ROTATION CROPS: WHAT IS THE IMPACT ON A IRRIGATED FARMING SYSTEM

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Introduction

Farming systems are continually attracting interest amongst the growing community, since input costs are continually increasing and returns behave in a cyclic nature. Growers are now stepping back from the enterprise, to assess the production unit for agronomic, economic and environmental issues before selecting the rotation crop for the farm, endeavouring to achieve the most sustainable production system. This has research dollars invested, to examine the effects of rotation crops on the cotton production system.

During the 1993-94 cotton season, two irrigated farming system experiments were established in NSW. One at 'Auscott' Warren and the second at 'Beechworth' located at Merah North. These two experimental sites were the initiative of the CRC for Sustainable Cotton Production. The sites are now starting to provide valuable insight into the effects and long term sustainabiliy of possible rotation systems. These sites have a life expectancy of seven years and consist of a range of treatments side by side in the one field under the same environmental conditions.

Within this paper, I will provide a review of research results from the CRC experimental sites. While highlighting both current environmental concerns and the possible future direction of an irrigated farming system.

Rotational sequence for the CRC Experiments

There are six rotations at the Merah North site, with the Warren site having a seventh treatment. Both sites have common treatments, however to address the individual needs of each location, some treatments have been altered. As outlined in Table 1. Following the 1997-1998 season, two complete rotational phases will be completed.

Table 1 : CRC Experimental Rotation Sequence

Merah North		Warren	
1	Continuous Cotton	1	Continuous Cotton
2	Cotton - Faba beans	2	18mth- Long Fallow
3	18mth Long Fallow	3	Cotton - Field Peas
4	Cotton - Low input Wheat	4	Cotton - Low input Wheat
5	Cotton - Dolichos Lablab	5	Cotton - High Input Wheat
6	Cotton - Dolichos Lablab + P/K Fertiliser	6	Cotton - Dolichos Lablab
***** All the legumes are green manured crops***		7	1993-95 Cotton- Lablab + P/K fertiliser 1995- 98 Cotton -Faba beans

Industry Profile

A survey of cotton growers has recently been conducted by the CRC cotton extension team, to determine the current industry profile with respect to choice of rotation crops. Of those respondents that acknowledged the use of rotation crops or fallow. The predominate response was to include wheat in the cropping system. Table 2 reports the results of this survey. While less than 14% of growers choose a long fallow, 19% have used legume crops whereas more than 60% of growers chose a cereal rotation.

Table 2 : 1997 Cotton industry analysis of rotations

Rotation	Queensland	New South Wales	Total Responses	Response %
Wheat	52	191	243	***41.25***
Fallow	23	57	80	***13.58***
Sorghum	32	28	60	***10.19***
Barley	13	29	42	***7.13***
Chickpeas	24	14	38	***6.45***
Faba beans	0	23	23	***3.90***
Soybeans	10	10	20	***3.40***
Dolichos Lablab	1	13	14	***2.38***
Mungbeans	3	11	14	***2.38***
Corn	6	7	13	***2.21***
Other	19	23	42	***7.13***
	183	*406*	*589*	

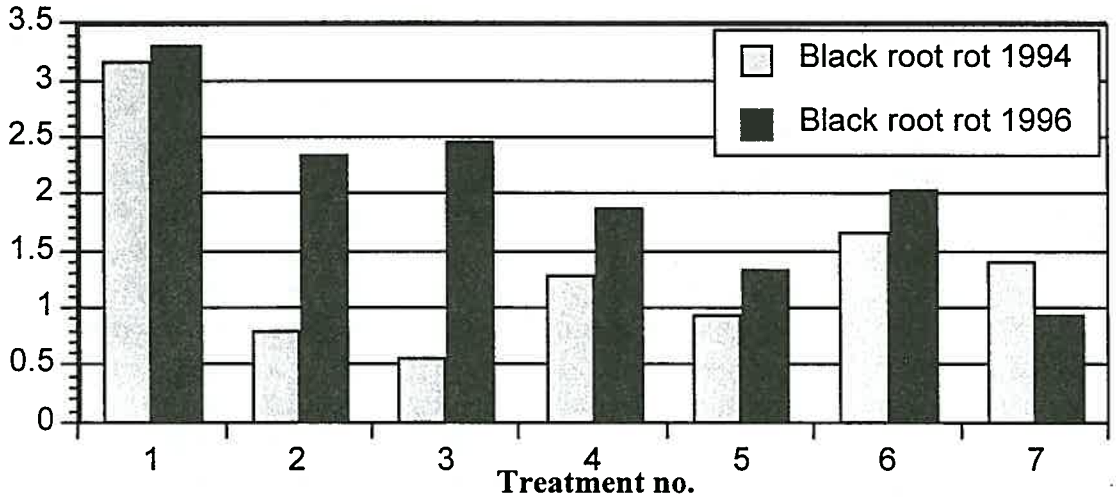
Agronomic Aspects

Disease Impacts

The Australian Cotton Industry is currently very concerned with the spread of Fusarium wilt (*Fusarium oxysporum vasinfectum*) across the industry. However other diseases such as black root rot (*Thielaviopsis vasicola*) have become increasingly significant in recent years and warrant similar attention to that applied to Fusarium wilt.

The experimental site at Warren has seen a dramatic increase in the level of black root rot infection since the 1993/94 season. The most recent results showed that the highest level of infection occurred under the continuous cotton treatments. Since the previous sampling the incidence of the disease has increased by 190% in the cotton-long fallow-cotton treatment and by a dramatic 327% in the rotation with field peas (refer to Figure 1). Healthy plants were found to be approximately 3 times larger than severely infected plants at six weeks after planting. The literature suggests that leguminous crops such as faba beans, mung beans, chickpeas and field peas are all hosts of the black root rot pathogen. Permanent bed systems result in a concentration of inoculum along the planting line thus favouring a rapid build-up of the disease.

Figure 1: (Allen et.al, 1997)



The mean incidence of Black root rot for each of the seven treatments in the Warren Farming Systems trial as assessed in 1994 and 1996.

The current widespread use of Verticillium wilt (*Verticillium dahliae*) resistant cotton cultivars appears to be contributing to a reducing incidence of the disease across the industry.

The concept of "Come clean - Go clean" has been the industry's catch-cry for Fusarium and this should also be applied to other diseases. Most diseases of cotton can be spread in trash and dirt attached to vehicles and machinery or moved about with irrigation tailwater or floodwater.

VAM (Vesicular Arbuscular Mycorrhiza)

In healthy cotton, VAM fungi infects the roots and acts as an extension of the root system, absorbing phosphorus for the plant. VAM fungi tends to die off during long fallows but cotton is easily infected by low populations of VAM in the soil (McGee et al, this proceedings). Dr David Nehl has examined VAM at the CRC sites finding normal VAM development in all the Warren treatments. Although levels were slightly lower after the continuous cotton, which reflects the high level of black root rot in this treatment (figure 1). At Merah North, VAM infection was low in the long fallow treatment but sufficient. VAM fungi continued to support cotton growth and yield was not effected. Adequate VAM development is likely to be maintained under a range of farming systems.

Weeds

Research was conducted on cotton crops following a rotational phase to investigate if the weed spectrum or population has altered as a result of the rotation crop. Herbicide options are limited for weed control in legume crops, consequently broadleaf weeds can develop into a problem. Surveys conducted by Dr Graham Charles on the experimental sites and other farming system sites has reported that no increase in weed populations or spectrums have occurred as a result of the rotations in the succeeding cotton crop.

Current fallow management and "in crop" weed control of various rotations is not occurring until the weeds are at an economical threshold for moisture. This is allows low numbers of plants to go undetected to maturity, setting seed that continually adds to the weed population. This is why the problem weeds are continually occurring in a system that appears to be addressing the problem. Table 3 outlines the level of seed that can be produced from various weeds. While not all the seeds are viable, certain species can have a high seed dormancy. Even if a low proportion, of these seeds germinate it will continually add to the problem. An autumn population of peachvine (*polymeria spp*) of 0.2 plants / m^2 potentially can produce 158 seedlings / m^2 (Charles , 1997). This concept also applies to legume crops that are not green manured before seed set or grain that escapes harvest. Dolichos Lablab in the summer and Faba beans in the winter have caused this problems for grower in the past.

Table 3 Range of weed seed potential based on the weeds size

Weed	Smallest		Largest	
	Plant Size (m^2)	Seed No.	Plant Size (m^2)	Seed No.
Bathurst Burr	0.11	94	0.60	2305
Noogoora Burr	0.25	242	3.20	1718
Peach vine	0.20	206	2.80	791
Sesbania	1 (m)	1091	2.70 (m)	18 644
Thornapple	0.86	4721	5.25	40 345

Source : Charles, (1996)

Another infestation source is the delivery of weeds by irrigation water, either pumped from the river or from your storage. This is especially the case for small grass seeds. Hawkey (1995) at Warren established that irrigation water contributed weeds to the level of 5% of the existing seed bank. A small percentage, but given the numbers in table 3, potential a significant contributor. Hawkey's water traps collected 900 barnyard seeds (*Echinochloa spp*) by the end of the last irrigation.

Soil Structure

The Warren experiment has shown the soil following a field pea treatment to be the most stable soil. Dr Nilantha Hulugalle is suggesting the high nitrogen status due to the legume input plus the extra organic matter has increased the microbial stabilisation within the soil. The legume stubble is rapidly decomposed into the system causing improved soil aggregates at the surface. This is often the visual effect growers of legumes comment on. However this benefit is not reflected in the subsequent cotton crop surface structure. When the rotation was completed and treatments were all planted to cotton, assessment indicated the overall change in soil structure was minimal. The only rotation that is suggesting a long term improvement in structure is the wheat systems. These systems undergo a slow decomposing of the stubble, resulting in a continual flux of organic carbon into the cropping system. Research by Hulugalle (1998) suggested a minimum tillage program of cotton - wheat was more effective in cycling carbon and improving structure than a continuous cotton treatment.

Soil Fertility

At Merah North Dr Hulugalle, has reported no significant change in organic carbon levels since 1993. Despite the values being non significant, there was a trend towards a decline in organic carbon. With the continuous cotton and the long fallow treatments having the higher levels. This can be explained by the Merah North site, has a saline subsoil and, of the rotational crops grown, the cotton treatments are more tolerant to these conditions. Allowing better growth and more carbon. Complementing this is the sites clay mineralogy and the high levels initially of organic carbon at this site. The site has a high level of smectite which binds and protects what carbon is available, reducing the breakdown rate.

At Warren, the level of smectite is lower and the overall total organic matter levels are slowly increasing with time due to less clay protection. There has been a slight decrease in pH, probably caused by the mineralisation of the organic matter, dissolving the calcium and magnesium carbonates into available calcium and magnesium. Abdul Conteh research supports the total carbon results after measuring the liable carbon percentage (this is the readily decomposable fraction of the total carbon). Since 1993 to 1996, the wheat, lablab and faba bean treatments at Warren have increased the liable carbon. Note: In any farming system, the total carbon level within the soil is dependent on the chemical nature of the carbon, the level of wetting and drying cycles to assist in decomposition and the volume of the carbon source that is added initially.

Nutrition and Management

The CRC experiments have all involved green manured legume crops. Weed management problems related to "in crop" herbicides options have already been mentioned. For winter legumes the sowing date is critical. The nitrogen benefit from the legume crop is determined by the size of the crop; ie the biomass or drymatter production (Rochester per comm). Consequently, a late planted legume crop, will produce very little drymatter and therefore is only able to fix small quantities of nitrogen. While green manuring recycles most of the nitrogen into the system as organic nitrogen, the overall benefit to the subsequent crops would be limited. Conversely early sown crops can maximise their growth and nodulation, to optimise the fixing of atmospheric nitrogen. This applies to irrigated and dryland crops. A number of surveys and research experiments on the nutritional benefits of legumes to cotton have been conducted by Dr Rochester (see paper in these proceedings).

Within the CRC farming system experiments, the nutritional uptake in the cotton and rotation crop have been closely monitored. There appears to be little benefit from any rotation crop upon the accession of nutrient by cotton at Merah North. However some savings in nitrogen fertiliser inputs have been established from the green manured legume crops; these savings are already factored into the gross margins analysis for each cropping system (Table 4).

In 1996-97, nutritional uptake effects at Warren appeared to be significant according to Dr Hulugalle's research. Green manured legumes increased the removal of sodium from the subsoil and redistributed elemental sodium at the surface (range 25-40 kg sodium/ha). This is a small amount in reality and the impact will be limited on this heavy clay soil. Research will continue to monitor this redistribution.

Water Use Efficiency

Dr Sunil Tennakoon has analysed the 1996-97 cotton season water results from Merah North. He found the two treatments; Dolichos Lablab plus fertiliser and Faba bean rotations to be significantly more efficient user of water than the remaining systems, with the continuous cotton being the lowest. The results are represented in figure 3.

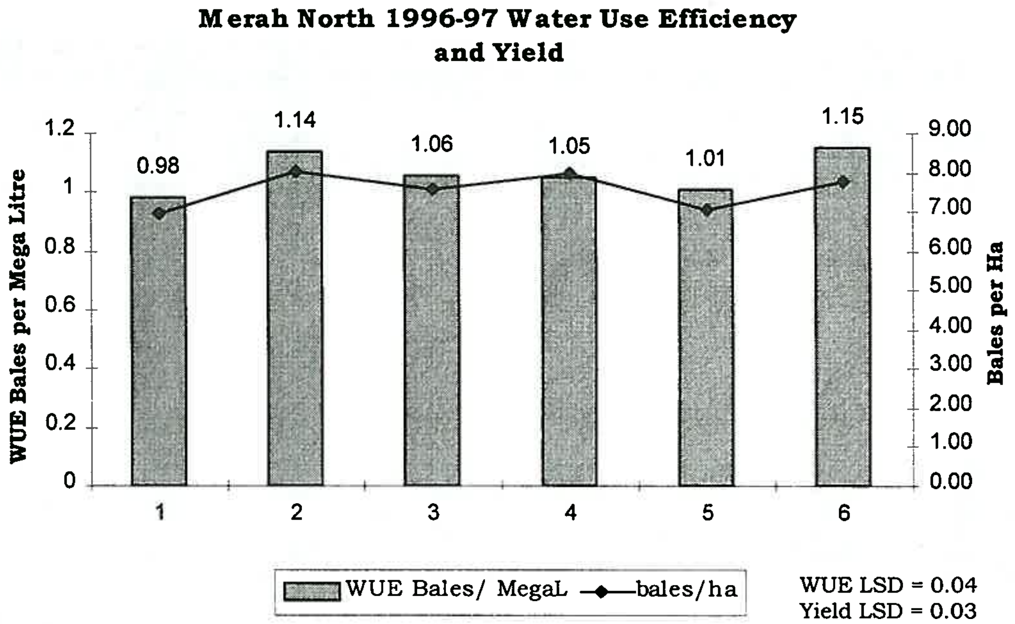


Figure 3: 1996-97 Water Use Efficiency and Yields for Merah North

Economic Aspects

Yields since 1993 at the Merah North site, indicate the faba bean system produced the highest average yielding cotton crops, followed by the wheat system. The Warren yields are indicating the two wheat systems produced the highest average yields. The continuous cotton system provided the lowest mean lint yields at both sites. Table 4 indicates the mean lint yield for each system and its associated gross margins.

Table 4 indicates the lowest yielding system had the best gross margin, since the continuous cotton had two more cotton crops within the time period. Combined with returns per bale being modest. At Warren, the two wheat gross margins are very similar and if this trend continues, with further rotation phases, the gross margins of the wheat systems will overtake the continuous cotton system. Especially when lint yields may continue to decline for the continuous cotton. At Merah North the faba bean system's gross margin was reduced in seasons where the crop failed to produce drymatter, and the associated establishment costs were still incurred. Despite yield performance, the gross margin was lower. The wheat yield (1995- treatment 4) failed to produce harvestable grain due to weather damage, causing a loss of income. Since 1993, the continuous cotton has been economically viable at this location.

Table 4 : Average Yields versus Gross Margins for the CRC Experiments since 1993-1996.

Merah North	Cotton Cotton	Cotton Faba beans	Long Fallow	Cotton Wheat	Cotton Lablab	Cotton Lablab P/K fert	
Average Yields '93-'96 b/ha	7.28	**8.03**	7.66	7.91	7.84	7.74	
Gross Margins $/ha	**8033**	3343	4471	4885	4111	4011	
Warren	**Cotton Cotton**	**Long Fallow**	**Cotton Field Peas**	**Cotton Wheat (Low)**	**Cotton Wheat (High)**	**Cotton Lablab**	**Cotton Faba beans**
Average Yields '93-'96 b/ha	6.00	7.80	8.41	**8.75**	8.53	7.73	8.16
Gross Margins $/ha	**7413**	5100	5122	6000	6025	5055	5146

Environmental Aspects

An environment can be defined by the farm boundary , a region, or catchment and beyond. In relation to the irrigated farming systems, cotton farms are only one component within catchment boundaries. Despite being one component, the impact is significant in terms of resource utilisation.

Warwick Mawhinney of Gunnedah's Department of Land & Water Conservation research station, conducted a survey of the average volume of pesticides used for the period 1996-97 in the Liverpool Plains NSW (table 5). This was compiled into a larger water quality study called "The 1996-97 Central and Northwest Regional Water Quality Program". The report detected endosulfan, profenofos, chlorpyrifos, proparite, parathion-methyl and diazinon. Once endosulfan is detected in a river, a breach of the Australian Aquatic Guidelines of 0.01 ug/L occurs. Of all the sampled valleys, only the Namoi River at Gunnedah returned a zero endosulfan level.

The herbicides detected include diuron, prometryn, metolachlor, atrazine, pendimethalin and fluometuron. Only the chlorpyrifos exceeded the ANZECC aquatic ecosystem guideline values and this was on three occasions in autumn and winter (outside the cotton season). Atrazine exceeded the Australian drinking water action guideline (0.5 ug/L) in 8.5 % river samples from November to March from irrigation agricultural areas. An important point is these samples included inputs of chemicals from other industries beside the cotton industry. The report suggest for the survey period, the catchment experienced higher rainfall periods that may of contributed chemicals to the river from storm water as either runoff or farm escapes. Liverpool Plains ground water sampling has detected low levels of metolachlor, simazine, trifluralon and atzarine up to 30 m in depth (Timms, 1997). Since the farming system involves rotation crops that contribute to the environment's pesticide load, cotton growers should be aware of pesticide movement.

Table 5: Summary of Chemical used within the Liverpool Plains in 1996-97

Crop	Total Kg Chemical	% of Total	Hectares Planted	Kg / Ha
Winter Cereals	165 752	16.9	109 310	1.52
Summer Cereals	410 380	41.9	75 694	5.42
Irrigated Cotton	284 885	29.1	19 160	14.87
Dryland Cotton	118 331	12.1	8 970	13.19
TOTAL	979 348	100	213 134	

Source : Mawhinney (per comm), 1998

High nutrient loads with low river flows are always of concern for blooms of blue green algal. For this reason, level of nitrates and phosphorus are being monitored constantly. The survey estimates the total annual phosphorus load into the north western section of the Barwon Darling system to be in excess of 460 tonnes. The Namoi River contributes 35% of the water flow but 65% of the phosphorus load (DLWC, 1997). Like previous studies, this phosphorus load was contributed to significantly by urban sewage works, however agricultural sources would still contribute to the total. To a irrigated farmer, this enforces the need to have a fully reticulated water system in line with the cotton industry's BMP.

Erosion Concerns

Sediment movement in an irrigated farming system can occur off farm and off field, in times of excess stormwater. Silburn(1994), conducted experiments on irrigated farms comparing bare soil and covered soil. The field was monitored for Endosulfan, since there is a correlation between endosulfan and sediment movement. Table 6 illustrates the filtering of runoff, resulting in the pesticide load removed under the wheat system being significantly reduced.

Table 6 : Effects of Stubble Cover in Irrigation Furrows

Treatment	Runoff mm	Soil Loss (t/ha)	Clay sized in runoff % Sediment	Clay sized in runoff t/ha
Covered	9.5	2.3	16.0	0.36
Bare	32.0	20.0	3.5	0.71

Effect of cover = 2t/ha wheat straw, Applied 95 mm/hr rain for 45 minutes

Source : Silburn 1994.

Possible Future Direction

Waters and Yule (paper in these proceedings) are currently experimenting with a system of double cropped wheat. Utilising the retention of standing stubble from the wheat for the purpose of controlling sediment and pesticide movement. Findings suggest significant (70%) reduction in total soil movement after 6 irrigations under the stubble treatment. Anchorage of the sediment is achievable by the protection of the erosion susceptible points within the field. Those points are the furrow side, which incur rain drop impact and this can be alleviated through the use of stubble. Effectively reducing the erosion component that minimises off farm pesticide movement. An additional observation, is the reduction in attractiveness of cotton planted under standing stubble to heliothis, resulting in noted spray savings.

Rotation stubble retained in a standing configuration can cause concerns with bed shape integrity, machinery limitations for planting, irrigation blockages, weed control within the stubble, fertiliser application, disease control, and compliance with pupal control.

A system could be developed which consists of the following: The use of more granular herbicides to increase weed contacts; zonal tillage or precision planted rows while maintaining stubble cover on the bed. This would mean strategic nitrogen placement. This system should allow improved infiltration based on the concepts used by the dryland community of water entry by natural cracks. Current work is concentrated on cereals, however the option of legumes as a cover crop, should not be dismissed.

Conclusion

Trends are developing as a result at the CRC farming systems sites. The yields at both sites are ranking the continuous cotton systems as the lowest average value. Economically, all treatments are lower, than the continuous cotton. However if the wheat and legumes systems continue to perform and the continuous cotton yields continue to decline, this trend will be reversed. Each system can provide advantages and disadvantages to the production system. Legumes can lower the dependence on artificial nitrogen, while wheat can provide good soil structure attributes.

With this basis, the industry should view with an open mind the research focusing on cover crops and fully retained stubble under minimum tillage. The adaptation of these principles into an irrigated farm is certainly a positive step towards anchoring sediment and minimising off field pesticide movement.

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