

# **Survey of Cotton Volunteers North of Latitude 22° South**

**Final report prepared by**

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## Summary

This study investigated whether transgenic cotton plants have established in environments away from cotton farms as a consequence of whole cottonseed being used as a feed supplement on dairy farms on the Atherton Tablelands. Whole cottonseed, commonly referred to as fuzzy seed or cottonseed (seed after ginning with short fibres retained on the seed coat), is sourced from gins in central Queensland (Emerald region) and transported via road to this northern market. The potential for transgenic cottonseed to be transported north is dependent on the area of transgenic cotton grown in the preceding cotton season within this Emerald region. In the season prior to the conduct of this survey the Insecticide Resistance Management Strategy for Ingard® cotton had restricted the use of this transgene to 30% of the total area and only 4% Roundup Ready® had been grown. The following is a summary of the survey results:

1. The annual quantity of cottonseed transported north of 22° south is highly variable, primarily as a result of the varying economics of using cottonseed as a feed supplement depending on cottonseed price.
2. Transport companies have voluntarily shifted to roll over tarp systems that eliminate the opportunity for fuzzy seed to escape on route.
3. Volunteer cotton plants were identified along roadsides north of 22° south, albeit in very low numbers (4 plants observed in 1200 km of road surveyed).
4. None of the roadside volunteer cotton plants observed in the survey were transgenic.
5. The capacity of cotton to establish on roadsides, they being highly and regularly disturbed environments, determines whether there are volunteer plants at all. The presence of current commercial transgenes would appear unlikely to offer any particular advantage in establishment.
6. Volunteer cotton plants (both transgenic and conventional) have established on some Atherton dairy farms but none have completed an entire reproductive cycle to produce new seeds or seedlings.
7. It is unlikely that feeding cottonseed (either transgenic or conventional) on Atherton dairy farms will enable cotton populations to establish and sustain themselves.

Our conclusion is that after 12 years of fuzzy cottonseed being transported by road north from Emerald to the Atherton Tablelands there are very few volunteer cotton plants established on roadsides. In addition while populations (both conventional and transgenic) do establish on dairy farms their ability to persist and produce new viable seedlings is low. Over the 12 year time frame they have failed to spread or exhibit weedy characteristics. Considering this, and given the move to rollover tarp systems, it is unlikely that the continued transport and feeding of fuzzy seed will pose significant risks of volunteer cotton developing into a weed of importance on either the transport routes or the Atherton dairy farms.

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## 2.0 Introduction

The use of cottonseed as a feed supplement in dairy farms on the Atherton Tablelands commenced in 1989 (pers. comm. James Geraghty). Access to a reliable supply of cottonseed from the Emerald cotton growing region provided Tableland farmers with their first opportunity to supplement pasture feeding on a daily basis. Improvements in milk production and milk quality were being achieved in a manner that also increased the stocking capacity of the farm system. Half of the 138 farms in the region have now invested in infrastructure for feeding cottonseed (pers. comm. Ian Stewart, Queensland dairy farmers cooperative).

Transgenic technology was commercially adopted by the cotton industry in 1996/97 with the commercial release of Ingard<sup>®</sup> cotton (Fitt and Wilson 2000). Its application continues to expand with Roundup Ready<sup>®</sup> varieties and Roundup Ready<sup>®</sup> + Ingard<sup>®</sup> stacked varieties commercially available from 2000/01. The commercial release of 2-gene Bt cotton (Bollgard II) has recently been approved and will progressively replace Ingard<sup>®</sup> types. Transgenic cotton varieties differ from their conventional counterparts only in the expression of the transgene/s. The purpose of adopting transgenic technology has been to enable more sustainable management of pests. Bollgard II will allow the proportion of cotton grown (and cottonseed produced) with the aid of transgenic technology to increase beyond the current limit of 30% of the industry.

The cotton industry leads the way in Australian agriculture's adoption of gene technology. To date environmental impact studies have concentrated on areas in and between cotton growing regions. With the advent of further seed transport to dairy farms in the Atherton Tablelands along approximately 1200km of road from Emerald the Office of the Gene Technology Regulator (OGTR) has requested a monitoring study be conducted to determine whether transgenic cotton plants have been able to establish along roadsides in the environment north of latitude 22° south.

Road transport is used exclusively to move cottonseed from Emerald to the Atherton Tablelands. The potential for any seed that falls from trucks during transport to germinate, establish and reproduce in the roadside environment is unquantified. It is also unclear whether cotton varieties containing transgenes have an enhanced capacity to survive and establish compared to conventionally bred varieties. The dairy farms where cottonseed is fed represent another environment away from cotton producing areas in which the potential for cotton plants to establish and reproduce is undetermined.

Cotton plants found to be growing in roadside and dairy farm environments are referred to as volunteers. Volunteer cotton plants are plants that have germinated and established unintentionally. Volunteers normally come from seed cotton (lint + seed) but can also establish directly from fuzzy seed (ginned seed) or planting seed (delinted seed). The source of this seed cotton in cotton fields and roadsides is mainly from previous cotton plants in which the seed cotton has fallen from the plant to the ground. Seed cotton is also distributed over cotton farms and surrounding roadsides at picking time when large volumes of harvested cotton are transported to cotton gins. Volunteers established from fuzzy seed are usually the result of seed escaping from the transportation of fuzzy seed away from gins to end point use destinations such as crushing plants or as stock feed. Occasionally planting seed may also be spilt accidentally in transportation en-route to, or within fields creating a ready source of volunteers. 'Ratoon' cotton is cotton that has regrown from a previous season from the same root stock. Volunteers can be regarded as weeds, that is; 'plants out of place'. Weeds

become problems to the community when their presence or abundance interferes with the intended use of the land that they occupy. Weeds may also represent a source of food to various organisms, hence the introduction of weeds to an environment may also bring about ecological change by altering the population dynamics of the food chain linked to their consumption. Thus it is important to recognise whether transgenic cotton volunteers exhibit high weediness potential in these alternative environments.

This report presents the findings of one survey conducted to determine; the incidence of cotton volunteers along the transport routes from Emerald to the Atherton Tablelands, and their incidence on Tableland dairy farms known to feed cottonseed. The characteristics of the roadside volunteer population observed in the Lower Namoi Valley are also compared with the findings of this northern survey. Information from these two regions allows a comparison of a temperate versus tropical climate and a contrast of an environment where large quantities of seed cotton or fuzzy seeds may be present on roadsides escaped seed compared to relatively small quantities of seed occurring along northern transport routes. These and other variables influencing the survival of cotton volunteers in the roadside and dairy farm environments are discussed.

### 2.1 Background

In August 2001 businesses transporting cottonseed to the Atherton Tablelands were advised by Monsanto, the owners of the Ingard® and Roundup Ready® technology, to cease these operations (per. comm. Ken Hartwig). The reason sighted was to prevent possible legal liability in the event of genetically modified populations of cotton becoming weedy in the environment north of latitude 22° south as a result of seed escaping during transport. Movement of cottonseed north of latitude 22° south was temporarily ceased while the OGTR was consulted. Transport of cottonseed recommenced with the voluntary agreement of transporters to only use trailers fitted with fully secured roll-over tarps for the transport of cottonseed north of latitude 22° south. This measure was viewed to be satisfactory until such time as further physical data regarding the number of volunteers in these environments could be collected and an informed risk assessment of the situation made.

#### 2.11 The Roll-over Tarping System

Precautions taken by cottonseed transporters to prevent the escape of seed along the roadside took effect in September 2001. The roll-over tarping system provides a completely enclosed load. The trailer floor is moulded to the sidewalls on the inside leaving no opportunity for seed to escape around the base, (Photo 1a). The fitting of the tarp across the top of the trailer, Photos 1b and 1c, does not permit the trailer to be loaded above the height of the sidewalls. As a result the sidewalls on these trailers are higher than standard to allow the same sized load to be carried. With the previous system seed would be filled above the height of the trailer, strapped in by the tarp and would settle to roughly the height of the trailer during the journey. Seed could readily escape between the top of the sidewall and the tarp as the load moved. The roll-over tarp is held up above the load by frames across the top of the trailer, (Photo 1a), so is not in contact with the load, further eliminating the possibility of seed working its way between the sidewalls and the tarp to fall to the ground. Unloading via a chute, (Photo 1d), or walking floors allows for accurate unloading with minimal spillage.

#### 2.12 Current and Historical Transport Routes

All cottonseed used in the Atherton Tablelands is sourced from the two cotton gins in Emerald. Hartwig Bulk Transport and Myers Transport are the two transport companies

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currently involved in the movement of cottonseed between these locations. Each company has a preferred route of transport. Hartwig Bulk Transport moves 90% of their cottonseed loads along the coastal road. The route taken is Emerald → Clermont → Charters Towers → Townsville → Innisfail → Atherton Tablelands. This distance travelled one-way is 936 km. The remaining 10% of Hartwig Bulk Transport loads and 100% of Myers Transport loads follow the inland route; Emerald → Clermont → Charters Towers → Greenvale → Mt Garnet → Ravenshoe → Atherton Tablelands. The distance travelled one-way is 977 km. In total there is 1400 km of road used to transport cottonseed from Emerald to the Atherton Tablelands.



**Photo 1a** (upper left) Trailer floor moulded to the side walls prevents seed escape. **Photo 1b** (upper right) and **Photo 1c** (lower left) Fitting of the tarp does not allow over-filling of the trailer. **Photo 1d** (lower right) The chute, allows for accurate unloading.

There are four sources of cottonseed that could result in volunteers on the roadside environment;

1. Fuzzy cottonseed<sup>(a)</sup> escaping during transport to market, such as to the dairy farms in the Atherton Tablelands.
2. Seed cotton<sup>(b)</sup> escaping during transport of modules from the farm to the cotton gin.
3. Black cottonseed<sup>(c)</sup> escaping during transport to cotton farms in readiness for planting.
4. Seed cotton produced by established cotton volunteers on roadsides.

- (a) Fuzzy cottonseed is seed that has been ginned to remove the bulk of the lint, leaving only a 'fuzzy' coating on the seed remains.
- (b) Seed cotton is seed in its natural form with lint intact.
- (c) Black cottonseed is seed that has been prepared for planting. The lint is removed during ginning, the fuzzy coat is then removed leaving the bare seed coat exposed. Commonly fungicide and insecticide treatments are applied to the seed.

The fourth source results as a consequence of the first three sources. The first three sources are transported most frequently in close proximity to cotton growing centres, such as Emerald. As the distance away from the cotton centre increases, the number of growers transporting planting seed and modules declines, as does the trade of cottonseed between farming enterprises such as from the gin to a local feedlot. In the survey area, cotton growing ceases near Belyando Crossing. Thus it is assumed that the only sources of cottonseed north of Belyando Crossing are fuzzy seed escapes on-route to the Atherton Tablelands and any consequential seed cotton produced by these volunteers.

### **2.13 The Northern Cottonseed Market**

The Emerald cotton ginning and marketing companies, Queensland Cotton and Dunavants, have jointly estimated the northern cottonseed market to be in the order of 6000 tonnes per year. All of the seed is used in the dairy industry. Market size is declining due to changes in both demand and supply. The freight cost incurred by dairy farmers is \$75/tonne. The affordable price range for dairy farmers is \$150 - \$175 / tonne (plus freight). Cottonseed price has remained above \$200/tonne since early 2001 causing a reduction in demand by dairy farmers to 1200 tonnes/year. The movement of the Australian dollar to below US\$0.60 has allowed the marketing companies to secure high volume export contracts. Thus a fall in the domestic price of cottonseed may not result in the northern dairy market regaining access to the full volume of seed demanded prior to the price rise in early 2001.

### **2.14 The Role of Cottonseed in the North Queensland Dairy Industry**

Dairy farmers are paid for their milk according to its composition. A standard litre of milk contains 3.95% butterfat and 3.15% protein and in March 2002 was valued at 32.5 cents. For each 0.1% variation in butter fat content the price per litre varies 0.3 cents. Each 0.1% variation in protein content attracts a 0.6 cent per litre change in value. In most instances the production of standard composition milk requires supplementary feeding (per. comm. Terry Tranter, dairy farmer). Those farmers surveyed who have continued to feed cottonseed, despite the extreme price pressure of the past 12 months, have done so in order to maintain standard composition. The extra cost of cottonseed has been partially offset by avoiding butterfat dockage on every litre of milk produced. In addition herd size has been maintained.

For dairy farms relying solely on pasture feeding, herd size is limited to the farm's 'wet' and 'dry' season carrying capacity when respectively, pasture wastage is highest and pasture growth is lowest. Planting ryegrass allows some improvement if there are sufficient flat areas on the farm, however the land used is completely unproductive during crop establishment. Supplement feeding with cottonseed has enabled gaps in pasture production to be managed without incurring declines in productivity. Seasonal feeding rather than daily supplementation has become more commonplace during the current period of high seed prices. Seasonal feeding involves high cottonseed rations during lulls in pasture production but no feeding while pasture is plentiful. In this way larger herd sizes can be maintained.

There are no substitutes for cottonseed currently available. Freight costs make prices of commodities such as lucerne hay and cannery waste less attractive than cottonseed. Peanut hay has been trialed by many farmers with mixed outcomes. The product requires more specific storage conditions, causes blockage of drainage systems around the dairy and does

not produce the same milk qualities as cottonseed. It is generally considered to be a product of 'last resort'. The Dairy Farmers Cooperative is currently investigating opportunities with new alternative feedstuffs.

### 2.15 The Cotton Plant

Modern cotton varieties have been developed from long-lived perennials with a slow rate of plant development. Characteristically wild cottons are perennial shrubs or small trees and are found in three broad regions of the arid and semi-arid tropics and sub tropics: Africa – Arabia, America and Australia. These regions include both summer and winter dominant rainfall areas as well as deserts. The common feature is long periods of drought through which the genus is well adapted to survive. (Lee, 1984)

The Australian cotton crop is grown to modern upland varieties that have been developed from a centre of genetic diversity near the border of Mexico and Guatamala. Modern cottons behave as annuals, allowing the crop to be harvested within a year of it being planted. However 'annual' cottons are not true annuals in that the death of the plant is a natural consequence of seed ripening. The capacity to grow perennially has been maintained, as has the sensitivity of fruit production to moisture availability. Wet conditions favour rapid vegetative growth and facultative shedding of fruit. As soil moisture declines vegetative growth moderates and fruit is retained. In dry conditions vegetative growth is terminated, young fruit are shed and old fruit are matured. Once this happens it is very difficult to restart vegetative growth and produce more squares (floral buds) until the bolls (fruits) already set have matured. (Hearn, 1994)

Transgenic cotton varieties have highly specific attributes which aid the sustainability of commercial cotton production. The Ingard<sup>®</sup> cotton varieties provide control of the key lepidoptera pests of cotton ( *Heliocoverpa* spp.), thereby reducing the farmer's need to apply synthetic insecticide sprays. The production of the Bt toxin declines as the plant matures into the reproductive phase (Fitt and Wilson 2000). Late in the growing season the expression of the Bt protein may become insufficient to control the target species. The Roundup Ready<sup>®</sup> cotton varieties express resistance to the herbicide glyphosate in their foliage. Reproductive parts are still susceptible. Application of glyphosate to the crop when at young vegetative stages aids in weed management. Application of glyphosate at reproductive growth stages can adversely affect boll formation and retention resulting in severe yield penalties in some cases (Jones and Snipes 1999).

## 2.2 Aims

1. Determine the incidence of;
  - a. roadside transgenic cotton volunteers north of latitude 22° south.
  - b. transgenic cotton volunteers on dairy farms in the Atherton Tablelands region where cottonseed is used for supplementary feeding purposes.
2. Provide data to the OGTR on future assessment requirements of roadsides and dairy farms north of latitude 22° south.

### 2.21 Scope

The key market for cottonseed north of 22° south is the Atherton Tablelands dairy farms. However this is not an exclusive market. Alternative, minor markets for cottonseed are

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known to exist north of latitude 22° south. The end users and transport routes servicing minor markets are not considered to be within the scope of this survey.

Risk exists as a negative consequence of uncertainty. Risk = hazard × probability (or exposure) (Cook 1999). The outcome of continuing to transport various types of transgenic cottonseed into the northern environment, in terms of their weediness potential, is at this time, uncertain. Hazard identification is the process of identifying what can happen, why and how. Identification is the first step in risk management. With proper identification, risk impact and risk likelihood analyses can then be performed so that appropriate means of treatment can be implemented.

The aims of this report relate only to hazard identification. Risk analyses and subsequent determination of appropriate treatments are not considered to be within the scope of this report.

## 3.0 Methodology

### 3.1 Roadside Survey

During March 2002 a total of 40 roadside sites were surveyed along the cottonseed transport routes from Emerald to the Atherton Tablelands. The sampling strategy aimed to survey one percent of the transport route. The number of cotton volunteers, the presence of transgenes, their growth stage and fruit load, together with a description of the soil type and other vegetation was recorded at each survey site. The survey protocol was developed in consultation with the OGTR and is presented in Appendix 1. The geographic distribution of survey sites is presented in Figure 1. Exact positions of each site were recorded, using a handheld GPS unit. The start and finish coordinates for each site are presented in Appendix 2.



**Figure 1** Road Map showing distribution of Roadside Survey Sites.

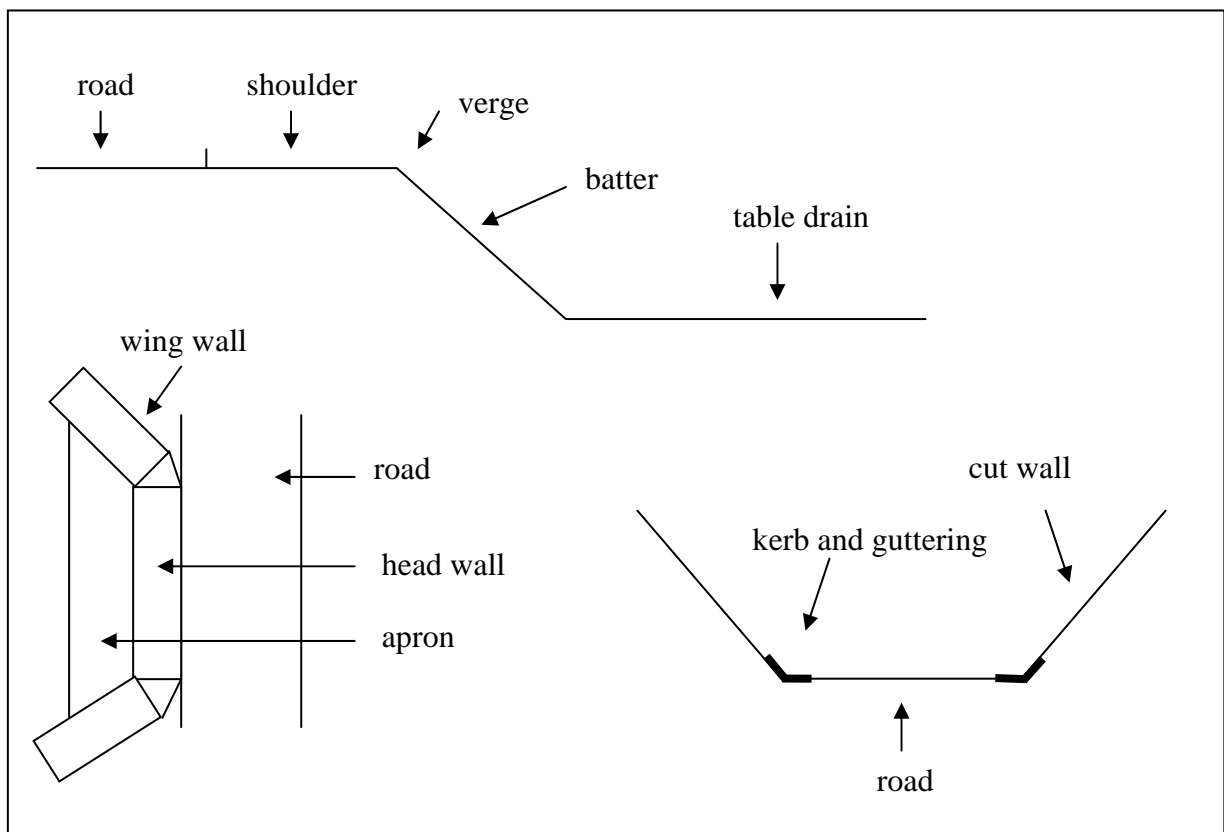
### 3.0 Methodology

The choice of exact site positioning along the highways was heavily influenced by accessibility. Safe parking and walking were key considerations, hence most sections of highway surveyed had a broad road shoulder or gently sloping batter and a clear view of oncoming traffic.

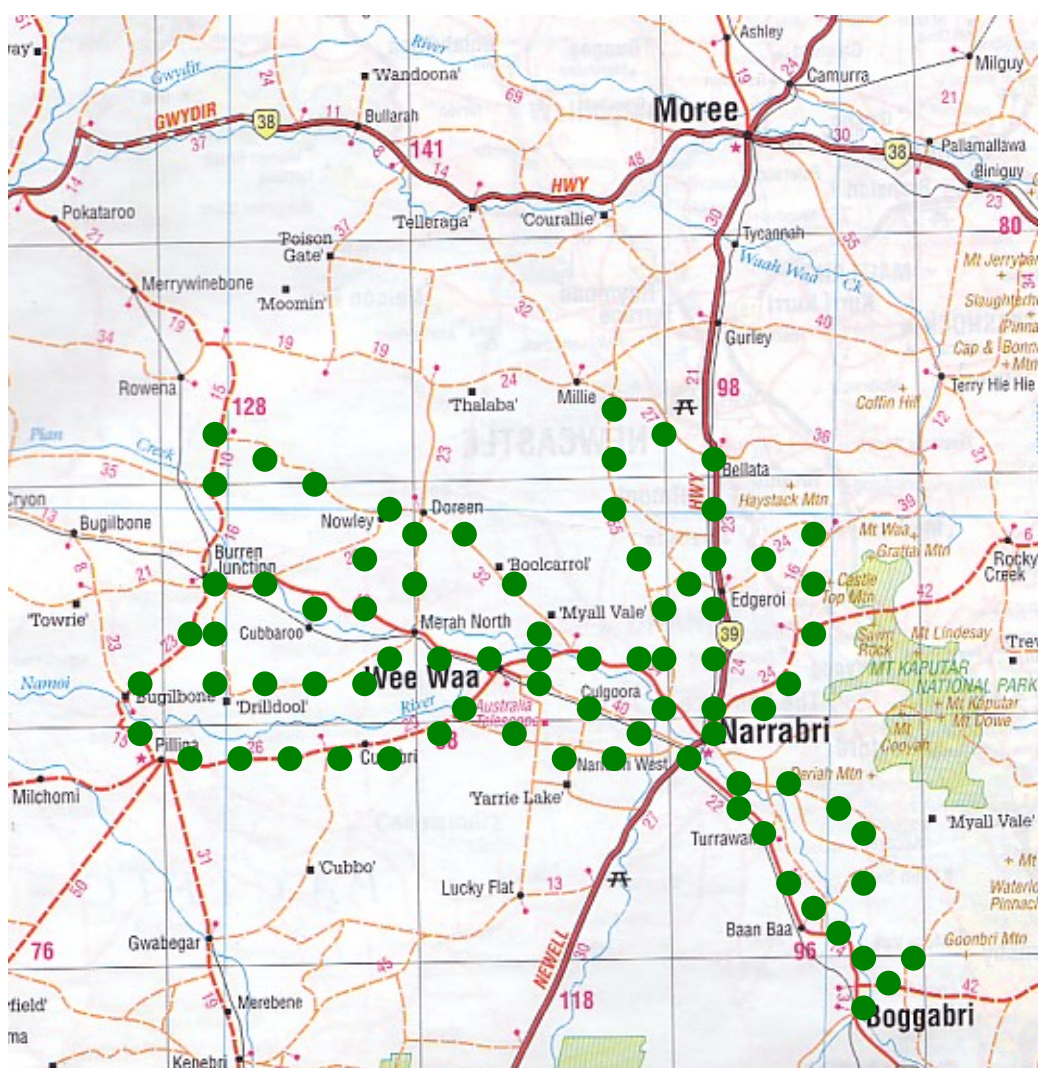
The 40 sites included 10 creek crossings. Creek crossings were of particular interest on the inland where annual rainfall is less than along the coast. The greater permanence of soil moisture close to creek banks were thought to be more favourable for cotton survivorship than more exposed areas of roadside. Conversely, creek crossings were not targeted along the coastal road from Innisfail to Townsville. Along the coastal stretch of highway creek banks were not specifically only steeper and generally more difficult to access, but the lushness of the vegetation supported by high rainfalls would offer extreme competition to establishment of cotton seedlings and thus seemed less likely to favour cotton volunteer survivorship than the more exposed areas of roadside due to the intense nature of competition. Within the coastal survey sites were large culverts to facilitate drainage. The intermittent wetting and drying around these structures more closely mimicked the western creek crossings and conditions thought to favour cotton volunteer survivorship.

In addition to the survey conducted above 22° South an additional roadside survey was conducted in the established cotton growing area of the Lower Namoi Valley. This provided an opportunity to compare the number of volunteers in an established growing area with the results from the Northern survey. Other volunteer crops were also counted in this survey to provide an estimate of their potential to occur as roadside volunteers.

Accurate description of the roadside environment requires the use of specific terminology. Figure 2 diagrammatically explains this terminology.



**Figure 2** Terminology used in the description of roadside structures



**Figure 3.** Road map showing the survey conducted in the Lower Namoi valley.

### 3.11 Germination Testing of Seed Cotton

Seed cotton was observed on some roadside sites in the northern survey. Seed cotton represents an alternative source of cotton volunteers in the roadside environment. Seed cotton enters the roadside environment through the transport of modules from farms to gins during the harvest season or is produced by established roadside volunteers. The lint is seen to persist for periods longer than 12 months. Samples were collected, the lint removed and remaining seed exposed to ideal conditions for germination. Seeds were wrapped in wet paper rolls. The rolls were stood in plastic container with free water in the bottom, covered in plastic and incubated at a constant temperature of 30°C for 7 days. The test aimed to assess the potential viability of cottonseed that had been in the roadside environment for an extended period but does not indicate the probability of germination in situ. Seedling vigour was not assessed.

### 3.2 Dairy Farm Survey

During March 2002 nine dairy farms in the Atherton Tablelands region with varying histories of cottonseed use were surveyed. A GPS reading was recorded for the location of the dairy at each of the farms visited. These are presented in Appendix 2. The intention was to survey 15 farms that were currently feeding cottonseed or had fed during the previous 12 months. This proved impossible to achieve, with the majority of farms being unable to feed during 2001 – 2002 due to unaffordably high cottonseed prices. The Dairy Farmers Farm Services Manager for NQ, Ian Stewart, estimates the volume of cottonseed used on the Tablelands when its price is ~\$285/tonne (delivered) is closer to 1200 tonnes/year as opposed to 6000 tonnes/year when the price is \$225/tonne. Hence the numbers of farms surveyed is thought to still provide reasonable representation of the total volume of cottonseed used in the Tablelands, with each farm surveyed using 50 – 75 tonnes/year. Details of the survey protocol are presented in Appendix 1.

In reference to the protocol, the growth stage of every cotton volunteer was not assessed due to time constraints. The range of growth stages on each farm was recorded and numbers of viable fruiting structures on each plant were also recorded.

### 3.3 Genetic Testing for the Presence of Transgenic Traits

Foliage or seed samples were collected from cotton volunteers observed at roadside sites and dairy farms. Ten plants were collected if possible, if more than ten were present, one in every extra ten plants were sampled. One leaf or one seed was collected from each plant. Foliage samples were transported in a car fridge and tested the day of collection. Seed samples were held in paper bags at ambient temperature and tested at the conclusion of the survey. One gene test was conducted per plant sample. The gene test was conducted by grinding a small piece of leaf or seed in 0.5ml of potassium buffer solution held in a 1.5ml microcentrifuge tube. A genecheck B.t.k. Cotton Lab Test Kit Strip, supplied by Strategic Diagnostics Inc, was inserted. The strips were left overnight to interact with the solution, the results were then recorded the following morning.

Due to the high cost associated with testing large numbers of samples, only the Bt protein, Cry1Ac, contained in the Ingard<sup>®</sup> varieties, was targeted by genetic testing. This allowed the identification of Ingard<sup>®</sup> plants but not Roundup Ready<sup>®</sup> plants or a distinction between those with both genes. The area of cotton grown with the Roundup Ready<sup>®</sup> and stacked gene technology was 4% of the Emerald crop in 2000/01, the first year of their release (per. comm. Adam Kay, general manager Cotton Seed Distributors). The probability of detecting the Roundup Ready<sup>®</sup> gene was considered to be extremely low and not worth the cost.

## 4.0 Results

### 4.1 Incidence of Cotton Volunteers on Transport Routes

Cotton volunteers were observed at five of the 40 sites surveyed along the transport routes from Emerald to the Atherton Tablelands. Table 1. summarises the results of the northern roadside survey.

**Table 1.** Summary result of roadside survey sites that volunteers were actually found from Emerald to the Atherton Tablelands. GPS coordinates are the starting positions at each site.

GPS Position	Site summary	Number of Cotton Volunteers	Presence of the Ingard <sup>®</sup> trait.
South of 22°			
S 23° 18.559"	1, Course gravel	12	Not tested
E 148° 06.620"			
S 22° 40.878"	3, Gravelly, red	2	Not tested
E 147° 43.729"	sandy loam		
North of 22°			
S 21° 35.566"	7, Gravelly light	2	No
E 146° 54.208"	coloured sandy loam		
S 19° 36.742"	16, Light sandy	1	No
E 145° 46.093"	loam		
S 17° 38.988"	25, White sandy	1	No
E 145° 20.358"	gravel		

#### 4.11 South of Latitude 22° South



**Photo 2** Cotton volunteer re-growing after being slashed. Site 1 - S 23° 18.559" E 148° 06.620"



**Photo 3** Cotton volunteer producing seed cotton. Characterised by short internode and fruiting branch lengths and woody stems. Site 1 - S 23° 18.559" E 148° 06.620"

Cotton plants were most frequently observed growing in the roadside environment south of latitude 22° south, close to Emerald. In the five sites surveyed south of latitude 22° south, 14 cotton volunteers were observed. Of these, 10 had previously been slashed, some on presumably more than one occasion. Slashed volunteers were re-growing but most were yet to produce fruiting structures, as shown in Photo 2. The presence of several pieces of seed cotton on the soil surface at the base of the picture suggests that either; this volunteer has arisen from this source of seed, or that prior to being slashed, this volunteer had successfully produced mature fruit.

Three of the volunteers, including one that had been slashed, produced seed cotton. The regrown volunteer and one other were at Site 1, the third at Site 3. Fruiting plants, shown in Photo 3, were characterized by short internode and fruiting branch lengths and woody stems, indicating slow growth.

**The sites below south 22° were the only places where volunteers were seen to establish amongst the other roadside vegetation.**

#### 4.12 North of Latitude 22° South

In the 35 sites surveyed in the 1200 km north of latitude 22° south, four cotton plants were observed. None were growing amongst other vegetation on the road shoulder, batter or table drain. All had established in niche environments created as a result of civil construction. Each site where volunteers were found is described below.

**Site 7**

Two non-transgenic cotton volunteers, each with mature bolls, were observed against the south-bound wing wall of Saltwater Creek, approximately 15km south of Belyando Crossing, S 21°35.628" E 146°54.210". The plants, Photo 4, were 30 cm apart and appeared to be well established with thick, woody stems and branches. The smaller of the two plants, carrying 7 mature bolls, was totally defoliated and appeared to be dead. The larger plant with 13 mature bolls had no foliage other than young regrowth leaves growing directly from the mainstem.

No other vegetation had established along the wing wall. The soil was a gravelly clay loam, its make-up along the wing wall being affected by the wall's construction. It appears from the eroded soil surface around the plants that during rainfall events water may drain off the road and be funnelled along the wing wall down into the creek. It could be assumed that this movement of soil and water is how the seed came to be lodged against the wall in the first place. These plants would now be rooted beneath the apron and have access to more permanent moisture.

The seed that lodged along the wall may have been deposited near the site as either fuzzy seed or seed cotton. While its frequency was low, seed cotton was observed scattered amongst other vegetation along the road edge at this site and the next one north, indicating that this site is still within the cotton producing region carting modules to Emerald. Both plants may or may not have arisen from the same source of seed at the same time.



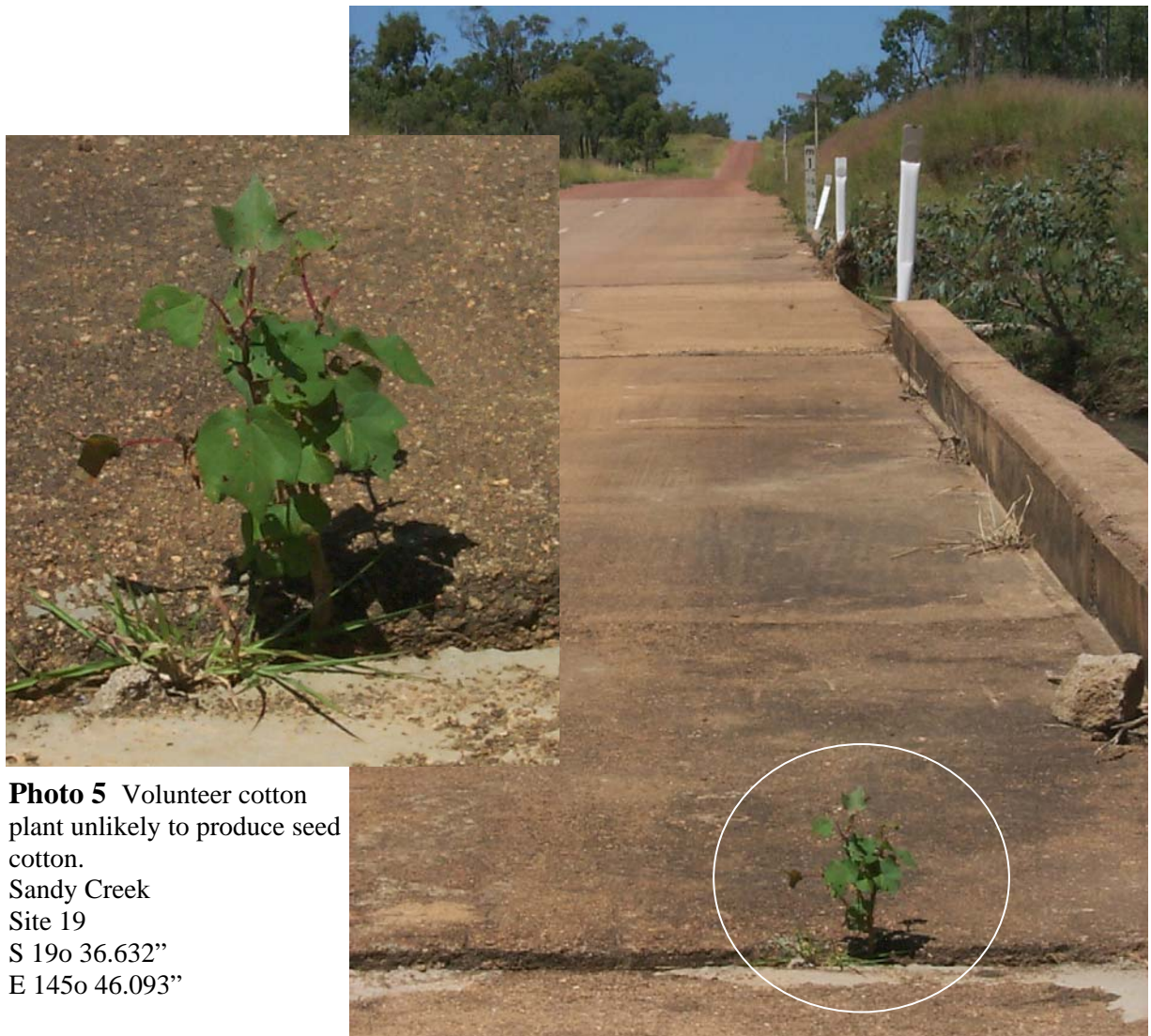
**Photo 4** Established volunteer cotton plants producing seed cotton  
Saltwater Creek.  
Site 7  
S 21° 35.566"  
E 146° 54.208"



**Site 16**

A single, non-transgenic cotton volunteer was observed on the causeway crossing at Sandy Creek, approximately 80 km north of Charters Towers, S 19°36.742' E 145°46.093'. No seed cotton was observed at this location. The volunteer, seen in Photo 5, was growing from the fissure between two concrete slabs. Despite the short stature of the plant, 16cm, the mainstem was approximately 1cm in diameter and woody, indicating that the plant has been growing there for a lengthy period, estimated to be between six and 12 months. Given the volunteer's position on the narrow crossing, it is highly probable that it is frequently run over and perhaps grazed by the cattle observed in the creek. It seems unlikely that the plant will be able to produce seed cotton.

It could be assumed that the seed came to rest in the fissure either by falling there directly or by being moved by wind or water. This position would have provided protection from predation, squashing and desiccation by intense heat. The burial-like conditions would have favoured germination. During rainfall events water would collect along the fissure and evaporation would be slowed by protection from the concrete. The low level crossing is prone to flooding. During flood events silt and mud would be washed over the causeway providing the media and nutrition needed for germination and establishment, however is unlikely to be plentiful enough for sustained periods of development.



**Photo 5** Volunteer cotton plant unlikely to produce seed cotton.  
Sandy Creek  
Site 19  
S 19° 36.632'  
E 145° 46.093'

**Site 25**

A single, non-transgenic cotton volunteer, Photo 6, was observed growing in the join of kerb and guttering at the base of a cut wall situated approximately 30 km east of Mt Garnet, S 17°38.954" E 145°20.400". No seed cotton was observed at this location. Similarly to the plant observed at Sandy Creek, this plant was short in stature with disfigured branching and a thick, woody mainstem indicating it too has been established for at least six months. Unlike the volunteer at Sandy Creek, this plant had less leaf area. The wider road suggests it is less likely to be runover, however it may be periodically slashed as part of roadside maintenance. It also appears to have been competing with other vegetation. It seems highly unlikely that this volunteer will be able to produce seed cotton.



**Photo 6** Volunteer cotton plant unlikely to produce seed cotton due to regular disturbance.  
30 km east of Mt Garnet  
Site 31  
S 17° 38.954"  
E 145° 20.400"

### 4.13 Seed Cotton – South of 22°

An alternative source of cotton volunteers was present in the form of seed cotton, observed at all roadside sites south of S 21°33.021” E 146°53.210”. The most northerly location where seed cotton was observed was 5km south of Belyando Crossing. The presence of seed cotton was expected as it is readily found along roadsides in cotton growing areas. It dislodges from module trucks transporting harvested cotton to gins. The frequency of seed cotton was observed to decline as the distance from Emerald increased and the number of cotton farms declined. Seed cotton count data (pieces of locks consisting of lint attached to one or more seeds) is presented in Table 2.

**Table 2** Distribution and viability of roadside seed cotton (pieces of locks) in the Northern survey.

GPS Coordinates	Seed Cotton per 100m	Germination Percentage
S 23°18.559” E 148°06.620”	186	Not available
S 22°40.878” E 147°43.729”	232	4.4% (n = 113)
S 22°00.290” E 147°04.647”	86	Not available
S 21°56.399” E 147°03.234”	10	0% (n = 58)
S 21°35.566” E 146°54.208”	14	0% (n = 43)

At all sites the appearance of the seed cotton was well weathered. In many instances it was being overgrown by the roadside vegetation, Photo 7, suggesting it was spread during the 2000/01 season’s harvest or earlier. Germination tests showed that most of the seeds within the lint were completely desiccated, Photo 8. Only a small portion appeared to be viable. These seeds tended to be from larger pieces of lint where several locks were clumped together, suggesting the lint covering was providing protection from the weathering elements. Not all of these seeds actually germinated when exposed to ideal conditions, resulting in very low germination percentages. In order for volunteers to arise from this source of seed, it appears that conditions suitable for germination need to be experienced within 12 months of the seed being deposited. It could be assumed that without the protective lint coating, the timeframe for the germination of fuzzy seed is less than this in these conditions.



**Photo 7** Escaped seed cotton becomes overgrown by roadside vegetation.



**Photo 8** Seed cotton collected from the roadside. The lint appears weathered and most seeds are completely desiccated.

### 4.14 Observation of Soil type and Vegetation in the Roadside Survey

A description of the soil type and vegetation was recorded at each roadside survey site. These descriptions, based on visual observations, are presented in Table 3. Site photographs in Appendix 2 may also be referred to for indications of the variability in conditions between surveyed sites. At many sites the soil type, particularly the surface (2-5cm) layer, was gravelly as a result of road construction and was not indicative of the surrounding countryside. The range of soils observed varied from being very sandy to having high clay contents. Grasses generally dominated vegetation. Along the coastal highway and areas of the western highways where clay content of the soil was high, sedges and rushes were common in the table drains, floodways and on creek banks. Vigourously growing introduced pasture legumes, particularly siratro *Macropitium atropurpureum* and calopo *Caopgonium mucunoides*, were also common north of Greenvale and across the Tablelands.

The soil types at each of the sites where cotton volunteers were located were described as 'sandy loam'. These are lighter textured soils and in contrast to the heavy clay soils preferred for commercial cotton growing. (Sites where volunteers were located appear shaded in Table 2.) 'Sandy loam' and 'gravelly sandy loam' were terms used to describe the soil type at many of the other survey sites. There were no clear differences in soil type between these other sites and the ones where cotton volunteers were found. Furthermore the soil immediately surrounding each of the observed volunteers was liable to change over time, being initially a product of road construction but affected by soil movement during subsequent rainfall events. Thus particular soil types do not appear to define the distribution of cotton volunteers in the northern roadside environment.

The type and density of vegetation varied between sites. Moisture availability and management appeared to be the factors exerting strongest influence on vegetation characteristics. Dense vegetation occurred where rainfall was frequent, or where the soil had a high clay fraction and the batter had sufficient slope to allow rainfall runoff to accumulate and prolong periods of wetness. Species with rapid growth rates and vegetative reproduction were favoured in these conditions. Conversely, sparse vegetation was associated with lower rainfall regions or very sandy soils, such as that observed at Site 11, Photo 8a. Slow growing, stress tolerant species were tending to survive in these conditions of limited resources. Intermediate conditions tended to support grass species, such as at Site 23, Photo 8d. While the clay content of the soil was high at this site, the low frequency of rainfall for the area combined with the road shoulder and batter being virtually flat, appear to limit growth to short bursts following each rainfall event.

In areas where vegetation was dense, particularly if tall grasses were dominant, evidence of roadside maintenance was observed. Shire councils practice regular slashing of tall vegetation to maintain safety to motorists. The regularity of slashing varies with rainfall. Along the coast, slashing may be as frequent as monthly, due to high rainfalls and year-round warm temperatures encouraging constant, rapid growth, particularly of grasses. The result is a lawn-like covering of grass intermingled with prostrate growing broadleaf species such as sensitive weed (*Mimosa invisa*), Site 36, Photo 8b. In lower rainfall and cooler winter areas slashing is more likely to be seasonal, targeting Christmas and Easter traffic, at the beginning and end of the main rainfall period. A dichotomy in the vegetation can be created such as that observed at Site 23, Photo 8c. Vigourous prostrate creepers now dominate the road shoulder. These include the pasture legumes siratro and calopo which are able to root at nodes, symbiotically fix their own nitrogen and regrow quickly after slashing, it having a similar affect to grazing. Tall grasses still dominate the batter outside the range of slashing. Their height creates a shading effect that ensures they out-compete the low-growing species for light.



**Figure 8a** (above) Sparse vegetation was associated with very sandy soil.  
**Figure 8c** (below) Vegetation dichotomy created by seasonal slashing.



**Figure 8b** (above) Lawn-like grass covering as a result of frequent slashing.  
**Figure 8d** (below) Moderately dense vegetation dominated by grasses.



**Table 3. Observations of Soil Type and Vegetation at Roadside Survey Sites.**

Site	Soil Type and Vegetation Description
1	Coarse gravel – due to road construction, reddish-brown sandy loam beneath. Shallow gradient batter. Grass domination. Areas where no grass cover – exposed gravel only.
2	North-bound – black, self mulching clay – steep batter - full grass cover, some broadleaf spp such as paddy melons and sesbania pea. South-bound – gravel on surface, soil very red and loamy beneath – batter less steep – first 1.5m from tar slashed today.
3	Gravelly, red, sandy loam. Low gradient batter north-bound, steeper south-bound. Grass domination but vegetation not dense, soil surface frequently visible.
4	Miclere Creek. Brown-red loam. Steep banks with dense grass cover. Creek bed dry.
5	Gravelly surface, red-brown loam beneath. Broad shoulder 2-3m with very steep batter. Very dense grass covering. Large drain with signs of recent water flow and well established sesbania pea.
6	Red sandy loam. Dense grass covering, gravelly patches covered by dead grass matting.
7	Saltwater Creek. Gravelly, light coloured sandy loam. Sparse grass covering. Shallow gradient batter. Water in the north-bound side only.
8	Red, gravelly, sandy loam. Sparse vegetation, mostly exposed soil. Grasses and broadleaf spp equally common. Shallow gradient batter with broad table drain.
9	Blackish-brown clay loam, hard setting. Dense grass covering, recently slashed.
10	North Bullock Creek. Gravelly approaches with steep batter, moderate grass covering, recently slashed. Thick grass covering on creek banks near to water. Noogoora burr also established on creek bank.
11	Sand. Broad, shallow gradient batter. Vegetation sparse, grasses and broadleaf spp equally common. Volunteer sorghum present.
12	Victoria Creek. Brownish-yellow loam. Moderate grass covering on approaches, recently slashed. Grasses dense along creek bank, volunteer sorghum present. Water in the north-bound side only.
13	Brown loam with coarse gravel surface layer. Moderate covering of grasses with odd broadleaf spp. Slashed previously, very dry suggesting no rain since.
14	Sandy gravel. Narrow shoulder with moderately steep batter. Mainly grasses, recently slashed, moderate covering.
15	Redclay loam, hard setting. Virtually flat batter. Vegetation sparse, mainly grasses.
16	Sandy Creek. Light sandy loam, hard setting, gravelly shoulders. Dense, tall grasses and suspected Malvaceae sp. along approaches, grasses patchy and grazed along creek bank.
17	Sandy-gravel close to tar, grey clay batter and table drain. Batter shallow gradient and table drain broad. Tall grasses and siratro along shoulder, moderately dense covering of sedges and tall rushes on batter and in table drain.
18	Crooked Creek. Grey clay, hard setting. Tall, dense grasses on approaches and along creek bank. Siratro competing with grasses close to the road edge. Volunteer sorghum observed along creek bank.
19	Gravelly near tar, brownish-grey clay loam away from road. Wide, shallow gradient batter. Moderately dense grass covering.
20	Redbank Creek. Yellowish-red sandy loam. Moderately dense grass covering on approaches. Steep decent to creek banks with grass covering becoming more dense closer to creek base. Volunteer forage sorghum and noogoora burr also observed on creek banks.
21	Gravelly surface layer with red sandy loam beneath. Wide shoulder (for passing) and gently sloping batter. Moderately dense grass covering, recently slashed.

#### 4.0 Results

22	Redish-brown clay loam. Recently slashed. North-bound dense grass covering. South-bound sparse covering of grasses, burrs and siratro.
23	Red basalt. Wide sholder, low gradient batter. Moderately dense tall rush/grass with variety of low growing and creeping pasture legumes and burrs, volunteer sorghum.
24	Unnamed Creek. White sandy gravel. Sparse vegetation, predominantly grasses along approaches. Steep decent to creek banks with grasses near to water's edge.
25	White sandy gravel. Narrow shoulder steep batter. Grasses, rushes and siratro. Recently slashed.
26	Red basalt. Gravel and rotting leaf litter on soil surface. No dominant sp. Mostly broadleaves and ferns. Kept slashed.
27	Barron River. Red basalt. Narrow shoulder on approaches with grass covering kept slashed. Steep decent to water. Very dense, tall covering of grasses along river bank.
28	Red/brown clay. Dense grass covering on shoulder and batter kept slashed like lawn. Evidence of herbicide control along east-bound table drain.
29	Coarse gravel surface layer with red basalt beneath. Narrow shoulder and steep batter. Vegetation dense, varied spp. Predominantly grasses and siratro. Evidence of herbicide spraying around guide posts.
30	Rich brown peat-like mulch. Narrow shoulder with steep batter. Dense germination of broadleaf spp along shoulder. Very dense covering of established grassed in batter and table drain.
31	Red Basalt soil. Low gradient batter, broad table drain. Dense grass covering kept slashed/mowed like lawn from edge of tar to edge of sugarcane crop. Germination of broadleaf sp under trees, none well established.
32	Red basalt. Low gradient batter, broad table drain. Dense grass covering kept slashed/mowed like lawn from edge of tar to edge of banana plantation. Established cobblers pegs growing around culverts – sprayed with herbicide.
33	Reddish-brown clay. Low gradient batter, broad table drain. Dense grass covering with some broadleaf spp kept slashed/mowed like lawn from edge of tar to edge of sugarcane crop. Large culverts appear to hold water for long periods. Cobblers pegs and sesbania pea well established.
34	Dark brown clay. Low gradient batter, broad table drain. Grass cover moderately dense appears to be regularly slashed.
35	Dark brown clay. Low gradient batter, broad table drain. Moderate-dense covering of grasses with some broadleaf sp such as sensitive weed and siratro. North-bound recently slashed. South-bound sprayed out form edge of sugarcane crop to ~30cm from edge of tar.
36	Brown clay loam. Low gradient batter with broad table drain. Table drain appears to stay wet for prolonged periods, mainly sedges. Grasses with some broadleaf spp such as sensitive weed providing dense coverage on batter and shoulder. Slashed, but not recently – some grasses flowering.
37	Sandy-grey clay. Low gradient batter and broad table drain. Predominantly grasses, moderately dense covering.
38	Brown loam with rich compost layer on surface. Low gradient batter and broad table drain. Grasses dominant around culverts. Great diversity of spp, grasses and braodleaves present.
39	Seven Mile Creek. Sandy gravel. Steep decent to creek edge. Sandy bottom. Tall dense grasses on creek banks. Sparse – moderate covering of varied spp on approaches.
40	Yellowish-grey sandy gravel, hard setting. Moderately steep batter. Predominantly broadleaf covering, dense siratro and other pasture legumes.

■ Shaded sites are those where cotton volunteers were observed.

### 4.2 Infrastructure for Feeding Cottonseed on Dairy Farms

In order to appreciate the various ways in which cottonseed can escape on dairy farms and the associated potentials for volunteer establishment, it is first necessary to appreciate the types of infrastructure and approaches to feeding adopted by the dairy farmers. No two dairies visited operated in exactly the same way or used exactly the same equipment. In most cases improvisation has been the key to their creating a system that works for their situation.

Cottonseed is delivered directly to the dairy farm in half-truck loads (12 tonnes) or full-truck loads (24 tonnes). The seed is unloaded into the storage facility, of which there are a number of variations. Some are existing structures with or without modification, while others have been purposely built for using cottonseed. Four examples are presented in Photos 9a, 9b, 9c and 9d. Photo 9a, the facility at Farm 8, has not been modified for storing cottonseed. Seed has to be relocated for feeding. Photo 9b, Farm 1, shows an existing structure with modification made to the wall facing the dairy. (Carryover seed from last winter is visible at the rear of the shed.) The mesh along the sidewall is taken down when seed is being fed, allowing the cows access to the seed directly from its point of storage. At Farm 3, Photo 9c a feed-out facility has been incorporated into the design of a machinery shed. The seed is unloaded into the shed and the daily ration pushed up against the feed-out using the front end loader bucket pictured. The fourth example, Photo 9d shows the front and rear views of a purpose built cottonseed feed-out facility. Backing onto the dairy at Farm 5, this facility is designed for easy delivery, storage and daily feeding.

In situations where the herd cannot feed from the point of delivery and storage, several options exist for feeding-out. Observed at Farm 6 and Farm 7 was the use of a front end loader bucket to move seed short distances (~50m) from the storage shed to troughs in a feeding area. Seed has to be moved on a daily basis. The feeding areas are shown respectively in Photo 10a and Photo 10b. The ground becomes heavily trampled right around the troughs in Photo 10a, greatly reducing the opportunity for spilt seed to successfully establish. Cows stick their heads through the railings seen in Photo 10b to feed. The space created between the railings and the side of the trough is protected from the traffic of the feeding herd. Consequently numerous volunteers have established. At Farm 9, Photo 10c, a front end loader bucket is also used to move seed however in this instance feeding takes place from the ground along a fence line rather than from troughs. While it is over 12 months since this practice last occurred, no cotton volunteers were seen to persist. The feedlot style of feeding observed at Farm 8 is shown in Photo 10d. The feeding of a total mixed ration (containing 10% cottonseed) occurs on a daily basis. No cotton volunteers were observed.



**Photo 9a** (above ) Cottonseed storage area with no modification.

**Photo 9c** (below) Design of machinery shed incorporates cottonseed storage and feed-out facility.



**Photo 9b** (above ) Cottonseed storage area with modification to allow direct feeding .

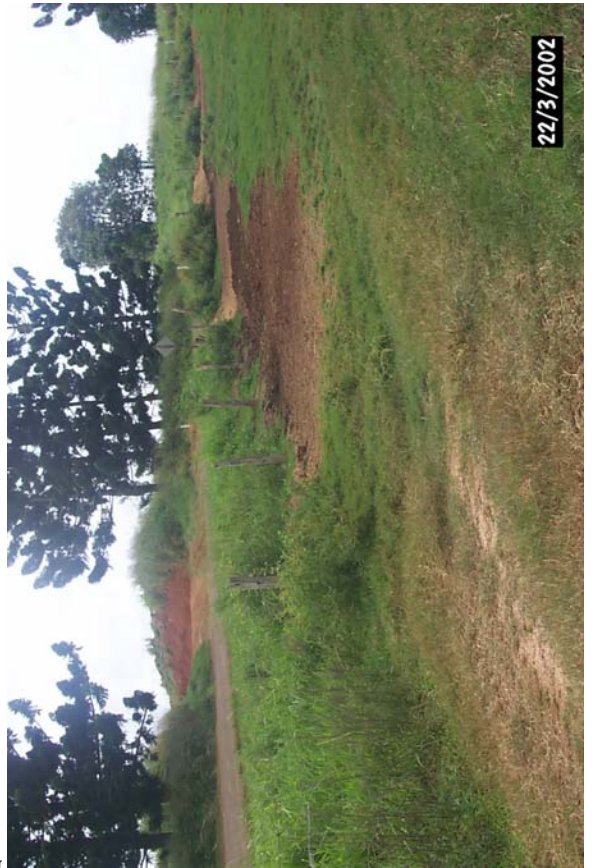


**Photo 9d** Front and rear views of a purpose built cottonseed storage and feed-out facility.





**Photo 10a** (above) Cottonseed moved to feed-out troughs on a daily basis.  
**Photo 10c** (below) Cottonseed spread along fenceline and fed off the ground.



**Photo 10b** (above) Cottonseed moved to feed-out troughs on a daily basis.

**Photo 10d** (below) Cottonseed being fed as part of a total mixed ration.



## 4.2 Cotton Volunteers on Dairy Farms

The number of farms feeding cottonseed over the past 12 months has been many fewer than the estimated 70 farms with the facilities for feeding. Nine dairy farms with varying histories of cottonseed use were surveyed across the Atherton Tablelands region. Cotton volunteers were observed on seven of the nine farms visited. Volunteers expressing the Ingard<sup>®</sup> gene were observed on four farms. (The volunteers at Farm 6 were defoliated and so remain unconfirmed.) Results of qualitative gene testing are presented below in Table 4.

The percentage of volunteer plants with the Ingard gene varied from 0% to 75% at any one farm. On average 46% of the volunteers tested contained the gene. The expected average was 30% based on 30% of the Emerald crop being Ingard<sup>®</sup> in the 2000/01 season. In the situations where Ingard<sup>®</sup> volunteers were dominant, particularly Farm 2, there were no differences in the range of growth stages observed for the Ingard<sup>®</sup> and conventional volunteers. Therefore it seems that the higher than expected frequency of Ingard<sup>®</sup> has occurred because of the randomness of seed types within each load of cottonseed and not as a consequence of superior survivorship characters.

**Table 4: Cotton Volunteers on Dairy Farms in the Atherton Tablelands, March 2002**

Farm	History of Cottonseed Use	Total No. of Volunteers	No. of Volunteers Gene Tested	Number of Ingard <sup>®</sup> Cotton Volunteers	Range of Growth Stages of conventional and Ingard <sup>®</sup> Volunteers
1	First Use > 5 years 2001 – seasonal 2002 – seasonal	7	6	0 (0%)	Cotyledon – 6 nodes
2	First Use > 5 years 2001 – daily use 2002 – daily use	117	24	18 (75%)	Cotyledon – 2 leaf
3	First Use > 5 years 2001 – no use 2002 seasonal	42	14	0 (0%)	Cotyledon – 1 leaf
4	First Use > 5 years 2001 – daily use 2002 – daily use	17	9	4 (44%)	Cotyledon – 9 bolls
5	First Use > 5 years 2001 – daily use 2002 – seasonal	46	16	9 (56%)	Cotyledon – 11 nodes
6	First Use > 5 years 2001 – seasonal 2002 – seasonal	3	0	Unconfirmed	Defoliated
7	First Use > 5 years 2001 – daily 2002 – seasonal	28	11	6 (55%)	8 nodes – 33 bolls
8	First use 2001 2001 – daily use 2002 – daily use	0	0	0 -	Nil
9	First Use > 5 years 2001 – no use 2002 – no use	0	0	0 -	Nil

No cotton volunteers were observed in grazing paddocks as a result of movement by cattle. All farmers reported that cotton plants had never been observed during spot spraying exercises. All observed cotton volunteers were growing close to the farms' dairies around the seed storage areas, feed-out areas and drainage facilities. In these areas single seeds and clumps of seed are frequently spilt and readily become moist. Variation in farm layout and the system of feeding created differing opportunities for volunteers to germinate and then continue to develop.

Survivorship of volunteers to reproductive growth stages occurred on only three farms. Flowering cotton was observed on two farms. Immature bolls were also observed on two farms. No seed cotton was observed at any farm. The growth stages most commonly



**Photo 11** Cotton plants germinate and emerge from mound of wet seed against outside wall of seed storage shed. Farm 1.



**Photo 12** Cotton plants germinate and emerge in sand on a concrete floor.

observed were cotyledon through to 2 leaves, seen on five farms. Photos 11, 12, 13 and 14 show four differing scenarios where cottonseed is frequently seen by farmers to germinate but not to establish. Photo 11 and Photo 12 each show cottonseed spilled from a seed storage area. In neither situation is there opportunity for continued development. At Farm 1, Photo 11, the layer of wet rotting seed is several centimeters thick reducing the likelihood of the plants rooting into the soil beneath. The path beside the area is hosed down twice daily after milking ensuring the seed is permanently saturated, encouraging root damaging disease. The area is also in a gateway, people walking over the area further reducing the likelihood of volunteer establishment. At Farm 3, Figure 12, seed has been spilt on a concrete floor during delivery and hosed into some gravel. While

moisture is plentiful, the nutritive supply to these plants is limited to the contents of the seed. Once exhausted these plants have no means of continuing growth. Hosing down pathways around the dairy after each milking is common practice. Photo 13, also at Farm 3, shows the

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recent emergence of several cotton seedlings next to a path, not far from the drainage point. Seed that had stuck in the cow's hooves during feeding drops off along the



**Photo 13** Cotton germinating in high disturbance area.

path back to the paddock and is then hosed off to the side into a mixture of wet soil and manure. This area is frequently disturbed by the hosing action and remains saturated. Fully developed cotton plants were not observed along the pathway. This together with the lack of grass cover indicates that the high level of disturbance prevents establishment.

Photo 14 shows 'scrap' cottonseed cleaned out of a purpose-built facility in readiness for the next seed delivery. The farmer chose to dump the scrap seed in the edge of the adjoining paddock.

Several days later, some seeds have germinated in response to rainfall. However the pasture covering is very thick meaning the 2-3 cm layer of seed is being held up off the soil surface by the grass squashed beneath. Seedlings pulled-up from the mound are shown up-close in Photo 15. Germination in this situation is unlikely to lead to plant establishment due to poor root development and the wet seed mass causing the lower stem tissue to rot.



**Photo 14** Cotton plants germinate and emerge in mound of seed dumped into a paddock.



**Photo 15** Cotton plants emerging from within wet mass of seed show poor root development and tissue rot.

While seed spilt from storage areas at Farms 1 and Farm 3, (Photo 11 and Photo 12) had very limited opportunity to establish, conditions for survival were more favourable for seed spilt at Farm 6 and Farm 7. Flowering cotton was observed at these two farms. Photo 16 shows the intersection of two slabs of concrete where the wall of the cottonseed storage shed has been constructed. Cottonseed lodged in the fissure has found a more stable environment for root development. Two plants were flowering and five others were squaring. The farmer has



**Photo 16** Flowering cotton volunteers along wall of seed storage shed.

**Photo 17** Flowering cotton volunteers with immature bolls alongside the entrance to seed storage shed.

Plant 1 – 10 squares, 3 flowers, 33 bolls

Plant 2 – 14 squares, 5 bolls

Plant 3 – 17 squares, 4 flowers, 9 bolls.



observed that cotton plants have only established along the wall during this summer. In past years cottonseed has been fed on a daily basis. Due to the extended period of price pressure, cottonseed is now being used seasonally when pasture growth during the winter is insufficient. When feeding recommences this wall will become a high traffic area from herd feeding and regular hosing down.

The most well developed, healthy cotton volunteers observed during the survey were growing at Farm 7 from the protected area under a small silo next to the seed storage area. Photo 17 shows five cotton plants, two juvenile and three producing squares, flowers and bolls. The farmer has observed that the plants are in direct sunlight for a short period each morning and dappled light for the rest of the day. The soil surface is gravelly with red basalt beneath and is well drained. It is probable that volunteers in this environment will be able to grow reasonably well. In a season with average rainfall it is probable that boll rots

#### 4.0 Results

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would also be more prevalent. Bolls were produced on cotton volunteers at one other site, Farm 4. However as shown in Photo 18, disease has prevented fruit from maturing and producing seed. Defoliation of the volunteers has been severe, the farmer presumes this to be a result of predation by insects (unidentified). New growth of foliage and fruiting structures has not occurred for some time. These plants were growing near to an effluent cleaning facility situated at the edge of the paddock nearest to the dairy. Known as a weeping wall, this concrete based structure has three permanent walls and one of timber logs. The gaps between the logs allow moisture to seep out, leaving behind the solid sludge. Cottonseed spilt around the dairy ends in the sludge and is seen to readily germinate but never been seen to grow larger than 'one or two' leaves before dying. The established plants observed next to the weeping wall are a result of sludge (containing cottonseed) being spilt as it is periodically removed from the structure. Sludge is spread as a source of fertilizer.



**Photo 18** Established cotton volunteers not able to produce mature fruit due to the onset of boll rots.

On two of the farms surveyed no cotton volunteers were observed. In the case of Farm 8, the dairy is located away from the traditional dairying area of the Tablelands at Innot Hot Springs, where the climate is considerably drier. It has been in operation for one year and has been feeding cottonseed as part of a total mixed ration on a daily basis. Seed is moved over 100m from its point of storage, to the mixing facility and on to the feed-out area. The farmer believes a combination of short history, dry conditions and frequent farm vehicle traffic along the route explain why cotton volunteers are yet to be seen.

Similarly to Farm 8, Farm 9 has a feedlotting style of feed-out facility however is in the higher rainfall area of the Tablelands and has a long history of cottonseed use. Cottonseed use commenced in 1992 but ceased in early 2001 and has not recommenced. At times cottonseed was also fed by spreading along a fenceline, seen in Photo 10c. No cotton volunteers have persisted along this fenceline, at the edges of the concrete feed-out area or around the seed storage shed.

### Observations of Vegetation and Soil type in the Dairy Farm Survey

Red clay loam (kraznozem) soils are characteristic of the Atherton Tablelands. These free draining soils of basalt parent material are in excess of 20m in depth across much of the Tablelands. Uniformity of the soil type across the area is reflected in the consistency of the vegetation. Much of the area was originally rainforest, small areas are still scattered across the landscape. Clearing has taken place to make way for farming practices.

Five varieties of *Setaria* accounts for approximately 90% of dairy pasture in the region, Photo 19. Braceria, kikuyu, couch, molasses and guinea grasses are also grown. Pasture growth in the summer is rapid and vigourous, supported by high rainfalls, warm temperatures and rich, permeable soils. As temperatures cool down and rainfall declines in April/May, the rate of pasture growth slows; all are susceptible to damage by winter frosts. Areas of flatter ground may at this stage be planted (direct drill, no till) to ryegrass or oats as a means of supplementing grass supply through the winter.



**Photo 19** *Setaria* dairy pastures on the Atherton Tablelands.

## 4.5 Climate

### 4.51 Rainfall

Rainfall is summer dominant across the entire survey area. Winter months are dry in the inland region and relatively dry on the Tablelands and along the coast. Mean annual rainfalls, shown in Table 5, vary significantly for the various regions within the survey area. In the inland region the range is 545mm at Hillgrove to 812mm at Mt Garnet. Coastal rainfalls increase with declining latitude, from 1,145mm at Townsville to 3,610mm at Innisfail. Across the Tablelands rainfall varies from 884mm in the western town of Ravenshoe to 2,613mm at Millaa Milla on the eastern edge. There are sufficient rainfall events at all centres to provide opportunity for the germination of cotton volunteers.

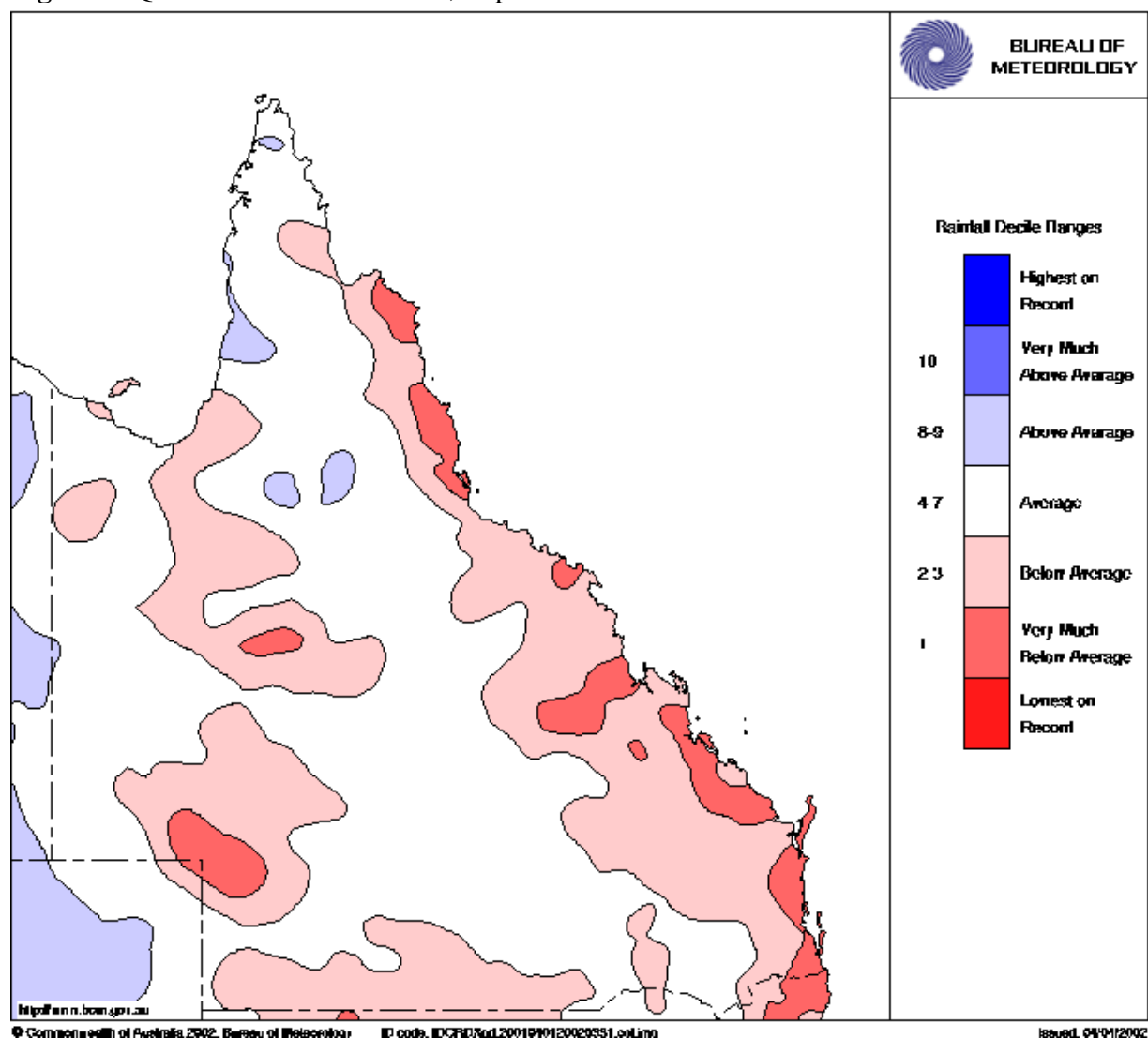
Mt Douglas and Hillgrove, the weather stations closest to the locations of cotton volunteers 1, 2 and 3, record the lowest average rainfalls of the survey area, 586mm and 545mm respectively and the least number of rainy days, each with 42 annually. Cotton volunteer 4, located between Mt Garnet and Ravenshoe, experiences more rainy days, 73 – 55, with falls averaging +800mm annually. The variability between these sites illustrate cotton to be well adapted in its ability to tolerate a range of rainfall conditions.

The fact that volunteers were observed growing in the driest region of the survey may emphasise the importance of microhabitat in providing the moisture conditions required for germination and establishment and then prolonging the availability of moisture for fruit production, such as observed at Saltwater Creek. However it is also the microhabitats of volunteers 3 and 4 which prevent them from fully exploiting the periods that are favourable for growth and fruit development. The conditions that favoured their germination and emergence now hinder their continued development.

The rainfall deciles map, Figure 3, shows that the rainfall in the Tablelands regions is 'very much below average' for the period April 2001 – March 2002. The Emerald region is also 'very much below' average rainfall over the past 12 months. Much of the roadside between Emerald and Charters Towers has experienced 'below average' rainfall, while north of Charters Towers to Mt Garnet has experienced 'average' rainfall. Thus opportunities for germination of escaped cottonseed may have been less than in most years as a result of fewer, lighter falls. Observations of vegetation and competition effects have also been made following a year in which moisture has been abnormally limited. In the Tablelands region the reduced frequency of rain events is likely to have also reduced the prevalence of diseases such as boll rots.

**Table 5 Average Annual Rainfall Patterns for Key Centres in the Survey Area.**

<b>Station</b>	<b>Latitude/ Longitude</b>	<b>Elevation m above sea level</b>	<b>Mean Annual Rainfall mm</b>	<b>Mean Annual Rainy Days</b>	<b>Rainy Season</b>
Emerald 513035264	S 23°34" E 148°10"	190	634	58	spring-summer- autumn dominant with drier winter months
Clermont 513035019	S 22°49" E 147°37"	267	669	57	summer-autumn dominant with dry winter months
Mt Douglas 513034022 (Belyando Crossing)	S 21°31" E 146°52"	170	586	42	spring-summer dominant with dry winter months.
Charters Towers 513034084	S 20°04" E 146°16"	310	654	62	spring-summer dominant with dry winter months
Hillgove 513030137 (Sandy Creek)	S 19°37" E 145°46"	305	545	42	summer-autumn dominant with dry winter months
Greenvale 513032122	S 18°58" E 145°07"	427	628	44	summer-autumn dominant with dry winter months
Mt Garnet 513031046	S 17°40" E 145°16"	671	812	73	summer-autumn dominant with dry winter months
Ravenshoe 51303119	S 17°40" E 145°16"	644	884	55	summer-autumn dominant with dry winter months
Atherton 513031161	S 17°16" E 145°28"	770	1,395	131	summer-autumn dominant with dry winter months
Malanda 513031038	S 17°20" E 145°35"	762	1,672	162	summer-autumn dominant with drier winter months
Millaa Millaa 513031042	S 17°31" E 145°37"	831	2,613	160	summer-autumn dominant with drier winter months
Innisfail 513032025	S 17°31" E 146°01"	4	3,610	158	summer-autumn dominant with drier winter months
Cardwell 513032004	S 18°16" E 146°01"	6	2,106	123	summer-autumn dominant with drier winter months
Townsville 513032040	S 19°14" E 146°46"	4	1,145	83	summer-autumn dominant with dry winter months

**Figure 3** Queensland Rainfall Deciles, 1 April 2001 – 31 March 2002.

### 4.5.2 Temperature

Not all weather stations record daily temperatures. The average monthly minimum and maximum temperatures of the available centres are presented in Table 6. In the coastal region temperatures are favourable for growth all year round, with average minimums remaining above 12°C during the winter months. However monthly maximums in summer are less than those for Emerald and other cotton growing regions (Appendix 4). Modern cotton varieties have been bred to reach optimal growth rates in 'local' conditions, temperatures included. Hence the rate of fruit development achieved by cotton volunteers in the north is likely to be less than that seen commercially, even when moisture and nutrition are plentiful. A soil temperature of 14°C is required for cotton germination. It is probable that the germination of cotton volunteers could also occur year round in the coastal region. In the inland and Tableland regions growth would theoretically cease during the winter months as average minimum temperatures fall and frosts are experienced. The incidence of frosts shown in Table 7. The impact of frosts on cotton volunteers is highly variable ranging from foliage burn and fruit abortion to plant death. The opportunity for the survivorship of cotton volunteers from one year to the next is thought to be less in the regions experiencing frosts.

**Table 6a Maximum and Minimum Average Monthly Temperatures for Inland Centres in the Survey Area.**

Station	Emerald		Clermont		Charters Towers	
Month	Mean Max °C	Mean Min °C	Mean Max °C	Mean Min °C	Mean Max °C	Mean Min °C
January	34.1	21.5	34.0	21.6	33.7	22.0
February	33.2	21.3	32.9	21.2	32.8	22.0
March	31.9	19.7	31.7	19.7	31.6	20.7
April	29.5	16.5	29.2	16.2	29.8	18.1
May	25.7	12.5	25.7	12.3	27.0	15.3
June	22.7	8.9	22.8	8.3	24.6	12.0
July	22.4	7.6	22.6	6.9	24.4	11.0
August	24.6	9.0	24.9	8.7	26.6	12.3
September	28.3	12.3	28.3	12.3	29.4	14.8
October	31.8	16.5	31.4	16.4	32.3	17.8
November	33.7	19.4	33.5	19.1	34.0	20.2
December	34.5	20.9	34.3	20.9	34.4	21.5

**Table 6b Maximum and Minimum Average Monthly Temperatures for the Tablelands and Coastal Centres in the Survey Area.**

Station	Herberton*		Innisfail		Townsville	
Month	Mean Max °C	Mean Min °C	Mean Max °C	Mean Min °C	Mean Max °C	Mean Min °C
January	28.1	18.2	30.3	23.0	31.3	24.3
February	27.5	18.4	30.2	23.1	31.0	23.9
March	26.3	17.6	29.3	22.4	30.4	22.8
April	24.5	15.9	27.9	20.8	29.1	20.3
May	22.7	13.6	25.9	18.9	27.3	17.5
June	21.5	10.4	24.1	16.3	25.3	14.4
July	21.3	9.7	23.7	15.4	24.8	13.6
August	23.0	10.6	24.8	15.9	25.8	14.7
September	25.2	12.3	26.1	17.2	27.4	17.1
October	27.4	14.3	27.7	19.2	29.1	20.4
November	29.0	16.3	29.2	21.2	30.8	22.8
December	28.9	17.5	30.2	22.3	31.6	24.1

\*Herberton, station no. 513031029, S 17°22' E 145°22', elevation 899m, has been used to represent the temperatures experienced on the dairy farms of the Atherton Tablelands as this centre has the only weather station on the Tablelands which records daily temperatures.

**Table 7 Incidence of Frosts at Centres in the Survey Area.**

Station	Average No. of Frosts / year	Frost Period
Emerald	5	June, July, August
Clermont	11	June, July, August
Charters Towers	0	
Herberton	5	June, July, August
Innisfail	0	
Townsville	0	

## 5.0 Discussion

The purpose of this survey was to determine if transgenic volunteer cotton was establishing north of latitude 22° south in significant numbers. This report identified two possible areas in which cotton could establish, roadsides between Emerald and the Atherton tablelands and dairy farms on the Atherton tablelands that use cotton seed as a feed supplement. These two areas are potential risk zones due to the volume of cotton seed transported by road (estimated at 6000 tonnes/year, when occurring) and the use patterns of cotton seed on dairy farms.

### Roadside survey

In the roadside survey north of latitude 22° south cotton volunteers were found to establish, grow and in some instances, produce viable seed. The incidence of these volunteers was very low with only four plants observed in 1200 km of road surveyed (including creek crossings) above 22° south. Based on the survey methodology this equates to an approximate frequency of one volunteer every 3.85 km. The expected total population would therefore be no greater than 103 (s.e.± 86) plants. The large standard error surrounding this number suggests that more intensive surveying would be more appropriate to reduce the error associated with this measurement. It is however important to remember that the total number of volunteers is very low and irrespective of the large standard error, there simply are not a large number of volunteers present or evidence of a second germination of seedlings establishing from existing plants. Of those observed, none were found to be expressing the Cry1Ac gene. While the survey represents a substantial distance of road surveyed at regular intervals care must be taken in the interpretation of this result as the sample frequency represents only 1.28% of the transport routes. The initial aims of this study were to determine both an appropriate survey methodology and an estimation of the number of volunteers north of 22° south. As a result of this initial survey it could be concluded that additional sampling around individual plants would have significantly reduced the statistical error.

While the number of volunteer cotton plants is low, the environment in which they were established is perhaps of more importance. The three sites where volunteers were found are climatically different based on rainfall and temperature, however all three sites had specific attributes which appear to have contributed to the establishment of volunteers. Civil construction was a factor in all four cases (Photo 4, 5 and 6). All four plants were found growing in protected microclimates that would have afforded the right conditions to imbibe, germinate and establish a rooting structure before desiccation killed the seed or seedling. It would therefore appear that the conditions that allow germination and establishment only occur in niche micro-environments.

In addition some of the observed volunteers were at least 6 months old or greater and had produced seed cotton which had fallen to the ground (Photo 4 and 6). A survey of the immediate area surrounding these plants did not find any new establishing seedlings which suggests that seed cotton reaching the ground does not automatically result in new cotton plants establishing. There is no way of determining how the initial seed came to being in roadside locations, however it is likely to have fallen from the back of a semi-trailer carrying seed north. Apart from transportation of cotton seed to the Tablelands, no other sources of cotton seed have been identified for the volunteers at sites 16 and 25. It is not possible to determine the seed source of the two volunteers at site 7 as cotton has been grown north of this point and transported back to Emerald. As the plants are at least 6 months old, it is likely that the seed fell off the trucks some time before the voluntary introduction of rollover tarps which minimize the chance of seed escaping during transportation (see section 2.1.1). Of

equal importance is the fact that no cotton plants were identified in vegetative areas immediately next to the road sides suggesting that cultivated cotton probably has difficulty establishing in the competitive environment created by the native, naturalized and introduced plants that already exist. It is also important to remember that the frequency of cotton volunteers observed along the transport routes in March 2002 is the result of 12 years of transporting seed using equipment with which the risk of seed escape has been much greater than is it now.

There is, however, the possibility that some seed cotton produced by roadside volunteers could be moved away into more favourable sites for germination and establishment. For example, the seed cotton overhanging the wing wall at Saltwater Creek could be washed downstream. However the fate of such seed (if any) is outside the scope of this survey.

While some volunteers have been successful in producing bolls and seed cotton, the subsequent germination of this seed has not been observed to occur in close proximity to the initial survivor. At all roadside sites where seed cotton was observed (particularly close to Emerald), the density of seed cotton was much higher than the density of cotton volunteers. Without this invasive character, the rate of population increase will be minimal.

### **Dairy farms**

Once seed is transported to dairy farms the opportunity for cotton to establish on farms from fuzzy seed appears to be high. In the survey of Atherton dairy farms the presence of cotton volunteers was quite common. In total, 260 volunteers (across 7 of the 9 farms) were actually observed, of which 46% were found to express the Cry1Ac gene (Ingard™). The percentage of Ingard™ plants is higher than the 30% expected, based on the area grown in Emerald the previous season. The higher frequency of Ingard™ plants is unlikely to be the result of the gene conveying an ecological advantage but more likely to be the result of uneven distribution of seed that was transported. Ingard™ crops often yield more than conventional equivalents and are nearly always harvested first in the season. As a result Ingard™ crops are often ginned first and their seed is ready for transport before conventional cotton. Conventional and Ingard™ fuzzy seed is not separated at the gin and there is no way of telling what percentage of Ingard™ or conventional seed is transported north in any particular load. It is therefore impossible to describe the actual percentage of Ingard™ that was transported to each of these dairy farms. Hence the higher than expected percentage of Ingard™ volunteers observed on the dairy farms is thought to be an artifact of what was actually delivered.

The majority of spilt seed observed on dairy farms was ungerminated. Desiccation, predation, disease, lack of burial and competition for resources, mean that each seed has a reduced probability of germinating. Those seeds which successfully germinated suffered the effects of physical damage, disease and competition which prevented most of them from continuing to develop.

### **5.1 Survival of Transgenic Cotton Volunteers**

Bt cotton has an enhanced ability to withstand attack by some lepidopteran predators. The species of lepidopteran predators in this environment, their frequency, the dose of Bt required for their control and the relative attractiveness of cotton compared to other food sources are all beyond the scope of this survey. The commercial advantage of Bt isn't related to survivorship as such, but the efficiency of fruit production. Cotton is perennial, thus in the roadside and dairy farm environments it has many seasons in which to produce the seed which can give rise to successive generation. The advantage of Bt may be less than, equal to or

greater than the advantage seen commercially, depending on the variables which influence survival.

No transgenic cotton volunteers were actually observed in the roadside survey. This does not suggest that transgenic volunteers are less fit than conventionally bred volunteers in this environment, nor that there are no transgenic volunteers in this environment. The fact that none were observed is most likely a result of the randomness with which seed has escaped from trucks during transport.

The genetic distribution of cotton volunteers on dairy farms appeared to be random. Some farms had no transgenic volunteers while some had mostly transgenic volunteers and others had more even mixtures. Where populations were mixed there was no distinction in growth stage, estimated age or fruit production between transgenic and non-transgenic plants. The variability in the ratios of transgenic volunteers appears more likely due to the ratio in the batches of seed. Due to randomness in ginning, seed storage and seed loading, the ratio of transgenic seed in any one load could be anywhere between zero and 100%.

The results of the survey in relation to the potential for population growth of transgenic volunteers show that either;

1. The Cry1Ac Bt gene provides no advantage in the northern environment.  
or
2. The population of cotton volunteers in the north is insufficient or too transient for the impact of the Cry1Ac Bt gene to be observed. The Cry1Ac Bt gene can only influence growth and fruit production once the plant has overcome the establishment limitations which apply to all cotton volunteers.

### **5.2 Variables Influencing the Survival of Cotton Volunteers**

Factors influencing the survival of cotton generally in the surveyed environments are summarised in Table 8. Distinction between conventional and transgenic survivorship does not apply. The roadside and dairy farm environments are very different due to their purposes and management styles. Hence the factors influencing cotton survivorship are varied for each environment.

**Table 8 Summary of Factors Influencing the Survival of Cotton Volunteers in Northern Roadsides and Dairy Farms.****Roadside Environment**

<i>LIMITING FACTORS</i>	<i>ENCOURAGING FACTORS</i>
<ul style="list-style-type: none"> <li>• Competition from already established vegetation.</li> <li>• Low quantity of seed escapes.</li> <li>• High disturbance in areas requiring frequent maintenance.</li> <li>• High rate of seed desiccation.</li> </ul>	<ul style="list-style-type: none"> <li>• Wide range of climates – all suitable for cotton establishment.</li> <li>• Continuous change of the roadside with the landscape creates niche environments.</li> <li>• Roadsides designed for road drainage and hence moisture accumulation.</li> <li>• Cotton species is well adapted to periods of drought.</li> <li>• Perennial growth habit allows fruit to be produced from the one plant indefinitely.</li> </ul>

**Dairy Farm Environment**

<i>LIMITING FACTORS</i>	<i>ENCOURAGING FACTORS</i>
<ul style="list-style-type: none"> <li>• Intense competition during the warmer months from pastures with rapid growth rates.</li> <li>• Regular disturbance by daily hosing, herd movement and farm equipment.</li> <li>• High humidity and frequently wet conditions favour boll rots.</li> </ul>	<ul style="list-style-type: none"> <li>• High quantity of seed.</li> <li>• High moisture availability during the warmer months.</li> </ul>

**Quantity of Cottonseed**

Not all cottonseed that escapes into the roadside environment will have the opportunity to germinate and establish. At all roadside sites where seed cotton was observed, the density of seed cotton was much higher than the density of cotton volunteers. This supports the assumption that cotton plants establishing as roadside volunteers do so under less than ideal conditions. Desiccation, predation and lack of burial reduce each seed's probability of germinating. Effects of competition, roadside slashing and predation can prevent emerged seedlings from establishing. Seeds that do escape in transport still have to negotiate the above limiting factors and hence it is not the quantity of cotton seed that is important but the ability to establish.

The frequency of cotton volunteers observed along the transport routes in March 2002 is the result of 12 years of transporting seed using equipment with which the risk of seed escape has been much greater than is it now. One cotton volunteer per 3.85km is considered a very low frequency. Particularly when considering that alternative sources of seed may account for the

presence of volunteers along part of the route. While some volunteers have been successful in producing bolls and seed cotton, the subsequent germination of this seed has not been observed to occur in close proximity to the initial survivor. Without the invasive character, the population stagnates.

This survey was conducted following of a year of low seed quantity transportation. The number of farms feeding cottonseed has been severely depressed meaning the frequency of trucks carrying cottonseed on transport routes has been many fewer than in previous years. The low frequency this year - in itself - is unlikely to have impacted on the survey results as this would not have prevented the observation of older plants.

On dairy farms the large quantity of seed that escapes its intended purpose is one of the most encouraging factors for volunteer establishment in this environment. Many kilograms of seed are spilt around dairies each year. The potential for seed to escape does vary depending on the setup adopted by the dairy farm. In some instances gaps in the walls of the storage facility also allows many kilograms of seed to seep onto the ground outside. Seed may need to be moved from the storage area in order to be fed, creating an additional opportunity for seed to be spilt.

Unlike roadsides where seeds spill and scatter individually, seed spilt around dairies is often in clumps. Seed will undoubtedly become moist, often it will be in contact with the bare soil and temperatures will be such to allow germination most of the year round. Clumping of spilt seed provides the central seeds with some shelter from desiccation, predation and damage through farm activities. Yet very few of these spilt seeds are observed to germinate and even fewer manage to establish. Farms where cottonseed has been fed constantly for several years can have no established cotton plants. The factors limiting cotton survivorship appear to outweigh the potential created by large quantities of escaped seed and the favourable conditions for germination.

### **Competition from other Vegetation**

The roadside is a completely disturbed environment, having undergone change in slope and soil type as well as a complete denuding of vegetation at the time of its construction. However the presence of vegetation along roadsides is important to prevent soil erosion. Top soil is replaced on the batter during the final stages of construction, returning the seed bank from the original vegetation. In areas where soil is not seed rich, seed is spread to encourage rapid establishment. This provides an immediate source of competition to cottonseed when it falls off the back of a truck. In addition to resource competition vegetation can physically impede seeds from finding a site to establish.

### **Weed Control**

Measures already being practiced for the control of recognized weeds in the roadside and dairy farm environments inadvertently control cotton volunteers. Roadsides weed control is general, aiming to prevent vegetation from interfering with road drainage and motorists' vision of signs and the road ahead. Conversely, weed control practices on dairy farms tend to be very specific, targeting specific species. Despite their differences, each has severe implications for the survivorship of cotton volunteers.

Shire Councils and the Department of Main Roads have the responsibility of maintaining roadside vegetation. In general slashing is used for the purpose of reducing the height of

vegetation. All species along the roadside are reduced to a height of 5-7cm. Cotton plants exposed to this treatment are not able to retain fruit and very little, if any, foliage. It would be extremely rare for cotton plant to ever have produced fruit below this height. The frequency of slashing determines whether fruit and seed production could be achieved between disturbances. The frequency of slashing tends to be determined by rainfall. Across the Tablelands and along the coast rainfall is such that slashing takes place monthly (information supplied by the respective Shire councils). In this area survival of repetitive slashing could occur but there is virtually no opportunity for surviving cotton plants to ever produce seed. Along the western highways slashing tends only to be performed at the beginning and end of the summer rainfall period. There are windows of opportunity for seed cotton to be produced in this region, as was observed at Saltwater Creek.

The consequential effect of slashing on the establishment of cotton volunteers is that it reduces their competitiveness relative to species with ruderal adaptation. Ruderals dominate disturbed environments, these species are adapted to exploit temporary favourable conditions. Many grasses for example, are able to thrive in regularly slashed conditions, having high rates of dry matter production, capacity to rapidly produce large quantities of seed or use vegetative reproduction to negate the seed production phase of their lifecycle. A slashed cotton volunteer surrounded by ruderals is rapidly out competed for resources, further slowing its development.

Herbicides may also be used to manage roadside vegetation. Due to expense and public sentiment, the use of herbicides tends to be limited to around guide posts, culverts and other drainage points where slashing is difficult and longer term control is desired. Herbicide use was observed across the Tablelands and along the coast but not inland. The herbicide used in most instances is Roundup® Biactive (a.i. glyphosate) due to its safety to creatures such as tree frogs. Cotton volunteers with the Roundup Ready gene could have a distinct survival advantage over other vegetation growing in these niche environments. However depending on the growth stage of volunteers at the time of herbicide application, fruit and seed production may still be severely restricted as the plant is only vegetatively tolerant.

Weed control on dairy farms aims to rid pastures of non-palatable species, the presence of which reduces the productive capacity of the fields. Selective herbicides are relied upon to achieve this. Most commonly herbicides are applied as spot sprays. Spot spraying allows the farmer to decide exactly which plants are sprayed and can ensure each receives adequate coverage for effective control. A number of herbicides may be used, depending on which weed species are being targeted. Grazon (picloram+triclopyr), Brush-off (metsulfon-methyl), 2,4-D and Starane (fluroxypyr) are most common. Many of the farmers surveyed commented on having never seen a cotton plant while carrying out spot spraying. This response was not unexpected as the survey identified minimal opportunity for seed to escape into areas of the farm away from the dairy.

### Climate

There are few climatic limitations to cotton volunteer survivorship in the surveyed area. *G. hirsutum* is naturally a tropical and subtropical species of the new world (Lee 1984). Temperatures north of 22° south permit year-round growth of cotton with the exception of the Tablelands where frosts are experienced in the winter months. The extent of injury caused by frost varies on a case-by-case basis, but would not necessarily cause plant death. Rainfalls in the inland region are similar to that of Emerald where cotton volunteers grow readily in rain fed conditions. In most years some fruit will be set before drying winter conditions become unfavourable for further development. Creeks and drains, which may be similar to natural *G.*

*hirsutum* littoral and riparian habitats, provide environments of more permanent moisture within this region (Hearn 1994). High Tablelands and coastal rainfalls encourage vigorous vegetative growth. Facultative fruit shedding by cotton established in habitats of high moisture availability has been observed to occur. This tendency in combination with higher incidence of boll rots occurring in tropical conditions, represents climatic limitation to volunteer fruit production despite the conditions being highly favourable for survivorship.

The survey was conducted following of a year of abnormal conditions. Rainfall has been “very much below average” and “below average” along parts of the transport route and in the Tablelands region during the previous 12 months.

### **Comparison of volunteers in Lower Namoi valley cotton region with north of 22° South**

An important comparison is the difference between traditional long established cotton growing regions with areas that cotton is not normally grown as a crop. In this regard the roadside survey of the Lower Namoi Valley provided some interesting results (Appendix 5) The Lower Namoi roadside survey was at a higher density (2% compared to 1%) than the northern survey and represented 700km of roadside. Cotton volunteers were only found at 6 out of the 70 sites sampled (a total of 59) which equated to 4.2 volunteers/km compared to 0.26 volunteers/km in the northern survey. The amount of seed cotton varied from 0 to 3220 pieces /200m of road surveyed but did not seem to influence the number of volunteers. Similar to the northern survey, volunteers were mainly found where civil construction was apparent (road drains, channel crossings etc) and rarely amongst other established vegetation. All plants were less than one year old and in their first year of fruit production. This contributes to the theory that establishment is the critical factor in determining the number and extent of cotton volunteers, rather than the types of transgenic genes the plants are carrying.

## 6.0 Conclusion

### Transport Routes

In a 1% survey of 1200 km of transport route from Emerald to the Atherton Tablelands cotton volunteers were observed at a frequency of one plant per 3.85 kilometers north of latitude 22° south. Only four volunteers were actually observed. Two of these volunteers were located at one site where seed cotton, spread by the movement of cotton modules, was present as an alternative source of seed. The other two volunteers were in locations where the only source of seed could be that escaping during the transport of cottonseed loads. No volunteers were observed to establish amongst other roadside vegetation. All four plants were in niche environments, three at creek crossings. All four plants were non-transgenic and are estimated to have been established for longer than six months. Due to their specific locations the volunteers had varying potentials to produce seed.

The low number of volunteers observed prevented the collection of sufficient data to define a profile of the roadside conditions more suited to the establishment of roadside cotton volunteers. Climatic conditions are suitable for cotton growth across the surveyed area, with some exceptions in the Tablelands region. Winter frosts may reduce survivorship potential from one year to the next and the high frequency of rainy days in late summer encourages boll rots, reducing potential seed production. Soil types were generally a product of road construction and not indicative of the wider surroundings. With the exception of very sandy soils observed between Belyando Crossing and Charters Towers, cotton volunteers could establish in all soil conditions along the roadside. Vegetation was generally dominated by grasses. Volunteer cotton was only observed to grow amongst the roadside vegetation close to Emerald (below 22° south). Established vegetation represents both a competitive barrier to volunteer establishment and a physical barrier to seed entering the environment. We suspect that niche environments offered by civil road structures (drains, causeways, bridges) offer the conditions most conducive to establishment.

We believe that the need for further monitoring of transport routes is extremely low. The move to roll-over tarping by the cottonseed transporters prevents the continued entry of cottonseed along these routes. The quantity of seed cotton currently being produced by volunteer plants north of latitude 22° south is estimated to be very low. Regular slashing of vegetation along most of the transport routes limits the potential for already established volunteers to produce seed. High levels of seed desiccation and the intensity of competition from other established vegetation limits the potential of seed to establish. Winter frosts in the Tablelands region reduces the survivorship potential of volunteers from one summer to the next.

Cotton volunteers observed were not transgenic. The current available transgenic genes do not appear to have enhanced survivorship potential in this environment. However cotton volunteers in general do not appear to establish readily in this environment even after 12 years of seed transportation.

### **Dairy Farms**

In a survey of nine dairy farms across the Atherton Tablelands region, cotton volunteers were observed on seven farms. Transgenic cotton volunteers were observed on four farms and represented 46% of the total number of volunteers gene tested. The range of growth stages of the transgenic volunteer population was similar to that of the non-transgenic volunteer population. Most commonly cotton volunteers were observed in the cotyledon – two leaf growth stages. Flowering cotton volunteers were relatively uncommon. The survivorship and fruiting potential of transgenic volunteer cotton did not appear to be enhanced in any situation.

Cottonseed has a long history of use by Tableland dairy farmers. Despite this cotton volunteers are not seen by dairy farmers as weeds requiring control. Volunteers were only seen to establish in close proximity to the dairy infrastructure suggesting their ability to invade is negligible.

The use of cottonseed on dairy farms in the Atherton Tablelands region has been below normal during the 12 months preceding the survey due to economic factors. The number of farms feeding cottonseed has declined and the way in which cottonseed is used as a supplementary feed has changed for many of those that continue to use it. While the survey has not been conducted in an average year of cotton seed use, it still represents the combined effect of 12 years of transport.

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## Appendix 1

### Survey Methodology Protocol – Roadside Survey

Both of the transport routes used by Hartwig Bulk Transport and Myers Transport from Emerald to the Atherton Tablelands will be surveyed.

Along each of the transport routes →

1. One site will be surveyed every 50 km.
2. At each site, 500 m in length and up to 4 m in width (at some sites this may need to be wider) extending away from the edge of the bitumen road, on each side of the road, will be surveyed. The surveyed area represents 1% (1m/100m) of the roads used for the transport of cottonseed.
3. The general soil type and roadside conditions will be recorded. Characterisation of all sites, with and without volunteer cotton, will enable the development of a profile for 'higher' risk sites.
4. In addition to the 0.5/50 km surveys, 1 creek crossing per 100 km will also be surveyed. The soil moisture conditions close to creek banks may be more favourable for cotton germination and survivorship than along more exposed areas of roadside.
5. Observations at creek crossings will extend 50 m along the road to either side of the crossing and as close to the bank of the creek as physically possible.
6. The general conditions and accessibility to the creek bank will be noted.
7. The GPS coordinates for each end of each survey site will be recorded.
8. The exact position of cotton plants will only be GPS recorded if plants have reached reproductive growth stages and the total number of cotton plants observed at any one site is less than 5.
9. At all sites where cotton plants are found, plants will be tested for the Bt gene using a ELISA field test kit. The test kit is produced by Strategic Diagnostics (USA). It provides a qualitative (yes/no) response to the presence of the Bt gene.

Based on low plantings of Roundup Ready cotton in the Emerald district in 2000/01 season, minimal quantities of Roundup Ready seed were available for transport and hence testing for the RR gene is not warranted.

10. The number of plants tested will depend on the overall population. In situations where less than 10 plants are present, all plants will be tested. In situations where more than 10 plants are present, a minimum of 10 and maximum of 1 in 10 plants will be tested.
11. At each site the number of cotton plants and their growth stages, including cotton boll number, are to be recorded.

12. At any site where there are flowering cotton plants, up to 5 plants are to be genetically tested, physically tagged and GPS positions recorded. In the future these sites may be revisited to monitor persistence.
13. Cotton plants found growing in tight groups may be the result of seed germinating from seed cotton rather than fuzzy seed. The sources of seed cotton are, module transporting (Emerald to Clermont only) and second/third generation seedlings from naturalised cotton populations. At each survey point a comment on the randomness of cotton plant distribution will be made.

### **Survey Methodology Protocol – Dairy Farms Survey**

The Queensland Dairy Organisation is aware of 148 dairy farms across the Atherton Tablelands. Cottonseed is delivered directly to the farms. The establishment of cotton plants around seed storage areas and feed-out areas will be surveyed on 15 farms across the district. The farms chosen will all have fed cottonseed during 2001. A sample size of 10% is considered adequate due to the close geographic proximity of the farms and similar rainfall and temperatures experienced across the district.

Plant numbers, growth stages and fruit loads will be recorded.

Plant samples will be tested for the Bt gene at each site on each farm. The number of plants tested will depend on the overall population. In situations where less than 10 plants are present, all plants will be tested. In situations where more than 10 plants are present, a minimum of 10 and maximum of 1 in 10 plants will be tested.

## APPENDIX 2

## GPS Coordinates of Roadside Survey Sites for North

Site Number	Start		Finish	
	Latitude	Longitude	Latitude	Longitude
1	S 23°18.559"	E 148°06.620"	S 23°18.547"	E 148°06.513"
2	S 22°58.615"	E 147°50.087"	S 22°58.467"	E 147°49.851"
3	S 22°40.878"	E 147°43.729"	S 22°40.681"	E 147°34.559"
4	S 22°32.990"	E 147°30.842"	S 22°32.872"	E 147°30.888"
5	S 22°19.600"	E 147°17.455"	S 22°19.363"	E 147°17.323"
6	S 21°56.399"	E 147°03.234"	S 21°56.195"	E 147°03.096"
7	S 21°35.566"	E 146°54.208"	S 21°35.654"	E 146°54.209"
8	S 21°33.021"	E 146°53.210"	S 21°32.901"	E 146°52.958"
9	S 21°20.119"	E 146°31.698"	S 21°20.372"	E 146°31.780"
10	S 21°09.662"	E 146°26.998"	S 21°09.852"	E 146°27.162"
11	S 20°56.114"	E 146°24.486"	S 20°56.378"	E 146°24.513"
12	S 20°49.313"	E 146°21.576"	S 20°49.367"	E 146°21.749"
13	S 20°33.949"	E 146°16.067"	S 20°34.179"	E 146°16.152"
14	S 20°09.513"	E 146°13.292"	S 20°09.776"	E 146°13.248"
15	S 19°49.059"	E 146°02.491"	S 19°49.105"	E 146°02.226"
16	S 19°36.742"	E 145°46.093"	S 19°36.583"	E 145°46.067"
17	S 19°32.497"	E 145°44.979"	S 19°32.279"	E 145°44.829"
18	S 19°14.953"	E 145°28.718"	S 19°15.099"	E 145°28.785"
19	S 19°11.049"	E 145°23.351"	S 19°10.935"	E 145°23.090"
20	S 19°00.265"	E 145°57.487"	S 19°00.155"	E 144°57.235"
21	S 18°55.566"	E 144°36.148"	S 18°55.423"	E 144°35.902"
22	S 18°34.481"	E 144°44.466"	S 18°34.269"	E 144°44.418"
23	S 18°10.007"	E 144°48.479"	S 18°09.750"	E 144°48.508"
24	S 17°47.179"	E 144°57.967"	S 17°47.016"	E 144°58.172"
25	S 17°38.988"	E 145°20.358"	S 17°38.868"	E 145°20.608"
26	S 17°30.056"	E 145°30.749"	S 17°31.866"	E 145°30.585"
27	S	E	S 17°20.423"	E 145°29.965"
28	S 17°18.077"	E 145°29.550"	S 17°18.821"	E 145°29.570"
29	S 17°26.336"	E 145°36.006"	S 17°26.611"	E 145°35.932"
30	S 17°34.571"	E 145°41.341"	S 17°34.764"	E 145°41.521"
31	S 17°34.142"	E 145°55.224"	S 17°34.048"	E 145°55.501"
32	S 17°31.045"	E 145°59.606"	S	E
33	S 17°43.844"	E 146°02.132"	S 17°43.655"	E 146°02.219"
34	S 18°11.995"	E 145°57.002"	S 18°11.752"	E 145°56.786"
35	S 18°34.093"	E 146°11.251"	S 18°33.728"	E 146°11.044"
36	S 18°49.477"	E 146°08.591"	S 18°49.246"	E 146°08.453"
37	S 19°13.441"	E 146°36.739"	S 19°13.325"	E 146°36.513"
38	S 19°36.536"	E 146°50.128"	S 19°36.798"	E 146°50.129"
39	S 19°50.254"	E 146°43.598"	S 19°50.241"	E 146°43.417"
40	S 19°54.490"	E 146°34.728"	S 19°54.617"	E 146°34.484"

**GPS Coordinates of Surveyed Dairy Farms**

Farm Number	Latitude	Longitude
1	S 17o31.905''	E 145o38.965''
2	S 17o31.582''	E 145o36.568''
3	S 17o33.173''	E 145o34.784''
4	S 17o36.943''	E 145o36.136''
5	S 17o27.880''	E 145o39.399''
6	S 17o29.616''	E 145o33.647''
7	S 17o20.351''	E 145o32.297''
8	S 17o42.623''	E 145o15.320''
9	S 17o20.389''	E 145o30.856''

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## APPENDIX 3

### Site 1

Emerald – Capella, S 23°18.559" E 148°06.620", Twelve cotton volunteers were found on this section of the roadside which shows that volunteers can establish in this vegetation.



### Site 3

Clermont – Belyando Crossing, S 22°40.878" E 147°43.729", Two cotton volunteers found in this road section.



Site 5

Clermont – Belyando Crossing, S 22°19.600" E 147°17.455". North of site 3, however no volunteers were found.



Site 7

Saltwater Creek, Clermont – Belyando Crossing, S 21°35.566" E 146°54.208", two cotton volunteers found, however both were in a niche environment created by this creek crossing.



Site 8

Belyando Crossing – Charters Towers, S 21°33.021” E 146°53.210”. This photo was only 5-8 kms from the previous site, however it shows a significantly more hostile environment for cotton to establish. No cotton volunteers were found here.



Site 9

Belyando Crossing – Charters Towers, S 21°20.119” E 146°31.698”. This photo shows the mechanical slashing of roadsides which would control any establishing volunteers.



Site 10

North Bullock Creek, Belyando Crossing – Charters Towers, S 21°09.662” E 146°26.998”. Many of the creek crossings have extensive concrete aprons which can create some opportunities through water runoff but also limit direct establishment because of the covering. Note the dense grass next to the creek limiting establishment opportunities.



Site 17

Charters Towers – Greenvale, S 19°32.497” E 145°44.979”. This site represents a roadside environment after a new road has been built (within 12 months).



Site 19

Charters Towers – Greenvale, S 19°11.049" E 145°23.351". This photo shows that not all roadsides are slashed but that the resulting vegetation is very thick making it difficult for cotton to establish.



Site 26

Ravenshoe – Atherton, S 17°30.056" E 145°30.749". This site represents herbicide control of roadside vegetation.



Site 30

Millaa Millaa – Innisfail, S 17°34.571” E 145°41.341”. This site represents an extreme high rainfall site. Note the lush green vegetation making it difficult for cotton to establish.



Site 32

Millaa Millaa – Innisfail, S 17°31.045” E 145°59.606”. Areas around roadside signs and posts are often controlled with herbicides.



## Appendix 4 Lower Namoi Valley roadside Survey

Site No.	Description of Location	Location Start	Location Finish
1	SR 45 Spring Plains Road	S 30° 07.751" E 149° 29.500"	S 30° 07.676" E 149° 29.382"
2	SR 45 Spring Plains Road	S 30° 04.138" E 149° 24.759"	S 30° 04.059" E 149° 24.759"
3	SR 45 Spring Plains Road	S 30° 01.101" E 149° 19.644"	S 30° 01.044" E 149° 19.525"
4	SR 45 Spring Plains Road	S 29° 56.162" E 149° 19.293"	
5	SR 220	S 29° 59.730" E 149° 12.404"	S 29° 59.704" E 149° 12.278"
6	SR 220	S 29° 56.264" E 149° 07.767"	S 29° 56.704" E 149° 07.707"
7	SR 46 Doreen Lane	S 30° 05.669" E 149° 18.502"	
8	SR 46 Doreen Lane	S 30° 10.362" E 149° 18.363"	S 30° 10.466" E 149° 18.323"
9	MR 343 (Cudgewar intersection)	S 30° 12.855" E 149° 23.468"	S 30° 12.875" E 149° 23.501"
10	SR 64 (Helebah end)	S 30° 08.325" E 149° 27.742"	S 30° 08.208" E 149° 27.758"
11	SR 64 (Kamilaroi hwy end)	S 30° 12.752" E 149° 25.000"	S 30° 12.864" E 149° 24.982"
12	MR 343 (at Merah North)	S 30° 11.082" E 149° 17.708"	S 30° 11.045" E 149° 17.597"
13	SR 47 (10km from Merah North)	S 30° 14.254" E 149° 12.814"	S 30° 14.312" E 149° 12.708"
14	SR 47	S 30° 14.980" E 149° 06.706"	S 30° 15.066" E 149° 06.616"
15	SR 47	S 30° 15.776" E 149° 00.777"	S 30° 15.797" E 149° 00.654"
16	SR 47	S 30° 15.854" E 148° 54.569"	S 30° 15.871" E 148° 54.461"
17	Burren Junction - Pilliga (near Namoi River crossing)	S 30° 16.534" E 148° 49.058"	S 30° 16.629" E 148° 49.029"
18	Burren Junction - Pilliga	S 30° 20.550" E 148° 52.006"	S 30° 20.649" E 148° 52.062"
19	MR 127 Pilliga – Wee Waa	S 30° 21.641" E 148° 57.452"	S 30° 21.627" E 148° 57.587"
20	MR 127 Pilliga – Wee Waa	S 30° 20.027" E 149° 04.016"	S 30° 21.044" E 149° 04.034"
21	MR 127 Pilliga – Wee Waa	S 30° 20.317" E 149° 10.103"	S 30° 20.308" E 149° 10.212"
22	MR 127 Pilliga – Wee Waa	S 30° 19.484" E 149° 16.042"	S 30° 19.471" E 149° 16.169"
23	MR 127 Pilliga – Wee Waa	S 30° 17.884" E 149° 21.926"	S 30° 17.854" E 149° 22.045"
24	MR 127 Pilliga – Wee Waa	S 30° 14.418" E 149° 25.416"	S 30° 14.325" E 149° 25.474"
25	MR 127 Wee Waa – Narrabri (SR 45 and ACRI)	S 30° 11.759" E 149° 31.092"	S 30° 11.734" E 149° 31.268"
26	MR 127 Wee Waa – Narrabri (~10km Narrabri)	S 30° 16.275" E 149° 43.661"	S 30° 16.339" E 149° 43.766"
27	MR 127 Wee Waa – Narrabri (near Yarral entrance)	S 30° 13.420" E 149° 37.504"	S 30° 13.332" E 149° 37.384"
28	SR 10 Maules Creek Road (between Old Gunnedah and Wave Hill turnoffs)	S 30° 23.710" E 149° 53.583"	S 30° 23.625" E 149° 53.674"
29	SR 10 Maules Creek Road (between creek and Amaroo)	S 30° 27.150" E 149° 57.171"	S 30° 27.239" E 149° 57.251"
30	SR 10	S 30° 28.401" E 150° 03.175"	S 30° 28.419" E 150° 03.303"
31	SR 11 (near Wodonga)	S 30° 30.965" E 150° 01.463"	S 30° 31.032" E 150° 01.366"
32	SR 17 (heading to Boggabri)	S 30° 35.166" E 150° 00.500"	S 30° 35.271" E 150° 00.541"
33	MR 72 (near Manilla turnoff)	S 30° 40.036" E 150° 02.494"	S 30° 40.143" E 150° 02.478"
34	SR 22 (before cattle yards)	S 30° 42.189" E 150° 05.850"	S 30° 42.203" E 150° 05.978"
35	MR 357	S 30° 40.544" E 150° 06.200"	S 30° 40.546" E 150° 06.075"
36	SR 16 (at Glenelg)	S 30° 30.463" E 149° 59.473"	S 30° 30.576" E 149° 9.428"
37	MR 72 (near 80s at Baan Baa)	S 30° 36.155" E 149° 57.577"	S 30° 36.141" E 149° 57.450"
38	MR 72 (Kurrajong ck)	S 30° 31.709" E 149° 55.047"	S 30° 31.608" E 149° 55.005"
39	MR 72	S 30° 25.534" E 149° 52.433"	S 30° 25.430" E 149° 52.313"
40	MR 72	S 30° 23.223" E 149° 47.916"	S 30° 23.153" E 149° 47.814"
41		S 30° 20.165" E 149° 44.838"	S 30° 20.103" E 149° 44.749"

42	SR 30 (just past Mollee)	S 30° 18.349" E 149° 39.065"	S 30° 18.268" E 149° 38.959"
43	SR 32	S 30° 15.783" E 149° 33.912"	S 30° 15.758" E 149° 33.809"
44	SR 32 (before CSD)	S 30° 14.357" E 149° 28.558"	S 30° 14.396" E 149° 28.232"
45	SR 111 (~6km from SR 45)	S 30° 09.379" E 149° 36.171"	S 30° 09.271" E 149° 36.188"
46	SR 111	S 30° 05.769" E 149° 38.943"	S 30° 05.784" E 149° 39.069"
47	SR 6 (~6km nth of end SR 111)	S 30° 03.447" E 149° 39.964"	S 30° 03.358" E 149° 39.897"
48	SR 6	S 29° 58.412" E 149° 37.584"	S 29° 58.300" E 149° 37.536"
49	SR 6	S 29° 53.022" E 149° 37.217"	S 29° 52.929" E 149° 37.241"
50	SR 1 (towards Bellata)	S 29° 50.555" E 149° 41.049"	S 29° 50.531" E 149° 41.101"
51	SR 1	S 29° 54.223" E 149° 44.911"	S 29° 54.286" E 149° 45.014"
52	SH 17 (towards Narrabri)	S 29° 57.936" E 149° 47.466"	S 29° 58.048" E 149° 47.466"
53	SH 17 (at Byalla Lane)	S 30° 03.438" E 149° 47.327"	S 30° 03.570" E 149° 47.352"
54	SH 17 (at Smithfield)	S 30° 08.767" E 149° 48.433"	S 30° 08.876" E 149° 48.468"
55	SH 17 (before Buddah)	S 30° 14.174" E 149° 48.438"	S 30° 14.311" E 149° 48.568"
56	MR 133	S 30° 15.895" E 149° 50.055"	S 30° 15.890" E 149° 50.131"
57	MR 133 (last of bitumen)	S 30° 13.005" E 149° 55.300"	S 30° 12.791" E 149° 55.308"
58	SR 3 (Steels' memorial)	S 30° 07.842" E 149° 55.737"	S 30° 07.732" E 149° 55.757"
59	SR 3	S 30° 03.089" E 149° 58.562"	S 30° 02.916" E 149° 58.610"
60	SR 7	S 30° 01.312" E 149° 54.977"	S 30° 01.359" E 149° 45.854"
61	SR 7	S 30° 05.658" E 149° 52.011"	S 30° 05.649" E 149° 51.886"
62	SR 105	S 30° 07.943" E 149° 46.510"	S 30° 07.853" E 149° 46.417"
63	SR 6 (near SR 121)	S 30° 12.409" E 149° 43.590"	S 30° 12.516" E 149° 43.620"
64	SR 6 (~3km sth SR 111)	S 30° 07.733" E 149° 41.547"	S 30° 07.846" E 149° 41.555"
65	SR 6	S 30° 12.807" E 149° 43.734"	S 30° 12.904" E 149° 43.733"
66	MR 343 (10km west Merah Nth)	S 30° 08.375" E 149° 12.275"	S 30° 08.703" E 149° 12.157"
67	MR 343	S 30° 06.901" E 149° 06.445"	S 30° 06.858" E 149° 06.320"
68	MR 343	S 30° 07.028" E 149° 00.549"	S 30° 07.011" E 149° 00.466"
69	Burren Jnction – Pilliga	S 30° 08.533" E 148° 56.777"	S 30° 08.653" E 148° 56.763"
70	Burren Junction – Pilliga	S 30° 12.894" E 148° 53.636"	S 30° 12.964" E 148° 53.520"

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**Climate at Narrabri West, station no. 513053030**


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Latitude/Longitude	S 30°19''	E 194°44''
Elevation		212m
Mean Annual Rainfall mm		646
Mean Rainy Days per year		64
Rainfall distribution	60% summer, 40% winter	
Mean Monthly Temperatures	Mean Max	Mean Min
	°C	°C
January	33.4	19.1
February	33.0	18.9
March	30.9	16.4
April	26.9	12.1
May	22.0	8.2
June	18.4	5.0
July	17.6	3.5
August	19.4	4.5
September	23.0	7.3
October	26.9	11.5
November	30.1	14.7
December	33.0	17.6
Mean Frosts per year		36
Frost Period	May, June, July, August, September	

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## APPENDIX 5

**Observations of Soil type, Vegetation, Seed Cotton and Crop Volunteers  
at Roadside Survey Sites in the Lower Namoi Valley Cotton Growing Region**

<b>Site No.</b>	<b>Road Type</b>	<b>Description of Roadside Soil Type</b>	<b>Description of Roadside Vegetation</b>	<b>Seed Cotton / 100m</b>	<b>Presence of Crop Volunteers / 200m</b>
1	Bitumen	Black self-mulching clay, gravelly surface layer.	Well grazed. Moderately dense grasses. Minimal new growth. Some clover and lucerne regrowth. Patterson's curse establishing. No woody stemmed vegetation.	2720	8 cotton plants – all uprooted and defoliated.
2	Bitumen	Black self-mulching clay, gravelly surface layer.	Grazed. Moderately dense grasses. Minimal new growth. Skeletons of Queen Anne's Lace and thistles. No other vegetation.	3220	
3	Bitumen	Black self-mulching clay, gravelly surface layer.	Grazed. Moderately dense grasses. Minimal new growth. Odd roly poly. Skeletons of Queen Anne's Lace.	1360	
4	Gravel	Browinsh-red sandy loam.	Not grazed. Moderately dense grasses. No new growth. No other vegetation.	180	
5	Bitumen	Black self-mulching clay, reddish-brown stoney surface layer.	Very well grazed. Moderately dense grasses diminishing away from road edge. Minimal new growth. No other vegetation.	120	
6	Bitumen	Black self-mulching clay, gravelly surface layer.	Grazed. Moderately dense grasses. Minimal new growth. Odd roly poly. No other vegetation.	290	
7	Gravel	Black self-mulching clay.	Not grazed. Little vegetation, mainly bare earth. Milk thistle is dominant species.	120	4 cotton plants, all conventional varieties - no fruit - 3 immature bolls - 1 immature boll - 45 mature bolls

8	Gravel	Black self-mulching clay, gravelly surface layer.	Not grazed. Sparse grasses. No new growth. Odd roly poly. No other vegetation.	2300	1 sorghum
9	Bitumen	Black self-mulching clay.	Very well grazed. Moderately dense grasses. No new growth. No woody stemmed vegetation.	7200	
10	Gravel	Black self-mulching clay, gravelly surface layer.	Well grazed. Moderately dense grasses. No new growth. Culvert supporting noogoora bur – desiccated.	100	
11	Gravel	Black self-mulching clay, gravelly surface layer.	Very Well grazed. Moderately dense grasses. No new growth. Odd roly poly. No other vegetation.	40	
12	Bitumen	Black self-mulching clay.	Well grazed. Moderately sparse grasses. No new growth. No woody stemmed vegetation.	2420	
13	Gravel	Red sandy loam, stoney surface.	Well grazed. Moderately sparse grasses. No new growth. Odd roly poly. No other vegetation.	100	
14	Gravel	Red sandy loam, stoney surface.	Very well grazed. Sparse grasses. Minimal new growth. Odd established tree. No other vegetation.	290	
15	Gravel	Red sandy loam.	Very well grazed. Moderately dense grasses. No new growth. No other vegetation.	120	
16	Black soil	Black self-mulching clay.	Very well grazed. Sparse grasses. No new growth. No other vegetation.	80	
17	Bitumen	Black self-mulching clay, gravelly surface layer.	Grazed. Moderately dense grasses. No new growth. Odd tree sapling. Odd skeleton of fleabane. Three culverts – one supporting galvanized burr and desiccated nut grass.	330	
18	Gravel	Reddish brown sandy loam.	Very well grazed. Very sparse grass covering. No new growth. Odd galvanized burr. No other vegetation.	50	

19	Gravel	Reddish brown sandy loam	Grazed. Sparse grasses. No new growth. Odd galvanized burr. No other vegetation.	60	
20	Gravel	Red sandy loam.	Grazed. Very sparse grasses. No new growth. No other vegetation.	90	
21	Gravel	Reddish brown sand.	Well grazed. Very sparse grasses. No new growth. No other vegetation.	20	
22	Bitumen	Greyish white clay loam becoming sandy away from tar.	Grazed. Sparse grasses. No new growth. No woody stemmed vegetation.	180	
23	Bitumen	Black self-mulching clay, gravelly surface layer.	Well grazed. Moderately sparse grasses. No new growth. No woody stemmed vegetation.	150	Sorghum remnants.
24	Bitumen	Black self-mulching clay, gravelly surface layer.	Well grazed. Moderately sparse grasses. No new growth. No woody stemmed vegetation.	760	Sorghum remnants.
25	Bitumen	Black self-mulching clay.	Well grazed. Moderately dense grasses. Some new growth. Skeletons of burrs in table drain.	2920	
26	Bitumen	Black self-mulching clay, gravelly surface layer.	Grazed. Moderately dense grasses. Minimal new growth. Skeletons of burrs and thistles.	940	1 cotton plant – 1 immature boll, a conventional variety

27	Bitumen	Black self-mulching clay.	Slashed and well grazed. Dense grasses. Minimal new growth. Lucerne regrowing. Skeletons of Queen Anne's Lace and burrs on the ground.	2280	10 cotton plants, all conventional varieties - 34 squares, 1 flower, 12 immature bolls - 12 squares, 1 flower, 22 immature bolls - 9 squares, 30 immature bolls - 8 squares, 23 immature bolls, 2 mature bolls - 6 squares, 22 immature bolls - 4 squares, 14 immature bolls - 3 squares, 14 immature bolls, 5 mature bolls - 2 squares, 16 immature bolls - 1 square, 10 immature bolls - 3 immature bolls  1 sunflower
28	Bitumen	Brown loam.	Grazed. Moderately dense grasses. No new growth. Shepard's purse, fleabane, established trees.	460	
29	Bitumen	Brown loam, stoney surface.	Well grazed. Moderately dense grasses. Minimal new growth. Roly poly, galvanized burr, wiregrass.	330	
30	Bitumen	Brown loam, stoney surface.	Well grazed. Moderately dense grasses. Leaf litter and shading from established trees 10m from road edge.	140	
31	Gravel	Black self-mulching clay, stoney, gravelly surface layer.	Slashed. Moderately dense grasses. Minimal regrowth. Cobblers pegs sensitive weed, Patterson's curse, mintweed.	0	
32	Black soil	Brownish black loam.	Well grazed. Moderately sparse grasses. No new growth. Leaf litter from established trees close to road.	90	
33	Bitumen	Black self-mulching clay, gravelly surface layer.	Slashed and grazed. Moderately dense grasses. Minimal new growth. Lucerne and thistles growing on batter.	1140	4 sunflowers
34	Gravel	Greyish brown loam.	Well grazed. Sparse grasses. No new growth. Skeletons of Queen Anne's lace. Established trees.	210	

35	Gravel	Greyish white loam.	Well grazed. Sparse grasses. No new growth. Leaf litter from established trees. Odd galvanized burr.	90	
36	Gravel	Greyish white gravel.	Not grazed. Sparse grasses. Dense Patterson's curse + verbena + wild oats + capeweed. Skeletons of Queen Anne's Lace, fleabane and burrs.	30	2 cotton plants, both conventional varieties - slashed, no fruit. - slashed, 1 immature boll.
37	Bitumen	Greyish white gravelly loam.	Slashed. Moderately dense grasses. Minimal new growth. Lucerne growing and flowering. Skeletons of cobblers pegs.	310	
38	Bitumen	Reddish brown loam, stoney surface layer.	Slashed. Moderately dense grasses and lucerne. Lucerne growing and flowering. Taller grasses outside slashing zone.	360	
39	Bitumen	Reddish brown loam, stoney surface layer.	Slashed. Sparse grasses. No new growth. Taller grasses past slashing zone. No woody stemmed vegetation.	250	
40	Bitumen	Reddish brown loam, stoney surface layer.	Slashed. Moderately dense grasses. Some new growth. Taller grasses past slashing zone. No woody stemmed vegetation.	270	

41	Bitumen	Brownish black loam.	Mowed. Moderately dense grasses. Minimal new growth. No other vegetation.	0	34 cotton plants, of the 27 gene tested – 21 Roundup Ready, 2 Roundup Ready + Ingard, 4 of conventional varieties. - 10 x no fruit - 26 squares, 4 flowers, 5 immature bolls, 25 mature bolls - 18 squares - 12 squares, 2 flowers, 8 immature bolls, 2 mature bolls - 10 squares, 6 immature bolls - 10 squares, 8 immature bolls, 1 mature boll - 9 squares, 1 flower, 7 immature bolls - 8 squares, 2 immature bolls - 5 squares, 2 immature bolls, 1 mature boll - 4 squares, 11 immature bolls - 4 squares, 2 immature bolls, 15 mature bolls - 3 squares, 1 flower, 2 immature bolls, 1 mature boll - 2 squares, 11 immature bolls - 2 squares, 4 immature bolls, 4 mature bolls - 2 squares, 4 immature bolls, 6 mature bolls - 1 square, 3 immature bolls, 10 mature bolls - 10 immature bolls, 1 mature boll - 3 immature bolls - 2 x 2 immature bolls - 2 immature bolls, 1 mature boll - 2 x 1 immature boll - 1 immature boll, 2 mature bolls
42	Bitumen	Reddish brown sandy loam.	Not grazed. Moderately dense grasses. Minimal new growth. Odd skeletons of burrs, no other woody stemmed vegetation.	60	
43	Gravel	Red sandy loam with very sandy surface layer.	Not grazed. Sparse grasses. No new growth. Skeletons of thistles. Leaf litter from tree line 10m from road.	10	

44	Gravel	Red sandy loam with very sandy surface layer.	Not grazed. Sparse grasses. No new growth. Skeletons of burrs. Established trees 10m from road.	40	
45	Gravel	Black self-mulching clay, sandy surface layer near road edge.	Not grazed. Moderately dense grasses - short. Minimal regrowth. Skeletons of thistles and burrs. No other woody stemmed vegetation.	380	
46	Gravel	Black self-mulching clay, gravelly surface layer.	Well grazed. Moderately dense grasses. Minimal new growth. Odd roly poly and thorny bush.	20	
47	Gravel	Black self-mulching clay, gravelly surface layer, sandy/dusty near road edge.	Well grazed. Moderately dense grasses. Some regrowth. Odd sedge in table drain. Odd skeleton of burrs. No other woody stemmed vegetation.	160	2 sorghum.
48	Gravel	Black self-mulching clay.	Well grazed. Dense grasses. Minimal new growth. Odd skeleton of burr and fleabane. No other woody stemmed vegetation.	280	
49	Gravel	Black self-mulching clay, sandy/dusty surface layer near road edge.	Well grazed. Dense grasses. Minimal regrowth in table drain. Wall of thistle skeletons 1.5m tall + thorny bushes 5-7m from road edge.	540	
50	Bitumen	Black self-mulching clay, newly constructed road.	No vegetation.	40	
51	Bitumen	Brownish black clay loam with stoney surface.	Grazed. Moderately sparse grasses. Minimal regrowth. No other vegetation.	70	
52	Bitumen	Black self-mulching clay, gravelly surface layer.	Slashed grasses. Moderately dense near tar edge becoming very dense into table drain. Regrowing. Lucerne and Johnson's grass growing and flowering near road edge.	140	24 sunflowers. 5 sorghum.

53	Bitumen	Black self-mulching clay, gravelly surface layer.	Slashed grasses. Moderately dense. Some new growth. In table drain grasses 70cm+ and flowering. Dense Patterson's curse established along batter. Lucerne growing and flowering near road edge.	160	175 sunflowers. 1 sorghum.
54	Bitumen	Black self-mulching clay.	Slashed grasses. Moderately dense. No new growth. Lucerne growing and flowering. Skeletons of cobbler's pegs. Dense Johnson's grass in table drain – flowered and desiccated.	40	22 sunflowers.
55	Bitumen	Black self-mulching clay, gravelly surface layer, stoney.	Slashed grasses. Moderately dense. Tall grasses past slashing zone. No new growth. Odd lucerne plant – growing well.	50	
56	Bitumen	Light brown sandy loam, stoney surface.	Well grazed. Very sparse grasses. No new growth. Established trees 7-10m from road. No other vegetation.	90	
57	Bitumen	Yellow sandy loam, very sandy near road edge.	Grazed. Moderately sparse grasses. No new growth. Yellow button flower plant.	10	
58	Gravel	Greyish white coarse stoney gravel.	Not grazed. Very sparse grasses. No new growth. Established trees 7-10m from road.	30	
59	Gravel	Greyish white loam, stoney surface.	Not grazed. Very sparse grasses. No new growth. Established trees 7-10m from road. Prickly pear growing in culvert.	0	
60	Gravel	Black self-mulching clay, gravelly surface layer.	Lightly grazed. Moderately dense grasses. Couch continuing to grow in table drain. No woody stemmed vegetation.	50	
61	Gravel	Black self-mulching clay, gravelly surface layer.	Grazed some time ago. Moderately dense grasses – flowering at 10cm. No new growth. No woody stemmed vegetation.	20	
62	Gravel	Brownish black clay loam, stoney sandy surface layer.	Well grazed. Dense grasses. Some regrowth in the base of the table drain. Patterson's curse and rhynchosia establishing.	50	

63	Gravel	Black self-mulching clay, gravelly surface layer.	Very well grazed. Dense grasses. Some regrowth in the base of the table drain. Odd roly poly and thorny bush. Skeletons of burrs and sedges.	230	
64	Gravel	Black self-mulching clay, gravelly surface layer.	Well grazed. Dense grasses. Minimal new growth. Odd thorny bush, no other woody stemmed vegetation.	210	
65	Gravel	Black self-mulching clay, gravelly surface layer.	Well grazed. Dense grasses. Couch and Burr medic with new growth in the table drain. Skeletons of burrs and fleabane.	20	31 sorghum.
66	Bitumen	Black self-mulching clay.	Very well grazed. Moderately dense grasses. Table drain full of sedge. Minimal new growth. Skeletons of thistles along N side.	3200	
67	Bitumen	Black self-mulching clay.	Very well grazed – more than once. Moderately dense grasses. Roly Polys 10m+ from tar – dried down. No new growth. No woody stemmed vegetation.	740	
68	Bitumen	Black self-mulching clay, red sandy loam surface layer.	Very well grazed. Moderately dense grasses. No new growth. Ground covered in burrs. No woody stemmed vegetation.	380	
69	Gravel	Red clay loam, sandy surface layer – particularly near road edge.	Very well grazed. Moderately dense grasses. Burr Medic establishing in the base of the table drain. Cat-head burrs on the ground. No woody stemmed vegetation.	60	
70	Gravel	Red sandy loam, very sandy surface.	Very well grazed. Moderately dense grasses. Capeweed and Patterson's curse establishing. No woody stemmed vegetation.	180	