8 Cotton, chemicals and the environment

Key points

- The cotton industry is a large user of chemicals, which are essential to protect the crop but potentially harmful to the environment. The industry has faced up to its responsibilities and instigated several programs aimed at minimising the effects of chemicals on the environment:
  - an independent environmental audit has been undertaken;
  - water quality monitoring programs are in place;
  - major research efforts are aimed at minimising the use of chemicals; and
  - management, especially of tailwater, is generally of a high standard.
- The challenge facing the industry is that public perceptions about cotton's contribution to environmental damage — right or wrong from a cotton growers' viewpoint — may lead to changes in regulations detrimental to the industry.
  - Further restrictions on the use of endosulfan, in particular, would leave the industry, in the short term, in a vulnerable position.
- The future use of transgenic cottons offers considerable scope to reduce the use of chemical sprays to control insects, but their introduction will also be a major challenge for industry cooperation and self-regulation. Expectations should not be inflated.
- That challenge will be to have effective integrated pest management programs in place before the introduction of Bt cotton so that resistance build up in pest populations is minimised and managed.
  - There have been several previous failures in this area.

Some of the chemicals used in agriculture are highly toxic to wildlife and humans, some are not, and for some their effects are not fully known. The use of chemicals in agriculture in general and the cotton industry in particular is a major issue which the industry is addressing. Governments are under pressure to further regulate chemical use. Thus it is important that any decisions about regulation be based on full information about actions being taken within the cotton industry.

Chemical usage

Chemical pesticides are a significant input into cotton production. They make up over 20 per cent of total crop costs and are necessary for the control of the heliothis species and other pests.

Growers vary in their approach to pest control. Some growers tolerate some pest damage to their crops, paying particular attention to the economic use of chemicals. Others use considerable quantities of chemicals, preferring to see little or no pest damage to their crops. The number of sprays applied to a crop varies but averages about ten in a season. The

number of herbicide sprays also varies but averages around three per season. A significant portion of the weed control budget is hand chipping. Minimum tillage techniques to contain soil moisture and structure tended to favour the use of herbicides but new insect resistance management strategies are now tending to favour between season cultivation for heliothis control which will also assist with weed control. This is likely to reduce the use of herbicides.

Many growers contract agronomic consultants to scout cotton fields for pests and advise on crop spraying. Growers seek the advice of these consultants and sometimes of the chemical companies' consultants to achieve an optimal balance between chemical costs and crop yield. However, it is possible that pressure from growers for pest free crops and the need of consultants to maintain sound reputations leads some consultants to counsel a greater use of chemicals than would be optimal from an environmental viewpoint.

Overuse of chemicals harms the industry in a number of ways. First, where integrated pest management strategies are not followed by all, problems with resistance developing among pests are heightened, leading to even greater usage of chemicals. Second, chemicals are a significant cost of growing cotton and overuse unnecessarily squeezes profit margins. Third, the greater usage of chemicals may pollute or may be seen to pollute the environment — this could result in regulatory restraints on chemical use. Finally, some chemicals used, such as endosulfan, are toxic to humans and involve health risk issues if they are not used correctly.

Occupational and community health

The CRDC has funded two significant studies by the Australian Agricultural Health Unit at Moree investigating pesticide exposure in cotton. One study (the results are yet to be published) focuses on the exposure of cotton consultants and bug checkers to pesticides in the Gwydir and Namoi Valleys. The aims of the study were to establish a profile of work practice in relation to reducing the risk of exposure and to determine the prevalence and degree of exposure to organophosphates and carbamates.

Earlier studies investigated pesticide exposure in cotton chippers in the course of the growing season in the Gwydir Valley. The conclusion from these studies was that since most of the pesticides used in cotton agriculture can be readily absorbed through the skin, there appears to be considerable opportunity for dermal exposure of cotton chippers to

pesticide residues on the cotton plants immediately after spraying, especially if the crop is still wet. Based on this information, the Australian Cotton Foundation has publicised recommendations regarding adequate clothing protection for workers in cotton fields.

The environmental audit of the cotton industry highlighted public concern that pesticide use is threatening the health of people living within cotton growing areas (GES 1991, p 130). While the audit found that these fears were overexaggerated and that no specific community health problem could be linked with pesticide use, the cotton industry needs to be mindful of public opinion about its use of chemicals.

The environment

The impact of the chemicals used by cotton growers on water quality and the environment in general is of particular concern to the industry. CRDC, the Land and Water Research and Development Corporation (LWRDC) and the Murray Darling Basin Commission (MDBC) have commissioned a major program investigating the impact of these chemicals on the riverine environment. This research aims to identify the transport and fate of all chemicals applied to the crop as well as to develop techniques to avoid or ameliorate any detrimental effect on the environment.

Sources of contamination

Both irrigated and dryland cotton production and other agricultural crops can introduce chemicals into the water resource. In agriculture, apart from direct application of chemicals to the water resource which, arguably, Barrett, Peterson and Bately (1991) report as having been eliminated, chemicals can enter a water resource through flows of contaminated water into the resource. There are three sources of flows. Tailwater and stormwater runoff can contaminate surface water and percolation below the root zone contaminates ground water.

Efficient irrigation requires the running of tailwater to allow sufficient time for water to infiltrate the soil. Typically, tailwater is captured in a tail drain and recycled for irrigation use. Aside from regulatory requirements, there are strong economic incentives for the recirculation of tailwater. The tailwater is a valuable resource. This and the fear of contamination has resulted in the recycling of most tailwater.

Contaminated water can percolate below the root zone and into underlying aquifers. Seepage can also result in increased salinity as salts are flushed

out of the root zone into underlying aquifers. Barrett, Peterson and Bately (1991) believe that percolation and seepage losses from the cotton soils of northern NSW and southern Queensland are likely to be minimal.

Probably the most significant source of chemical contamination of water resources is through stormwater run off. Stormwater flushes the chemical from the crop. Some of the run off will be captured in tailwater drains and recirculated but the volume of the run off will, in large storms, exceed the capacity of the tailwater return system and will flow off-farm and into surrounding surface water resources. Research has shown that the first flush after a storm can contain significant quantities of chemicals (Barrett, Peterson and Bately 1991) .

Raingrown cotton production is typically located away from water resources but where it does occur near a water resource, stormwater run off can lead to the contamination of the water resource. Because raingrown cotton fields do not usually trap stormwater running off the field, the potential for stormwater contamination may be a major future problem which must be addressed.

How much contamination is occurring?

Water quality

The Department of Water Resources (DWR) and the water users of the Macintyre, Gwydir, Namoi, and Macquarie Valleys jointly fund the Central and North West Regions Water Quality Program. The primary aim of the program is to collect water quality data within each of the four river valleys to identify stretches of the rivers with adverse water quality characteristics, and to disseminate this information to DWR personnel and to key user groups so that it can be used to establish priorities for management action. The program has been running for three full years (1991-92, 1992-93, and 1993-94). For the 1993-94 year, four reports have been prepared which cover the areas of pesticides, insecticides and herbicides (18 sites), nutrients and general water quality (19 sites), trace metals, and biological activity.

Key findings for the 1993-94 pesticides monitoring program were as follows.

- Pesticide monitoring over three years has shown the seasonality of endosulfan presence in surface waters. Its appearance each year is closely tied to its use as the principal pesticide used on cotton. Eighty per cent of samples from sites in the four river valleys within irrigated agriculture were found to exceed the ANZECC 1992 protection of the

aquatic ecosystem guideline for total endosulfan (0.01 micro grams per litre) during the 'in season' period (November to March) in 1993-94.

- Atrazine was the only chemical detected in sites upstream of irrigated cotton developments where there were very few reported detections of endosulfan. In fact, Atrazine was the most widely detected pesticide during the year.
- All samples complied with the NHMRC (1987) drinking water guideline for endosulfan (maximum of 40 micro grams per litre). The only drinking water guidelines to be exceeded during 1993-94 were those for the chemicals profenofos (on two occasions), atrazine (on two occasions), and diuron (on six occasions). High concentrations of atrazine were a common feature at sites within irrigated agriculture for the Gwydir, Namoi, and Border Rivers in each of the three years, and in the Macquarie River in 1992-93.
- Diuron was most commonly detected at river sites within irrigated agriculture. Fluometuron, metolachlor, and prometryn were each infrequent contaminants of surface waters in the study area.
- No endosulfan was detected in ground water samples but atrazine was detected at depths of 20 metres in samples taken from the Upper Namoi Valley. Low concentrations of organochlorines and organophosphates were found in the upper one metre of soil layers.

Atrazine is not used on cotton crops because of its toxicity to plants. Its main use is for weed control in maize and sorghum crops. It was removed as a registered chemical for weed control in irrigation channels in late 1994. Ground water is the source of water for many towns and farms so the presence of atrazine in water samples has prompted the DWR to develop a strategy to reduce the incidence of the chemical in the water resources.

Endosulfan, which is used widely in the program areas, is used in the cotton industry to control insect pests. However, it is also used to control pests in oilseed crops such as sunflowers and soybeans.

Nutrients and blue green algae blooms

Aside from the occurrence of pesticides in water resources, community concern has been voiced over the incidence of blue green algae in several waterways in New South Wales and Queensland. The growth of blue green algae is influenced by the relative concentrations of nitrogen and phosphorus and the flow rate of the water body. A ratio of nitrogen to phosphorus of less than 29:1 and slower moving flows of water provide

more conducive conditions for the growth of algal blooms but many other factors are involved.

The DWR's water quality program found that the balance between nitrogen and phosphorus was at levels that may encourage algal blooms. However, there was little evidence of algal blooms in the rivers studied in the program. The levels of phosphorus and nitrogen were generally at or above concentrations considered by the ANZECC to be conducive to promoting nuisance plant growth (DWR 1994).

There are numerous sources of phosphorus in rivers and other water resources including urban environments (for example, sewage treatment works), dryland and irrigated agriculture, and natural sources. Natural sources are significant. For example, the soils of the Namoi River basin are particularly rich in phosphorus and make up a significant proportion of the soil entering the Barwon–Darling River via the Namoi (DWR 1994).

Drainage arrangements on cotton farms reduce the risk of nitrogen and phosphorus contamination from cotton production. In many of the inland river systems, tail and stormwater flow away from the river so that any nitrogen and phosphorus contamination of the river is more likely to occur from dryland farmers in the catchment. The incidence of blue green algae is not restricted to areas downstream from cotton growing regions.

Cotton growing removes significant quantities of nitrogen and phosphorus from the system but nitrogen, in particular, is added as a fertiliser.

The overallocation of water rights on some rivers in NSW may have led to some adverse environmental effects. Demands by environmental lobby groups for increased allocations of water for the environment add to the pressure of demands for increased water from other competing users.

Other impacts on the environment

Gibb Environmental Sciences and Arbour International (1991) identified soil compaction as a problem for the cotton industry. The cracking clay soils in which cotton is typically grown are prone to compaction, especially when heavy machinery is used on wet soil. Compaction is widely considered as a reversible problem and the development of cultural methods reduces the extent to which it occurs.

Compaction can lead to right angle root condition (where roots are unable to penetrate the dense layer of soil), reduced soil aeration, reduced infiltration of water, and increased denitrification. This in turn reduces

yields and farm income. In the longer term a reduction in soil quality reduces the land value and this, combined with shorter term reduction in yields and income, provides growers with strong incentives to avoid or reverse soil compaction. Because of the methods available to deal with soil compaction and the strong incentives for growers to make use of them, soil compaction is not considered a major problem for the cotton industry.

GES (1991) does not consider soil erosion to be a major problem associated with the cotton industry in Australia. The gentle gradient in most cotton growing areas and the typical clay soils are not conducive to water or wind induced erosion.

Noise and dust emission are common byproducts of the ginning process. However, the location of most gins away from residential areas reduces the environmental impacts of these problems beyond the factory boundary (GES 1991).

Industry initiated efforts to reduce environmental impacts

The cotton industry has been involved in commissioning a number of studies investigating the impacts of its activities on the environment. The Cotton Research and Development Corporation (CRDC), along with the Land and Water Research Development Corporation (LWRRDC) and the Murray Darling Basin Committee (MDBC), funded a program to investigate methods of minimising the impact of pesticides on the riverine environment. The program, which uses the cotton industry as a model, has three specific objectives:

- to assess the impact of current pesticide use on the riverine environment;
- to develop practical and economic methods to minimise the transport of pesticides from application sites, and to minimise their effect on the riverine environment; and
- to provide a sound scientific basis for the development of management and regulatory requirements (LWRRDC 1994).

The three year program began in mid-1993 with preliminary findings allowing considerable progress toward understanding and quantifying the transport and fate of endosulfan. Final results from the various projects within this program require careful review to allow the development of best practice management techniques.

The aim of the audit was to identify the major environmental issues relating to the cotton industry in Australia and to assess the overall performance of the industry with respect to these issues. The consultants reported to the ACF in 1991 and concluded that:

- the majority of people working in the cotton industry are conscientious about environment standards and, within the limits of their knowledge and abilities, take care to minimise the damage they cause;
- the use of peer pressure and education programs to ensure industry standards are maintained is of paramount importance; and
- a particular strength of the cotton industry is the well developed R&D system which has evolved in parallel with the industry itself, and the strong channels of communication between growers and researchers.

Issues for the industry

The objective of the CRDC/LWRRDC/MDBC program is to provide a sound scientific basis for discussion of issues relating to chemical usage and the environment. While the results of the program have yet to be finalised, this should not stop the cotton industry from developing plans for the various outcomes that might eventuate.

The cotton industry may not have the luxury of deciding an appropriate course of action — the industry may be subject to regulation imposed by state regulators such as the New South Wales EPA or Queensland's Department of Environment and Heritage. McGregor, Harrison, and Tisdell (1994) estimate the cost of compliance with various regulations imposed as a response to possible outcomes of the CRDC/LWRRDC/MDBC program. These results are presented in t able 8.1.

Table 8.1 **Cost of compliance with regulation scenarios**

Scenario	*Regulation response*	*Cost to cotton industry*
		$m
Endosulfan sourced to old river sediments or non-farming sources	No new regulations imposed	0.00
Endosulfan sourced to stormwater, which transports tailwater and sediments into rivers, but riverine biota found to be less sensitive to endosulfan in natural water than in laboratory testings	Irrigators required to store the first 25 mm precipitation of any storm event	Negligible (existing systems should accommodate this requirements)
Endosulfan sourced to stormwater, which transports tailwater and sediments into rivers, and riverine biota are found to be highly sensitive to endosulfan in their natural environment	Irrigators required to store first 50 mm precipitation of any storm event	18.00
The source is spray drift or plume	Restrictions applied to spraying	25.00
Contamination arises from movement of ground water or from diffuse sources, not remediable by changed management practices	Applications of endosulfan is not permitted	67.68

Source: McGregor, Harrison and Tisdell, 1994.

In the worst case scenario endosulfan is banned, resulting in extra costs to the industry of $67.68 million per year (this figure assumes that the replacement chemicals are acceptable on environmental grounds). Kimber, Ahmad and Kennedy (1995) estimate that a switch from endosulfan would cost the industry approximately $44 million per year, although their analysis assumes constant crop revenue and scouting costs which McGregor, Harrison, and Tisdell do not. A voluntary shift away from endosulfan toward less efficient pesticides would cost the industry a similar amount to a forced ban.

The withdrawal of Helix from cotton use this year as a result of the meat contamination scare left the industry unprepared without reasonably priced replacements.

Pest resistance and transgenic cotton

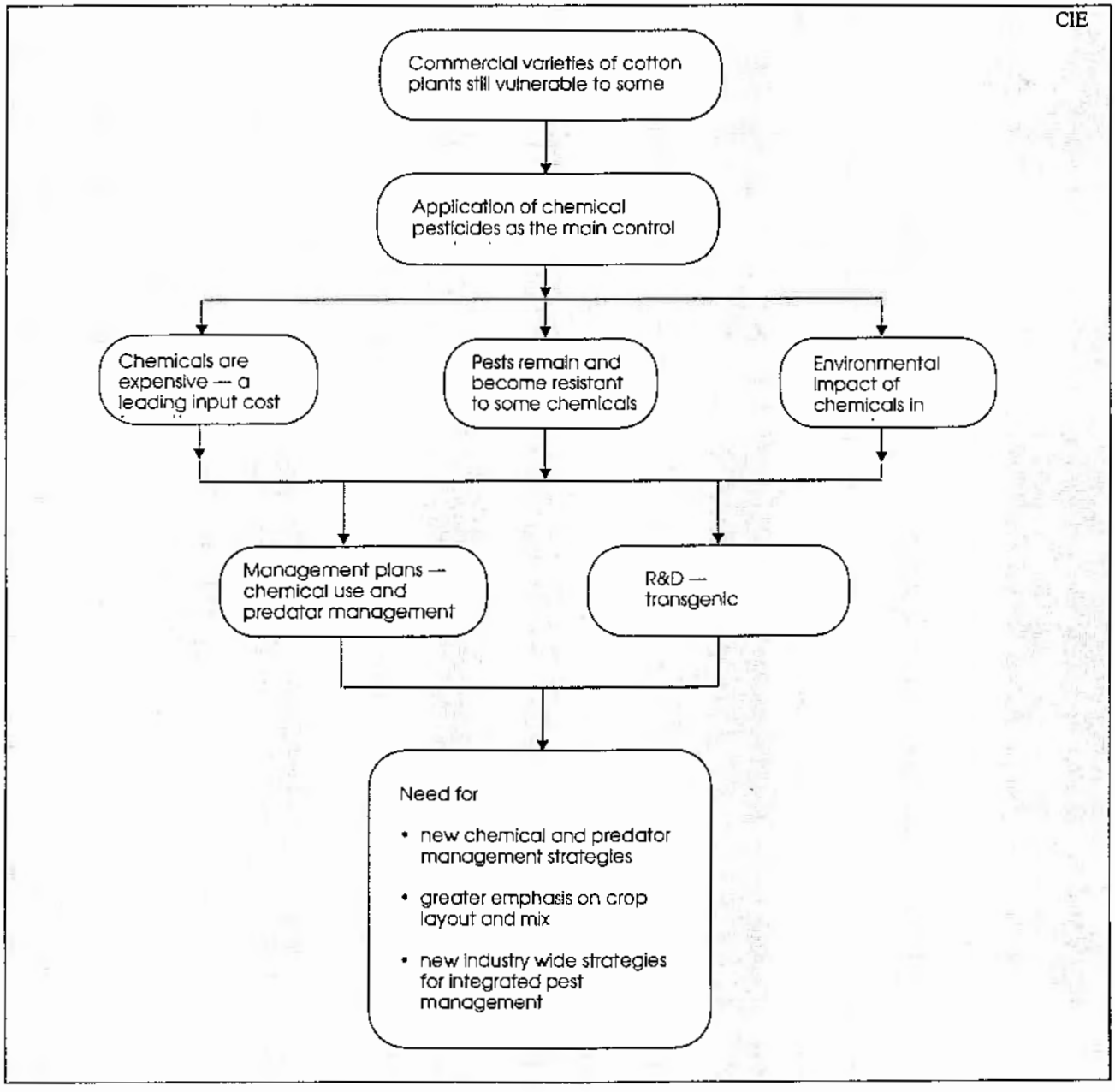
Conventional breeding programs have done much to increase plant resistance to pest attack.

Transgenic cottons represent a scientific leap forward which the industry may be able to harness to further protect the crop and contain the harmful effects on the environment of chemicals like endosulfan. By offering a cotton type with genes producing proteins toxic to the 'Heliothis' pests (especially *Helicoverpa armigera* and *H. punctigera*), they will minimise the need for chemical pesticides, provided an appropriate integrated pest management (IPM) strategy accompanies their introduction.

Resistance management strategies (chart 8.1) must be in place before these transgenic cottons are launched on a commercial scale. This is a big challenge for the industry. Examples abound of previous failures to effectively manage resistance buildup. These include resistance buildup to DDT in the early 1970s (resistance being a significant cause of the failure of the Ord River experiment), resistance to synthetic pyrethroids in the early 1980s and growing resistance to endosulfan more recently. Without sufficient areas of *refugia*, in the form of non-pest resistant plantings to host the moths, resistance in the pests to the plant toxins could rapidly create survivor populations of pests with greatly enhanced resistance and devastating implications for the industry. On the other hand, the complete removal of all target pests could cause non-target pests to thrive and become a problem.

The simultaneous use of food sprays to attract pests to non-resistant refugia and help to maintain low resistance strains of pest in the population may be of help in an integrated management strategy.

Chart 8.1 **The dynamics of cotton pest control**



Another strategy will be the development of transgenic cottons with two or more Bt genes or cotton strains with different Bt genes used in sequence.

It is unlikely that the introduction of the Bt gene alone will provide an effective defence. It will have to be incorporated into an integrated pest management strategy.

These strategies require a cooperative approach within the industry, possibly backed by some innovations by way of 'conditions of use' agreements to be signed by growers before sale of the transgenic seed is permitted. Another possibility along these lines would be for growers to be

registered seed users and supplied with only enough seed to plant an agreed area.

While there may be strong incentives for cotton growers of long standing to behave with collective responsibility in these areas, opportunistic plantings of raingrown cotton may occur with little incentive to look to the long term. This wedge between the interests of long term growers and others could become a difficult management/self-regulation problem for the industry.

Box 8.1 **What is transgenic cotton?**

Transgenic cotton plants are the end result of a genetic engineering process in which a modified gene (with desirable characteristics from some other organism) has been introduced back into the plant's genetic make up. In cotton this technology is being used primarily to develop plants with a so-called Bt gene (Bt from *Bacillus thuringiensis*) which expresses highly effective insecticide crystal proteins which act specifically on two major pests in cotton — *Helicoverpa armigera* and *H. punctigera*. This technology is also being used in an effort to develop cotton strains with resistance to other insect pests, improved field performance, higher yields and better quality fibre and also cotton with naturally occurring colour (for example, 'blue cotton').

The Bt genes from *Bacillus thuringiensis* have been known for over forty years and Bt insecticidal sprays have been used commercially for some time. There are many different types of Bt genes each expressing a slightly different insecticidal crystal protein or delta endotoxin. Each toxic protein is very specific in the way it combines with specific receptors in the gut of the caterpillar causing a break down of the gut lining, thus effectively starving the caterpillar to death. When a Bt gene is introduced into cotton plants only the target species of *Helicoverpa* will be affected. This is highly desirable in that 'leakage' into non-target populations is virtually eliminated.

In small scale trials 'Bt cotton' has been shown to be highly effective in resisting insect attack and to be very specific. The 1995-96 season will be the first large scale field trials and predictions are that within two seasons commercial Bt seed will be available through Cotton Seed Distributors and Delta Pine Australia. In the meantime there is considerable work to be done to have the plants registered (which requires satisfying rigid tests), educating the public to allay concerns and developing appropriate integrated pest management programs for the industry to ensure that this technology is not lost through resistance buildup in the target insect population. One option being researched is to introduce two (or more) slightly different Bt genes in the one cotton plant — this would substantially reduce risk of resistance buildup.

Source: D.Llewellyn and C.Buller, personal communication.

Issues for the future

- The technology for transgenic Bt cotton has been developed but there are time-consuming regulatory steps to be followed before its commercial release. A recent survey of public perceptions (DIST 1994) of genetic engineering indicates that in the case of cotton, the public is likely to be supportive of the Bt gene technology.
- There are probably unrealistic expectations as to what Bt cotton can achieve — which could lead to complacency and disregard to the fundamental principles of combating pest resistance.
- Yield potential and several other issues have yet to be fully evaluated.
- The price of the technology needs to be attractive to encourage the adoption. Otherwise, growers are likely to continue with the use of traditional pesticide methods.
- The appropriate combination of use of Bt cotton and IPM strategies, including use of *refugia,* late season spraying when the expression of the endotoxin declines, and cultivation to minimise over wintering pupae survival also need to be refined.
- Issues in developing the best integrated pest management systems include:
  - are all cropping systems — irrigated and dryland — appropriate for Bt cotton?
  - how best to maintain *refugia* populations of insects not opposed to selection and which can be used to dilute resistant insect strains; and
  - appropriate staged introduction of Bt cottons with different Bt genes.

Strengths and points of potential vulnerability

Strengths

- The industry is clearly addressing the problem of chemicals used on cotton.
- It has a vested interest in reducing the dependence of cotton growing on chemicals. Chemicals are a major cost item in growing cotton.
- Focused R&D on pest resistance to chemicals, management practices, more resistant varieties as well as cooperative, Integrated Pest Management programs have enabled cotton to be grown profitably while reducing to a minimum the impact of chemicals use on the environment.
- So far the geographic concentration of the industry has benefited cooperative IPM programs.
- Development of transgenic cottons provide the potential to substantially reduce the use of chemicals on cotton and reduce the impact on the environment.

Points of vulnerability

- The industry faces public perceptions that it uses large quantities of chemicals which are harmful to the environment and in some cases to human health.
- These perceptions could lead to pressure being placed on regulators to change the 'rules' in a way which would be detrimental to the industry.
- In particular, any severe restrictions on the use of endosulfan, the main chemical used to combat the Helicoverpa species, would place the industry in a very vulnerable position in the short term — before the introduction of transgenic cottons.
- Insects have developed resistance to several other chemicals in the past and may develop resistance to chemicals now in use unless industry-wide IPM programs are widely adopted.
  - opportunity raingrown crops may make industry cooperation harder.
- While transgenic cottons may be introduced commercially in a few years, the industry will lose the full impact of this potentially valuable resource through insect resistance buildup unless the whole industry cooperates in IPM programs.

9 Research and development

Key Points

- Effective R&D has been a major factor behind the rapid development of the modern cotton industry.
- Widespread adoption of improved cotton varieties bred for Australian conditions and improved crop management techniques underlie yield increases of around 60 per cent since the early 1970s.
- Breeding research has also achieved significant increases in the average quality of Australian cotton.
- The close links between growers, researchers, marketers and research funders (for example, CRDC) have significantly contributed to the rapid adoption of research results.
- The industry faces major challenges in reducing the dependence of cotton growing on chemicals and in improving the efficiency of water use.
- Continued evaluation of the industry's research portfolio and CRDC's goals is needed.

R&D is an investment in the future improved performance of the cotton industry. As such, research funders, such as the Cotton Research and Development Corporation (CRDC), can usefully be viewed as investment managers of a portfolio of R&D investment opportunities. Viewed in this way, past investments in cotton R&D activities, particularly breeding new varieties, have been highly successful. Current investments will form the basis of industry performance in years to come.

Research organisation and expenditure

The CRDC is the key industry body which drives the direction of cotton research and provides funding for project research of around $5m or a quarter of total expenditure on cotton research. Each year it contributes to about 100 research projects. The source of funding is through a levy of $1.75 per bale with expenditures on research being matched on a dollar for dollar basis by the federal government up to a maximum of 0.5 per cent of the gross value of cotton production.

Like R&D corporations in other rural industries the CRDC was established in 1990 under the *Primary Industries and Energy Research and Development Act 1989*, taking over the role and operations of the previous Cotton Research Council. Under the Act the CRDC is required to submit to the Federal Minister for Primary Industries and Energy a rolling Five Year Corporate Plan and an Annual Operating Plan and report the achievements of the research outcomes against these Plans in its Annual Report which is tabled by the federal Minister for Primary Industries and

Energy in Parliament. The CRDC is directly answerable to the Federal Minister and the Australian Cotton Growers' Research Association (ACGRA), the designated grower organisation in the Act.

These requirements provide focus and accountability to the CRDC. The corporation's mission is:

> to increase the contribution that R&D makes to the well being of the Australian cotton industry and the community in general.

The major objectives of the Corporation together with proposed funding allocations for 1995-96 against each objective are shown in table 9.1. The CRDC is investing most of its funds in the areas of crop protection and reducing dependence on chemicals, sustainable farming practices and the breeding of new varieties. This reflects the major challenges being faced by the industry.

There is relatively little being invested in market research and reducing post-harvest costs. To the extent that market research may be undertaken by private marketing organisations, it is appropriate that CRDC not fund research which is being done anyway by the private sector. But CRDC would want to satisfy itself that adequate research on marketing and reducing post-harvest costs is being done elsewhere.

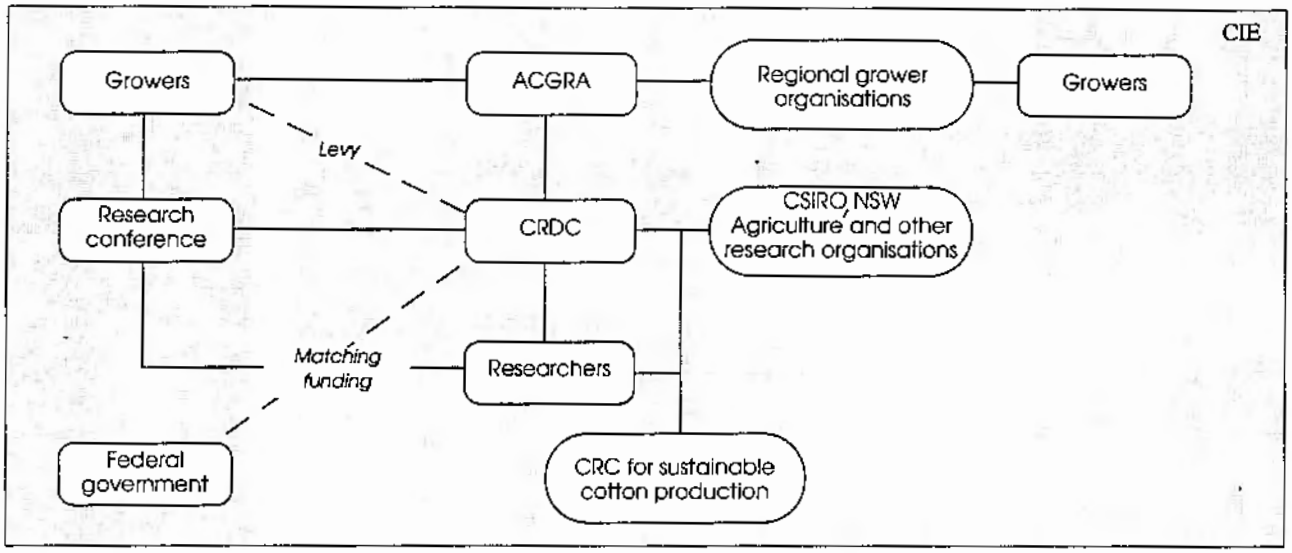
The relevance of CRDC investments to industry problems is enhanced by the close cooperation between CRDC, researchers, the ACGRA and other research organisations. The head office of CRDC is deliberately located in Narrabri. It is close to the main centre of research activity and is in the heart of a major growing region. Growers have considerable input into the CRDC's research program through the ACGRA which examines and comments on all research proposals prior to the CRDC Board deciding on

Table 9.1 **CRDC objectives and funding allocations**

Major objective	*1995-96*	*Allocation*
	$'000	%
1. Protect the crops against pests while reducing chemical dependence.	1439.3	29.6
2. Develop and promote the adoption of environmentally sound, sustainable farming practices.	1518.7	31.4
3. Develop new improved cotton varieties.	890.0	18.3
4. Reduce post-harvest costs and improve the industry's response to market needs.	50.0	1.0
5. Maintain the effectiveness of the R&D effort.	313.0	6.4
6. Improve technology transfer.	144.5	3.0
7. Improve the availability and quality of human resources involved in R&D.	500.0	10.3
Total expenditure on projects	**4855.7**	**100.0**

Source: CRDC Annual Operating Plan 1995-96.

Chart 9.1 **Research organisations in the cotton industry**



allocation priorities. ACGRA is also consulted on the overall direction of the research program, and recipients of CRDC funds report the progress and relevance of their research at the ACGRA's biennial research conference which is frequently attended by over 1000 delegates, a third of whom are usually cotton growers.

An additional line of research cooperation has recently been set up with the establishment of the Cooperative Research Centre for Sustainable Cotton Production. Set up under the federal government's cooperative research grants program in 1993, its aims are to foster the development of sustainable cotton cropping systems and 'to ensure the future of the cotton industry as a responsible and contributing corporate citizen'. Considerable emphasis is being placed on development and implementation of environmentally responsible production strategies.

Core participants include CRDC, CSIRO, NSW Agriculture, Department of Primary Industries, Queensland, and the universities of Sydney and New England. The annual budget is around $10 million per year, $8 million of which comes from the partners.

Table 9.2 provides an estimate of the main sources of total funding for research in the cotton industry. It is based on the 1992-93 year because that year provides a more normal season and is based on data presented to the Industry Commission inquiry into R&D by ACGRA. To this should be added some of the expenditure of the new CRC on sustainable cotton production.

Table 9.2 **Estimate of cost of total cotton research** 1992-93

Contribution	*$'000*
Federal government contribution to CRDC R&D	2 218
Industry contribution to CRDC R&D	2 218
Direct farm research estimate	8 400
Cotton seed distributors (grower owned) research	1 000
Other farm contribution based on R&D — for example, North West Regions Water Quality Programs and gin research	500
Other non-farm funded R&D (state and federal governments, universities, etc.)	6 650
Total	20 986

Source: Cotton Research and Development Corporation.

Evaluation

There is little doubt that the rapid development of the cotton industry in Australia owes much to the success of research and adoption of research results. Average cotton yields have increased by about 60 per cent since the early 1970s and the quality of Australian cotton is now recognised as among the best in the world. (Evaluation of cotton varieties is detailed in appendix A.) Focused research efforts have also made major contributions to management practices aimed at lessening the dependence of cotton production on chemicals potentially harmful to the environment. The environmental audit (Gibb, Environmental Science and Arbour International 1991), noted earlier, detailed the achievements the industry has made in this regard.

While in hindsight it is relatively easy to point to success stories — and the CRDC undertakes extensive ex post evaluations of key areas of its research portfolio — the thing that matters most is getting the 'right' portfolio of research activity in the current period. R&D investments today will determine the shape of the industry in future years.

The CRDC carefully scrutinises research proposals which are submitted to it in terms such as:

- Is the research of real potential benefit to the cotton industry and community?
- Is it well focused and likely to succeed and can success be measured against performance criteria?
- Is there potential for commercialisation or would the outcomes be more efficiently and effectively exploited by rapid free adoption?
- Does the research meet the priority objectives of the Corporation (which in turn should reflect those of government and industry)?

The Corporation also adjusts its overall portfolio and sets performance targets for its various programs. For example, it has set performance indicators of:

- 50 per cent reduction in the use of chemical insecticides by the year 2000;
- 90 per cent adoption rate by cotton farmers of Integrated Pest Management (IPM) by the year 2000;
- 50 per cent reduction in farm origin contaminants identified in the riverine system and the environment generally; and
- 10 per cent improvement in water use efficiency (measured as bales per megalitre of water used).

Portfolio management principles

Allocating funds to R&D portfolios, ex ante, is not easy. Likewise, the evaluation of industry R&D efforts is not easy. If R&D is to be viewed as an investment in the future of the industry it is useful to ask if there are investment portfolio principles which can be applied. Some of these are briefly discussed below in relation to the CRDC.

- There is a critical mass of expenditure to achieve any benefits from R&D expenditure on particular programs and after that there are diminishing returns to R&D expenditure.
  - Furthermore, the assessment of net benefits will be invariably biased toward overstatement of the benefits — the implication is that the downside risk increases disproportionately as more money is spent on a program.
- From a portfolio viewpoint, maximum returns to the portfolio will accrue when allocations among alternative programs are made so that the marginal dollar of funding goes to the program with the highest expected marginal benefit.
- Priorities in funding R&D programs will shift over time depending on past levels of expenditure. This follows from the point immediately above.
- Allocations to obtain maximum returns need to be balanced against the need to spread risk and not have all investment 'eggs in one basket'.
- The R&D portfolio should include long term investments in cultivating the technical and skills base of the R&D providing 'industry' (this is something the CRDC does very well).

- Investment by CRDC should not include areas which would otherwise 'crowd out' private research. The aim of CRDC should be to ensure the largest R&D 'pie' for the whole industry.

In terms of these principles, the CRDC is heavily investing in 'on farm' R&D with the aim of reducing dependence on chemicals, addressing environmental problems and improving production efficiency. In this respect the industry is responding to outside concerns as well as attempting to reduce costs of production. The community at large has a stake in the environmental issues and both the community and the cotton industry have a stake in reducing the use of chemicals in cotton production. The CRDC's target of 50 per cent reduction by 2000, for example, has significant implications for how much it spends on this program relative to other areas of R&D.

When a single goal assumes such large relative importance, the need to continually assess it is all the more pressing. For example:

- While other broadacre industries use chemicals, would such a large reduction in chemical use in cotton production change perceptions?
- Would a smaller, say, 30 per cent reduction in chemical use be sufficient to change community perceptions?
- Is it a perception problem that will not go away while any chemicals are used at all?
- Should some of the R&D effort devoted to reducing the use of chemicals be shifted over to continuing monitoring of the actual effects on people and the environment?

Finally, there is the issue of the overall size of CRDC's budget. It was never intended that the government's matching contribution to R&D expenditure up to the point of 0.5 per cent of the value of production should limit the contribution of industry to R&D expenditure. Contributions from cotton growers already make up slightly more than 50 per cent of CRDC expenditure on R&D but the proportion could go higher if the industry chose to increase the levy rate.

The arrangements for government contributions to R&D funding may change in the future as a result of recommendations of the Industry Commission (IC). The IC has recommended that the government's contribution be on a dollar for dollar basis up to 0.25 per cent of GVP and thereafter on the basis of one dollar for every two dollars contributed by industry with no limit. The government's response to the IC Report, following its own comprehensive review, is expected in late 1995 or early

1996. Industry groups have generally responded adversely to the IC recommendations.

In summary

On balance the regional concentration of the cotton industry, its commonality of problems, the market driven, export oriented nature of the industry along with the 'in the field' location of R&D headquarters have all gone to make the task of R&D portfolio management somewhat easier than for many other Australian rural industries. Whereas the CRDC deals with around 100 projects each year, the Grains Research and Development Corporation, for example, funds nearly 1000 projects each year and has a budget ten times that of the CRDC. Besides the immediate and pressing challenges associated with water and chemicals, other longer term issues facing R&D management will occur as the share of non-specialist and rain-growing production increases, as production in other regions (for example, the Ord River region) expands and as differences emerge in people's willingness and capacity to adopt new technologies.

Strengths and points of potential vulnerability

Strengths

- **Research effort in the cotton industry has been well focused on industry problems, particularly on improving yields and quality of cotton and reducing dependence on chemicals.**
- **There is a high degree of coordination and cooperation among stakeholders on setting directions for research and monitoring research results. This is facilitated by the geographic compactness of the industry.**
- **The CRDC places considerable weight on maintaining the research base and fostering good researchers to stay with the industry.**
- **Industry research is complemented by practical on farm research by cotton farmers.**

Points of vulnerability

- **The industry faces significant problems with respect to chemical use and, more recently, water availability. A key issue is not only the proportion of the R&D budget which should be spent on these issues but also on whether the total R&D budget is adequate.**
- **There are very little CRDC funds being spent on marketing and post-harvest research. CRDC should ensure that either this type of research is being done by other research bodies or the private sector, or that the marginal returns to investment in other areas are higher.**
- **With the expansion of cotton into more geographically diverse regions, such as in the Ord River region, coordination and focus of research effort may become more difficult in the future.**

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Appendix A An introduction to cotton and cotton growing in Australia

Cotton is one of the oldest known fibres. It is versatile and is one of the most profitable crops grown in Australia. Almost all of the plant can be put to a profitable use. This appendix provides a brief sketch of cotton growing and processing for those unfamiliar with the cotton industry. The various stages of cotton production and the uses which the cotton plant can be put are illustrated in chart A1.

Growing cotton

Cotton (*Gossypium hirsutum*) being commonly known as the Upland plant variety and accounting for the bulk of the world's production is a member of the Hibiscus family and grows best in climates with low humidity, long hours of sunshine, high temperatures and low rainfall. Although low rainfall is preferable — it reduces the incidence of waterlogging, plant disease and fibre quality losses — a reliable supply of water is essential for a high yielding crop.

Cotton is grown commercially as an annual crop. Australian bred varieties of the Upland cotton are predominantly grown in Australia. Chart A2 depicts the growing process which typically lasts around 150–180 days from planting until harvest but this varies depending on the variety and the climatic conditions. The trend is toward a shorter growing period.

The cotton crop is planted as soon as the soil is warm enough. The Australian cotton crop is usually planted from late September to mid-November.

Cotton is mainly grown in rows approximately one metre apart. Crop yields are increased through the use of fertiliser, irrigation, and weed and insect control. Five or six irrigations may be applied throughout the growing season when there is adequate water. Weeds are controlled through the application of herbicides, hand weeding (chipping) and mechanical cultivation. Insects are primarily controlled by chemical insecticides.

Chart A1 **Australian cotton: from plant to final user**

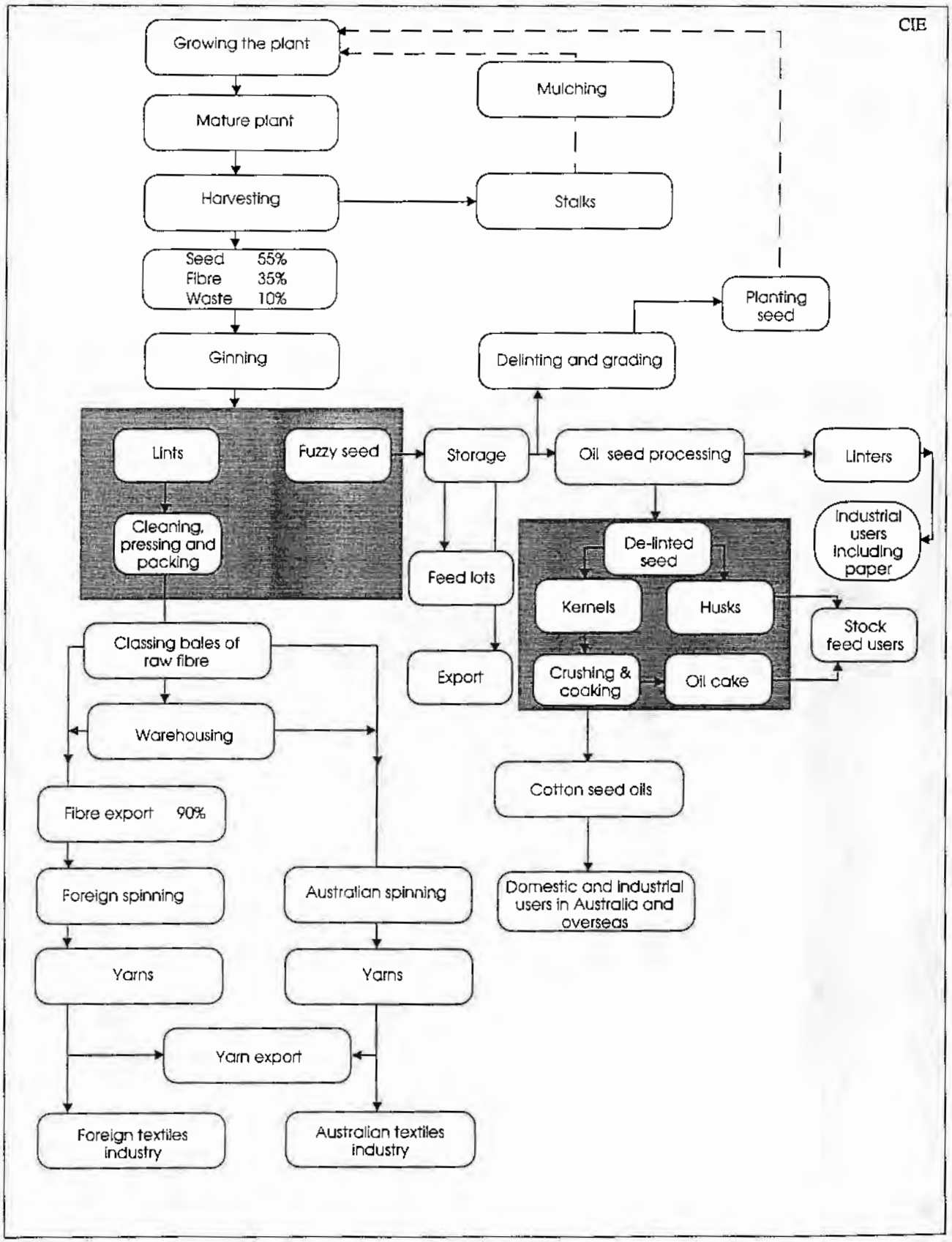
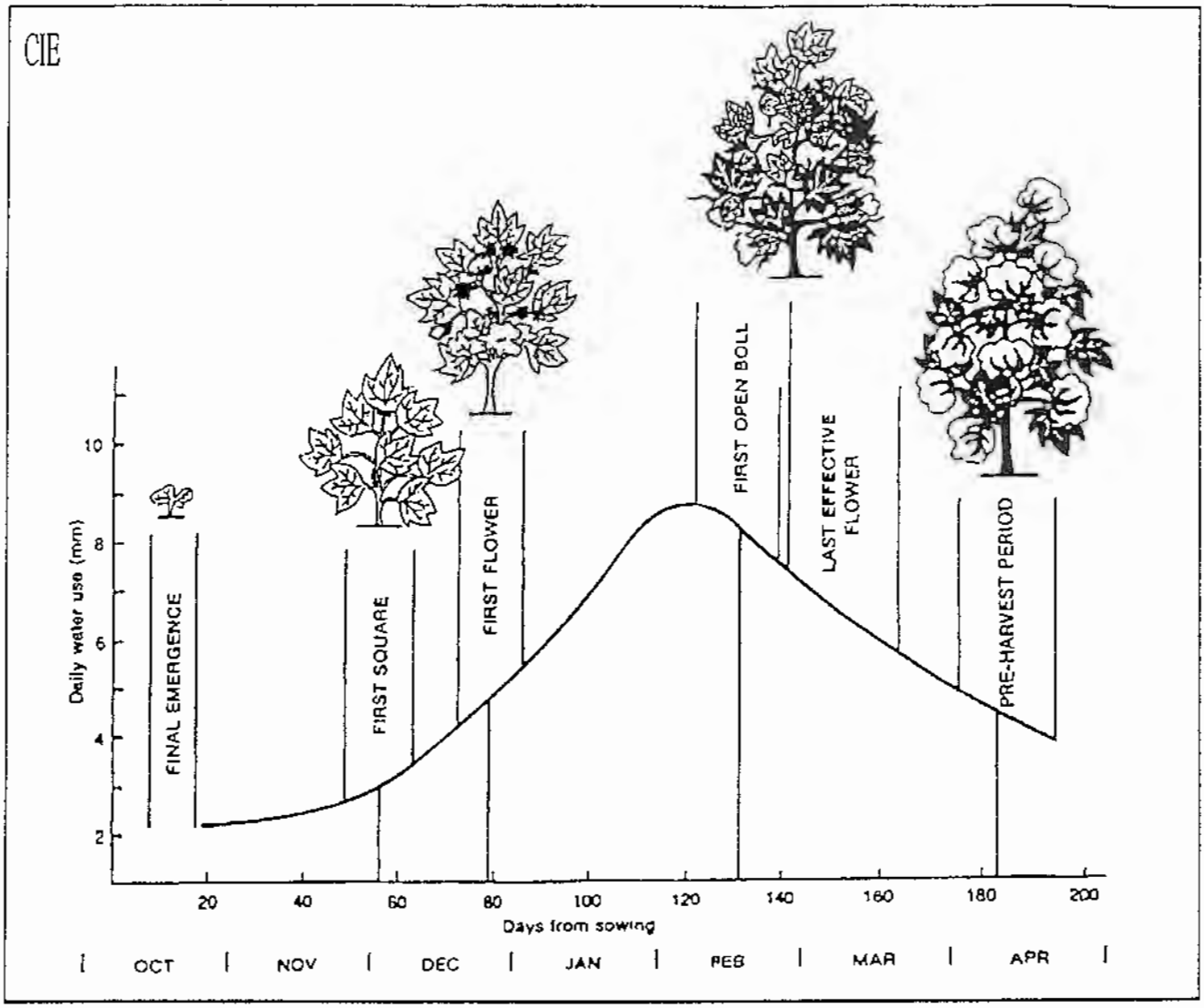


Chart A2 Growing process of cotton



Source: Department of Agriculture, NSW.

Depending on the variety and season the crop is ready for harvest in late summer or early autumn when the bolls are open. A defoliant is applied to simplify picking and to avoid contamination and staining of the lint. Mechanical cotton pickers are used throughout Australia and they pick two or four rows at a time. Mechanical pickers then dump the seed cotton into a module builder which compresses it into a 8–15 tonne stack (module) which is covered and transported in specially designed trucks to the first stage of processing (ginning).

Processing

Ginning

The modules arriving at the gin contain seed cotton (lint fibres attached to seeds) contaminated with leaves and trash. Ginning is the process by which the lint fibres are removed from the seeds (chart A3). Seed cotton is dried and cleaned prior to separation. The cotton is dried to bring the moisture content down to around 7 per cent which facilitates the removal of leaf trash and dirt.

Saw gins are generally used to remove lint from the seed for medium to long staple. In saw ginning, which is the common process in Australia, high speed rotating circular saws draw fibres through a series of fine ribs. The fibres break loose from the seed and are drawn through, leaving the seed behind for further processing. The fibres are removed from the saws by brushes. For the extra long staple varieties roller ginning is best for separating the lint from its seed. For instance, a roller gin is located at Lake Tandou near Broken Hill where extra long staple Pima (G. berbadense) varieties are grown.

Even though the cotton plant produces more seed by weight, the major product in value terms is lint. Once the seed cotton has been ginned, the lint is packed into 227 kg bales ready for sale. Samples of the cotton are taken from bales for inspection and/or testing usually at the point of bale pressing.

Spinning

The lint or raw cotton undergoes several processes at mills before being converted into fabric. The spinner formulates a lay-down of bales to produce the desired quality of yarn and this is then cleaned and fed into carding machines. The carded cotton is drawn through a series of rollers which decreases the bulk of the cotton and makes the fibres parallel. The fibres are given a slight twist to improve their strength.

The resulting fibre is then spun into yarn. The fibre is either ring spun, open-ended spun or rotor spun. Ring spinning produces a finer quality yarn which is stronger and thinner than open-ended spun yarn. However, the open-ended process produces a more uniform yarn. The spun yarn is now ready for either knitting or weaving into fabric.

Cotton seed

For each bale of lint cotton produced, the gin has an output of some 330 kilograms of 'fuzzy' seed. A small amount of this seed is treated by seed companies for sale. The remainder is either exported, fed to cattle, or crushed for oil and other byproducts.

The crushing process involves a number of stages: the removal of the remaining short fibres (linters) from the fuzzy seeds, removal of the hulls from the kernels and finally the crushing (either by chemical or mechanical means) of the kernels. The process at the oil mill yields four products: oil, meal, hulls and linters.

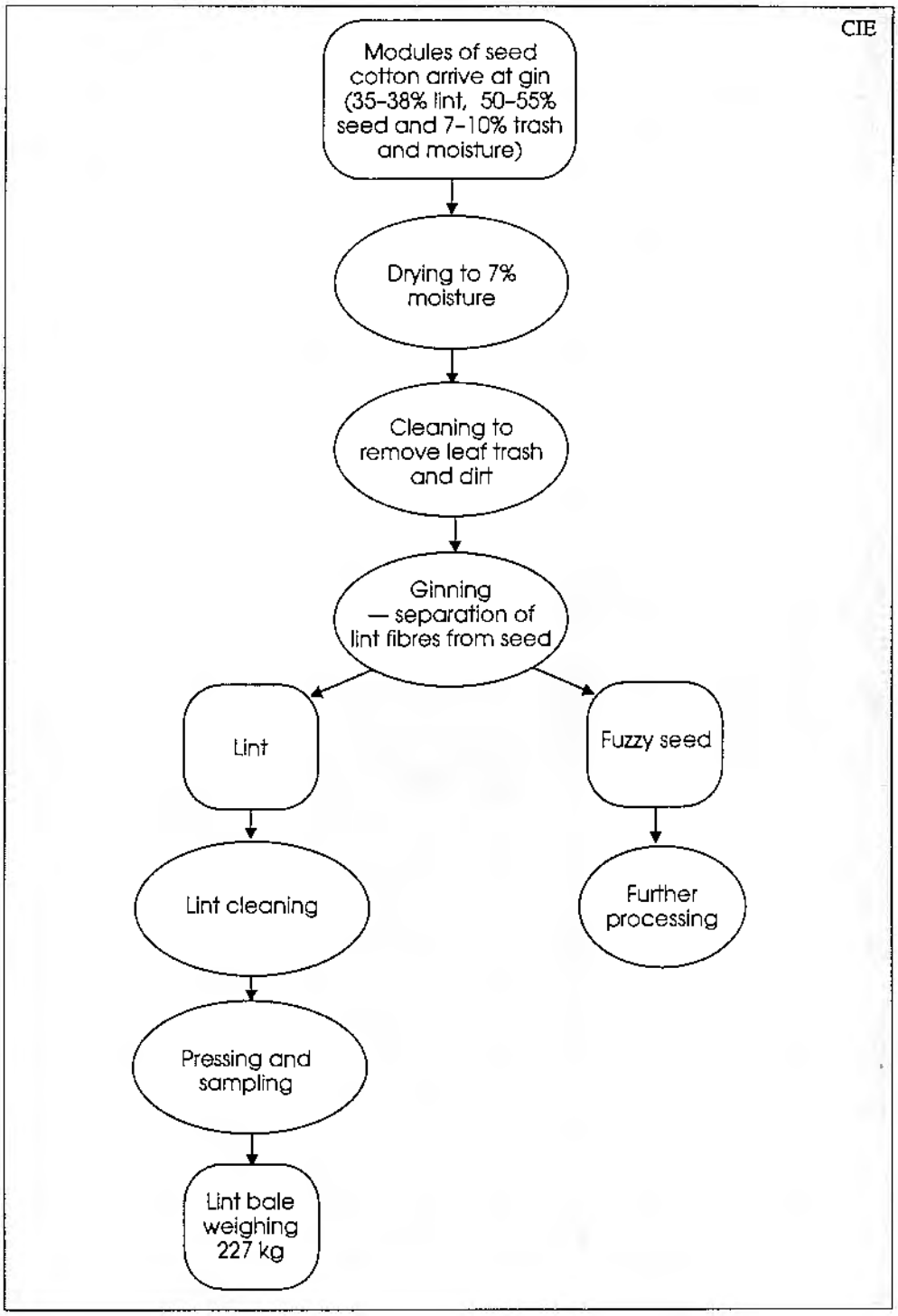
Uses

Cotton fabric is widely used in the production of textile based products such as clothing, furniture, furnishings and manchester. Research and innovation are continually expanding the uses for cotton. For example, the development of 'wrinkle free' cotton fabric, produced by the application of a chemical wash, either at the fabric or garment stage changing the molecular structure of the cotton, may have great market potential (Cotton Yearbook 1994, p. 39).

Naturally coloured and organically grown cotton products are also becoming popular with consumers concerned about the use of chemicals in the production of cotton, or who simply like the natural look (Milliken 1995, p 111). Research into non-textile applications for cotton fibres, particularly linters and motes, is also being carried out by a wide range of industries.

Cottonseed oil is used for human food such as cooking oils and in margarine. Other uses include a great variety of non-food products such as soaps, pharmaceuticals, insecticides, fungicides, cosmetics, rubber and plastics. The meal from the crushing process is used in stockfeed as a major source of protein. The hulls are also used in stockfeeds, mulch and poultry litter. The linters are a source of a variety of cotton fillings, cotton buds, paper and other uses for low quality cotton.

Chart A3 **The ginning of cotton**



Cotton in Australia

All cotton in Australian is produced in New South Wales and Queensland with the majority produced in the irrigated river valleys of northern NSW and in southern and central Queensland.

Over 90 per cent of Australian cotton is exported. In 1993-94 Japan, Indonesia, South Korea, and China were the biggest export destinations taking 73 per cent of total exports. The remaining 10 per cent of production was sold to Australian based spinners and weavers.

Cotton around the world

Cotton is grown on all continents throughout the world — wherever climate permits commercial production. China, the United States, India, Pakistan, Brazil, Turkey, Australia, Uzbekistan and Turkmenia dominate world production, producing over 80 per cent of the total world crop. The United States and Uzbekistan are the major exporters with the United States exporting over six and half million bales and Uzbekistan over five and half million (the bulk of which has traditionally gone to Russia). This compares with the third and fourth largest exporters, Turkmenia and Australia, which export between one and two million bales per annum (Cotton Yearbook 1994).

Major importers of lint cotton are Russia, Japan, Indonesia, Brazil, Thailand, South Korea and Italy. While China is the biggest producer of cotton in the world it is sometimes an importer and sometimes an exporter of cotton lint depending on domestic production. China is also a major exporter of finished cotton products.

Cotton in the world fibre market

Cotton's share of the market has declined from 68 per cent in 1960 to 48 per cent in 1993 (chart 3.1). Despite the need for blending in some natural fibre to offset disadvantages of pure polyester fabric such as non-absorbency and slipperiness, the fact that cotton typically has a relative price disadvantage continues to drive manufacturers to substitute the maximum acceptable synthetic component into their products.

However, the increasing demand for natural fibres and the jeans revolution have helped offset market share decline.

Cotton growing in Australia

Cotton growing has had a long and chequered history in Australia with cotton seed brought from England with the first fleet. However, as box A1 shows, the recent expansion commenced in the early 1960s, with irrigators making use of a reliable water source from the newly constructed Keepit Dam on the Namoi River. Cotton production in the river valleys of northern New South Wales and southern Queensland has grown steadily since that time. In 1992 cotton was Australia's fourth largest crop and it is a major contributor to the economies of the various regions where it is grown.

Box A1 **History of cotton in Australia**

1788	Cotton introduced to Australia.
1830	First export shipment of three bags sent to England.
1857	Small quantities of raingrown cotton grown in Queensland.
1861–65	American Civil War caused American cotton production to fall with Australia filling the gap.
1871	Cotton production peaked in Australia but fell away as world prices for cotton declined.
1926	Queensland Cotton Marketing Board established and government subsidy introduced to promote cotton production in central Queensland.
1934	Cotton production of 17 000 bales.
1954	Cotton industry all but non-existent.
1958	Keepit Dam completed on the Namoi River providing irrigation water to the Namoi Valley.
1960	Limited irrigated cotton production in south-west Queensland.
1961	Two Americans, Frank Hadley and Paul Kahl, plant a commercial crop at Wee Waa using water from the Keepit Dam to irrigate the crop.
1963	A bounty on raw cotton was introduced to encourage expansion of the industry. Cotton production starts in the Ord River Irrigation Scheme in NW Western Australia.
1966	Cotton established in the Macquarie Valley following completion of the Burrendong Dam. Cotton production also begins in Bourke.
1968	Emerald Irrigation Area established and first exportable surplus produced.
1971	Raw Cotton Bounty removed. Cotton production of 87 000 bales.
1973	Cotton production in the Ord River Scheme ceases due mainly to insect resistance to pesticides.
1975	Cotton production of 110 000 bales.
1976	Cotton established in the Gwydir Valley at Moree using water from the newly constructed Copeton Dam.
1977	The construction of the Pindari and Glenlyon Dams allows cotton to be grown in the Macintyre Valley.
1980	Approximately 435 000 bales of cotton produced.
1985	Cotton production reaches 1.1 million bales.
1992	World record yields lead to a record harvest of 2.2 million bales.
1995	Crop fell to around 1.4 million bales because of drought.

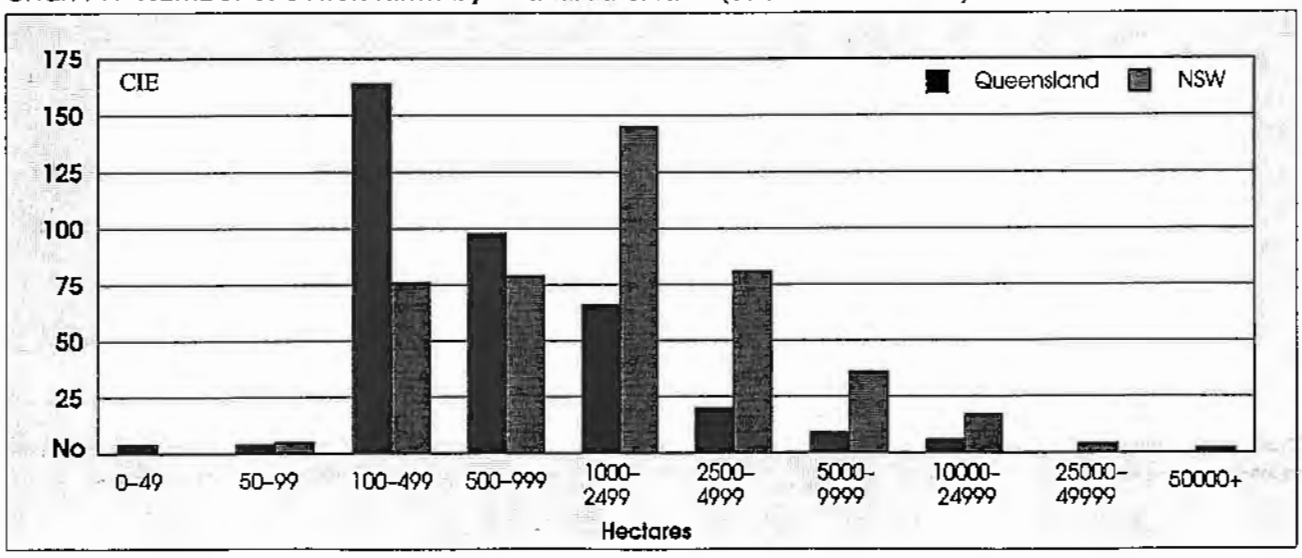
Growers

There is a diverse range of growers in the Australian cotton industry. Some growers specialise in producing irrigated cotton while others grow cotton as one of a number of raingrown crops. The majority of farms are operated as family concerns but there are also a number of large corporate growers.

Chart A4 shows the diversity in the sizes of farms growing cotton in Australia and the large number of small farms in Queensland.

The average area of cotton grown by non-corporate growers is approximately 500 hectares in New South Wales and slightly smaller in Queensland. Corporate growers may grow in excess of 12 000 hectares of cotton annually (Gibb Environmental Sciences and Arbour International 1991).

Chart A4 **Number of cotton farms by total area of farm** (as at 31 March 1993)



Production

The steep rise in production from about 100 000 bales in the 1970s to a peak of 2.2 million bales in 1991-92 was a result of improving yields (chart 2.3), the completion of the Copeton Dam on the Gwydir River and Pindari Dam on the Macintyre River and the expansion of cotton on the Macquarie River. A lack of water as a result of the drought halted the expansion of production in 1992 following a year of record yields and production. Since the drought began cotton production has slipped from 2.2 million to 1.4 million bales.

The expansion in cotton production has been brought about through:

- improved varieties and increased yields;
- more land devoted to cotton production; and
- improved ginning and handling techniques.

Of the world's major producers, Australian yields of irrigated cotton are among the highest. Australian yields have fluctuated over time but have exhibited a significant upward trend. The upward trend in yields has been brought about through improved growing techniques and farm management, improved pest control, and superior varieties. The size of the cotton area has been heavily influenced by the amount of water that has been available. As more government dams have been built, water supply at first became more reliable, and commercial cotton production in those areas has become viable.

Cherry (1994) points to the invention of module technology as assisting the expansion of the industry. The development of modules allowed the expansion of the industry as unginned cotton (in modules) could be stored in the field. Harvesting could then be carried out over a shorter period and ginning over a longer period.

Location

Cotton grows best in conditions of higher temperatures, low humidity, clear skies and long hours of sunshine. Of these conditions temperature is the most important influence on the growth and development of the cotton plant, and on the quality of the fibre. A common method of measuring the suitability of an area for cotton production is to calculate its 'day degrees' of heat in the growing season. For instance Emerald, the northernmost region, produces 2260 day degrees, Moree (Gwydir, NSW) 1966 day

Table A1 **Cotton producing regions and their major water supply**

Growing region	*Water source*
Emerald	Fairbairn Dam
Biloela/Theodore	Callide Dam/Dawson River
Darling Downs	Leslie Dam
St George	Beardmore Dam
Macintyre Valley	Pindari and Glenlyon Dams
Gwydir Valley	Copeton Dam
Namoi Valley	Keepit and Split Rock Dams
Bourke and Lower Darling	Darling River (unregulated flows)
Macquarie Valley	Burrendong and Windmere Dams

degrees and Trangie (Macquarie, NSW) 1748 day degrees. It seems probable that the Ord Valley in WA — a potential growing area — will produce sufficient day degrees for a winter (dry season) crop to grow successfully. The latitudinal flexibility of cotton worldwide (ranging from the equator to 46 degrees of latitude in the northern hemisphere) indicates that potential may exist in Australia for expansion subject to the availability of sufficient quantities of water and suitable varieties.

The importance of water

While many areas in Australia have climates suitable for growing commercial quantities of cotton, the importance of water in increasing crop yields determines where cotton is grown. The main water sources for the various regions are presented in table A1.

In the early stages of its recent development, the Australian cotton industry was relatively concentrated in the river valleys of northern New South Wales and in southern Queensland, which were selected because of their location in terms of physical features for irrigated cotton production. The suitability of these valleys for irrigated cotton production is clearly demonstrated by the fact that they produce some of the highest average yielding crops of cotton in the world and provide a very high gross margin when compared to many other crops. It is only recently that persistent drought conditions have prevailed in the north of New South Wales and state dams have been inadequate. The drought and improved varieties has meant that some growers are reviewing cotton production options in other areas. These include the Lachlan and Murrumbidgee Valleys of southern New South Wales and the Upper Namoi and the Ord River Valley of Western Australia.

Table A2 **Cotton farms as a per centage of total farms in region**

NSW	*Cotton farms as % of total farms in region*	*Shire and QLD*	*Cotton farms as % of total farms in region*
Lachlan		Emerald	23.08
Carrathool	0.37	Pittsworth	13.97
Macquarie		Balonne	12.3
Warren	20.99	Jondaryan	11.85
Narromine	5.94	Wambo	11.4
Castlereagh		Millmerran	9.73
Coonamble	0.60	Waggamba	8.62
Coonabarabran	0.55	Banana	4.53
Namoi		Chinchilla	2.50
Narrabri	21.86	Wondai	1.58
Gunnedah	7.31	Belyando	1.07
Quirindi	0.41	Rosalie	0.67
Parry	0.20	Laidley	0.44
Gwydir/NSW side		Tara	0.28
Macintyre		Murilla	0.0
Moree Plains	27.74		
Yallaroi	4.17		
Bingara	0.67		
Barwon			
Walgett	6.55		
Brewarrina	0.79		
Darling			
Bourke	4.61		
Central Darling	0.69		

Source: The Australian Cotton grower, Cotton Yearbook, 1992, 1993 and 1994, Toowoomba, QLD.

Cotton is a highly concentrated industry

Within the cotton growing areas cotton is a major agricultural crop. Table A2 shows that in the Moree Plains, Narrabri and Warren areas of New South Wales and the Emerald area of Queensland over 20 per cent of all farms produce cotton. Other areas, particularly in Queensland, have significant numbers of cotton producing farms. This high concentration of cotton farms has probably contributed to cooperation within the industry and the 'cotton culture' that emerged in the early years of commercial cotton growing.

The highly concentrated nature of the industry is mainly a result of water availability. The location of gins did have some impact on the development and growth of the industry. However, while the location of existing facilities influenced where cotton was grown it did not preclude the development of areas which could grow cotton economically — as evidenced by production in locations such as the Menindee Lakes area where a gin (owned by the operators Tandou) was built following the establishment of a successful cotton farm.

Table A3 **Estimated cotton yield** 1991-92 to 1994-95 by growing region

State and district	Irrigated yield (Bales/ha)				Raingrown yield (Bales /ha)				Total yield (Bales/ha)			
	1991-92	1992-93	1993-94	1994-95	1991-92	1992-93	1993-94	1994-95	1991-92	1992-93	1993-94	1994-95
New South Wales												
Macquarie	6.91	6.52	7.79	7.50		1.00	1.00		6.91	6.34	7.60	7.50
Bourke	7.75	6.63	6.80	7.00					7.75	6.63	6.80	7.00
Namoi	7.73	7.21	6.90	7.30	3.00	2.00	2.20	2.50	7.45	6.46	5.93	7.10
Gwydir	8.19	6.00	4.00	6.60	3.85	1.20	1.17	2.50	7.49	5.00	3.32	4.60
Macintyre	8.31	7.81	4.00	7.20	3.86	1.25	1.00	2.50	7.51	6.64	3.06	5.80
Others	6.80	5.80	5.00	5.50					6.80	5.80	5.00	5.50
Sub total	**7.83**	**6.87**	**5.96**	**7.20**	**3.74**	**1.44**	**1.53**	**2.50**	**7.39**	**6.11**	**5.15**	**6.60**
Queensland												
St George	7.45	7.00	7.17	7.40					7.45	7.00	7.17	7.40
Darling Downs	7.42	6.56	5.52	7.50	3.41	1.50	1.41		5.53	4.18	3.78	5.80
Biloela/ Theodore	7.20	7.00	5.80	7.30	3.00		1.00	3.00	6.50	7.00	5.00	6.70
Emerald	7.57	9.00	7.31	7.50	2.50	1.00	2.00	2.00	6.94	8.50	6.72	7.10
Sub total	**7.45**	**7.47**	**6.32**	**7.50**	**3.30**	**1.47**	**1.45**	**1.80**	**6.25**	**5.88**	**4.93**	**6.40**
Total	**7.75**	**7.00**	**6.05**	**7.30**	**3.53**	**1.45**	**1.50**		**7.11**	**6.05**	**5.09**	**6.60**

Source: The Australian Cottongrower, Cotton Yearbook, 1992, 1993 and 1994, Toowoomba, QLD.

Methods of production

Cotton is fairly tolerant to droughts and can be grown commercially as a raingrown crop. However, as table A3 shows, irrigation significantly increases crop yield.

In Australia irrigated yields in excess of eight bales per hectare were recorded in some valleys for the 1991-92 crop. The average irrigated yield in Australia was 7.75 bales per hectare but this declined to 6 bales per hectare in 1993-94 due to drought and irrigated crops running out of water. In 1994-95, when water shortages were more severe, irrigated yields averaged 7.3 bales per hectare but on a reduced area. In comparison, the national average yield for raingrown cotton ranged from 1.5 bales per hectare in 1993-94 to 3.5 bales per hectare in 1991-92. Available soil moisture and lack of rain severely restricted the size of the 1993-94 crop.

Irrigation

In 1993-94 over 92 per cent of cotton production was irrigated cotton.

Almost all irrigated cotton grown in Australia is furrow irrigated. The design of furrow irrigation layouts takes into account the natural slope of the land, the soil type, the need to capture tailwater and the need to have adequate drainage. In general, the result is a very efficient system in which

all tailwater and the majority of local stormwater is collected and recycled. On average, the total water use on an efficient farm is around 20 per cent to 25 per cent above the crop's total water requirement. In Australia the yield obtained per megalitre of water used is among the highest in the world. In Australia, a general rule of thumb is one bale of lint cotton per megalitre of water applied. In Uzbekistan approximately one megalitre of water produces 0.30 bales of lint cotton.

Australia's water using efficiency is therefore more than three times higher than that of the second largest exporter of lint in the world.

Small areas of cotton are grown under drip and sprinkler irrigation. A small area of cotton is grown commercially under drip irrigation in the Darling Downs. Elsewhere experimentation with buried drip irrigation as a water efficient form of irrigation is occurring in response to extended drought conditions.

Crop rotation

Irrigated cotton is typically grown on a four or five year rotation cycle — usually four years of cotton followed by wheat or a legume. The alternate crop is often not irrigated, giving the soil an opportunity to dry out, facilitating aeration and ameliorating soil borne diseases. The rotation of raingrown cotton (discussed below) depends upon a variety of factors such as rainfall, farm cropping mix and soil type. The current drought is enforcing the fallowing of much cotton producing country.

Raingrown

Raingrown cotton is an opportunity crop in Australia, grown when conditions are suitable.

The irrigator who has made the capital investment and obtained water rights will grow cotton to the extent that water availability permits, given the high gross margins relative to other crops. Similarly, the raingrown farmer will be influenced by cotton's high margins. However a grower's decision to produce raingrown cotton depends initially on soil moisture status. The net return will primarily depend on the expected price and yield from the crop. The price of cotton is determined in the world market, in which Australia is a small player. The crop yield varies significantly with seasonal conditions. In particular, the yield from the crop will depend critically on the level of soil moisture and rainfall. Soil moisture condition

depend on rainfall prior to planting and the capacity of the soil to store water.

While cotton prices and the expected yields are the major influences, other factors will affect the net return and the decision to produce a raingrown crop. These include the availability of contract pickers, if required, proximity to a gin and the appropriateness of on-farm equipment for cotton production. To some extent these factors affect where raingrown production occurs — raingrown production is more likely to occur in established cotton areas where the facilities such as gins, skilled labour and farming equipment are readily available.

For growers with ready access to equipment, contract labour and ginning facilities there are no great barriers to the production of raingrown cotton if conditions are suitable.

Water requirements and availability

The peak demand for moisture is during the summer months, especially during late flowering and early boll fill. The New South Wales Department of Agriculture estimates that between 6 to 7.5 ML per hectare of water needs to be applied to an irrigated cotton crop. This figure includes rainfall and stored moisture in the soil but excludes system losses from evaporation or seepage. Aside from the value of the water, growers have an additional incentive to avoid overwatering because too much water can lead to waterlogging, resulting in a reduction in yield. Generally, irrigated cotton uses no more water than other high yielding summer crops, and much less than some.

The greater part of cotton in Australia is grown in river catchments where it is becoming increasingly common for the demand for water to exceed the supply.

This necessitates rationing of river irrigation water. Excess demand arises partly because existing supplies of water have been overallocated and partly because the official price of river water is below its market clearing level. The problem has been exacerbated by climatic conditions where reduced rainfall has reduced the existing stocks and increased demand. This has led to further reductions in allocations to cotton growers and other water users. The issue of water use by the cotton industry is discussed in chapter 8.

Pest control and chemical use

Cotton productivity can be seriously limited by all the major pests that afflict crop plants. Unless properly managed, weeds, insect pests, plant pathogens and nematodes can cause serious crop losses, and each year a major portion of cotton management strategy and cost is devoted to their control. Losses are reflected both in terms of yield and quality reduction.

The major pests of cotton are the two heliothis species Helicoverpa punctigera and Helicoverpa armigera, but a wide variety of other species such as spider mites, aphids and mirids can cause significant damage if not controlled.

The majority of chemicals used on cotton are insecticides and of these the most heavily used currently is endosulfan. This is used to control both species of heliothis as well as a variety of other pests. After endosulfan the next most widely used insecticides are the synthetic pyrethroids, followed by the organophosphates and carbamates.

Being an intensive crop, weed control is also necessary for successful cotton production as weed populations can reduce yields. Pre-emergence herbicides are the principal tools used although inter-row cultivation and hand weeding are also important after the emergence of the crop.

In 1983 the industry introduced an insect resistance management strategy (IRM) to control resistance to pesticides specifying time 'windows' for the use of different classes of chemicals. The strategy relied upon the voluntary compliance by summer crop growers which Gibb Environmental Sciences and Arbour International (1991) report as being virtually total. This is likely the result of peer pressure among growers and grower recognition of their own long term interests. However, even with the strategy in place, resistance is developing among cotton pests and continues to be a major problem for the cotton industry.

The introduction of the Bt gene in (transgenic) cotton within the next few years is a new measure to reduce dependence on chemicals. A new IRM strategy will be required.

In addition to controlling weed and insect pests, chemicals are used as an aid to harvest the crop. Defoliants are applied to the crop shortly before harvesting with the purpose of drying and defoliating greener parts of the plant to facilitate cotton picking and ginning.

Incidents such as mass fish kills and the chloroflurazuron (Helix) contamination of meat exports have rightly or wrongly focused public attention on the cotton industry's reliance on chemical pesticides. While there is currently very little scientific evidence linking pesticide contamination to cotton production, the industry is increasingly under attack over its use of pesticides. These issues are taken up in chapter 9.

Fertilisers

In a paper on cotton crop nutrition delivered to the 1988 ACGRA conference on the Gold Coast, Dr G.A. Constable from the Agricultural Research Station at Narrabri stated that proper crop nutrition is one of the many factors necessary in achieving a high yielding and high quality crop.

The paper states that most cotton growing soils are relatively fertile but there are three categories of deficiency where fertiliser use is necessary for maximum production. These are:

(i) where the soil is incapable of providing the full crop requirements of the nutrients;

(ii) where soil or other conditions do not favour the release of nutrients at a time or rate required by the crop; and

(iii) where temporary imbalances occur between nutrients during events such as water logging.

Of the major element a typical uptake for cotton in kilograms of nutrient per hectare is: nitrogen 110; potassium 125; phosphorus 30; calcium 90; magnesium 30; and sulphur 10.

In the category (i) nitrogen is an excellent example as virtually all irrigated cotton needs nitrogen fertiliser. Most areas in the far north of New South Wales also require phosphate and, with long term cropping, other nutrients such as potassium and sulphur may become deficient. In category (ii) zinc provides an example. Situations such as high pH and heavy cut areas may make this nutrient unavailable to the plant. Little information is available on examples in the category (iii).

Adding nitrogen fertiliser increases yields primarily by prolonging growth and increasing the number of bolls set. Nitrogen can be applied in a number of forms — the choice will depend on cost and convenience. Anhydrous ammonia and urea are commonly used forms.

Varieties and their evolution

As a result of progressive breeding in the 1980s Australia now largely grows varieties of Upland cotton (medium staple length) which have been bred by the CSIRO. These varieties account for over 90 per cent of the Australian crop. The small amount of fine Pima cotton (extra long staple) grown in Australia commands a premium over the Upland types but it is susceptible to water damage at harvest. This is the main reason why more Pima is not grown.

The varieties now dominating Australian plantings were developed by CSIRO plant breeders with the objectives of increased yield, improved fibre quality, and greater pest and disease resistance. The imperatives of profitability and sustainability have shaped these goals. Better fibre quality has helped to meet the needs of the changing technology of the spinning industry and so address profitability. Disease and pest resistance in plants lower the need for chemical use and therefore reduce costs to the grower and to the environment. They therefore impact on both profitability and sustainability. The predominant varieties presently grown have progressively replaced the previously dominant American varieties such as Delta Pine (DP) which dominated the seed market as recently as 1987.

The CSIRO cotton breeding program commenced in the early 1970s and was aimed initially at developing insect resistance. The next stage concentrated on developing a commercially competitive, high yielding variety with increased strength and resistance to bacterial blight. The parents chosen for this second stage were the Namcala variety with (among other properties) high strength, Tamcot SP37 with blight resistance and fibre fineness, and an experimental Okra leaf line of mainly DP16 and DP61 background with smooth leaves and stems and high turnout propensity.

The result was the first of the Siokra lines with their novel leaf structure, near immunity to bacterial blight, higher yield and gin turnout, and longer, stronger and finer fibre. Table A4 shows the emergence of the dominant Australian varieties such as CS and Sikala.

It must be noted that the data does not include the Delta Pine (DP) varieties between 1992 and 1994. In 1995 DP accounted for about 7 per cent of the market. The characteristics of each of the most popular Australian varieties are shown in table A4.

Table A4 **Cotton planting seed types 1985-1995** Per cent of total plantings

Year	*Sicala*	*Siokra*	*L-22/23*	*DP 90*	*CS Var*	*Pima*	*Total*
1985	1			91	8		100
1986		14		86			100
1987		39		61			100
1988	10	62		28			100
1989	27	45		28			100
1990	22	47		31			100
1991	10	28	17	35	10		100
1992	18	28	44	N.A.	10		100
1993	25	16	32	N.A.	27		100
1994	21	11	33	N.A.	32	1	100
1995	26	11	22	7	31	3	100

Note 1992 to 1994, Cotton Seed Distributors data only.
Source: Cotton Seed Distributors and industry.

The quality of the Australian varieties (table A5) compares favourably with the USA Acala cottons and the San Joaquin Valley (SJV) series from California in most years. Australian spinners have stated that current Australian varieties meet their requirements as regards length and strength, but that further work needs to be carried out on fibre maturity and on differences in dye affinity between varieties (CRDC February 1995). In Australia several manufacturers have been installing new ring spinning equipment. This has been made possible in part by the high quality of the Australian cottons.

Table A5 **Characteristics of the main Australian varieties of cotton**

Quality	*Unit*	*Siokra L23*	*Siokra V15*	*Sicala V2*	*CS8S*	*CS50*	*CS 189+*
Length	Inches	1.14	1.16	1.14	1.08	1.14	1.13
Strength	Grams/tex	30	30	30	28	29	29
Micronaire value		4.0	3.8	4.1	4.2	4.0	4.1
Maturity ratio		0.87	0.90	0.91	0.90	0.93	0.91
Length uniformity	%	83	84	83	83	83	83
Disease and pest resistance							
Bacterial blight		Highly resistant	Highly resistant	Highly resistant	Highly resistant	Highly resistant	Highly resistant
Verticillium wilt		Susceptible	Good tolerance	Very good tolerance	Good tolerance	Susceptible	Good tolerance
Heliothis		Some tolerance	Some tolerance	Susceptible	Susceptible	Susceptible	Susceptible
Mites		Appreciable tolerance	Appreciable tolerance	Susceptible	Susceptible	Slightly tolerant	Susceptible

Source: Cotton Seed Distributors.