# Updated: Comparing grain and cotton in northern NSW. Impacts on the cropping systems and the advantages of growing summer crops to improve $/mm and as a disease break from winter cereal dominated systems

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**Take home message**

- Incorporating summer crops such as sorghum and cotton can improve farming returns in terms of $/ha and $/mm
- Sorghum based sequences and winter cropping rotations are very productive and produce higher grain yields, but cotton dominant systems had higher potential system gross margins
- The legacy impact of cotton can last a number of subsequent seasons (especially soil water), so productivity needs to account for the whole cropping system, not the one crop
- When conditions allow for planting moisture, a sorghum/chickpea double-crop does improve gross margins, but there are added risks of planting the second crop compared to cropping after fallow
- Summer crops provided a significant reduction in soil-borne pathogens and nematode numbers, allowing greater choice of crops and cultivars in rotations.

**Introduction**

The dynamic climate of the northern grains region allows growers to implement diverse cropping systems, from winter dominant to summer cropping including both grain and fibre crops. Hence, there are several options available for grain growers to diversify their crop rotations to help manage disease, weed and herbicide options. Summer crops can generate high-value end products (e.g. cotton), make efficient use of spring/summer rainfall and use nitrogen (N) from mineralisation, which predominately occurs during the warmer months. But there are implications when transitioning into summer crops. Firstly, the length of the pre-plant fallow can elongate when waiting for profile moisture to fill and secondly, the crop legacy impact when returning to winter crops. These implications can decrease the economic gains associated with summer crops and reduce the benefits of a summer cropping transition. There is also the question of how the summer crop will perform? Will the forecasted rain be adequate to achieve yields with high economic returns?

In much of northern NSW and southern Queensland, the pillar summer crops are sorghum and dryland cotton. Dryland cotton requires cropping land to be set aside in a lengthy fallow prior to planting (>10-12 months) to accumulate sufficient moisture to support cotton's long growing season. Post-harvest operations (e.g., pupae busting) can result in further fallow periods prior to the next crop in sequence. In comparison, sorghum can often be double cropped back to chickpea involving a shorter fallow period and easier transition back into winter cropping. Both sequences were investigated within the farming systems project over the last six years at various points in time and locations. In this paper, we compare the performance of crop sequences involving sorghum and cotton compared with those focusing on winter crops grown over a common period at three sites (Narrabri, Spring Ridge and Pampas). This paper looks at the legacy implication of summer cropping, particularly sorghum and cotton and the implications they may have on a farming system in the northern grains region (NGR) and the economic risks of these systems. The paper details the impacts on nitrogen (N), water use and disease/pathogen levels collected from the northern farming systems project over the last six years.

**Farming systems research approach and assumptions**

The Northern Farming System project was initiated in 2015 and is co-funded by GRDC, CSIRO, QDAF and NSW DPI, with six regional sites (Qld – Emerald, Billa Billa, Mungindi and NSW – Narrabri, Spring Ridge and Trangie), plus a project core site located at Pampas, Qld. Over the last six years, this project has compared over 80 combinations of sites and cropping systems. This provides an opportunity to compare different crop sequences and the legacy effects of crop choice and management over several years in a cropping system on nutrition, disease, weeds and soil water.

This paper will focus on systems where the cropping sequence included crops aligned with the three themes listed below within the same period (2016-2019 and 2020-2022).

1. Winter – winter only crops with short summer fallows, planting occurring at 50% plant available moisture (PAW). Crops included wheat, chickpea, canola and field pea.
2. Sorghum – sequence containing winter crops (wheat) leading into sorghum with the opportunity of double-crop chickpea.
3. Cotton – cropping sequence focusing on a dryland cotton crop, with rotation crop dependant on available profile moisture. The cotton plant was activated when soil moisture reached 80% PAW to increase yield potential.

Soil moisture and N status were measured at all sites before and post every planted crop or twice annually during fallow years. Crops were managed and sown according to local best management guidelines. For example, relevant to our paper here, cotton was planted on single skip (2 in 1 out) configurations in the higher rainfall regions, and super single or double-skip in the western sites (e.g. Mungindi). Similarly, sorghum was sown on 1 m solid in the eastern sites, but on single skip in drier environments.

Across the systems, the inputs required in each system were recorded to calculate the system gross margin return using a 10-year average grain price to Brisbane port minus a set freight charge. Commodity prices per tonne included – wheat = $269, chickpea = $504, fababean = $382, sorghum = $220, cotton = $1090 (lint and seed), which equates to a cotton price of $490/bale and seed price of $260 per tonne.

**Summer crop sequence performance**

Using the farming systems data from Narrabri, Spring Ridge and Pampas we explored how crop sequences involving a summer pillar crop of sorghum or dryland cotton performed compared to a winter crop only system. This paper will focus on a 3-year period and 2-year period where common periods of comparison were possible between all research sites.

There is a contrast in weather conditions between the sites and the two periods of study. The first period (2015-2019) received lower than average rainfall across the sites (approximately 1600-1800 mm of rain over this period, or 400-450 mm per year), which induced longer fallow periods across all sequences, and several crops achieved low or negative gross margins owing to very little in-crop rainfall.

Nonetheless, these comparisons show the sequences involving a summer crop of sorghum were superior to the winter-only sequences at all 3 sites in terms of gross margin and system water-use efficiency (i.e. $/mm). Crop sequences targeting dryland cotton were variable, achieving lower GM returns at 2 sites (Narrabri and Pampas). The dryland cotton yields were reduced by hot and dry conditions, achieving yields of 2-2.5 bales per ha (Table 1). On the other hand, the crop sequence targeting dryland cotton at Spring Ridge, achieved a similar total gross margin from this single crop, despite being fallow the remainder of the time.

The winter-only sequence did not plant a crop in the 2018 winter at any of the sites due to lack of accumulated moisture and/or a lack of surface soil moisture to allow sowing.

**Table 1.** Performance and N balance of 3-year crop sequences (2016-2019) comparing the systems based on winter crops including break crops or using a sorghum or cotton crop at three farming systems experimental sites. The notation for the sequence of crops include: x = 6-8 month fallow, Cp = Chickpea, Wt = Wheat, Fp = field pea, Cn = Canola, Sg = Sorghum, Ct = Cotton.

| Location | Pillar crop | Rotation | Grain yield (T/ha) | Total gross margin ($/ha) | N applied (kg/ha) | N exported (kg/ha) |
|---|---|---|---|---|---|---|
| Narrabri | Winter | x-Fp-x-Cn-x-x-x-Wt | 2.7 | -116 | 154 | 96 |
| | Sorghum | x-Cp-x-Wt-x-x-Sg-x | 5.7 | 1292 | 81 | 137 |
| | Cotton | x-x-Ct-x-x-x-x-x | 1.1 | 766 | 58 | 45 |
| Spring Ridge | Winter | x-Fp-x-Wt-x-x-x-Cn | 7.0 | 1057 | 57 | 200 |
| | Sorghum | x-Cp-x-Wt-x-x-Sg-x | 6.7 | 1487 | 86 | 173 |
| | Cotton | x-x-x-x-Ct-x-x-x | 2.1 | 1440 | 29 | 66 |
| Pampas | Winter | x-Cp-x-Wt-x-x-x-x | 6.7 | 2195 | 41 | 198 |
| | Sorghum | x-x-Sg-Cp-x-x-Sg-x | 13.2 | 2661 | 46 | 239 |
| | Cotton | x-x-Ct-Wt-x-x-x-x | 3.2 | 1776 | 151 | 37 |

The second period of this study occurred between 2020 and 2022. During this time, the research sites received above average rainfall, improving grain yield and crop gross margins. This study highlighted the gap between system productivity and system economics, as the sorghum system achieved high grain yields at both Narrabri and Spring Ridge, but resulted in the lowest system gross margin (note a planned chickpea crop for the 2022 winter after the sorghum may boost the sorghum system's crop returns). In contrast, the cotton system produced lower grain yield but the highest system GM, with $5111 per ha at Narrabri and $4539 per ha at Spring Ridge.

The system N use (change in mineral N plus applied N fertiliser) was similar between treatments at Narrabri, ranging from 202 to 235 kg N per ha over the cropping sequence, but Spring Ridge with the higher grain yields of both the winter and sorghum systems resulted in greater variance. The winter system had lower N use, as the fababean legume crop provided a significant portion of required N, reducing N fertiliser application by 130 kg N per ha to the cotton system and 290 kg N per ha to the sorghum system.

**Table 2.** Performance of 2-year crop sequences between 2020 and 2022 comparing systems containing a winter break, and a summer sequence containing either sorghum or cotton. The notation for the sequence of crops include: x = 6-8 month fallow, Cp = Chickpea, Wt = Wheat, Sg = Sorghum, Ct = Cotton.

| Location | Pillar crop | Rotation | Grain yield (T/ha) | Total gross margin ($/ha) | System N use (kg N/ha) | Change in mineral N (kg N/ha) |
|---|---|---|---|---|---|---|
| Narrabri | Winter | x-Wt-x-Cp-x | 6.5 | 2490 | 202 | 122 |
| | Sorghum | x-Wt-x-x-Sg | 8.1 | 1960 | 235 | 105 |
| | Cotton | x-Wt-x-x-Co | 7.9 | 5111 | 215 | 165 |
| Spring Ridge | Winter | x-Wt-x-Fb-x | 12.2 | 4196 | 110 | 80 |
| | Sorghum | x-Wt-x-x-Sg | 12.7 | 2810 | 300 | 140 |
| | Cotton | x-Wt-x-x-Co | 8.1 | 4539 | 240 | 120 |

**Relative returns of summer crop options**

The results from the three sites shows that it is crucial to consider the impact on profitability of the sequence of crops rather than individual crops grown in a particular season. When comparing the potential of sorghum and cotton as prospective summer crops, it is important to consider the future crop opportunities and legacies, particularly the opportunity to double crop following sorghum with chickpea which is rarely viable following cotton.

As such our farming systems sites have demonstrated a couple of examples of these two comparisons. Firstly, at Pampas in summer 16/17 both sorghum and cotton crops were sown following a long fallow, but a chickpea crop followed the sorghum crop in 2017. In this comparison, sorghum yielded 7.2 t/ha (GM of $1376) plus chickpeas produced a further 1.6 t/ha (GM of $573), for a total of $1950/ha, while the cotton crop yielded 1.9 t/ha (i.e., 3.8 bales/ha) for a GM of $1468.

The second comparison occurred during a lower yielding 2018/19 summer with grain yields significantly lower for sorghum (4.5 t/ha) with a net return of $710 per ha. There was no opportunity to double crop following the sorghum. By comparison, the cotton crop yielded (1.4 t/ha or 3.0 bales/ha), resulting in a net return of $1175 per ha.

Another example occurred during 2020-2022 at both the Spring Ridge and Narrabri sites where either a wheat-sorghum sequence or a wheat cotton sequence was studied. This study produced higher yields and gross margins than reported in 2018/19 ranging from 7.9 to 12.7 t/ha (Table 2). The higher yields during this study provided a base to compare these sequences in years with higher yield potential than the yields we observed during the 2016-19 phase. The key finding from this period was the impact of growing high value grains, as the cotton system at Narrabri had the highest system GM of $5111. This was more than double the GM of the sorghum and winter systems at Narrabri during the same period.

**System water use**

To evaluate the system legacy impact on water use, we evaluated WUE as the system GM divided by rainfall during the cropping sequence ($/mm). The indicator is a tool that values system returns per mm of rainfall.

The dataset from the project found systems containing cotton generated greater rainfall efficiency than both winter and sorghum systems when accumulated grain yield exceeded 5t/ha (Figure 1). Hence the cotton systems required less grain production compared to the other system to improve WUE. For example, for a cotton system to generate a WUE of $2/mm, it required 5.2t/ha, while the winter system required 8t/ha and the sorghum system required 13t/ha.

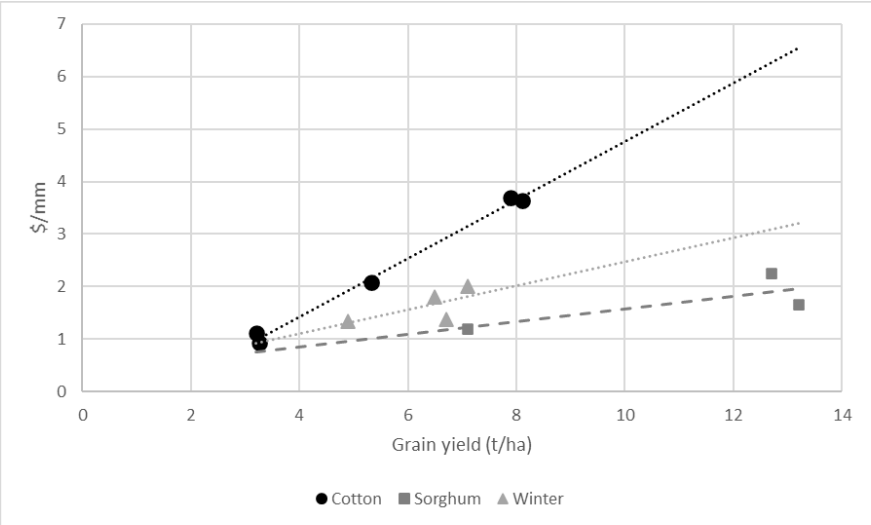


**Figure 1**. Crop water use efficiency (WUE as system gross margin by rainfall - $/mm) against cumulative system grain yield of three sequences based on winter only cropping, sorghum and cotton focused sequences at Narrabri, Spring Ridge and Pampas.

**Water and N legacies of sorghum vs cotton**

Further to the differences in system economic returns offered by different summer crop options, it is also important to understand and consider their legacies on soil water and nitrogen availability that can impact the performance and input requirements of subsequent crops.

**Water use and harvest soil water**

Several comparisons where both sorghum and dryland cotton were sown in the same season provide some comparisons of the legacy impacts on PAW and available N (Table 3). The data highlighted how low PAW after harvest restricted the potential for double cropping behind either sorghum or cotton. There was only one scenario (Pampas 2016/17) where sorghum was followed by a chickpea double crop. In the same season at Pampas, the cotton was followed by a salvage wheat crop, but there was a large difference in final soil water of over 100 mm. This difference persisted through a long fallow period, where a 60 mm difference in soil water was present at the sowing of the next crop.

The greater PAW after sorghum compared to cotton was also found at Pampas 2018/19, where post-crop PAW was ~0 mm after sorghum and negative 32mm after cotton. Similar levels of soil water extraction occurred at Mungindi (2016/17) and at both locations, the longer-term PAW was higher after sorghum compared to after cotton (range 5-35 mm).

We also note that cotton due to its lower biomass accumulation often left more residual N post-harvest than sorghum. The lower levels of mineral N after sorghum could have implications for N inputs required in subsequent crops

**Table 3.** Summer cropping impacts on plant available water (mm), water use efficiency (WUE) and residual mineral N

| Site | Crop sequence | Pre-sowing PAW (mm) | Final PAW (mm) | Post short fallow PAW (mm) | Post long fallow PAW (mm) | Pre-sowing mineral N (kg N/ha | Final mineral N (kg N/ha) | Applied N fertiliser (kg N/ha) |
|---|---|---|---|---|---|---|---|---|
| Mungindi 2016 | Sorghum | 138 | 11 | | 110 | 57 | 29 | 2 |
| | Cotton | 139 | 19 | | 105 | 30 | 67 | 11 |
| Pampas 2016/17 | Sorghum-chickpea | 240 | 100 | 155 | 130 | 195 | 55 | 5 |
| | Cotton-wheat | 253 | 0 | 80 | 70 | 178 | 100 | 76 |
| Pampas 2018 | Sorghum | 120 | 2 | 70 | 150 | 114 | 94 | 34 |
| | Cotton | 149 | -32 | 30 | 115 | 120 | 94 | 2 |

Note: short fallow = <6 months, Long fallow = >10 months.

**Nitrogen use and residual N legacy**

A key aspect of dominant summer rainfall areas is the beneficial N mineralisation from soil organic N occurring during the warmer months. The total amount of mineral N from organic sources in northern farming systems has been documented by Baird *et al*., (2018), where fallow periods, especially over the summer months, significantly increased mineral N within the system. Growing summer crops did reduce the mineral N accumulation during the warmer months, but applied fertiliser N was low (2-76 kg N/ha) as native N sources from the soil supplied a significant amount of N to the plant. The project found that the longer season growth of cotton had greater use of mineralised N and maintained soil mineral N levels compared to sorghum. As a result, residual N after cotton in all comparisons in Table 3 were greater than the residual N after sorghum crops (the difference ranging from 38-75 kg N/ha).

**The legacy impact on rotation crops**

The immediate returns of summer crops can be negated by the poor performance of the subsequent winter crop (Table 4). Firstly, when we compare a winter dominant cropping system (chickpea-fallow-wheat) to a summer-winter double crop (cotton-wheat or sorghum-wheat) situation at Narrabri, we demonstrate the significant yield penalty (60%) likely from the reduced soil water prior to planting the subsequent crop.

Second, the longer growing season of cotton had a greater influence on soil water use, decreasing the sowing PAW for the following crops and resulting in a significant reduction in yield compared to the crop grown following sorghum. Consequently, there is a high risk of crop underperformance when cropping after cotton, and generally growers will need to fallow their fields until the soil has been able to restore soil water levels to reduce the risk of lower crop yields.

**Table 4.** Legacy impact of summer crops on the subsequent crop yield

| Site | Crop | Previous crop (season) | Following crop yield (t/ha) |
|---|---|---|---|
| Narrabri 2017 | Wheat | Cotton (2016/17) | 1.0 |
| | Wheat | Chickpea (2016) | 2.2 |
| Pampas 2020 | Sorghum | Cotton (2016/17) | 2.8 |
| | Sorghum | Sorghum (2016/17) | 4.1 |
| | Mungbean | Cotton (2016/17) | 1.1 |
| | Mungbean | Sorghum (2016/17) | 1.3 |
| Mungindi 2018 | Wheat | Cotton (2016/17) | 1.2 |
| | Wheat | Chickpea (2016) | 0.8 |

**Measured disease and nematode levels**

Summer crops provided a break for winter crop disease and nematode loads in our cropping soils. At Narrabri *P. thornei* root lesion nematode numbers were maintained at low levels after a cotton crop within the Low intensity system (Figure 2). At the same time, a winter-based sequence containing wheat and chickpea (Baseline), resulted in a spike for *P. thornei* (8.8 *Pt*/g soil). As a result of this spike in nematode numbers within the Baseline system, management was required to select wheat cultivars with higher nematode tolerance.

The use of summer crop options also reduced moderate to high levels of yellow leaf spot inoculum down to low concentrations at the Spring Ridge site. This break in disease and nematodes allows for a greater diversity of crop choices for future rotations, as the susceptible crops are unlikely to suffer yield loss from the lower pathogen loads in the cropping system (Erbacher, 2019).

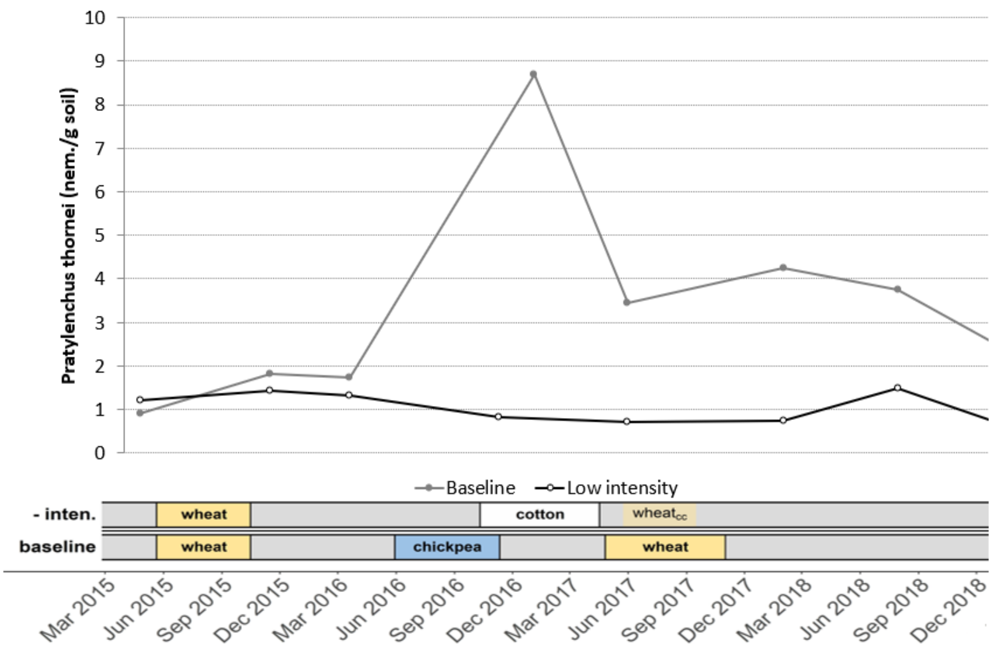


**Figure 2**. *P thornei* levels at Narrabri between 2015 and 2018. Baseline = Baseline, - inten. = Low intensity.

## Conclusion

Summer crops provide a complementary addition to cropping systems in northern NSW and southern Queensland. The improvement in rainfall use efficiency due to the immediate use of summer rainfall, can provide growers with greater returns in terms of $/mm, as compared to waiting to plant a winter crop. Despite the risk of missing crops and the need to either long fallow or double crop in order to return to a winter crop sequence, even under the dry seasonal conditions between 2015-2019, sequences involving a summer crop have performed better. If rainfall does become limited late in the growing season and the harvest PAW is low, the opportunity for a winter double crop is low and significant yield penalties (up to 60%) are likely for such crops following a summer crop (especially cotton).

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