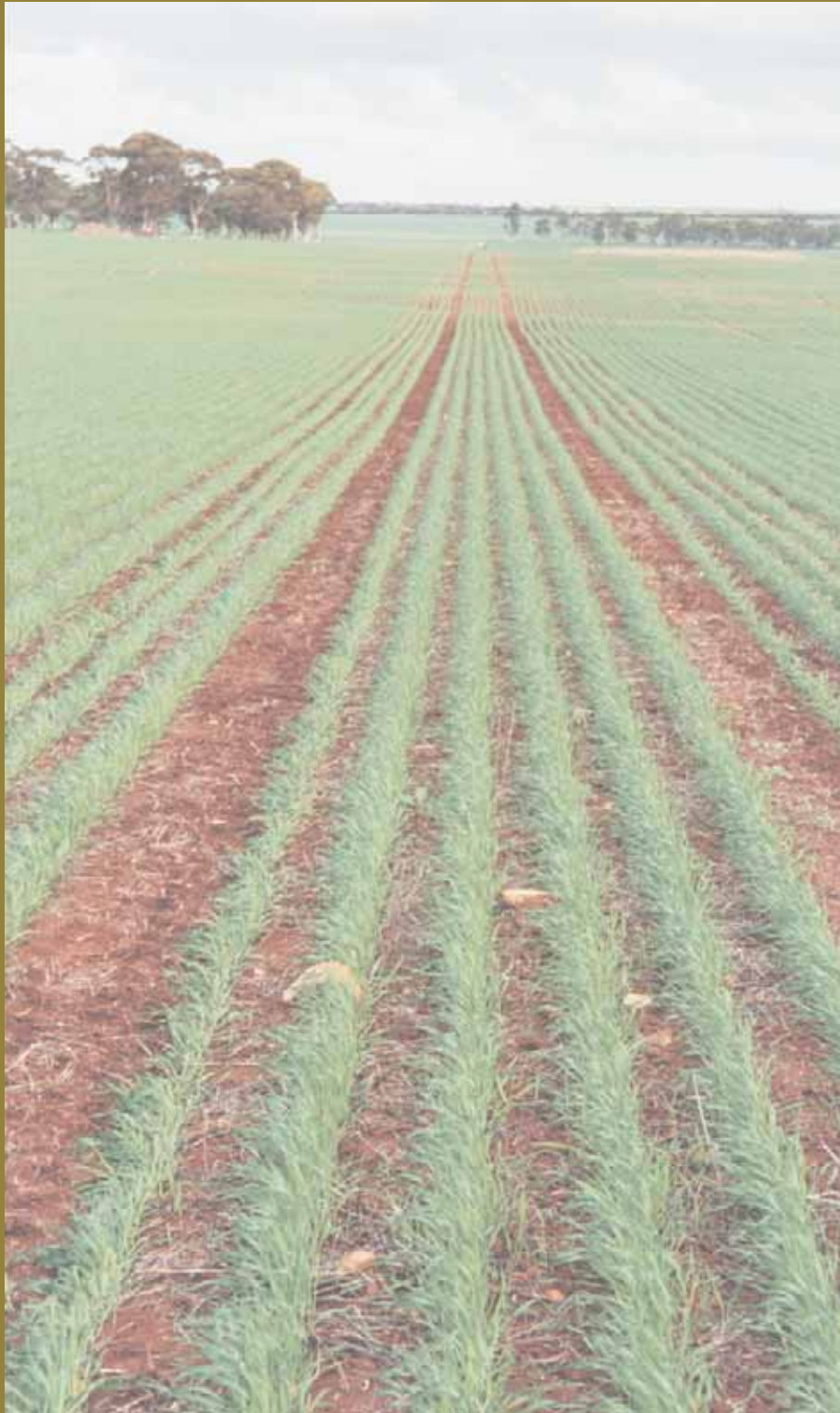
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Useful websites

www.controlledtrafficfarming.com

www.agric.wa.gov.au

www.grdc.com.au



Department of Agriculture
Government of Western Australia



GRDC
Grains Research & Development Corporation