

Part 1 - Summary Project Details

Final Report

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Best Management Practices to Minimise Pollutant Transport from Cotton Production Systems

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Best Management Practices to Minimise Pollutant Transport from Cotton Production Systems

CRDC FINAL REPORT

By David Waters
Department of Natural Resources and Mines
February 2001

Plain English Summary

The transport mechanisms and fate of cotton pesticides and nutrients were investigated as part of a major R&D program undertaken by the cotton industry in the early 1990 s. Key findings were that the highest risk of moving pesticides off site occurred:

- early in the growing season
- during storms that caused runoff and sediment losses
- where soil cover was low.

To reduce the risks, growers sought practical solutions for reducing pesticide movement.

In 1997 after a series of industry and grower meetings, the project Best Management Practices to minimise Pollutant Transport from Cotton Production Systems was developed. The aims were to develop practical and innovative management practices that would reduce off-site movement of soil, water, nutrient and pesticides. In particular, the goal was to apply small scale research findings on farm at the paddock scale to assess the practicality and feasibility of growers implementing the systems. Trials began first in the Emerald Irrigation Area (EIA) and extended into NSW in the second year.

Three management practices were trailed on farms :

1. wheat-cotton double crop rotation,
2. polyacrylamide (PAM) application to irrigation water
3. planting of vegetative filter strips in irrigation channels.

Sediment, nutrient and pesticide movement from rainfall and irrigation runoff were monitored over two seasons at a paddock scale of 30 Ha for the three treatments and an adjacent conventional cotton treatment.

All three techniques were highly effective at reducing soil erosion, nutrient and pesticide movement. Wheat-cotton rotation reduced soil erosion by 70% and endosulfan concentrations by 40%. Three less insecticide sprays were needed for the wheat-cotton rotation crops. PAM applications to irrigation water reduced sediment loads in runoff by 80%. Vegetative strips filtered runoff water entering tail drains and trapped 65-85% of total endosulfan and 67% of chlorpyrifos in the sediment from runoff water.

The project has built on the research principles developed in the CRDC Minimising Pesticides in the Riverine Environment Program.

Three practical techniques developed from the work are now being used by growers to reduce soil erosion, nutrient and pesticide movement leaving farms. The on farm action research proved to be highly effective for maintaining grower involvement and adoption of research.

1. Outline the background to the project

The cotton Industry funded program Minimising Pesticides in the Riverine Environment (1993-1996) found unacceptable levels of soil, insecticides, herbicides and nutrients in surface runoff water moving off paddocks and farms. This program also identified transport processes particularly the dominant role of (a) sediment as a pollution carrier, and (b) the major contribution made by storms to the process. High risk periods were found to be early season (when ground cover is low) and soon after chemical application (when field burdens of pesticides are high). Research in the grain industry has identified the capacity of stubble cover to reduce erosion and winter cereals provide the most effective cover. Plot scale (< 1ha) research in cotton found that a significant reduction in pesticide movement was achieved from surface treatments such as wheat stubble. Past erosion research shows that cover is the most important variable because cover improves infiltration, reduces erosion, slows runoff, increasing deposition.

Winter cereal stubble provides excellent cover because of high plant populations, strong straw, high stubble amounts. Stubble is reduced mainly by cultivation. Endosulfan intercepted by stubble is rapidly volatilised thus reducing the amount of chemical available for transport.

The broad project aim was to develop management strategies to minimise off-site movement of soil, insecticides, herbicides and nutrients at the paddock or farm scale. In particular, this project aimed to apply principles from the small scale studies with wheat stubble, at the paddock scale, and to assess the practicality and feasibility of this management practice to minimise off site movement of soil, insecticides, herbicides and nutrients. The project also looked at two other innovative management techniques to reduce pollutant transport off farm, application of PAM to irrigation water and using vegetative filter strips.

In year two of the project, sister sites were established in northern NSW by Steve Kimber of NSW Department of Agriculture.

2. List the project objectives and the extent to which these have been achieved

Objective 1

**Develop practical and innovative management practices to reduce off farm movement of sediment, insecticides, herbicides and nutrients.*

Objective 1 has been met to a much greater extent than the project ever believed could be achieved in the 3 year time frame. Three management practices were trialed on farms in the Emerald Irrigation Area initially and then the Wheat cotton rotation work was extended to northern NSW cotton areas.

The first management practice was double cropping of cotton into standing wheat stubble. Whilst in year 1 this was tested on one farm by the third year of the project, 15 farmers had planted cotton into standing wheat stubble. The substantial reductions measured in chemical and sediment concentrations moving off -site in irrigation and storm runoff have been widely documented. The discovery of a reduced insect pressure in cotton planted into wheat stubble, resulted in an even greater reduction in chemical concentrations moving off site than just the stubble alone.

The second management practice investigated was the application of a flocculant or Polyacrylamide (PAM) to irrigation water to flocculate out any suspended sediment in runoff water hence containing any sediment and the associated sediment bound pollutants to the cotton field. Again adoption was rapid when supported by the on farm research data with 22 growers adopting the practice in three years.

The third practice evaluated was the use of vegetative filter strips (vetiver grass) to filter runoff water once it had left the cotton field. Filter strips have not been widely adopted in an irrigated cropping system as yet, however the technique proved highly effective at filtering sediment and sediment bound pollutants. Only three growers adopted the technique over the three years. Growers were reluctant to adopt the practice due to concerns about tail water back up on small farms due to low slopes in irrigation channels. Whilst growers were not quick to adopt the technique, the Department of Natural Resources who manage the irrigation drainage network, adopted the technique as a means of reducing pollutant movement through the drainage network once the water had left the cotton farms.

Objective 2

**Identify relationships between management practices and pollutant transport processes at the farm scale.*

This study focused on the practicality of adopting management options previously demonstrated. Where alternative management practices were trialed, adjacent conventionally farmed paddocks were instrumented to quantify the effectiveness of the practice to reduce sediment, nutrient and pesticide loads leaving the paddock or farm. Detailed investigation of relationships between runoff rate, erosion rates, nutrient and pesticide concentrations and management for various treatments was successfully carried out as outlined in section 4 & 5 of this document.

3. Detail the methodology and a justification for the methodology used

Paddock scale (25Ha) monitoring of sediment, nutrient and pesticide movement from rainfall and irrigation runoff, was carried out on two typical irrigated cotton farms in the Emerald Irrigation Area, commencing in October 1997. Two Stage rectangular weirs were fitted at the tail drain outlet of two fields on two farms. Runoff depth was continuously logged at 2 minute intervals using ultrasonic transducers attached to monitor sensor data loggers. Sediment, nutrient and pesticide samples were collected on a flow weighted basis using Issco pumping samplers (Figure 1). Runoff, sediment nutrient and pesticides were monitored all year round and additional hand sampling was carried out during storm events. Rainfall was monitored using a monitor sensor pluviometer and data logger on a 1 minute interval. Detailed records of farming practices, irrigation practices, crop growth and entomology were recorded throughout the season.

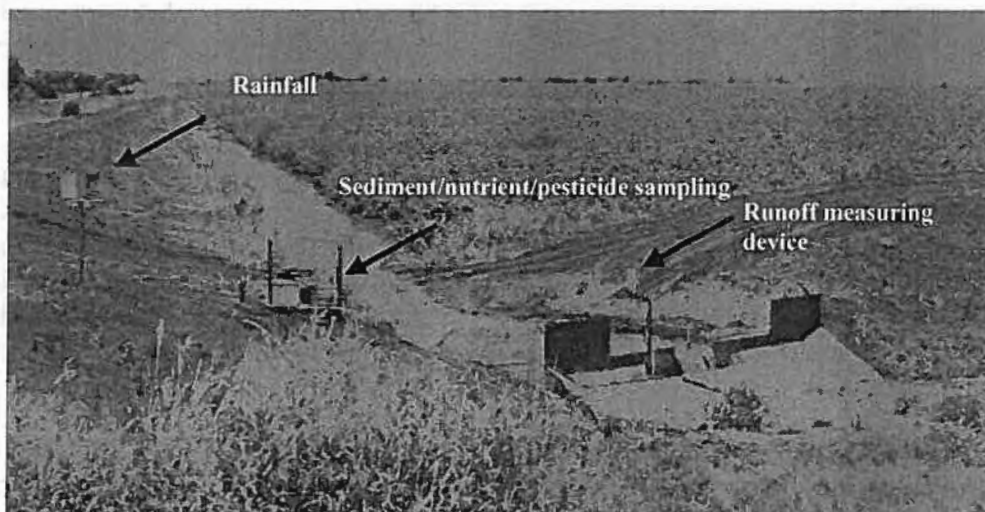


Figure 1: 30Ha Conventional Cotton bay instrumented to measure irrigation and rainfall runoff and sample runoff for sediment, nutrient and pesticides.

For the filter strip treatment, vetiver grass was planted in two strips at the taildrain outlet perpendicular to the direction of water flow out of the tail drain (Figure 2). Plastic sheeting (10 x 20m) was placed 10m upstream, 0 m upstream and 10m downstream of the grass to assess the trapping efficiency of the grass. Deposited sediment remaining after rainfall and irrigation was weighed and sub samples collected for analysis of nutrient and pesticide concentrations.

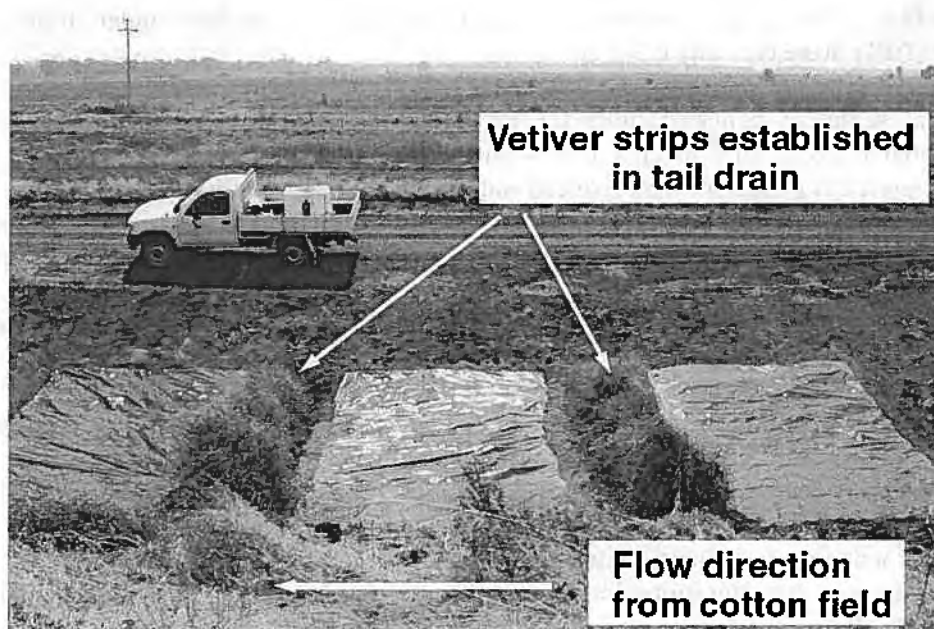


Figure 2: Vetiver grass filter strips planted in tail drain

Paddock scale as opposed to furrow scale monitoring was chosen because this study focused on the practicality of implementing furrow scale findings from previous studies and applying them to a farm scale. Treatments were not replicated due to the enormous costs and the difficulty in finding replicates which have similar history, size and farming practices.

4. & 5 Results & Discussion

Specific Findings

- Wheat-Cotton rotation reduced erosion by 70% over 6 irrigations
- Average endosulfan concentration in Conventional cotton treatment (2.9ug/l) were three times greater than wheat-cotton (0.91ug/l)
- For wheat cotton rotation sediment concentration leaving the field under high stubble cover (70%) were typically 0.5-3 g/l
- Soil movement was reduced by 80% for PAM applied to irrigation water over 6 events
- Typical sediment concentrations for PAM applied to irrigation water were 0.5 g/l compared to 2.6 g/l for Conventional Cotton
- PAM applied to irrigation water reduced endosulfan concentration in runoff by 60% .
- Highest sediment concentrations for conventional cotton were measured from pre-plant watering to Canopy closure typically 3-10ug/l with sediment concentrations dropping to 1-2 g/l towards the end of the season
- Average soil loss from irrigation was 1.1 t/ha/irrigation or 6.6t/ha for 6 irrigations with maximum of 1.8t/ha from a single irrigation
- Runoff ranged from 15-25% of water applied over 2 seasons
- Sediment concentration leaving the field were typically 6-15 g/l for conventional cotton during storms , 2-6g/l for irrigation
- A single early season rainfall runoff event generated the equivalent soil loss as 6 irrigation events(6.1t/ha) the previous season
- Average sediment concentrations were 20% higher for rainfall runoff across treatments
- Total Nitrogen concentrations for rainfall were approximately double those of irrigation events for all treatments
- Total phosphorus (TP) concentrations in rainfall runoff were three times greater than irrigation.
- Vetiver hedge trapped 65-85% of total endosulfan in the sediment from runoff water and 67% of chlorpyrifos
- Total nitrogen levels in sediment trapped upstream of vetiver strips were 73% higher than downstream sediment and total phosphorus 52% higher

Rainfall

We were fortunate in that we sampled two distinct seasons : A dry season where runoff was dominated by irrigation and secondly a season with well above average rainfall, where rainfall runoff dominated. Rainfall for the two seasons demonstrated the extremes of the Central Queensland environment. The total rainfall from July to June for 1997/98 was 386mm in the lowest 10% on record. In contrast the 1998/99 season produced above average rainfall, double the previous season (767mm). The 1998/99 season had record breaking rainfall totals for the months August, September and October with monthly totals in the top 10% on record (Figure 3). Rainfall for 1997/98 was well below the median long term rainfall or decile 5 for all of the cotton growing period and 80% exceeded the median rainfall for 1998/99. The contrasting rainfall for the two seasons is reflected in the runoff and erosion results.

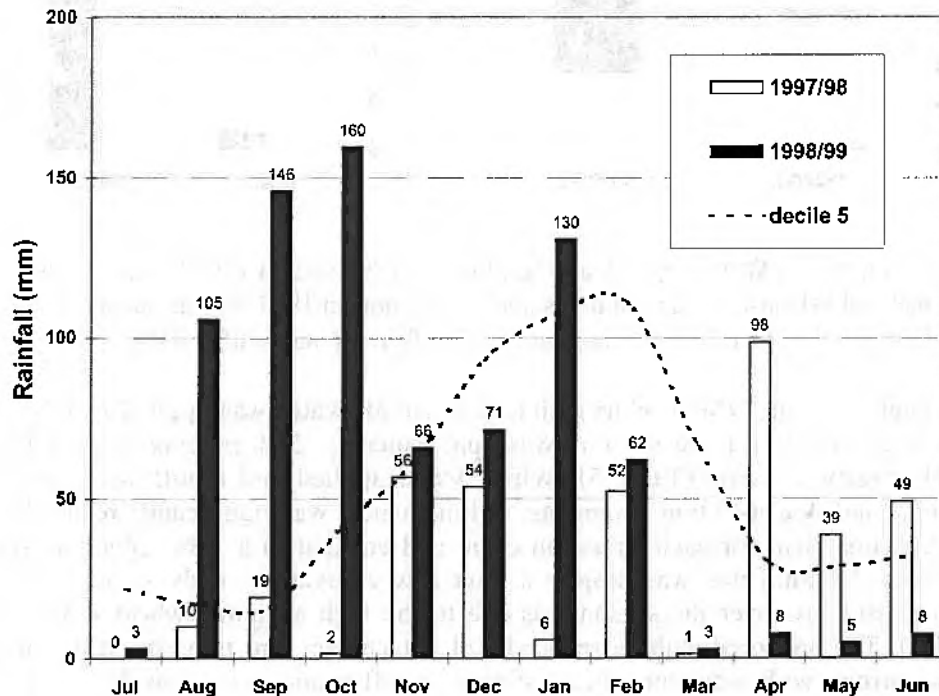


Figure 3 : Monthly and long term median rainfall (ie decile 5) for experimental sites in 1997/98 and 1998/99 cotton seasons.

Runoff and soil movement

Runoff depth, sediment, nutrient and pesticide samples were collected for all irrigation and rainfall events over 2 seasons. Data was collected for (Conventional Cotton and Wheat Cotton rotation) and (PAM & Conventional Cotton treatments). A summary of runoff and soil movement totals for each rainfall/irrigation event are given in Table 5-8 of Appendix A.

There were no clear differences in runoff volumes or rates between treatments as irrigation inflow was managed by the grower with the aim of ensuring uniform wetting of furrows not to minimise tail water loss. However, significant savings in irrigation runoff are achievable for both Wheat cotton and PAM treatments (Doherty 1999).Runoff in the second season was 40% greater than the first season due to high rainfall totals. Soil movement was reduced by 70% for the wheat cotton rotation from irrigation events and 80% for PAM treatment. Soil loss was four times greater in the second season and sediment concentrations were 20% higher, again due to the high rainfall totals early season.

Wheat/cotton double crop

In 1997/98 approximately 90% of runoff was from irrigation, due to the below average rainfall for the year (Figure 4). There was no clear difference in the volume of irrigation water applied between Wheat-Cotton and Conventional Cotton treatments apart from the pre-plant irrigation. Additional water was applied for the wheat/cotton treatment at pre-plant (approx 50mm) to account for the additional extraction by the wheat crop. Variations in irrigation water between the 2 treatments was a function of irrigation management rather than treatment effects.

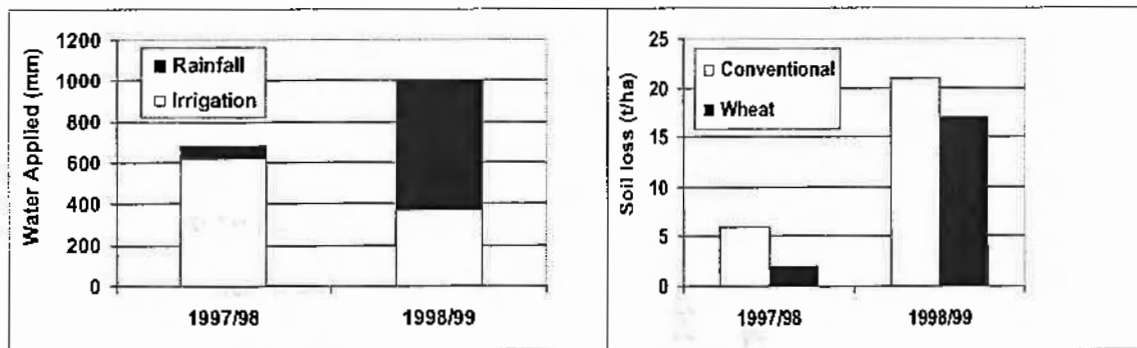


Figure 4 : Summary of Water applied and soil loss for 1997/98 and 1998/99 seasons for Conventional and Wheat-Cotton treatments... 91% of runoff in 1997/98 was due to irrigation runoff and rainfall 9%, In 1998/99 Irrigation — 37%of runoff and rainfall 63%.

Approximately 700mm (7ML) of irrigation and rainfall water was applied to the crop in 1997/98. Total runoff for the season was approximately 20% ranging from 9-35% for individual irrigation events (Table 5). Whilst water applied and runoff were similar for Conventional and Wheat-Cotton treatments, soil movement was significantly reduced for the wheat/cotton treatment for each irrigation event and equated to a 70% reduction over the season (6.6 v 2.2 t/ha) this was despite 2 inter row cultivations early season. The large reduction in soil loss over the season was due to the high anchored wheat stubble levels (1500kg/ha). The anchored stubble reduced soil detachment and transport in runoff from within the furrows with sediment concentration in runoff maintained below 2g/l at all runoff rates (Figure 5).

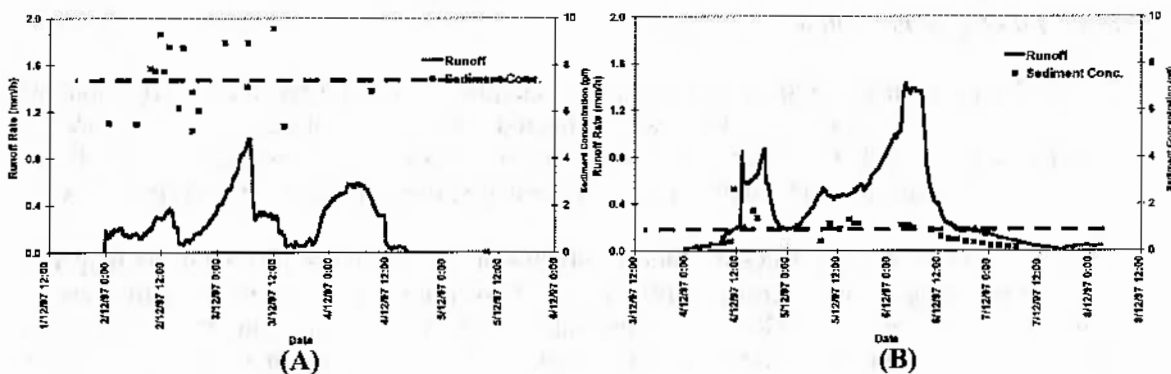


Figure 5 : Runoff hydrographs and sediment concentrations for (A) conventional and (B) wheat/cotton double crop treatments —irrigation 2. Soil loss for the event was 1.3 t/ha and 0.3t/ha respectively. Average sediment concentrations were 7.0 g/l and 0.9g/l respectively (dashed lines in graph).

1998/99

Due to the extremely wet start to 1998/99 a high proportion of the wheat stubble was burnt and some inter-row cultivation carried out prior to cotton planting to dry out the field. The loss of stubble resulted in 600 kg/ha of wheat stubble being retained less than half of the previous season. The loss of wheat stubble and hence soil ground cover was reflected in the reduced treatment effects. Soil loss for the season for Wheat-Cotton was 20% less than Conventional Cotton (Table 6). The high rainfall early season resulted in no irrigation water being applied until the middle of December. In contrast to the 1997/98 season (4 storm events), the 1998/99 season had 17 runoff producing rainfall events. The 118mm on the 25/10/98 caused about 25% of the season soil loss which again highlights the high risk of soil erosion at a time of the season when ground cover is low, inter-row cultivation and storms are frequent (Table 6).

Comparing the first season, dominated by irrigation runoff and the second season, dominated by rainfall runoff several important conclusions can be drawn from the data:

- Runoff in 1998/99 was 40% higher
- 1998/99 had three times more soil loss
- Average sediment concentrations were 20% higher in 1998/99

NSW Experience

The NSW field site was based at Darling Farms, Bourke. Runoff, sediment and pesticide samples were collected for wheat cotton and conventional fields.

Sediment load was reduced by almost 90 per cent during the first irrigation and about 60 per cent in the second irrigation, in the wheat stubble field, compared to the bare fallow cotton. This reduction in early season erosion is critical, as it coincides with the period of endosulfan use and when field cover levels are normally low, resulting in higher pesticide load on the soil. During the following irrigations, the amount of soil leaving the two fields was approximately equal.

During the first irrigation, endosulfan concentration in water leaving the wheat stubble field was reduced by 80% relative to the bare fallow field. This reduction is related to the reduction in soil movement, but also is a reflection of the fact that the bare fallow field had received a recent endosulfan application. During subsequent irrigations, the endosulfan movement from the wheat stubble field was always less than the bare fallow field. On average, the endosulfan concentration in the tail water of the stubble field was approximately three and a half times less than the concentration of the wheat stubble fields.

For further information on NSW work see attached paper

PAM applied to irrigation water

1997/98

In 1997/98 total water use for 6 of the 7 irrigations was approximately 600mm and if we assume 1ML/ha or 100mm used for the pre-plant irrigation then water applied would correspond to the seasonal application on the Black farm (Table 7). Runoff ranged from 11-18% of applied water for individual irrigation events and averaged 14% for the season on both conventional and PAM treatments. As found with the wheat/cotton treatment there was no significant savings in water application for the PAM treatment and runoff was highly dependant on management .not the application of PAM. There was an 80% reduction in soil movement over 6 irrigations (2.3 v 0.4 t/ha). Whilst this is an encouraging result, PAM has little impact under rainfall runoff. Therefore usefulness of PAM is dependant on the ratio of rainfall to irrigation runoff.

1998/99

The high rainfall totals recorded in August to October 1998/99 delayed irrigation until 29/11/98 therefore limiting the amount of PAM used. PAM was applied to 5 irrigations from November with significant reductions in soil loss over the season (Conventional Cotton 26.2 t/ha v PAM 10.5t/ha). The reduced soil loss was due to a reduction in sediment concentration in runoff where PAM was applied with the average sediment concentration for PAM treatment half the concentration of Conventional Cotton. Runoff for the season was 30% of water applied for both Conventional Cotton and PAM and runoff was predominantly from rainfall not irrigation (Table 8).

Pesticide and nutrient movement in runoff

Pesticide and nutrient samples were collected for all irrigation and rainfall events over 2 seasons. Data was collected for 1) Conventional Cotton & Wheat Cotton and 2) PAM & Conventional Cotton treatments. A summary of pesticide concentrations (Table 1&2) and nutrient concentrations (Table 3&4) for each rainfall/irrigation event are summarised below.

Pesticide concentrations leaving the field were highly variable with highest concentrations early season and soon after application. The two main chemicals recording high concentrations were Diuron and Endosulfan. Average endosulfan concentration in wheat-cotton was 40% lower than conventional cotton (2.9ug/l C-C, 0.9ug/l W-C). PAM applied to irrigation water reduced endosulfan concentration in runoff by 60%.

Total Nitrogen (TN) concentrations for rainfall were approximately double those of irrigation events for all treatments. Similarly with total phosphorus (TP) mean concentrations were three times greater than irrigation.

Pesticides

Concentrations for four of the more frequently used insecticides and four herbicides were sampled over two seasons and are given in Tables 1&2. Pesticide concentrations leaving the field were highly variable with highest concentrations early season and soon after application. The two main chemicals recording high concentrations were Diuron and Endosulfan. Mean Diuron concentrations were 1000 times greater than guideline values and peak values of 170ug/l were recorded during an irrigation soon after application. High levels of Endosulfan were detected with average concentration of 2-6ug/l particularly early season on the 2 farms where monitoring occurred. The high concentrations of Endosulfan can also be attributed to the number of applications with 3-4 applications occurring during a season.

Highest concentrations were found in runoff soon after application and significantly reduced by the end of the season. Herbicides which are generally a one off application had highest concentrations around planting time when some inter row cultivation occurs.

Insecticide concentrations were highly variable between runoff events depending on when application occurred. Maximum concentrations occurred in the first 3 months from planting and significantly reduced (0-2ug/l) by the end of the season.

Table 1: Pesticide concentration - mean, range and number of samples collected from rainfall & irrigation for conventional and wheat/cotton double crop cotton over 2 seasons.

Chemical	Conventional Cotton				Wheat/ Cotton			
	Number Samples	Mean (ug/l)	Min (ug/l)	Max (ug/l)	Number Samples	Mean (ug/l)	Min (ug/l)	Max (ug/l)
Trifluralin	41	0.54	0.06	1.00	43	0.30	0.02	2.00
Prometryne	41	0.66	0.03	5.40	43	12.13	0.03	99.00
Pendimethalin	41	0.06	0.05	0.17	43	0.55	0.05	3.59
Diuron	41	39.16	0.15	170.00	43	3.99	0.13	9.50
Total Endosulfan	41	2.94	0.42	10.50	43	0.92	0.25	4.50
Chlorpyrifos	41	0.95	0.05	5.37	43	0.36	0.05	8.00
Profenofos	41	0.14	0.05	0.38	43	0.17	0.10	1.65
Parathion	41	0.08	0.01	30.00	43	0.07	0.05	0.10

Table 2: Pesticide concentration - mean, range and number of samples collected from rainfall & irrigation for conventional and PAM applied to irrigation water over 2 seasons.

Chemical	Conventional Cotton				PAM			
	Number Samples	Mean (ug/l)	Min (ug/l)	Max (ug/l)	Number Samples	Mean (ug/l)	Min (ug/l)	Max (ug/l)
Trifluralin	36	0.95	0.05	0.80	44	1.00	0.04	20.00
Prometryne	36	1.47	0.02	63.00	44	0.87	0.05	6.59
Pendimethalin	36	0.04	0.05	6.10	44	0.03	0.05	0.16
Diuron	36	7.74	0.25	51.40	44	8.60	0.40	68.90
Total Endosulfan	36	6.75	0.05	126.00	44	2.89	0.15	9.60
Chlorpyrifos	36	0.23	0.04	1.50	44	1.61	0.05	43.10
Profenofos	36	0.09	0.05	29.00	44	0.30	0.10	7.41
Parathion	36	0.08	0.05	0.10	44	0.09	0.10	0.91

Treatment Effects

Average endosulfan concentration of 3.8ug/l for Conventional Cotton and 1.0 ug/l for Wheat-Cotton were typically measured. The reduction in concentration of Endosulfan for the Wheat-Cotton was due to a reduction in application of Endosulfan applied to Wheat-Cotton and secondly the higher cover levels provided by the stubble limiting the amount of Endosulfan reaching the bare soil surface hence being available to move off the field in runoff and bound to sediment.

PAM applied to irrigation water reduced endosulfan concentration in runoff by 60% over two seasons. PAM was highly effective at removing suspended sediment in runoff. Endosulfan concentrations were reduced by a similar amount, which was attributed to the strongly sediment binding nature of this chemical.

Nutrients

Typical Total Nitrogen (TN) concentrations leaving the field in runoff ranged from 9-15mg/l. Nitrogen concentrations remained at these levels for 8-10weeks after planting declining to 2mg/l by the last irrigation. Whilst mean concentrations ranged from 9-15mg/l TN concentrations for rainfall were approximately double those of irrigation events for all treatments. For example mean TN concentration for 6 irrigations for conventional cotton was 4.5mg/l compared to 18.4mg/l for all rainfall events in year 2 with similar Nitrogen fertiliser application. Similarly with total phosphorus (TP) mean concentrations ranged from 0.3-1.1mg/l with rainfall runoff concentrations being three times greater than irrigation (storm 1.29 mg/l, Irrigation 0.41mg/l).

Table 3: Nutrient concentration - mean, range and number of samples collected from rainfall & irrigation for conventional and wheat/cotton double crop cotton over two seasons.

	Conventional Cotton				Wheat/ Cotton			
	Number Samples	Mean (mg/l)	Min (mg/l)	Max (mg/l)	Number Samples	Mean (mg/l)	Min (mg/l)	Max (mg/l)
Total Nitrogen	32	9.15	0.32	40.18	38	12.9	1.15	24.4
Total Phosphorus	32	1.1	0.12	2.8	38	0.82	0.15	5.3

Table 4: Nutrient concentration - mean, range and number of samples collected from rainfall & irrigation for conventional and PAM applied to irrigation water over 2 seasons.

	Conventional Cotton				PAM			
	Number Samples	Mean (mg/l)	Min (mg/l)	Max (mg/l)	Number Samples	Mean (mg/l)	Min (mg/l)	Max (mg/l)
Total Nitrogen	27	15.6	1.04	83.96	28	8.35	1.05	42.15
Total Phosphorus	27	0.84	0.09	3.9	28	0.55	0.13	1.8

Treatment Effects

Total nitrogen concentrations for Wheat-Cotton were 25% higher than Conventional Cotton due to additional nitrogen being added to irrigation water. Phosphorus concentrations were 25% less over 2 seasons, however treatment differences were greater in the first season (70% reduction in phosphorus concentration) where high stubble cover was achieved.

TN and TP concentrations were significantly reduced where PAM was applied to irrigation water. The reduction in TP in particular is attributed to the removal of sediment bound phosphorus by the PAM.

Vegetative Filter Strips

Soil samples were collected at various distances upstream and downstream from the vetiver hedges (Figure 6&7) and analysed for selected organochlorine (α , β and sulfate endosulfan) and organophosphates (chlorpyrifos, parathion and profenofos) and total nutrients. Soil and plant samples were collected at the completion of final irrigation in March 1998 and February 1999.

Initial findings indicate that vetiver grass appears to be effective at trapping the sediment bound chemicals: endosulfan and chlorpyrifos, two of the more commonly used pesticides.

During the first year of growth the vetiver hedge trapped 86% of total endosulfan in the sediment from runoff water and 67% of chlorpyrifos (Figure 6). In the second year 65% of total endosulfan was trapped by the grass (Figure 7).

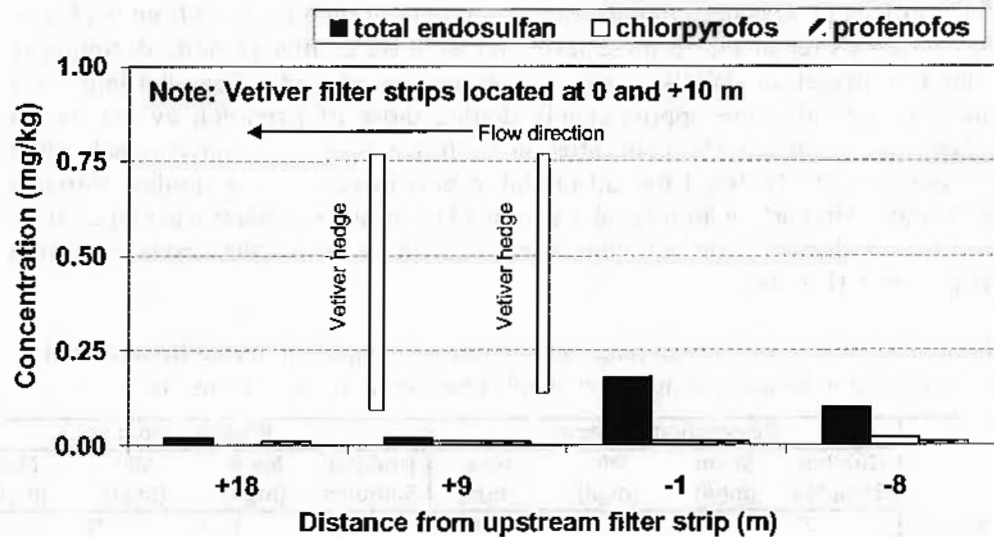


Figure 6: Pesticide concentration in deposited soil up and downstream of vetiver filter strip collected March 1998.

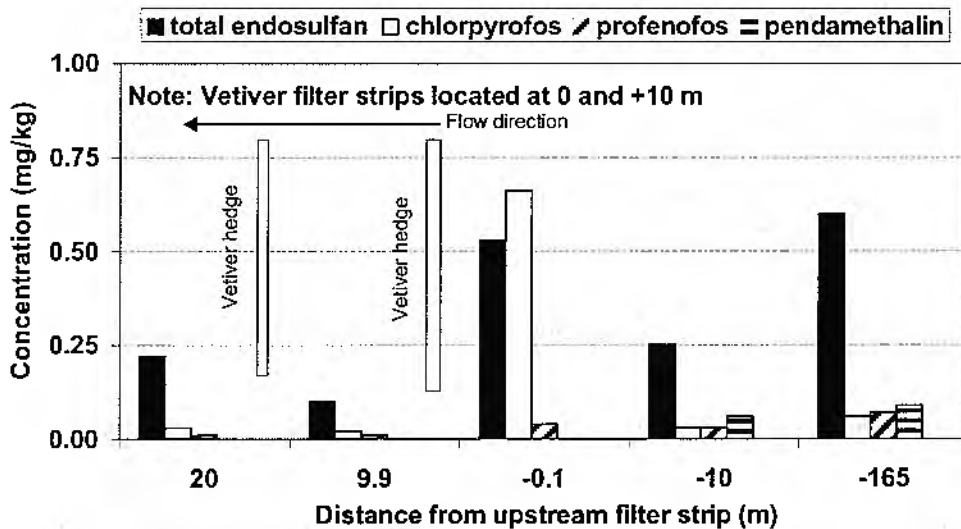


Figure 7: Pesticide concentration in deposited soil up and downstream of vetiver filter strip collected February 1999.

Soil samples were also analysed for major nutrients. Results of major nutrient analyses for the second year found a significant amount of nutrients were trapped by the vetiver hedges. During the second year, total nitrogen levels in sediment trapped upstream of vetiver strips were 73% higher than downstream sediment and total phosphorus 52% higher.

Entomology Results

The unexpected finding of reduced endosulfan applications, lower heliothis numbers and increased predators, in the Wheat cotton treatment, has been well documented in Cotton Conference Proceedings (Refer section 10). The findings have positive implications for reducing off-site movement of chemicals.

Analysis of research outcomes compared with objectives

Objective 1

***Develop practical and innovative management practices to reduce off farm movement of sediment, insecticides, herbicides and nutrients.**

Three management practices were trialed on farms in the Emerald Irrigation Area. The first was double cropping of cotton into standing wheat stubble. There was substantial reductions in measured chemical and sediment concentrations moving off-site in irrigation and storm runoff events. The discovery of a reduced insect pressure in cotton planted into wheat resulted in an even greater reduction in chemical concentrations moving off site.

The second, was the application of a flocculant or Polyacrylamide (PAM) to irrigation water to flocculate out any suspended sediment in runoff water hence containing any sediment and the associated sediment bound pollutants to the cotton field. Again adoption was rapid when supported by the on farm research data with 22 growers adopting the practice in three years. It was demonstrated that sediment and chemical concentrations in irrigation runoff can be dramatically reduced with low dosages of PAM.

The third treatment was the use of vegetative filter strips (vetiver grass) to filter runoff water once it had left the cotton field. Filter strips have not been widely adopted in an irrigated cropping system as yet, however the technique proved highly effective at filtering sediment and sediment bound pollutants. Only three growers adopted the technique over the three years.

In summary three practical, innovative and effective management strategies were developed and adopted during the project. Growers now have management options available and proven and need to adopt these sustainable practices to demonstrate the industries commitment to Better Management Practices.

Objective 2

**Identify relationships between management practices and pollutant transport processes at the farm scale.*

Where the alternative management practices were trialed, adjacent conventionally farmed paddocks were instrumented to quantify the effectiveness of the practice to reduce sediment, nutrient and pesticide loads leaving the paddock or farm. Results outlined in section 4&5 of the document clearly demonstrate the effects of the alternative management strategies on water quality leaving the field.

6. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. Where possible include a statement of the costs and potential benefits to the Australian cotton industry and future research needs.

The cotton industry has received criticism over the past decade because of the off farm movement of pollutants such as endosulfan in to the riverine environment. Minimising Pesticides in the Riverine Environment Program carried out by CRDC in the early nineties identified transport processes of pollutants and established that wheat stubble was effective at capturing some of the chemical applied, however grower adoption of the practice was minimal.

This project has already had a significant impact on the cotton industry with adoption going from zero to 60% of growers adopting techniques to reduce off site movement of pollutants in the Emerald Irrigation area in three years. In addition, growers in Condamine and Bourke have had similar success in 1999/2000.

It has been stated by many in the cotton industry that heliothis resistance is the major threat to the industry, the wheat/cotton double crop farming system has provided the cotton industry with an alternative management technique which not only reduces sediment and chemical movement off site by up to 70%, it has enabled growers to cut pesticide application for heliothis control by as much as 75%.

The economic benefits to the industry are enormous when considering the environmental, agronomic and economic benefits that have already been demonstrated by this farming system.

The project worked closely with the Department of Natural Resources State Water Projects and brought about a reduction in drainage levy to growers in the Emerald Irrigation Area were willing to adopt techniques which reduce off farm movement of sediment and pollutants.

Whilst it is hard to put a price on soil erosion to the cotton industry, erosion rates of 2-21 t/ha were measured over the trial period under conventional cotton farming practices. Where cotton was planted into wheat stubble and PAM was applied to irrigation this figure was reduced by as much as 70%. In dryland farming systems it has been shown that erosion

rates of this magnitude result in long term yield reductions. Similar effects could be expected if these erosion rates were to continue as per the past 15-20 years.

The project also offers many benefits to cotton growers who are looking to move towards ISO14001 accreditation by offering alternative proven management options to improve their environmental management.

Further research

This project has identified several techniques to reduce off site movement of sediment bound pollutants, however further work is needed to extend the work to look at whole farm containment and in particular containment of the more water soluble pollutants once they have left the field.

Further work is need in the entomology area to gain a clearer understanding of the effect of wheat stubble on heliothis behaviour and to take advantage of this unexpected benefit.

An effective means of applying Nitrogen fertiliser into cotton planted into wheat stubble is not available. Water run nitrogen has helped growers in this area however, it is inefficient and significantly increases nitrogen concentrations in runoff.

Water logging of young cotton is also proving a challenge to growers where cotton is grown on low slopes in standing wheat stubble. Further investigation of effective stubble quantities required and improved irrigation management would go a long way towards addressing this problem.

The presence of the wheat stubble in the crop has been shown to improves infiltration. Whilst there are many benefits for surface hydrology and water quality, the impacts on deep drainage have not been quantified.

The impacts of a wheat cotton rotation and or the use of PAM on deep drainage require further investigation.

7. Describe the project technology (e.g. commercially significant developments, patents applied for or granted, licenses, etc).

NIL

8. Provide a technical summary of any other information developed as a part of the research project. Include discoveries in methodology, equipment design, etc.

The major unexpected finding of the project was a reduction in early season insecticide sprays required on cotton planted into standing wheat stubble. Findings have been well documented refer Australian Cotton Conference Proceedings 1998, 2000.

9. State the recommendations on the activities or other steps that may be taken to further develop, disseminate, or to exploit the project technology.

The wheat cotton rotation system needs to be pushed in the southern cotton growing regions of QLD such as St George and Northern NSW by extension officers and researchers alike. The techniques adopted by growers in the project were initially seen as too difficult however on farm action research in the district proved to be the most valuable tool to achieve wide spread adoption by growers. Therefore, adoption by growers of any technique will be extremely difficult without some local guidance and or demonstration sites driven by

growers. Growers need to be encouraged to experiment with small areas initially to compare first hand alternative management practices.

Research projects such as this one are imperative in cotton growing districts as a means of assessing alternative management practices and to challenge growers current way of farming.

A brochure has been developed by Dave Waters and Dave Kelly (See Attached) to be distributed to all growers in the industry which answers many of the more commonly asked questions by growers.

This document will be dynamic and would need to be updated periodically as growers experiment and refine techniques.

Future updates of the BMP Manual needs to incorporate material on management practices which reduce off site movement of pollutants particularly if growers are looking to move towards ISO14001 accreditation.

10. List the publications arising from the research project.

Waters, D., Riches, S. & Kimber, S. (2000). Techniques to reduce off-farm movement of soil, water, nutrients and pesticides — Proc. 10th Australian Cotton Conference. Brisbane-Qld, August, (pp 241- 252).

Waters, D., Sequeira, R. (2000). Cereal Stubble and Trap Crops — - Proc.10th Australian Cotton Conference. Brisbane- Qld, August, (19-26).

Truong, P., Mason, F., Waters, D., Moody, P. (2000) Application of Vetiver Grass Technology in Off-Site Pollution Control. - Proc. International Vetiver Conference. Thailand, January 2000.

Doherty, D. (1999) Surface Irrigation in the Emerald Irrigation Area — USQ Faculty of Engineering and Surveying 4th year honours thesis pp 43-50

Waters, D., Drysdale, R., Kimber, S. (1999) Wheat-cotton double cropping gains in popularity - The Australian Cotton Grower Magazine, Volume 20 No. 6 pp 78

Waters, D., Drysdale, R., Kimber, S. (1999) Benefits of planting into wheat stubble. - The Australian Cotton Grower Magazine, Volume 20 No. 4 pp 8-13

Waters, D., Drysdale, R., Kimber, S. (1999) Reducing off-site movement of sediment and nutrients in a cotton production system. - Proc. NPIRD Nutrient Conference. Brisbane- Qld, June.

Waters, D., Noble, B. (1999) Nutrient and sediment loads in drains in the Emerald Irrigation Area. - Proc. NPIRD Nutrient Conference. Brisbane- Qld, June.

Silburn, M., Waters, D., Connelly, R., Simpson, B., Kennedy, I. (1998) Techniques for stabilising Soil Erosion on Cotton Farms. Managing Pesticides in the Riverine Environment — Outcomes of the LWRDC/CRDC/MDBC R&D Program.

Rhode, K., Waters, D., Yule, D. (1998) Sustainable land management systems for cotton. Proc.World Cotton Conference . Athens-Greece, September.

Waters, D., Black, S., Yule, D., Drysdale, R. (1998). Wheat/Cotton Double cropping — A farming system to reduce soil erosion and pesticide use. - Proc. 9th Australian Cotton Conference. Gold Coast- Qld, August, pp 87-92.

APPENDIX A

Table 5: Water applied, runoff and soil movement totals by rainfall/irrigation for conventional and wheat/cotton double crop cotton at Black Farm, 1997/98 season.

Date	Irrigation/ storm	Conventional						Wheat/cotton					
		Total Water Applied (mm)	Total Runoff (mm)	Total Runoff (%)	Average Weighted Sed. Con. (g/l)	Soil Movement		Total Water Applied (mm)	Total Runoff (mm)	Total Runoff (%)	Average Weighted Sed. Con. (g/l)	Soil Movement	
						(t/ha)	(t/ha/mm runoff)					(t/ha)	(t/ha/mm runoff)
19/09/1997	Irrigation	113	36	32	4.97	1.80	0.050	167	40	24	0.02	0.08	0.00
17/11/1997	Storm	11	0	0	0.00	0.00	0.000	11	0	0	0.00	0.00	0.00
19/11/1997	Storm	25	0	0	0.00	0.00	0.000	25	2	8	0.12	0.00	0.00
02/12/1997	Irrigation	104	19	18	7.09	1.34	0.071	114	35	31	0.87	0.30	0.01
14+21/12/97	Irrigation	87	19	22	4.74	0.89	0.047	81	20	25	1.13	0.23	0.01
19/12/1997	Storm	10	0	0	0.00	0.00	0.000	10	0	0	0.00	0.00	0.00
24/12/1997	Storm	16	3	19	5.34	0.14	0.047	16	8	50	1.05	0.08	0.01
08/01/1998	Irrigation	88	17	19	8.15	1.03	0.061	81	22	27	2.48	0.54	0.02
18/01/1998	Irrigation	117	11	9	8.30	0.88	0.062	127	19	15	2.60	0.49	0.03
03/02/1998	Irrigation	109	13	12	5.45	0.70	0.054	100	28	26	1.73	0.45	0.02
Total Irrigation		6	618	115	19	6.45	0.06	670	162	24		2.09	0.01
Total Rain		4	62	3	5	0.14	0.05	62	10	16		0.08	0.01
Season Total		10	680	118	17	6.59	0.06	732	172	23		2.18	0.01

Table 6 Water applied, runoff and soil movement totals by rainfall/irrigation for conventional and wheat/cotton double crop cotton at Black Farm, 1998/99 season.

Date	Irrigation/ Storm	Conventional						Wheat						
		Water applied (mm)	Total Runoff (mm)	Total Runoff (%)	Average weighted Sed. Con. (g/l)	Soil Movement		Water applied (mm)	Total Runoff (mm)	Total Runoff (%)	Average weighted Sed. Con. (g/l)	Soil Movement		
						(t/ha)	(t/ha/mm runoff)					(t/ha)	(t/ha/mm runoff)	
31/08/1998	Storm	79	0	0.0				79	1	1	0.0	0.0	0.00	
10/09/1998	Storm	31	0	0.0				31	1	2	0.2	0.0	0.00	
12/09/1998	Storm	30	4	13.7	6.2	0.3	0.06	30	11	38	4.2	0.5	0.04	
13/09/1998	Storm	22	21	93.2	29.2	6.1	0.29	22	22	100	4.6	1.0	0.05	
24/09/1998	Storm	54	22	40.3	9.1	2.0	0.09	54	25	47	9.9	2.5	0.10	
09/10/1998	Storm	22	6	27.7	8.1	0.5	0.08	22	0	2	14.0	0.1	0.14	
12/10/1998	Storm	14	2	11.1	6.7	0.1	0.07	14	0	1	10.3	0.0	0.10	
25/10/1998	Storm	80	26	32.4	10.7	2.8	0.11	80	49	61	11.7	5.7	0.12	
25/10/1998	Storm	39	34	86.8	9.6	3.2	0.10	39	29	75	5.8	1.6	0.06	
13/11/1998	Storm	33	1	2.2	1.2	0.0	0.01	33	1	5	1.7	0.0	0.02	
24/11/1998	Storm	13	0	0.0				13	0	0				
05/12/1998	Irrigation	101	20	19.8	4.5	0.9	0.04							
09/12/1998	Irrigation							97	27		4.7	1.2	0.05	
18/12/1998	Irrigation	72	19	26.4	5.5	1.1	0.06							
19/12/1998	Storm	28	19	66.5	6.2	1.1	0.06	28	5	17	6.7	0.3	0.07	
29/12/1998	Storm	25	0	0.0				25	0	0				
03/01/1999	Storm	85	38	45.4	4.1	1.6	0.04	85	25	30	6.4	1.6	0.06	
16/01/1999	Irrigation							102	14		6.5	0.9	0.06	
17/01/1999	Irrigation	91	17	19.3	3.3	0.6	0.03							
25/01/1999	Storm	35	1	1.8	1.1	0.0	0.01	35	1	3	4.9	0.0	0.05	
04/02/1999	Irrigation	105	31	29.8	2.9	0.9	0.03							
05/02/1999	Irrigation							78	16		5.8	0.9	0.06	
15/02/1999	Storm	15	0	0.0				15	0	0				
22/02/1999	Irrigation							94	15		4.3	0.6	0.04	
24/02/1999	Storm	30	0	0.0				30	15	51	6.5	1.0	0.06	
Total Irrigations		4	368	87	23.7	4.0	3.4	0.04	372	71	19	5.3	3.6	0.05
Total Storm		17	633	172	27.1	8.4	17.6	0.10	633	186	29	6.2	14.4	0.08
Season Total		21	1001	259	25.9	7.2	21.1	0.08	1005	257	26	6.0	18.0	0.07

Table 7 Water applied, runoff and soil movement totals by rainfall/irrigation for conventional and PAM applied to irrigation water at Deepfield Farm, 1997/98 season.

Date	Irrigation/ storm	Conventional						PAM					
		Total Water Applied (mm)	Total Runoff (mm)	Total Runoff (%)	Average Weighted Sed. Con. (g/l)	Soil Movement (t/ha) (t/ha/mm runoff)		Total Water Applied (mm)	Total Runoff (mm)	Total Runoff (%)	Average Weighted Sed. Con. (g/l)	Soil Movement (t/ha) (t/ha/mm runoff)	
	Irrigation	Pre-plant irrigation not measured for this treatment											
17/11/1997	Storm	11	0	0	0.00	0.00	0.000	20	2	10	0.64	0.01	0.005
19/11/1997	Storm	25	0	0	0.00	0.00	0.000	25	1	4	0.08	0.00	0.001
28/11/1997	Irrigation	94	15	16	2.93	0.43	0.029	75	9	12	1.54	0.13	0.015
09/12/1997	Irrigation	88	14	16	2.67	0.37	0.027	88	10	11	0.57	0.06	0.006
19/12/1997	Storm	10	0	0	0.00	0.00	0.000	10	0	0	0.25	0.00	0.000
24/12/1997	Storm	16	0	0	0.00	0.00	0.000	16	0	0	0.00	0.00	0.000
29/12/1997	Irrigation	80	14	18	2.60	0.35	0.025	75	12	18	0.77	0.09	0.007
11/01/1998	Irrigation	105	17	18	2.98	0.51	0.030	95	14	16	0.63	0.09	0.006
21/01/1998	Irrigation	111	14	13	2.65	0.37	0.027	92	11	12	0.20	0.02	0.002
30/01/1998	Irrigation	87	13	15	1.80	0.24	0.019	73	13	18	0.21	0.03	0.002
Total Irrigation		7	565	87	15	1.49	0.02	507	50	10		0.20	0.00
Total Rain		4	62	0	0	0.35	0.00	62	22	35		0.09	0.00
Season Total		11	627	87	14	2.27	0.03	569	72	13		0.43	0.01

Rainfall + Irrigation

Table 8 Water applied, runoff and soil movement totals by rainfall/irrigation for conventional and PAM applied to irrigation water at Deepfield Farm, 1998/99 season.

Irrigation/ Storm	Conventional						PAM					
	Water applied (mm)	Total Runoff (mm)	Total Runoff (%)	Average weighted Sed. Con. (g/l)	Soil Movement		Water applied (mm)	Total Runoff (mm)	Total Runoff (%)	Average weighted Sed. Con. (g/l)	Soil Movement	
					(t/ha)	(t/ha/mm runoff)					(t/ha)	(t/ha/mm runoff)
Storm	79	7	8.8	0.0	0.0	0.00	79	8	10	0.0	0.0	0.00
Storm	31	2	7.5	0.5	0.0	0.01	31	0	1	2.1	0.0	0.02
Storm	30	18	59.5	10.4	1.8	0.10	30	17	57	7.2	1.2	0.07
Storm	22	22	100.0	20.6	4.6	0.21	22	20	91	7.1	1.5	0.07
Storm	54	22	42.0	9.9	2.2	0.10	54	22	41	7.5	1.6	0.07
Storm	22	6	27.0	8.9	0.5	0.09	22	5	24	6.2	0.3	0.06
Storm	14	5	35.1	7.2	0.4	0.07	14	3	23	5.0	0.2	0.05
Storm	80	39	49.0	19.2	7.5	0.19	80	36	46	8.2	3.0	0.08
Storm	39	37	96.4	14.4	5.4	0.14	39	31	80	4.8	1.5	0.05
Storm	33	0	0.0				33	0	1	0.4	0.0	0.00
Storm	13	0	0.0				13	0	3	6.3	0.0	0.06
Irrigation							94	28	30	1.4	0.4	0.04
Irrigation	89	25	28.0	1.8	0.4	0.02						
Irrigation							88	11	13	0.8	0.1	0.01
Irrigation	130	19	14.4	2.7	0.5	0.03						
Storm	28	9	31.7	3.7	0.3	0.04	28	0	2	1.8	0.0	0.02
Irrigation							6	1	28	0.7	0.0	0.01
Storm	25	0	0.0				25	3	12	0.4	0.0	0.00
Storm	85	49	57.6	3.4	1.6	0.03	85	43	50	1.1	0.5	0.01
Irrigation	48	19	39.6	2.1	0.4	0.02						
Irrigation	3	0	0.0				66	21	33	0.2	0.1	0.00
Irrigation	42	18	43.3	1.2	0.2	0.01						
Storm	35	1	3.0	1.5	0.0	0.01	35	1	2	1.4	0.0	0.01
Irrigation							79	34	43	0.4	0.1	0.00
Irrigation	105	29	27.4	0.8	0.2	0.01						
Storm	15	8	51.9	0.7	0.1	0.01	15	0	3	0.5	0.0	0.01
Storm	30	0	0.0				30	0	0			
	5	416	109	26.3	1.7	0.02	368	96	26	0.8	0.7	0.01
	17	633	225	35.6	7.7	0.11	633	191	30	3.8	9.8	0.05
	22	1049	335	31.9	5.2	0.08	1001	289	29	2.5	10.5	0.04



Other findings from this trial:

- Where additional nitrogen is water run or added prior to first irrigation, nitrogen levels in runoff water increased
- The presence of standing wheat stubble can increase infiltration thus irrigation management is critical to avoid excess deep drainage. It is recommended that inflow rates are increased to account for the improved infiltration, provided there is no increase in furrow erosion



Retained wheat stubble provided a 70% reduction in soil movement over a season

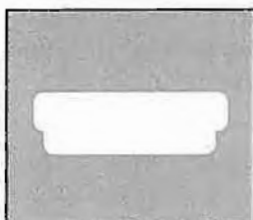
Reduced early season Heliothis pressure:

Over the past years of trialing the standing wheat stubble system, there have been reductions in early season insect pressure, particularly heliothis.

QDNR in Emerald carried out a detailed study in 1999 on 5 farms, monitoring insect numbers in wheat stubble. The low heliothis pressure early season meant that there were no significant differences found. Similar monitoring carried out 2 years prior in a heavy insect year showed a 75% reduction in cumulative heliothis numbers and a saving of 3 insecticide sprays over the season.

Analysis of insecticide applications of 6 Emerald farms in 1999-2000 showed 2 fewer total insecticide sprays for the year, with a total saving of pesticide and application cost of \$90/ha. Pesticide saving could be greater in a year where the pressure is higher.

Ingard® crops planted into standing wheat stubble at Emerald in the 99 - 00 season resulted in no saving of insecticide costs. It is assumed that this was because the Ingard® was already



"We were 2-3 sprays behind our neighbours who didn't have wheat stubble" Scott Black, 'Liskeard', Emerald

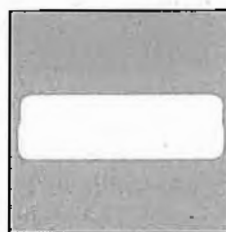
Significant savings in sprays were reported in Bourke, although growers in the Macquarie Valley in past seasons have not seen the same trends. This may be attributed to generally lighter early season pressure than Central Queensland.

Improved infiltration on hard setting soils:

Planting into standing wheat stubble has proven to be a great alternative means of improving infiltration particularly on hard setting or crusting soils and soils where lateral wetting is a problem.

The anchored stubble slows down water, and increases points of entry into these soils, increasing infiltration significantly. This was demonstrated on a trial carried out by Twynam Cotton at Warren in 1997-98. In a field with hard setting red earth, neutron probe readings showed that under conventional tillage, after the initial irrigation it was difficult to fill the soil profile again, resulting in very frequent irrigations. In irrigating the same field under wheat stubble, it was possible to fill the profile on every irrigation in the season. (Further detail: 1997-98 Macquarie Valley Cotton Trial Reports).

This action also serves to improve the uniformity of irrigation across fields with varying soil types.



Improved soil conditions

"Before we were irrigating every 5-6 days peak season. With wheat stubble it takes it out to 7-8 days .. in line with our heavier soil"

Nathan Soulsby
Twynam Cotton Trangie

at planting and during seedling stage:

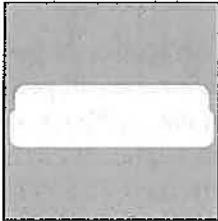
The following benefits have been found in terms of improving soil conditions at planting/ seedling stage.

- **Buffering of Soil Temperatures:** Monitoring by NSW Agriculture, Narrabri and grower experience has shown that the presence of standing wheat stubble has a buffering effect on the soil, minimising temperature extremes, both hot and cold
- **Reduce Sand Blasting:** Growers have noticed a reduction in sand blasting to crops in the presence of standing stubble

□□□□□□□□□□□□□□□□□□□□

Deciding to plant cotton into standing wheat stubble signals a significant change in management to a conventional farming system. The following headings aim to address most of the issues.

Do I need to harvest my wheat?



"My main concern with the system is the timeliness of fitting it all together"
Neek Morawitz 'Argoon',
Emerald

Double cropping is possible in Central Queensland and is also being carried out as far south as Dalby. In southern growing areas this is not possible although leaving adequate stubble standing for 12 months is beneficial for infiltration, organic matter and reducing erosion.

The numerous benefits being observed by growers has led to an increased number of growers planting wheat and spraying it out prior to cotton planting in both northern and southern cotton areas.

If spraying out wheat it should be done at flowering. This will ensure the stubble will stay upright and no viable seed is produced.

Herbicide options:

- Translocated Herbicides: Glyphosate (ie. Roundup CT @ 2.0 L/Ha). Ensure crop is not stressed
- Contact Herbicide (ie. Sprayseed @ 2.0 L/Ha. Good coverage is essential with contact herbicides so water rates of 60-100L/Ha are recommended. Contact herbicides can either be used as a first application or a salvage spray if the translocated herbicide fails.

Which wheat varieties?

If double cropping or spraying out: A fast maturing variety is better to improve timeliness. Some favoured quick maturing varieties include Hartog, Sunstate and Wollaroi or Kamilaroi (Durum wheats) at 40-80kg/ha.

If aiming to fallow the stubble, there is less need to choose variety based on timeliness however varieties that have higher stubble strength such as Hartog, Janz, Kennedy or Sunline and may be an advantage for stub-

How do I plant my wheat?

However you plant, the main aims are

- To achieve good even stand
- To keep the top of the beds relatively free of wheat to prevent problems at cotton planting.

Methods that have become popular are direct drilling wheat into the sides of the beds at 4 rows per metre or applying wheat with a spreader and with a second pass clearing off the top of the beds.

Wheat is generally planted between April and June depending on location. If spraying out, the key is to plant early enough to flower at least 1 month prior to planting cotton so maximum benefit can be gained from the stubble without impacting on the timeliness of cotton planting.

Spraying out a young non flowering crop may result in low stubble strength.

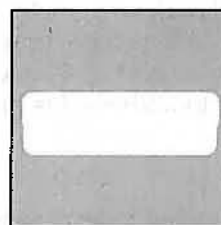
One complication of standing stubble in cracking clay soils, occurs with prolonged dry period during the growth of the wheat. There is tendency for a large crack to form down the centre of the bed, this can result in a gappy plant stand when cotton is sown on the crack.

How do I control weeds in my cotton?

The presence of standing wheat stubble between cotton rows does not lend itself to managing weeds by more conventional methods such as:

- Cultivation
- Incorporation of pre-plant residuals (ie Trifluralin)
- Pre plant knockdown herbicide following pre-irrigation (if planting dry and watering up).

There are a number of options available to manage weeds in a standing wheat stubble/



"It was difficult until we became proficient with the shielded sprayer"
Charles Clark

cotton system, although growers should be aware that it might be more expensive.

- In furrow weed control can be achieved by over-crop sprays, shielded sprays and chipping
- Grass can be controlled by selective over-crop

- Applying residual grass herbicide at a 100% band at planting, rather than 50%. This may prevent the need for a selective grass herbicide later.

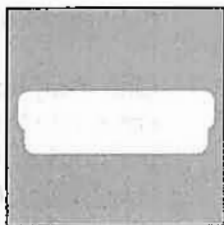
The introduction of Roundup Ready® cotton into the system will provide some solutions to weed control, especially where cotton is watered up.

Do I pre-irrigate or water cotton up?

There are advantages and disadvantages with both systems. These will vary with specific conditions such as soil type and climate. Growers considering planting into standing stubble need to weigh up the options:

Pre irrigation:

- + Warmer soil temperatures: Given favourable weather, the soil has time to warm up following the pre-irrigation.
- + Allows use of pre-plant knock-down herbicide: In some of the warmer growing areas, growers rely on pre-irrigation to encourage a weed emergence and allow the application of a pre-plant knockdown herbicide.
- Presence of wheat stubble will mean greater time between irrigation and planting. -This will vary by soil type, climate etc but needs to be considered as it may impact on timeliness.



Water up:

- + Better timeliness of planting: Fields with stubble will take longer to dry out than conventionally cultivated fields. This delay following pre-irrigation may impact on timeliness. Watering up will avoid this problem.
- Cooler soil temperatures: Watering up tends to reduce soil temperatures, slowing seedling vigour and increasing the risk of seedling disease.
- Does not allow pre-plant knockdown herbicide: Watering up means weeds will germinate at the same time as cotton. The advent of Roundup Ready Cotton® will help to address this problem.

Does irrigation management need to be changed?

The presence of standing wheat stubble will slow down the movement of water across the field from both irrigation and rainfall events. In fields with low slopes (1 in 2000) this has resulted in waterlogging problems. Work by Queensland Department of Natural Resources, Emerald found that on steep

1/2 hour before end of furrow. This improved irrigation efficiency by 25%. To overcome water logging problems wheat planting rates should be kept below 60 kg/ha or alternatively the bottom of furrows can be kept clear of wheat by direct drilling wheat away from the furrow bottom.

Do I need to change my fertiliser program?

In a conventional system, a majority of pre-plant nitrogen is placed under the hill prior to planting. With standing wheat stubble the situation is more complicated, especially in a double crop situation where there is a very short turn-around time between wheat harvest and cotton planting.

Decomposing wheat stubble can tie up nitrogen in the root zone of the small cotton plants

- setting them back. It is highly recommended that an extra 10 -20 kg N/ha be applied before sowing to account for N tied up by wheat stubble. Apply normal rates of starter fertilizer but not in contact

with the seed (+10cm) to prevent root burn .

In the 1999-00 season in Emerald, several crops in wheat stubble suffered nitrogen stress prior to flowering because:

- They were unable to get nitrogen into the hill pre-planting
- The decomposing wheat stubble caused a lot of immobilisation of nitrogen. This was made very evident in sections of fields with high levels of trash on the ground (ie underneath the header)

On average, during the 1999-00 season in Emerald, cotton planted into wheat stubble required 75 kg of N/ha more than conventional plantings. The main reasons for this were:

- Harvested wheat crops would have removed up to 60 kg of N/ha in grain. A similar amount would be tied up in stubble
- Alternative methods used to apply nitrogen without disturbing the stubble are less efficient (ie water run, top dress and watering in), resulting in nitrogen being lost from the system

Some people tried applying the full allocation of cotton fertiliser prior to the wheat, hoping to retain most of it. Given adequate moisture, a wheat crop has the potential to use all of this fertiliser. Denitrification in wet soil condi-

"It takes more management; you don't get the chance to put in the steel if you make a mistake"
James Clark

