

Techniques to reduce off-farm movement of soil, water, nutrients and pesticides

Dave Waters¹, Steve Riches², Steve Kimber³

Department of Natural Resources, Toowoomba ¹,Q
Department of Natural Resources, Emerald ²,Q
Department of Agriculture, Wollongbar ³,NSW

Introduction

The cotton industry in Australia continues to be reliant on insecticide and fertiliser inputs to maintain yields. Over the past decade the off farm movement of these pollutants in runoff water has created a number of environmental issues of concern for the industry (Edge; 1996). In particular, pesticide can be transported off farm in solution or attached to suspended sediment, which are a major factor in pesticide contamination of rivers particularly as storm runoff (Schoefield *et al*; 1998).

As part of a major R&D program undertaken by the cotton industry, the transport mechanisms and fate of cotton pesticides and nutrients were investigated to address the contamination issue. Key findings from the work identified the high-risk period as early season and highlighted the importance of storms and sediment in moving pesticides off-site and the importance of ground cover in reducing movement (Simpson *et al*; 1996 and Silburn *et al*; 1996).

At the completion of the program, the cotton industry had a much better understanding of the process of pollutant movement from farm to river. However, few proven practical techniques were available to growers to reduce the risk of off-site movement of pollutants in runoff.

In 1997 a CRDC funded project "Best Management Practices to minimise Pollutant Transport from Cotton Production Systems" was undertaken in the Emerald Irrigation Area (EIA) and extended into NSW in the second year. The aim was 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 and to assess the practicality and feasibility of these management practices for growers.

The following paper outlines 3 management strategies :wheat cotton rotation, polyacrylamide application and vegetative filter strips which gave encouraging results in reducing sediment, nutrient and pesticide levels in runoff water. The paper also discusses the adoption by growers over a three year period. Section two gives a summary of similar work carried out in Bourke, NSW in 1999/2000 season.



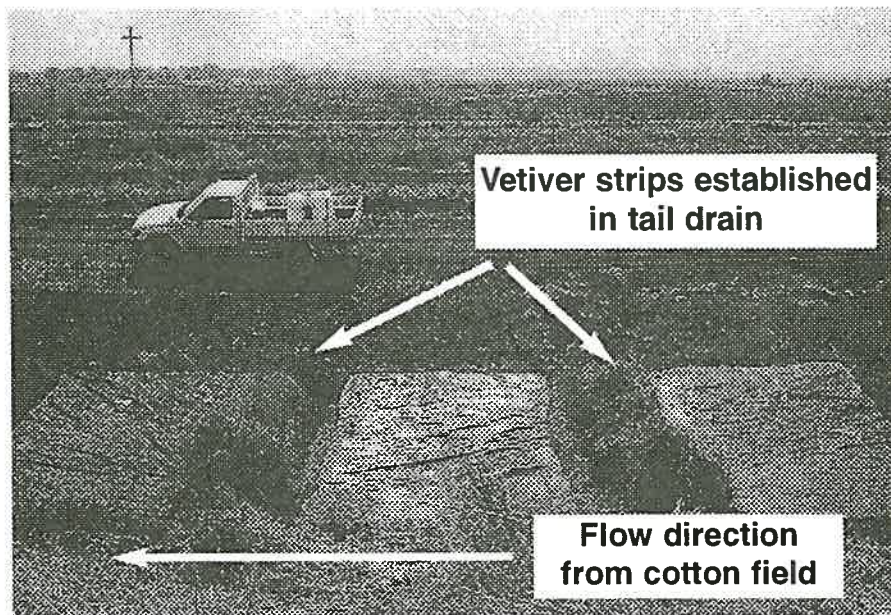


Figure 1: Vetiver strips planted at the outlet of tail drain perpendicular to the direction of flow to filter irrigation and rainfall runoff.

Results

Wheat cotton rotation

The two years of monitoring had very different rainfall conditions. Rainfall in 1997/98 from July to June (386mm) was half that of 1998/99 (767mm). This was reflected in the contribution to runoff from rainfall making up 5% and 70% of total runoff in 1997/98 and 1998/99 respectively.

The high rainfall season also increased total runoff by 60% (eg C-C 118mm in 1997/98 to 259mm in 1998/99) (Table 1). Runoff for the W-C was higher than C-C in 1997/98 due to the additional irrigation applied at pre-plant. In 1998/99 total runoff was similar for both treatments due to the limited amount of wheat stubble retained (600 kg/ha) in comparison to year one (1500 kg/ha).

W-C reduced soil loss in both seasons, by a lesser extent in year two due to reduced ground cover provided by the wheat stubble. Soil loss for the season was approximately three times higher in 1998/99 for C-C (21.1 t/ha) in comparison to the previous season (6.6 t/ha). Average sediment concentrations for the season were markedly increased in the high rainfall year due to higher runoff rates. The increased rainfall runoff in year two, resulted in higher average concentrations of sediment bound pollutants, phosphorus and endosulfan for the season, supporting findings by (Simpson *et al*; 1996 and Silburn *et al*; 1996) who highlighted the importance of storms and sediment in moving pollutants off-site.

Table 1: Seasonal soil loss, runoff, nutrient and pesticide concentration for conventional cotton (C-C) and wheat cotton rotation (W-C) for two seasons.

Cotton Season	1997/98		1998/99	
	C-C	W-C	C-C	W-C
Runoff (mm)	118	172	259	257
Soil loss (t/ha)	6.6	2.2	21.1	18.0
Avg. Sediment Conc. (g/l)	5.7	1.3	7.2	6.0
Avg. Endosulfan Conc. (ug/l)	2.2	1.1	3.5	0.8
Avg. total Phosphorus (mg/l)	0.5	0.4	1.7	1.4
Wheat Stubble amount (kg/ha)	N/A	1500	N/A	600

PAM

PAM proved to be effective at reducing erosion and endosulfan concentrations in runoff for irrigations (Waters *et al.*; 1999). In year one, the addition of PAM to irrigation water reduced soil loss by 80% over 6 irrigations (2.3 t/ha v 0.4 t/ha). Average endosulfan concentrations in runoff were reduced by 70% from 11.4 ug/l to 2.9 ug/l in the same season. In the second season the high proportion of rainfall runoff limited the number of PAM applications however, soil loss was reduced by 50% where PAM was applied to irrigation water.

VETIVER

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 2). In the second year 65% of total endosulfan was trapped by the grass (Figure 3).

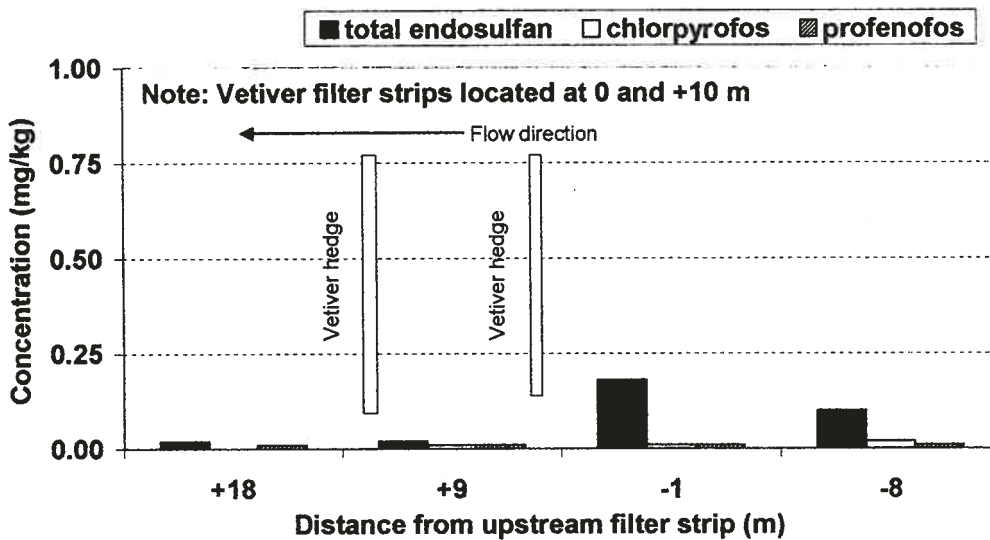


Figure 2: Pesticide concentration in deposited soil up and downstream of vetiver filter strip collected March 1998.

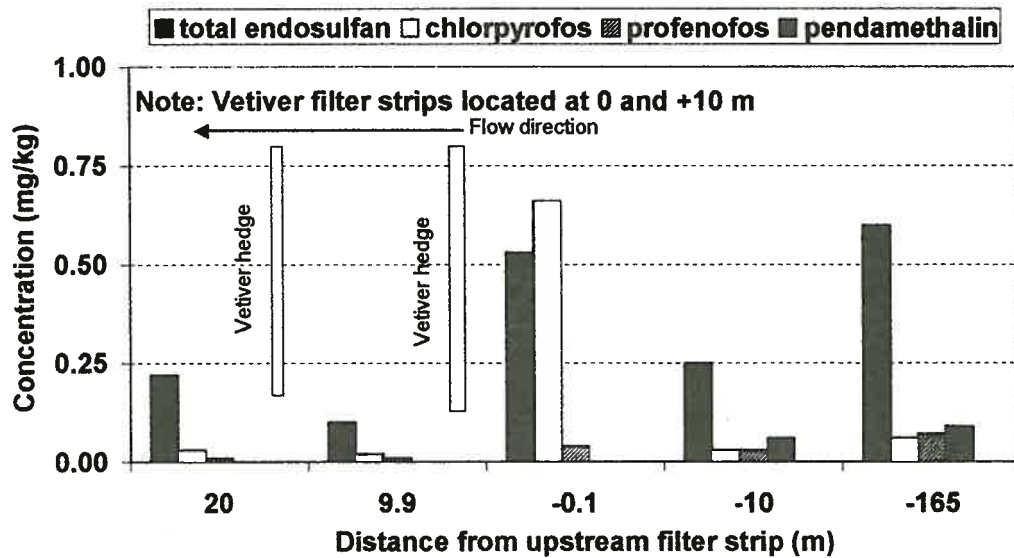


Figure 3: Pesticide concentration in deposited soil up and downstream of vetiver filter strip collected February 1999.

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 (Truong *et al*; 2000).

Grower Adoption

Growers in the EIA were extremely cooperative and committed to adopting the improved management practices of the project (Figure 4). The W-C system generated significant interest in the EIA after early results found significant benefits with additional returns on a wheat crop, reduced erosion, nutrient and pesticide and reduced chemical applications. The potential to reduce chemical applications has generated further interest both in the EIA and in southern Qld and NSW cotton growing areas. Whilst this unexpected benefit was not part of the initial aims of the project, a reduction in chemical applications will reduce the risk of chemical movement off-site. The rapid adoption by growers of PAM coincided with the release of a suitable application unit for the product. Growers are now reporting significant increases in infiltration and reduced erosion where PAM has been applied to irrigation water.

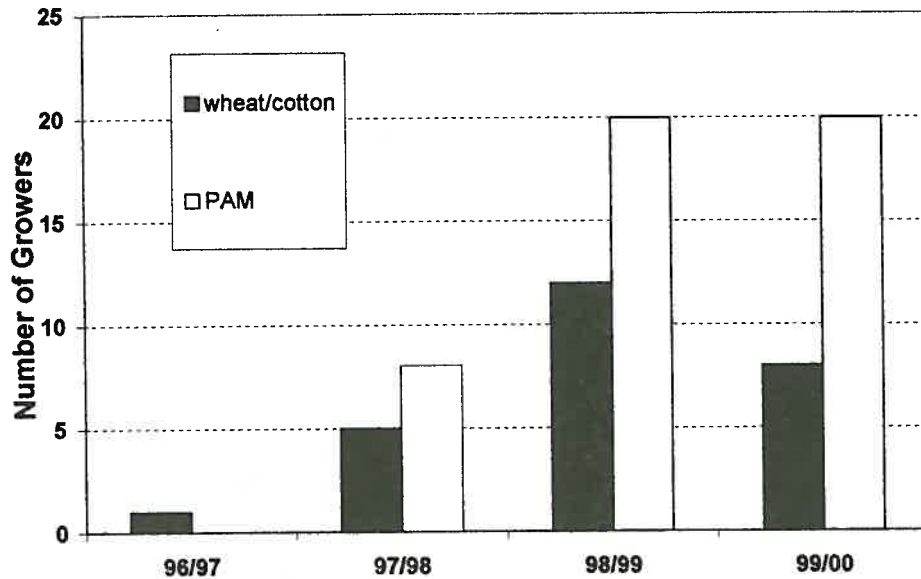


Figure 4: Number of growers using wheat/cotton and PAM prior to and for project duration

DISCUSSION

Wheat Cotton Rotation

The data presented for the project period is promising. The W-C treatment reduced erosion, phosphorus and endosulfan concentrations over the two year monitoring period. The W-C system has multiple benefits, the most significant of which is the ability to reduce erosion, nutrient and pesticide movement off-site in a high rainfall year. The data set also highlights the impact of storms on runoff, erosion and water quality. Erosion rates in the high rainfall year were 3-4 times greater than in a dry year. Preliminary data from the EIA and Bourke, NSW have found similar results from sprayed out wheat where high stubble levels can be maintained. Growers who have conducted W-C trials have identified a number of benefits with increased infiltration, reduced erosion and increased cotton yields in some cases. With such a dramatic change in management a number of problems have also been identified with nitrogen application, weed management and water logging of cotton. However, with the increased number of growers trialing W-C, previously identified problems are being addressed on farm.

PAM

PAM has provided an effective and easy technique for growers to reduce erosion, improve water quality and improve infiltration. Due to the ease of application and minimal cost, growers have adopted the technology rapidly. Whilst PAM does reduce erosion under irrigation conditions, growers need to be aware that at present PAM will have minimal effect on reducing erosion, nutrient and pesticide movement off paddock during storms. For early season irrigations and newly formed fields PAM is essential.

Vegetative Filter Strips

The Vetiver pilot study has demonstrated a simple and effective method of filtering sediment and chemicals once they have left the cotton field. Vetiver grass is only one of a number of vegetative filter systems being used world wide. Vetiver has the advantage of being easy to establish, is sterile and is highly tolerant to most chemicals and heavy metals.

Future Research

The project has highlighted a number of issues that require further investigation. Little is understood about the wheat stubble height -heliiothis interaction. Further work needs to be undertaken to look at the role of crop rotations with cotton and how they impact on heliothis management.

Another issue identified by growers has been fertiliser application methods and timing, in particular nitrogen. Water run nitrogen is one solution used by growers to add additional nitrogen to the system. Data from year one suggests that nitrogen concentrations in runoff will be significantly increased by adopting this technique. Assessment of the various techniques and the impact on agronomy and water quality needs further investigation Weed management in cotton is also proving to be a problem for growers. Shielded sprayers have been used effectively to control weeds, however where more conventional management is used further work needs to be carried out.

W-C and PAM systems have been shown to improve infiltration. These changed management systems may alter the total water balance. Little is known of how new improved management practices such as cereal stubble - cotton rotation will affect total water balance in particular deep drainage. To address this issue, all components of the water balance need to be monitored not only surface runoff.

Conclusion

The on farm action research approach has proven to be highly effective to maintain grower involvement and adoption of research.

The project has outlined three techniques available to growers which will reduce soil erosion, nutrient and pesticide movement. Containment of pollutants on farm requires a whole farm approach. Techniques such as sumps, silt traps, vegetative filters are effective in collecting sediment once it has left the paddock. However they are treating the effects not the cause.

Crop rotations/stubble retention offers the most effective means of reducing "off-site" movement of sediment bound pollutants for both irrigation and storms at this point in time. Cereal crops have been shown to be the most effective in terms of achieving high cover levels and having minimal impact on soil borne diseases. PAM does have a role to play in reducing soil and chemical movement from furrows for irrigation.

To control chemicals which are more water soluble is a separate issue again. Therefore one technique alone will not address all the problems, however an integrated approach which looks at the whole farm design and management will be highly effective in reducing the associated risks of off-site movement of pollutants.

Growers should be aware that implementation of management practices which reduce the risk of cotton farming on the environment are also enhancing their BMP process.

Acknowledgments

This research is funded by Cotton Research and Development Corporation until June 2000. We would like to thank the Emerald Cotton growers in particular Scott and Kim Black, Harvey and Mary Rich, Tony Ronfeld who participated in the study for their support in site selection and maintenance and feedback.

References

- Edge, V. (1996). Environmental issues facing the cotton industry related to pesticide use - *Proc. 8th Australian Cotton Conference*. Gold Coast- Qld, August 1996, 47-54
- Schofield, N., Edge, V., Moran, R. (1998) Minimising the impact of pesticides on the riverine environment. Using the cotton industry as a model. *Water* . Jan/Feb pp 37-40.
- Silburn, M., Wockner, G., Bourke, J., Hargreaves, P., Thomas, E., Connelly, R., Spann, K., Freebairn, D., Osborne, B., Beasley, H., Kimber, S., Kennedy, I., Dorr, G., Woods, N., Hogendyke, C., Gaynor, H. (1996) Rainulator studies of pesticide movement from cotton production systems Pesticide dissipation from soil and subsequent transport in runoff. *Proc. 4th annual Pesticide workshop*. Brisbane, September 17-18.
- Simpson, B., Thomas, E., Hargreaves, P., Noble, B., Kuskopf, B., Carroll, C., Spann, K., Budd, N., Osborne, B., Ruddle, L., Lee, B., Hastie, M. (1996) Pesticide transport from cotton production systems - Queensland site. *Proc. 4th annual Pesticide workshop*. Brisbane, September 17-18.
- Sojka, R.E., and Lentz, R.D. (1997) Reducing Furrow Irrigation Erosion with Polyacrylamide (PAM) - J. *Prod. Agric.*, Vol 10, no. 1 pp 47-51
- 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.
- Truong, P.N., Mason, F., Waters, D. and Moody, P. (2000). Application of Vetiver Grass Technology in off-site pollution control. I. Trapping agrochemicals and nutrients in agricultural lands. *Proc. Second Intern. Vetiver Conf.* Thailand, January 2000 pp 303-309.
- Truong, P.N. (1999). Vetiver Grass Technology for land stabilisation, erosion and sediment control in the Asia Pacific region . *Proc. First Asia Pacific Conference on Ground and Water Bio-engineering for Erosion Control and Slope Stabilisation*. Manila, Philippines, April 1999.
- Waters, D., Sequeira, R. (2000). Cereal Stubble and Trap Crops -. - *Proc.10th Australian Cotton Conference*. Brisbane- Qld, August, (in press).
- 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., 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.

The NSW Experience

The NSW field site was based at Darling Farms, Bourke during the 1999/2000 season. Agronomist Jason Fritsch adopted the technology after observing the success of another Bourke grower in the 98/99 season. Darling Farms planted 20% of their cotton into standing wheat stubble this season. Two adjacent fields, planted with V16 were monitored over the season.

Farm management has been impressed by the results, and will continue to use wheat stubble in their farm management plan. However, unseasonable rain late in the season has proved a real setback to the Bourke region, with picking delayed on all fields, and low yields expected due to boll rot. This has also limited wheat planting for next season as the whole farm schedule has been put back.

Agronomy

Wheat was planted into the sides of the bed using an air seeder dropping grain over the furrows. A half PVC pipe was run over the top of the furrow and sweeps were used to clear the wheat seed from the bottom of the furrow. This system worked remarkably well, with a good stand of wheat restricted to the side of the hill only. Irrigations on the stubble field took 16 to 18 hours compared with 8 to 10 hours for the conventional field. The management team is considering foliar nitrogen application to combat the effects of waterlogging associated with the longer irrigations.

Insect pressure

Insect pressure early to mid season was much lower than usual in the Bourke region, particularly *H. punctigera* that normally are the main insect problem.

Intensive bug checking early in the season revealed slightly greater egg numbers in the bare fallow field, but not statistically different. Larval numbers however, were 14 times lower in the stubble field. The discrepancy between eggs and larval numbers was attributed to predation in the stubble field. Spider populations were 3 times higher and there were 60% more ladybirds in the stubble.

These results are reflected in the insecticide spray applications as shown in Table 1 below. In spite of the low insect pressure experienced this season, the wheat stubble system showed great benefit, with half the number of insecticide sprays applied to the adjacent bare fallow field. The wheat stubble-cotton system received a similar number of sprays to the Ingard cotton grown in other fields on the farm.

TABLE 1: Insecticide applications to the two fields at Darling Farms. Planting dates for the fields appear under the rotation name.

Insecticide Spray Number	Wheat/Cotton (17-10-99)	Bare fallow/Cotton (13-10-99)
1	02-12-99	22-11-99
2	06-12-99	25-11-99
3	16-12-99	01-12-99
4	29-12-99	04-12-99
5	13-01-00	08-12-99
6	01-02-00	10-12-99
7	11-02-00	18-12-99
8	25-02-00	30-12-99
9	23-02-00	04-01-00
10		17-01-00
11		21-01-00
12		29-01-00
13		10-02-00
14		18-02-00
15		24-02-00
16		29-02-00
17		23-03-00

Off-field soil and insecticide movement

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.

Results of sediment and endosulfan movement in tailwater are shown in figure 1 below.

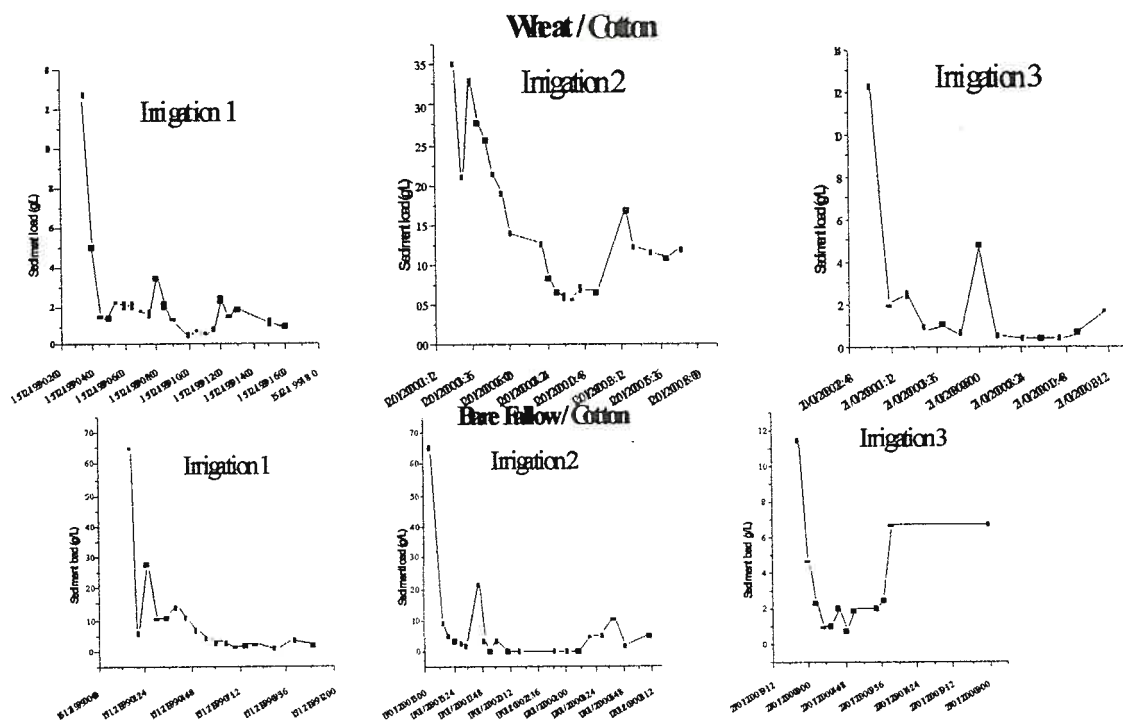


Figure 1 Sediment concentrations (top two rows) and endosulfan concentrations (bottom two rows) in tailwater from the two production systems.

