# DRYLAND FARMING SYSTEMS

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## Introduction

Dryland cotton production is an important component of cropping systems in the northern grain belt. It has been a difficult crop for many growers to integrate into their existing cropping systems because of its high soil water usage, narrow planting window, long growth period, and high pesticide inputs, to name just a few factors. A number of cotton industry research projects have commenced in the last 5 years to look at different aspects of dryland cotton cropping systems. This work, in conjunction with the practical experiences of many growers who have been developing conservation farming systems over the last decade is providing some clear guidelines towards the development of sustainable cropping systems and best management practice for this section of the industry.

## Efficiency in Accumulation and Management of Soil Water

### Determination of Stored Soil Water

Soil water scarcity is the greatest management limitation encountered in the production of dryland cotton of an adequate yield and of a satisfactory quality. Planting a crop on a full soil water profile partly addresses this constraint. A number of techniques have been developed to assess the quantity of stored soil water approaching planting time (Freebairn et al, 1998) These include:

- soil coring to determine the volumetric moisture % of sections of the soil profile
- push probing with a steel rod to provide a physical indication of the depth of wet soil
- use of HOWWET computer program which calculates soil water from fallow rainfall and evaporation records

A combination of all three techniques will provide the best estimate of the quantity of soil water in the profile.

A thorough understanding of the properties of the particular soil must be combined with this information. The Agricultural Production Systems Research Unit (APSRU) based at DPI, Toowoomba has been gathering information on water holding characteristics of Darling Downs dryland cotton producing soils over the last five years. The study shows that bulk density values range from 1.1 to 1.6 at 60cm depth (Dalgleish, pers.comm) Root exploration and water extraction is reduced in denser subsoils. As well, some of the grey/brown clay soils which originally carried Brigalow vegetation can contain moderate to high levels of salt from about 90cm depth, another factor which lessens the actual quantity of crop available soil water. Across the major cotton growing soils there is a range of values for maximum potential quantity of stored soil water. Growers have generally recognised this, different planting configurations being one management practice used to cater for this range.

## Risk Assessment at Planting Time

CSIRO researchers at ACRI, in conjunction with APSRU, have developed a cropping systems model which incorporates the OZCOT cotton model and APSIM simulation (Bange,1998) This model allows growers to look at a range of summer crop planting options, taking into account not only stored soil water levels, but also soil N levels, projected returns of various crops, and climate forecasting via the current SOI phase . A grower with an incomplete soil water profile can better assess the risk of proceeding with planting dryland cotton for instance, as opposed to alternative summer crops at various planting dates.

## Capture of Fallow and In-crop Rainfall

Maximum efficiency in capture of fallow and in-crop rainfall in a dryland cropping situation is essential. The combination of timely weed control, minimum tillage and maximum stubble cover has been repeatedly shown to be the most efficient technique for capturing and accumulating rainfall as soil water. These principles have been applied by many growers to their fallows during the last decade. However, their extension into the cotton cropping phase has not occurred to the same extent, predominantly because of weed control and machinery constraints.

A cotton crop occupies a field for a long period of time during the wettest part of the year. Most in-crop rain occurs as small falls of 10-20mm and from a bare dry soil surface in Southern Queensland midsummer, 8 mm/day is lost to evaporation initially (Hammer, pers.comm). On average, one or two short duration, high intensity rainfall events, often of 20-40mm total, occur each summer. For both situations, maximum rainfall capture and restoration of soil water comes with stubble cover on the soil, the more the better.

Various mechanical techniques such as pitting or diking have been used over time to trap runoff from high intensity storm rainfall on bare fields. Yield improvement has seldom been reported, generally because of high evaporation losses from these compacted pits. Inter-row cultivation still remains the principal in-crop weed control technique in dryland cotton. It is also credited with reducing soil water loss by closing cracks. This very process however reduces the opportunity for rapid infiltration of high intensity rainfall events. The destruction of any stubble present during the operation also aggravates the situation.

The combined use of tramlining, shielded sprayers and herbicide tolerant cotton has the potential to allow more timely weed control, reduce inter row cultivation, and allow retention of standing stubble well into the life of the cotton crop. The end result of this will be improved efficiency in storage of in-crop rainfall.

### Variation in Row Configuration

Growing cotton in skip row configuration as opposed to 1.0m row solid plant increases the size of the soil water reservoir available to the crop, thereby extending the time period before the onset of stress by 5-10 days. While double skip configuration in particular has a slightly lower top yield potential, it can reduce major growing costs such as herbicides, insecticides, defoliant and picking . While skip row planting is standard practice on soils with lower levels of crop available water, it also has a role on soils of high water holding capacity, in those years when planting soil water is below optimum and/or seasonal indicators point to a drier than average season.

### Maximising Whole Farm Rainfall/ Runoff Capture

Alternating strips of crop and fallow of varying soil water status laid out on the true contour on floodplains provides an effective mechanism for harvesting both local and upstream runoff. At the simplest level, with heavy rainfall early in the cotton growing season, cotton strips will shed runoff into adjacent maturing cereal crop strips with a dry profile. Later in the season, as the cotton crop matures and the cereal fallow fills, the reverse situation occurs. Some degree of land levelling is often necessary to ensure flows do not concentrate in old depressions or gullylines.

## Successful Plant Establishment

### Improving Marginal Planting Conditions

The planting window for dryland cotton is relatively short, being of 6-8 weeks duration for most growing areas. In many seasons, only one opportunity, of limited duration, occurs within this window. Deep furrow planting, which involves removal of a band of dry soil 5-10cm deep is a proven technique for extending the planting window with many cereal crops. It has less application in cotton, because of the cotton plant's extreme sensitivity to depth of soil cover and press-wheel pressure, the need for excellent seed-soil contact and the likelihood of herbicide damage should heavy rain occur soon after planting. An alternative used by some growers has been a furrowing operation late fallow, as a means of creating a wetter zone in the furrow suitable for planting, should a short sharp storm produce runoff.

Seed soaking to reduce the quantity of soil water necessary to initiate germination, and moisture injection into the furrow during the planting operation are two techniques used on occasions to enhance establishment. A major shortcoming with these activities is that they can only be carried out during planting, causing a loss in planting efficiency, losing on one hand what is gained on the other.

### Maximising Planting Efficiency

Rapid planting under optimum seedbed conditions is the ideal to strive for. Extremely high efficiency can be achieved with wide low draft equipment eg a 16m seeding only machine planting 4 pairs of rows double skip, This is achievable in tramlined fields where all herbicide and fertilizer operations can be accurately carried out pre-planting, without fear of wheeltracks creating compaction in planting zones. Good depth control is an obvious requirement of such a machine.

### Controlled Traffic and Tramlining

Controlled traffic farming aims to restrict machinery movement to permanent wheel tracks set out in a paddock. In this way, soil compaction can be restricted to a small percentage of the field, taken up by machinery tramlines, and the remainder of the field can regain soil structure and productivity (Walsh et al, 1998) Dryland cotton lends itself to a version of the concept. The picker is the limiting factor in total adoption, as it frequently is only covering a field area 4-6m wide. However, it is possible for more permanent wheel-tracks to be retained through a number of rotation crop cycles.

The greatest benefit from CT in row cropping comes at planting as it can greatly reduce machinery draft, allow pre-plant spraying and planting operations to be carried out accurately around the clock, and will ensure that no wheeltracks or compacted zones are positioned in the planting line.

### Strip Tillage

The concept of strip tillage is to cultivate and manage narrow strips or zones in preparation for planting while retaining the majority of the field as no-till standing stubble. Incorporating herbicide pre-plant improves the likelihood of obtaining satisfactory weed control in the row, because herbicides applied at planting are not activated until rain occurs, which can at times be weeks away. Nitrogen and starter fertilizer can also be applied in these zones pre-plant, saving valuable time during planting.

Limitations with the technique include a narrow surface soil moisture working range to prevent formation of large soil aggregates or soil smearing, and the necessity to have controlled traffic layout throughout the fallow to eliminate any surface compaction..

## Controlling Erosion and Runoff

### Erosion and Dryland Cotton

Dryland cotton is grown on two major landscape forms in Australia. The biggest proportion is grown on alluvial soils in floodplain areas, with some also being grown on long low sloping ridges, in brigalow and basalt land systems. Both landscapes are subject to erosion but of a different form, and hence requiring a different approach to its control. Soil erosion has an effect through:

- On site loss of soil productivity.
- Off site movement of sediment, associated nutrients and pesticides
- Siltation of on- farm and downstream drainage systems

### Preventing Soil Detachment and Movement

The first step in controlling soil detachment is to minimise runoff, by maximising the chance of rainfall entering the soil. This can be achieved by either protecting the soil surface with crop stubble, and/or using a growing crop, which maintains a soil water deficit as well as surface protection.

Only low levels of stubble remain after a cotton crop, and as a growing crop, especially in skip row, it does not provide reasonable ground cover until well into the season. Table 1 shows the effectiveness of cover and various stubble types in reducing runoff and soil loss from a furrowed up field, after a high intensity rainfall simulator storm of 65mm. The soil loss has been 40 times greater in the bare treatment than in that with anchored wheat stubble.

Table 1- Runoff and soil loss from furrows in a cotton field, produced by a rainfall simulator storm (Source: Silburn et al, 1998)

| Furrow treatment | Cover (%) | Runoff (mm) | Soil loss (t/ha) |
|---|---|---|---|
| Bare | <5 | 29.4 | 4.6 |
| Loose cotton trash | 35 | 15.8 | 1.1 |
| Anchored wheat stubble | 50-60 | 5.4 | 0.1 |

On sloping land, contour cultivation and contour banks have been the traditional method of controlling sediment movement. Quite severe erosion still occurs with this system when runoff concentrates in rills. However recent work conducted in Central Queensland indicates that a much more effective system can be implemented (Rodhe et al, 1998). It uses a controlled traffic up and down slope bed and furrow layout which aims to prevent cross flows and runoff concentration, supported by intensive stubble management. Workover contour banks are still a necessary component of the system to pick up and drain the furrows at regular intervals down the slope.

Erosion control on the floodplains relies on spreading floodflow by a combination of measures including stripcropping, eliminating fencelines and levee banks, and lowering road crown heights. The key to the system is to maintain floodflow at a non-erosive velocity by keeping it shallow, and utilising the hydraulic roughness associated with standing crop and stubble in strips 50-120m wide.

## Managing Runoff

When considering pesticides which can be strongly adsorbed on soil particles, controlling sediment movement is effective in reducing pesticide movement off farm. However, a number of pesticides are highly soluble or poorly sorbed on soil, moving predominantly in the runoff water, rather than on associated sediment (Silburn et al, 1998). On many dryland cotton farms, especially on the floodplains, little can be done to prevent or control runoff leaving the farm. Once soil water profiles are full, stripcropping cannot prevent runoff. Any attempt to concentrate runoff into storages using levee banks on these farms would magnify the erosion problems. A different control strategy is required. There is a direct relationship between concentration of pesticide in runoff and concentration in soil at time of runoff. A wet soil with a forecast of rain is not the time to apply a highly soluble product. Use of banding, ground rigs and skip row configurations all result in a lower use rate of product per hectare. Accuracy in application assists as many pesticides dissipate more rapidly on the cotton plant than on the soil. (Silburn et al, 1998)

While control of runoff from each individual dryland farm on the floodplains is impractical, the increasing number of on-farm storages being constructed in locations where flows are more concentrated is providing some control on a wider catchment basis. This approach is most effective early season, because this time of high probability of runoff with dryland cotton soil moisture profiles full, coincides with empty storages.

## Other Agronomic Considerations

### Long Fallow Disorder

Long fallow disorder, the failure of crops to thrive even with adequate soil moisture is a common problem of dryland cotton. The disorderis caused by a rundown in the level of a root invading fungus Vascicular Arbuscular Mycorrhiza (VAM) at planting time. The fungus plays an important role in making phosphorus and zinc available to the young cotton plant.

Figure 1- VAM Influence on Cotton Plant Growth

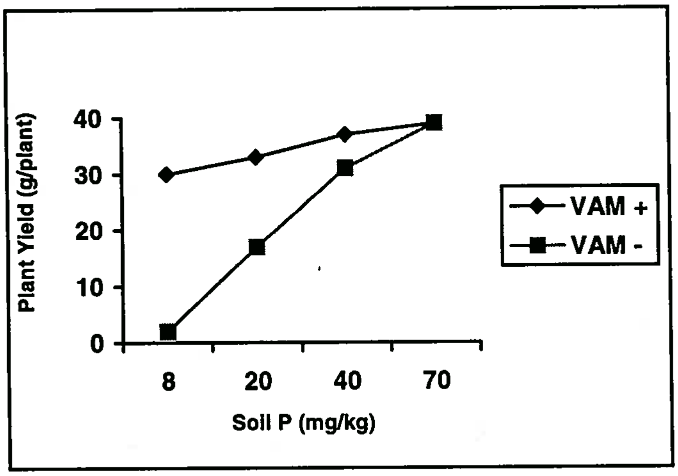


Figure 1 illustrates why cotton is one of the crop species considered very highly dependent on VAM for its growth. The dry weight of cotton plants grown in +VAM soil was 30 g/plant at a soil P level of 8mg/kg . To achieve the same plant size in –VAM soil, the soil P level required was 36 mg/kg. VAM was worth 28mg of P per kg of soil. Addition of extra fertilizer does not always make up for lack of VAM . (Thompson et al, 1998).

With a cultivated long bare fallow after cotton, VAM can be severely depleted because the soil is basically sterilised for 18 months. Cultivation, especially early in a fallow such as that required for pupae control destroys VAM hyphae, as well as closing down soil cracks. This highlights the importance of making every attempt to establish a crop immediately after dryland cotton. Cereal planters modified to carry out aggressive tillage as part of the planting operation is one way of meeting both requirements. Planting chickpeas in 1.0m rows central between cotton rows and interrow cultivating for pupae control is another.

### Nitrogen Input

A trend to no-till in dryland cotton farming systems creates some management problems for nitrogen input. Adoption of controlled traffic allows for N placement in rows prior to planting. Sidedressing N post plant is another alternative, but uptake can be low and delayed in a dry growing season. The addition of additional N to a prior crop eg double cropped winter cereal, is another alternative to build up N reserves for the cotton crop.

### Disease and Weed Control

As back to back cotton is not a common feature of dryland farming systems, the opportunity for disease to develop does not occur because there is little carryover of cotton stubble and resting bodies Canopy conditions are generally much more open, reducing the likelihood of boll rots and foliar disease developing.

Weed control is absolutely critical in dryland cotton, preservation of soil water being the highest priority in the production of the crop. Skip row can aggravate weed problems because of lack of shading and reduced competition. Application of residual herbicides pre-plant requires special management practices in a no-till field. The increasing use of shielded sprayers, and the introduction of herbicide tolerant cotton will greatly assist with weed control in cotton.

## Rotational Choices with Dryland Cotton

The introduction of other crops into a dryland cotton farming system provides a number of potential benefits including:

- Improved fallow and crop water use efficiency
- Reduction in long fallow disorder
- Source of crop stubbles for improving infiltration, reducing sediment movement
- Greater biodiversity in soil fauna, insects
- Greater spread in cash flow

Sorghum and wheat/barley appear to be the major crops with a role in dryland cotton farming systems. Sorghum is important because of its very wide planting window, its ease of establishment, rapid growth, durability of its standing stubble which an important asset in areas subject to flood flow, and being able to terminate its growth at physiological maturity with herbicide. Wheat/barley are important in providing cover on cotton ground after it has been cultivated for pupae control, to dry the soil out to alleviate soil compaction and to provide a good break to address summer weed problems. Legumes create a dilemma because of their lack of stubble for the fallow and subsequent cotton crop. Chickpeas might have a limited role.

Table 2 – Crop production - CRC Warra dryland cotton farming system trial 1993-1998

| Season | Treatment 1 | Treatment 2 | Treatment 3 | Treatment 4 | Treatment 5 |
|---|---|---|---|---|---|
| Summer 1992/93 | Cotton | Cotton | Cotton | Cotton | Cotton |
| Winter 1993 | | | Barley 0.22 t/ha | Barley 0.22 t/ha | |
| Summer 1993/94 | | Sorghum 2.1 t/ha | | | |
| Winter 1994 | | | | Chickpeas 0.66 t/ha | Wheat 1.43 t/ha |
| Summer 1994/95 | Cotton 3.73 b/ha | Cotton 3.05 b/ha | Cotton 4.05 b/ha | | |
| Winter 1995 | | | Wheat 0.42 t/ha | | |
| Summer 1995/96 | | Sorghum 5.77 t/ha | | Cotton 4.45 b/ha | Cotton 4.50 b/ha |
| Winter 1996 | | | | Wheat 2.70 t/ha | Wheat 2.70 t/ha |
| Summer 1996/97 | Cotton 3.35 b/ha | Cotton 3.21 b/ha | Cotton 3.80 b/ha | | |
| Winter 1997 | | | Wheat 3.05 t/ha | Chickpeas 2.45 t/ha | |
| Summer 1997/98 | | Sorghum 3.05 t/ha | | | Cotton 2.70 b/ha |

Table 2 presents the crop production figures to date from the CRC dryland farming system trial at Warra. It clearly indicates that the inclusion of cereal crops in rotation with cotton leads to enhanced crop productivity, with little reduction in overall cotton production . As at June 1997, gross margin was $1818/ha for treatment 1, $2472 for treatment 2 and $2260/ha for treatment 3. The other two treatments could not be compared at that stage, having produced only one cotton crop in the trial.

On soils with higher water holding capacity, and where stripcropping is being used, adoption of a rotation system similar to the one outlined below across a farm ensures that ground cover is high and the soil is dry in some strips at any time of the year, to cater for runoff or flood flow. It allows for 43% of the farm to be under cotton in any one year, with a range of fallow lengths. The need to use risk management analysis for planting options becomes of much greater importance in intensive cropping systems such as this.

| | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** | **Year 6** | **Year 7** | **Year 8** |
|---|---|---|---|---|---|---|---|---|
| **Planting** | **Oct** | **Dec** | | **Oct** | **Oct** | **Oct** | **May** | |
| **Crop** | Cotton | Sorghum | - | Cotton | Sorghum | Cotton | D/C Wheat | As for Year 1 |

An alternative rotational system is given below for lower water holding dryland cotton soils.

| | Year 1 | Year 2 | Year 3 | Year 4 |
|---|---|---|---|---|
| **Planting time** | **Oct** | **May** | **May** | **Oct** |
| **Crop** | Cotton | D/C wheat or D/C chickpeas | Wheat | Cotton |

## Conclusions

Significant progress has been made in the development of sustainable farming systems for dryland cotton in the past few years. Provision of ground cover is the key component of these systems. Because cotton itself is a very poor provider of stubble, the inclusion of cereal crops in rotation with dryland cotton is important for this and other agronomic considerations. Developments in areas such as controlled traffic, risk management analysis and climate forecasting ,accuracy in pesticide application, and herbicide tolerant cotton are all assisting in progress towards profitable yet stable farming systems.

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