MANAGEMENT GUIDELINES FOR GROWING HIGH YIELDING COTTON CROPS

COTTON SEED DISTRIBUTORS
INTRODUCTION

The name of the game these days is to create the most efficient cotton crop that converts the resources available into a high yielding and good quality product. There is no doubt that, over time, the costs associated with growing cotton have risen, therefore placing pressure back on growers to always be chasing higher yields.

Yield itself is determined by two distinct factors, boll numbers and boll weight. In this booklet we will address some of the factors that are conducive to achieving a high yield and also some that are detrimental.

This management booklet will be broken up into eight sections that will allow growers to focus on the stage their crop is up to.

1. Establishing the crop
   1.1. Selecting the right variety
   1.2. Plant population and row spacing
   1.3. Temperature effects
   1.4. Planter set-up
   1.5. Seed quality and seed treatments
   1.6. Soil conditions
   1.7. Stubble management

2. Nutrition
   1.1. Nutrients requirements
   1.2. Nutritional analysis

3. Irrigation
   1.1. Water required
   1.2. Water stress

4. Fruit retention
   1.1. Boll number and boll weight relationship
   1.2. Impacts on retention

5. Weed and volunteer cotton control
   1.1. Cotton volunteers
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6. Plant growth regulation
   1.1. Balanced crop growth
   1.2. Varietal difference

7. The impact of plant stress on yield and fibre quality
   1.1. Waterlogging
   1.2. Heat stress

8. Defoliation and picking
   1.1. Knowing when to defoliate
   1.2. Timing of picking
1. ESTABLISHING THE CROP

1.1. Selecting the right variety

Plant breeding and crop management improvements are both contributing to yield gains of 1.0 bale/hectare/decade for Australian cotton growers. Most of this improvement has come from germplasm at 48%. The rest is made up of 24% from use of improved crop/field management practices (eg. irrigation strategy, precision farming) and 28% from the interaction of germplasm and management (eg. varietal disease tolerance).

Selecting a variety that has the right regional fit is a very important decision. Knowing what you require for your soil type and climate allows you to select a variety for your circumstance.

The concern with selecting the wrong variety is that it can impact on yield and overall gross return as seen in Figure 2.

THE FOLLOWING LIST SHOULD BE CONSIDERED BEFORE SELECTING A VARIETY

- What season conditions (short or long season) exists where I farm?
- What are the soil conditions like and what level of soil borne disease exists (Verticillium and Fusarium wilt)?
- Do I have enough water to provide a full allocation to this crop (semi-irrigated, dryland or full irrigation)?

By answering these questions you will come up with the varietal requirements for your circumstances. Your local E&D Agronomist can assist you in selecting the variety of choice. Contact them or visit www.csd.net.au.
### 1.2. Plant population and row spacing

A successful planting means attaining the desired plant stand without gaps and double-ups. Evenness in the stand is very important. We know that an even stand, regardless of the population as seen in Figure 3, generally results in no significant yield difference. This can’t be said for populations that have gaps through them.

Populations that have skips or gaps, with greater than two 50 cm gaps in five metres can have reduced yield potential, as plants struggle to compensate for these gaps. The same can be said for double-ups with two seeds being planted on top of each other. Both seedlings compete against each other for resources and usually neither plant succeeds in reaching full potential.

**Figure 2:** Varietal yield difference and its impact on gross return.

**Figure 3:** Yield comparison of different plant populations. CSD plant population trials (results of 20 trials over 6 regions and 10 years).
When making the planting rate decision, take into considerations what soil, climate and variety you have. Plant to achieve an even plant stand remembering that by planting at a rate slightly higher than normal, there is no yield loss penalty, and this may reduce the probability of any gaps in your plant stand.

Using the correct row spacing for irrigated cotton is important, but there has not been a lot of research to fine tune recommendations. Generally most irrigated cotton is grown on 100 cm (40 inch) row spacing. In southern growing areas row spacing is often narrowed down to 91 cm (36 inch) and even to 84 cm (33 inch). These row spacings have been inherited from corn and vegetable programs and more research is required.

Wider row spacing’s such as 1.5 m (60 inch), 2 m (80 inch) and double skip (2 rows in 2 rows out) are often used in situations where water is limited. The aim of the wider row spacing is to maximize the water use efficiency of the crop. Generally the water use efficiency of wider row spacing crops is better than that of solid 1 m row spacing and hence if you know how much water you have for the season, appropriate wider row spacing may allow you to produce more bales than planting a smaller acreage of solid plant irrigated cotton. This is assuming that water is more limiting than available irrigatable land. For further information on row spacing please contact your local E&D agronomist or visit www.csd.net.au and look up ‘Getting the most out of skip row irrigation configurations’.

1.3. Temperature affects on establishment

Suitable temperature has a major impact on cotton establishment. Cotton is a temperature sensitive crop and the way the crop deals with the extremes of temperature is by shutting down or slowing physiological processes in the plant. An example of this is when photosynthesis slows when extreme temperatures exist. Temperature experienced post planting will have an impact on the time taken for the plant to emerge.

The slower the plant grows, the greater the chance of seedling death occurring through disease and insect damage. Figure 4 shows the critical times of an early seedling’s life in terms of sensitivity to temperature.

Figure 4: Cotton sensitivity to cold temperatures during germination. National Cotton Council USA, Hake, McCarty, Hopper, Jividen, 1990.
It is very important to monitor soil and air temperatures to find the appropriate window to plant the crop. The old rule still holds true in that planting shouldn’t commence until soil temperatures reach 14°C at 10 cm at 9am (AEST). In some of the southern growing regions, it can be difficult to reach these temperatures in early October and therefore a forecast for rising air temperature and hence soil temperature will allow growers to start planting.

In Figure 5, we see a commercial situation from 2012 involving two different planting dates. The second is actually the replant of the first planting. For the first planting, soil temperature was ok on the planting day but the forecast was poor and soil and air temperatures dropped significantly over the next few days. The crop took 15 days to start to emerge, with a very patchy plant stand. The second plant or replant occurred when soil temperature was similar to the first, but temperature forecasts were for rising air temperature. This time the crop established in seven days. The calendar day of planting the crop in this example is not important it is its timing in relation to air temperature patterns.
1.4. Planter setup

Incorrect planter setup and calibration can have a major impact at planting time on seedling establishment. The main aim with planter setup is to have uniformity across the planter. If there are mechanical or electrical issues replace the parts to create this. Calibrate the planter by checking sensors, monitors, vacuum plates, the seed delivery tube and gauge and press wheels. Have spare parts available and quick access to parts from machinery dealerships if required. Run all staff through a planter setup and calibration meeting, pointing out the things that can go wrong at planting. The following list is some of the problems that can occur with planters while sowing:

- Blockages by mud or by stubble in some of the units.
- Dust on the seed sensor.
- Loss of vacuum through the vacuum hose coming loose.
- Foreign particles in the planter box.
- Seized bearings on planter discs.
- Poor down force setup.
- Wrong or varying planter depth hole settings.

One of the main problems that occur at planting is related to operator error. Planter ground speed can have a significant effect on where seeds are placed in the seed bed. Planter bounce causes seed to be lodged at different depths, with poorer stands, double ups and skips being the end result. Figure 6 shows by decreasing planter speed, plant establishment increases. This was seen at three out of four sites in Queensland where measurements were made during planting last season.

<table>
<thead>
<tr>
<th>Location</th>
<th>Speed (kph)</th>
<th>Seed drop (seeds/m)</th>
<th>Stand (plant/m)</th>
<th>Establishment %</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theodore Irrigated</td>
<td>12</td>
<td>13</td>
<td>10.2</td>
<td>82</td>
<td>• Back to back cotton</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>13</td>
<td>11.1</td>
<td>92</td>
<td>• Pre-irrigated</td>
</tr>
<tr>
<td>Emerald Irrigated</td>
<td>9</td>
<td>11.2</td>
<td>8.7</td>
<td>78</td>
<td>• Back to back cotton</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>11.2</td>
<td>8.7</td>
<td>78</td>
<td>• Watered up early Oct</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Soil temp &gt; 20°C</td>
</tr>
<tr>
<td>Darling Downs Dryland</td>
<td>12</td>
<td>9.8</td>
<td>4.2</td>
<td>43</td>
<td>• Short fallow from millet</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>9.8</td>
<td>5.8</td>
<td>59</td>
<td>• Planted 6cm into moisture</td>
</tr>
<tr>
<td>Darling Downs Dryland</td>
<td>9.5</td>
<td>15.2</td>
<td>10.2</td>
<td>67</td>
<td>• Short fallow from sorghum</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
<td>15.2</td>
<td>11.1</td>
<td>73</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6:** Relationship between planter speed and plant establishment. *CSD planter speed analysis affect on establishment 2012-13, John Marshall E&D agronomist.*
1.5. Seed quality and seed treatments

CSD make every effort to supply high quality seed to the industry. For the past few years CSD has concentrated much of their effort on producing management guidelines for dealing with low density seed, a characteristic of new, high yielding varieties. Much of this document covers information in relation to varieties such as Sicot 74BRF and Sicot 75BRF.

It must be remembered that there are differences between SVI (Seed Vigour Index) and seedling vigour. While SVI is an indicative tool used by CSD to evaluate the germination characteristics of seed being produced, it should not be confused with seedling vigour which is the rate of seedling growth in the field. Temperature, moisture, insects and disease all impact on seedling vigour.

CSD provides a Statement of Seed Analysis which has data that may help when deciding which variety or seed lot should be planted first. Warm temperature germination %, SVI, seed size and cool temperature germination % is available from the CSD website by going through the following procedure.

- Enter the www.csd.net.au.
- Select Agronomy Tools.
- Select Statement of Seed Analysis.
- Put in Variety Name and Auslot Number supplied on the bottom of the cotton seed bag.
- A table of results will appear that can be printed out for your use.

Figure 7 illustrates what is contained in the Statement of Seed Analysis result.

<table>
<thead>
<tr>
<th>Statement of Seed Analysis</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td><strong>Purity</strong></td>
</tr>
<tr>
<td><strong>Species:</strong> Gossypium Hirsutum</td>
<td>Pure Seed: 99.99%</td>
</tr>
<tr>
<td><strong>Common Name:</strong> Cotton</td>
<td>Other Seed: 0.0%</td>
</tr>
<tr>
<td><strong>Variety:</strong> Sicot 74BRF</td>
<td>Inert Matter: 0.01%</td>
</tr>
<tr>
<td><strong>Auslot Number:</strong> N/12/14/034</td>
<td>Mechanical Damage: 3%</td>
</tr>
</tbody>
</table>
| **Treatment:** D2C | **Testing Date:** 2013-07-30 | **
Seedling disease has the greatest impact on seedling survival. Generally the more southern areas have the greatest level of seedling mortality. Much of this is caused by seedling disease as seen in Figure 8. Every year CSD conduct a range of seed treatment trials to test new seed treatments (both fungicides and insecticides) against what is commercially available. Any new products that show longterm effectiveness in seedling disease control in most cases will become available as a seed treatment option. A good example of this is the recently introduced Dynasty Complete product. Dr Steve Allen from CSD, working in conjunction with Syngenta showed this product provided superior protection against numerous seedling diseases. In keeping with CSD charter to supply the best products to the market place, it was commercialized in 2011.

**THE KEYS TO UNDERSTANDING WHAT SEED TREATMENT TO USE IS TO KNOW WHAT EXISTS IN THE FIELD THAT IS BEING PLANTED**

- Check field history for disease and insects.
- Monitor the field for disease and insect incidence.
- Treat insects on a field to field basis.
- Know the activity of the product. If it takes 14 days for the crop to establish, the active level of some products will already have halved.

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**Figure 8**: Seedling mortality by valley 2008 to 2013. DPI, QDPI and CSD long term disease surveys 2008-2013.
1.6. Soil conditions

The aim of soil renovation is to have soil well prepared in advance, so that it’s possible to achieve good seed soil contact at planting. There are number of factors that will impact on seedling establishment if soil conditions/tilth are poor.

- Cloddy soils that have been recently renovated can cause poor seed soil contact and variation in seed depth. If cloddy conditions exist close to planting, an extra pass may be required to break down clods, pre-irrigation and rolling can help.

- Crusting soils typically cause issues with seedlings trying to push through a solid layer of soil. Use of liquid gypsum and a prickle bar may help. Also, running the planter shallow back over a field that has crusted before emergence has been beneficial on occasions.

- Bed slump can occur when watering up, allowing the seed to sink. This occurs frequently on highly sodic soils. Consider pre-irrigation and planting into moisture and use of a roller.

- Trash from previous crops can impact on planter effectiveness as a planter can get blocked by the trash or ride up over heavy cotton stalks remaining from the previous crop. Consider using trash wipers to clear a path in the planting row.

If any of the above issues exist, consider raising planting rates as they may impact on final plant stand.

At planting, be on the look out for the following:

- Slot compaction occurs when planting into (excess) moisture and can produce a compacted face on both sides of the seed slot. This affects moisture uptake by the seed and can reduce establishment.

- If press wheel pressure is too high, this also can cause compaction in moist soil and the resultant crust can impact on the seedling trying to push through. Pull up and check the planter in every field particularly when planting into moisture.

- The planting row should be covered with a thin layer of dry soil insulating and keeping the moisture around the seed, and slowing down the rate of drying of exposed wet soil faces. Issues arise when too much dry soil is swept into the seed slot, causing poor moisture uptake by the seed. Crusting can also occur following rain with a thick impenetrable layer above the seed.

The key is to check and re check planting conditions. If field conditions are not right, go to another field or stop!

1.7. Stubble Management

The benefits of having stubble in the zone of the emerging plants, such as moisture retention, less erosion, protection from windblasting etc. can all be out weighed if at planting, stubble causes significant reduction in the plant stand.

Too much stubble can affect water infiltration and subbing up and can impact on seed placement and depth. In fact stubble can be a perfect environment for diseases.

There are generally two types of stubble either wheat stubble after a fallow or cotton stubble in back to back fields. The amount of either is dependant on numerous scenarios. Large crops produce more stubble, little winter rainfall means less stubble breakdown and cultural practices such as pulling stalks or burning will influence how much stubble overwinters. Regardless of how much stubble is left, it is important at planting that hairpinning or planter unit bounce does not occur due to stubble in the planter row.

Trashwipers are commonly used to remove stubble from the tops of beds and will allow discs to plant into friable soil and not over or into solid stubble.
1.1. Nutrients requirements

Cotton is a crop that has a high demand for nutrients. To obtain high yields the nutrients must be available. Forward planning is critical as a crop that lacks nutrition at key stages of growth will never reach its full potential.

Cotton will use around 10-12 kg of nitrogen per bale, which effectively means a 12 bale/ha crop will NEED or remove around 150 units of N. The very high yields being experienced in recent years means that a lot more N is required for the plant physiological processes in these crops. Figure 9 shows the nutrient removal of macro and micro plant nutrients at various yield levels.

<table>
<thead>
<tr>
<th>Yield b/ha</th>
<th>N (Kg/ha)</th>
<th>P</th>
<th>K (g/ha)</th>
<th>S</th>
<th>Ca</th>
<th>Mg</th>
<th>Zn</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>125</td>
<td>24</td>
<td>37</td>
<td>10</td>
<td>6</td>
<td>14</td>
<td>110</td>
<td>164</td>
</tr>
<tr>
<td>12</td>
<td>155</td>
<td>28</td>
<td>44</td>
<td>12</td>
<td>7</td>
<td>17</td>
<td>129</td>
<td>191</td>
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<tr>
<td>16</td>
<td>216</td>
<td>37</td>
<td>59</td>
<td>17</td>
<td>9</td>
<td>23</td>
<td>166</td>
<td>244</td>
</tr>
<tr>
<td>18</td>
<td>245</td>
<td>42</td>
<td>67</td>
<td>19</td>
<td>10</td>
<td>26</td>
<td>185</td>
<td>270</td>
</tr>
</tbody>
</table>

Figure 9: Nutrient removal by cotton of the macro and micro plant nutrients. Rochester I and Constable G, 2006.

1.2. Nutrients analysis

Regular nutrient testing should occur so a pattern of crop nutrient use can be established. Testing of soils, petioles and leaf samples should occur throughout the season:

- **Soil Analysis** (forms the base for a nutritional program): Sample from May to August, 0-30 cm for all nutrients, 30-90 cm for nitrogen.

- **Petiole Analysis**: Best done ~ 600, 750, 900 day degrees after sowing. Three samples taken about 10 days apart to assess nitrate-N and potassium around flowering.

- **Leaf Analysis** (flowering and cut-out): Helps monitor all critical levels throughout the growing season.
Potassium is also a very important nutrient for cotton. With larger boll loads and higher yields, inevitability there are incidences of premature scenesense and early cut out. The demand for potassium comes late (see Figure 10) in the crop’s life but it is critical for the development of bolls and fibre quality.

Placement of fertilizer is very important as root burn can occur if placed to close too the root system. It is recommended that nitrogen be applied 10 cm to the side of the plant line (Incitec). Phosphorus and potassium can be placed under the row but far enough away not to cause root burn. In general, assess the time of year that fertilizer is being applied and what product is to be used. This will impact on where and how the fertilizer is placed.

High rates of nitrogen applied after New Year can delay crop maturity and cause defoliation problems, while high rates early has the potential to produce excessive vegetative growth.

Figure 10: Nitrogen and Potassium requirements throughout the season. *SL Tech Cotton Nutritional Guide 2012.*
3. Irrigation Requirements for High Yielding Crops

1.1. Water required

Along with adequate nutrition, correct irrigation frequency is one of the most important steps to achieving high yields. Any water stress through flowering can impact on the yield and fibre quality of the crop. Boll size and weight are reduced when moisture stress occurs. Figure 11 shows the impact of stress at early flowering and the impact on yield.

1.2. Water stress

Even with irrigation being one day late, the effect on yield is substantial. Since the introduction of Bollgard II®, this has become even more important as these crops have higher retentions and boll load can impact on plant growth. Any stress in an evolving heavy boll load will impact on yield. In Figure 12 we see the impact in a hot season of six versus five irrigations on a crop.

<table>
<thead>
<tr>
<th>Growth stage</th>
<th>Lint yield loss (kg/ha/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squaring</td>
<td>9</td>
</tr>
<tr>
<td>Peak Flowering</td>
<td>19</td>
</tr>
<tr>
<td>Late Flowering</td>
<td>16</td>
</tr>
<tr>
<td>Boll Maturation</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 11 (above): The effect of a one day water stress at various growth stages throughout the season. Milroy, Goyne and Larson (2002).

Figure 12 (below): The Impact on Yield of six irrigations versus five irrigations. CSD irrigation comparison trial Bourke 2013.

| Variety   | Sicot 74BRF
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>Irrigations (6)</td>
</tr>
<tr>
<td>Bolls/m</td>
<td>163</td>
</tr>
<tr>
<td>Bolls/plant</td>
<td>18.1</td>
</tr>
<tr>
<td>Retention 1-12</td>
<td>71%</td>
</tr>
<tr>
<td>Retention 1-4</td>
<td>63%</td>
</tr>
<tr>
<td>Retention 5-8</td>
<td>76%</td>
</tr>
<tr>
<td>Retention 9-12</td>
<td>74%</td>
</tr>
<tr>
<td>Boll weight (g lint/boll)</td>
<td>2.18</td>
</tr>
</tbody>
</table>

| Variety   | Sicot 74BRF
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>Irrigations (5)</td>
</tr>
<tr>
<td>Bolls/m</td>
<td>135.5</td>
</tr>
<tr>
<td>Bolls/plant</td>
<td>15.1</td>
</tr>
<tr>
<td>Retention 1-12</td>
<td>60%</td>
</tr>
<tr>
<td>Retention 1-4</td>
<td>63%</td>
</tr>
<tr>
<td>Retention 5-8</td>
<td>63%</td>
</tr>
<tr>
<td>Retention 9-12</td>
<td>54%</td>
</tr>
<tr>
<td>Boll weight (g lint/boll)</td>
<td>2.09</td>
</tr>
</tbody>
</table>
In this example both retention, boll numbers/m and boll weight were better with six irrigations. The effect of a hot year combined with only five irrigations impacted on the crop.

**OVERALL THE KEYS TO GOOD IRRIGATION PRACTICE INCLUDE**

- Check all pumps, bores and engines before the start of the season
- Check dams and channels for maintenance
- Fill dams for ease of irrigation and timing
- Use irrigation tools, c-probes, canopy sensors etc. to help schedule irrigation
- Order water well in advance and predict changes in weather patterns as early as possible
- Re-laser fields to create better slope and uniformity in fields
- Get irrigation water on and off fields as quick as possible to reduce waterlogging
4. FRUIT RETENTION REQUIREMENTS FOR HIGH YIELDING CROPS

1.1. Boll number and boll weight relationship

High yielding crops require good retention and good size bolls for them to yield well. Final yield is a combination of the interaction of these two factors:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>High yielding crops</th>
<th>Lower yielding crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boll number</td>
<td>150 +</td>
<td>130 -</td>
</tr>
<tr>
<td>Grams lint per boll</td>
<td>2.2 +</td>
<td>2.0 -</td>
</tr>
<tr>
<td>First position fruit retention (whole season)</td>
<td>65 +</td>
<td>50% -</td>
</tr>
<tr>
<td>Total nodes</td>
<td>24 to 25</td>
<td>23 -</td>
</tr>
<tr>
<td>Flowering period (days)</td>
<td>50 to 60</td>
<td>50 -</td>
</tr>
<tr>
<td>Flowering period (day degrees)</td>
<td>700 +</td>
<td>600 -</td>
</tr>
<tr>
<td>NAWF at first flower</td>
<td>8 to 9</td>
<td>6 -</td>
</tr>
<tr>
<td>Nutrition</td>
<td>Good</td>
<td>Late</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Good</td>
<td>Late</td>
</tr>
</tbody>
</table>

Using CSD’s long term data set, 150 bolls/m or above will produce high yields as long as nutrition and irrigation have been managed well. Figure 13 is based on 10 years of segment picking data and is related to high and lower yielding crops:

Figure 13: Table of high yield parameters versus lower yielding parameters. CSD long term segment picking data 2003-2013.
In general, crops that have high boll numbers, above 150 and have bolls that weigh above 2.2 grams (ginned) will yield higher. In Gwydir studies conducted by CSD the longer the plant flowers means more yield is created. In this study yield is worked out as 0.25 b/ha for every day of flowering. Therefore, if a crop flowers for 50 days it will have a potential yield of 12.5 b/ha.

It is important to develop a crop with high first position fruit retention above 65% for the season and to be around 8-9 NAWF at first flower to have the potential for high yield. The longer the plant can continue to flower, the greater the yield potential. This is dependent on seasonal conditions and where the crop is up to. In southern NSW, it is difficult to get a crop to flower for more than 50 days due to the short season length.

Some varieties have inherent higher boll weight than others. This is important as these varieties require fewer bolls to achieve the high yields (Figure 14).

1.2. Impacts on retention

Retention levels must be kept high to reach the good boll numbers required for high yield. Assess your circumstance in terms of insect pressure, timing of irrigation and anything that may cause stress leading to fruit shed or loss.

![Figure 14: CSD variety boll weights. CSD long term segment picking data 2003-2013](image-url)
5. Weed and Volunteer Cotton Control Requirements for High Yielding Crops

1.1. Cotton volunteers

One of the biggest threats to yield is uncontrolled volunteer cotton. Volunteer cotton are the “gift that keeps on giving” and can have devastating effects on yield with volunteers not being able to be picked on the sides of beds but still using both fertilizer and moisture. In extreme cases, a plant stand can go from 12 plants/m up to 24 plants/m which will definitely cause yield reduction. There are number of ways of controlling them:

- Pre-irrigation is still the best way to gaining control by germinating the volunteers in early spring ahead of planting and then spraying them out before it begins.
- Once in the crop they are more difficult to control but the key is to get them early whether using a herbicide or cultivation.
- Liberty Link cotton is a good rotation to control volunteers.

Volunteer plants are also the perfect host for some insects and diseases. Insect numbers can start to build up early in fields, giving them a head start, and causing spraying earlier than usual.

1.2. Weed resistance

Weeds have been part of the cotton system for a long time, but recently there has been a spike in levels of resistance to the most common herbicide used in their control, namely glyphosate. This would suggest that there has been an over reliance on this product for weed control. In cotton we have seen a reduction in use of many other registered herbicides. Pre-emergent residual and lay-by herbicides have become cheaper over the last decade and they are a good tool to support glyphosate.

The keys to successfully keeping weeds and volunteer cotton under control are to use all the tools available, there by taking the pressure of glyphosate.

<table>
<thead>
<tr>
<th>Product</th>
<th>Active (s)</th>
<th>Rate (s)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprayseed 250</td>
<td>Gramoxone/</td>
<td>1.6 - 2.4 L/Ha</td>
<td>1 - 4 Leaf</td>
</tr>
<tr>
<td></td>
<td>Paraquat</td>
<td>2.4 - 3.2 L/ha</td>
<td>5 - 9 Leaf</td>
</tr>
<tr>
<td>Bromicide 200</td>
<td>Bromoxynil</td>
<td>1.5 L/Ha</td>
<td>Cotyledon - 6 Leaf</td>
</tr>
<tr>
<td>Hammer</td>
<td>Carfentrazone - Ethyl</td>
<td>75 - 100 mL/Ha</td>
<td>2 - 6 Leaf</td>
</tr>
<tr>
<td>Balor</td>
<td>Flumioxazin</td>
<td>45 g/ha</td>
<td>1 - 4 Leaf</td>
</tr>
</tbody>
</table>

**Figure 15:** Commonly used herbicides for controlling Roundup Ready volunteers.
6. PLANT GROWTH REGULATION REQUIREMENTS FOR HIGH YIELDING CROPS

1.1. Balanced crop growth

Plant growth regulation is seen as a necessary step to control excessive vegetative growth during the season, and also as a way of cutting the crop out once the desired amount of fruit has been set. Many factors influence when a crop needs growth regulation and the science is based on the ‘sink source’ relationship. There are many factors that can influence whether growth control measures are required. They include the following:

- Variety eg. Determinacy of the variety.
- Climate eg. Warm or cool season.
- Fruit Retention eg. High fruit retention less rank growth.
- Soil Type eg. High Growth Rate (HGR) for self mulching loams.
- Nutrition eg. High N rates causing excessive growth.
- Planting Time eg. Late planting can lead to HGR.

These examples show that everything needs to be assessed before making the decision to use growth control. Too high or too low rates can result in too much or insufficient plant control. Mepiquat Chloride (Pix® etc) is normally applied in two broad manners:

1. During early flowering to restrict excessive vegetative growth (only moderate rates are required); or
2. At cut-out to suppress unnecessary vegetative growth above the last effective fruiting site (relatively higher rates are required).

Figure 16: Growth differential between Sicot 74BRF and Sicot 71BRF in terms of NAWF. Average of Gwydir CSD Trials NAWF 2010-2013.
The correct management strategy for Pix® decisions during early growth is to regularly monitor the crop in the weeks leading up to flowering to assess vegetative growth rate. Pix® should be applied only if the crop is predicted to become rank and this circumstance is more common on light soils and with late sowing dates. Early Pix® applications to crops not predicted to become rank or under plant stress can decrease yield.

There are differences in variety responsiveness to Pix®. This can be seen in Figure 16 where there is a difference in the way Sicot 71BRF and Sicot 74BRF behave in terms of NAWF. Sicot 74BRF has the ability to hold NAWF for a longer period of time than Sicot 71BRF. While this is seen as a positive in many circumstances, Sicot 74BRF would potentially have greater risk of becoming too vegetative if the right conditions and circumstances exist.

1.2. Varietal difference

The following list is the key to knowing what the potential is for growth management of CSD varieties. Typically, varieties that are more indeterminate tend to require more growth control throughout the season.

<table>
<thead>
<tr>
<th>Full Season</th>
<th>Indeterminacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sicot 75</td>
<td></td>
</tr>
<tr>
<td>Sicot 730</td>
<td></td>
</tr>
<tr>
<td>Sicot 70BL</td>
<td></td>
</tr>
<tr>
<td>Sicot 75BRF</td>
<td></td>
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<tr>
<td>Sicala 340BRF</td>
<td></td>
</tr>
<tr>
<td>Sicot 74BRF</td>
<td></td>
</tr>
<tr>
<td>Sicot 71RRF</td>
<td></td>
</tr>
<tr>
<td>Sicot 71BRF</td>
<td></td>
</tr>
<tr>
<td>Sicot 18BL</td>
<td></td>
</tr>
<tr>
<td>Sicot 43BRF</td>
<td></td>
</tr>
</tbody>
</table>

Figure 17: CSD variety requirement for growth control.
Plant stresses can come in different forms and occur throughout the season. Many of these stresses are caused by weather conditions such as heavy rainfall resulting in waterlogging, heat causing pollen sterility and fruit abortion and cold weather at planting causing poor plant establishment. This can lead to onset of seedling disease and overall poor early growth.

1.1. Waterlogging

The effects of waterlogging can be devastating on yield and also quality. Waterlogging starves the plant of nutrients as the soils become anaerobic. Soils with less than 10% air porosity cause stress in the plant. Beneficial soil micro flora die and nutrients are leached, volatilised or tied up in the soil. Root systems switch to survival mode and the plant labours until the soil dries out and aerobic conditions return. The effects of this are well documented and are seen in Figure 18. There is a linear decrease in yield related to the number of days that a plant is waterlogged. Plants can lose up to 3 bales/ha if waterlogged for 14 days.

Waterlogging is difficult to control when caused by weather events but good farm practices with irrigation should be aimed at reducing the amount of time that the soil is saturated. This may mean:

- Re-lasering fields to achieve better slopes for irrigation, or by shortening fields.
- Changing irrigation technique eg. bankless channel or overhead irrigation.
- Using larger syphon pipes or doubling up pipes to increase water flow.
- Having well formed tail drains and channels with sufficient blowout capacity for large rainfall events.

![Figure 18: Yield loss caused by waterlogging. Hodgson, 1980](image-url)
In terms of management, monitor forecast weather changes and don’t irrigate if there is a probability of large rain fall events. If there looks like the chance of a waterlogging event, an application of nitrogen well in advance of the event may reduce the impact of waterlogging. Note that there is little to gain by fertilizing crops while they are still waterlogged and roots are inactive. Waterlogging can also impact on iron, phosphorous and sulphur availability. An application of these nutrients after the waterlogging event may help.

1.2. Heat Stress

When the leaf temperature exceeds 32°C plants attempt to regulate the leaf temperature. Cotton plants can evaporatively cool but when air temperature reaches 44°C and humid temperature reaches 32°C the crop goes into major stress. A number of physiological processes occur:

- Photosynthesis is reduced and hence carbohydrate production declines significantly.
- Less carbohydrate during flowering means less seed, less bolls and smaller bolls. “Cavitation” is a strong visual symptom of carbohydrate shortage.
- Leaf waxiness increases - this increases light reflection and lowers solar efficiency.
- Plant growth slows and NAWF decrease rapidly.
- Air temperatures at night above 26°C begin to cause pollen sterility. Moist warm air is even more damaging to fertility.
- Plants continue to respire at night. Respiration is more rapid at higher temps.
- Higher temps at night leave less net carbohydrate for growth and boll filling.
- Young bolls, flowers and squares are aborted as a survival mechanism

The issues that arise once these processes are started means that management becomes more critical. Cooling the crop is very important and supplying water to the crop and into the canopy will help cool it. Under heat stress conditions up to 99.9% of water use is used for cooling within the plant and even minor reductions in soil water will result in rapid increases in leaf temperature. Anything that interrupts the flow of water from the soil to the leaf surface will cause plant stress. These include diseases, insects and compaction.

If fruit has been lost this may predispose the crop to rank vegetative growth which could require growth regulation. The quality of the crop could be affected depending on what fruit has been lost and from where it was situated on the plant. Lower bolls and first position bolls have higher micronaire than subsequent second and third position fruit and top fruit.

eg. If the stress event occurs early and fruit loss occurs in the bottom half of the plant this could set the crop up for low micronaire as the top third of the crop normally has lower micronaire. Hence not being able to blend the bottom third could create a low micronaire plant.

We can’t control the weather. Look at the seven day outlook and where irrigation water is available, decrease the interval between irrigation to avoid water stress. Do not stretch irrigations, this can compound the problems and cause significant yield loss and poor fibre quality.
1.1. Defoliation

Defoliation should occur as soon as the crop reaches crop maturity. There are a number of ways of testing to see where the crop is up to in terms of maturity and defoliation:

- 4 NACB (Nodes Above Cracked Boll) can be used as a guide for first defoliation. Find the uppermost first position cracked boll. Find the last harvestable boll. Count from the cracked boll upwards to the last harvestable boll. When this figure is at 4 NACB the crop can be defoliated.

- Cutting through bolls half way up the plant allows you to see whether the seed has reached physiological maturity. When the seed skin (epidermis) has turned brown and there is no jelly inside the seed, the seed has reached maturity. Depending on where this is on the plant will determine when to defoliate.

- When the crop reaches 60% open the crop can generally be defoliated. Issues arise where the crop has uneven fruit distribution and missing fruiting positions.

The use of all methods should give a realistic timing for first defoliation.

There are issues that arise with cotton micronaire if defoliation is applied before 4 NACB. This can be seen in Figure 20. If the crop is defoliated at 6 NACB this has an impact on micronaire by dropping it by 0.2, similarly at 8 NACB it drops by 0.4 in micronaire. Not only is there a reduction in micronaire, but yield is being sacrificed as the bolls at the top of the plant have not yet matured.

![Figure 20: Micronaire issues caused by early defoliation. Bange CSIRO FibrePak, 2009.](image-url)
1.2. Picking

Picking of the crop should occur as soon as all leaf is off the crop and most bolls are open. Delaying picking gives greater potential for grade losses due to rain and loss of yield on lower branches through ageing and wind damage. The penalty for a drop in grade is around $30/bale which on a 10 bale/ha crop is $300/ha.

If using a picker contractor organise them early and make sure of their availability when your crop is ready to be picked. Timeliness is everything with picking as for the last six months, much time and energy has been put into getting the crop to this stage.
RECOMMENDATIONS

High yield is the best way to achieve profitable farming into the future and Australian cotton growers are the best in the world at producing high yields. To do this the management of high yielding crops must be spot on. The key to achieving this is:

• Get ground work done early and create a good seed bed.

• Apply fertilizer in a timely manner so the crop can access it as needed. Don’t under fertilize as this will reduce your yield potential.

• Make sure all machinery, pumps, bores and ring tanks are in good order before the season begins.

• At planting, make staff aware of a common goal of establishing the crop and getting it out of the ground as quickly as possible. Train them in planter setup and operational speed.

• Select the right variety and seed treatment for your circumstance.

• Plant the crop with a forecast of rising temperatures.

• Reduce the chances of plant stress by understanding the weather forecasts.

• Irrigate on time with no delay using the irrigation tools available.

• Don’t let irrigation or nutrition be a limiting factor.

• Use growth regulation if required to reduce excessive vegetative growth. Do not apply growth regulation when the plant is under stress.

• Develop high fruit retention crops with the aim of having 150 bolls per metre or more by the end of the season.

• Defoliate using the methods mentioned in this booklet and don’t defoliate too early.

• Pick on time without delay to reduce potential for grade penalties and yield loss.
FOR MORE INFORMATION CONTACT YOUR LOCAL EXTENSION AND DEVELOPMENT AGRONOMIST

CENTRAL NSW
BOB FORD • 0428 950 015 • bford@csd.net.au

SOUTHERN NSW
JORIAN MILLYARD • 0428 950 009 • jmilyard@csd.net.au

NAMOI
ROBERT EVELEIGH • 0427 915 921 • robeye@csd.net.au

GWYDIR
JAMES QUINN • 0428 950 028 • jquinn@csd.net.au

BORDER RIVERS
ALEX NORTH • 0428 950 021 • anorth@csd.net.au

DARLING DOWNS AND CENTRAL QLD
JOHN MARSHALL • 0428 950 010 • jmarshall@csd.net.au

WEE WAA OFFICE
‘Shenstone’ 2952 Culgoora Road
Wee Waa, NSW 2388
Phone (02) 6795 0000
Fax (02) 6795 4966

DALBY OFFICE
Corner Edward & Napier Streets
Dalby, QLD 4405
Phone (07) 4662 6050
Fax (07) 4662 6060