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
- 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
- A sorghum/chickpea double-crop does give similar gross margins as a single cotton crop but there are added risks of planting the second crop compared to cropping after fallows
- Applied fertiliser N was low for summer crops (2-76 kg N/ha) as the dominant source of N was from the residual mineral N and in-crop cycling from organic sources
- 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, weeds, 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. On top of these issues there is also the question of how the summer crop will perform, will the forecasted rain be adequate for achieving yields that have 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 the 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, which provides an opportunity to compare different crop sequences and the legacies 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 below themes within the same period (2016-2019).

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), and 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 – chickpea = $504, sorghum = $220, cotton = $1080 (lint and seed), which equates to a cotton price of $480/bale and seed price of $260 per tonne.

Summer crop sequence performance

Firstly, using the farming systems data from Narrabri, Spring Ridge and Pampas we have explored how crop sequences involving a summer pillar crop of sorghum or dryland cotton have performed compared to a winter crop only system. This was done over a 4-year period to account for the differences in fallow periods required both before and after each crop. The common period of comparison was between December 2015 and December 2019. It is worth noting that this period was drier than average at all 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. Economic performance and N balance of 4-year crop sequences (2016-2019) comparing the systems based on winter crops including break crops or using a sorghum or cotton crop during 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	Total gross margin ($/ha)	WUE ($/ha/mm)	N applied (kg/ha)	N exported (kg/ha)
Narrabri	Winter	x-Fp-x-Cn-x-x-x-Wt	-116	0	154	96
	Sorghum	x-Cp-x-Wt-x-x-Sg-x	1292	0.92	81	137
	Cotton	x-x-Ct-x-x-x-x-x	766	0.64	58	45
Spring Ridge	Winter	x-Fp-x-Wt-x-x-x-Cn	1057	0.83	57	200
	Sorghum	x-Cp-x-Wt-x-x-Sg-x	1487	1.17	86	173
	Cotton	x-x-x-x-Ct-x-x-x	1440	1.14	29	66
Pampas	Winter	x-Cp-x-Wt-x-x-x-x	2195	1.37	41	198
	Sorghum	x-x-Sg-Cp-x-x-Sg-x	2661	1.66	46	239
	Cotton	x-x-Ct-Wt-x-x-x-x	1776	1.11	151	37

Relative returns of summer crop options

The results from the three sites shows that it is crucial to consider the impact or 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.

These datasets show that cotton can generate more revenue and a higher return than a sorghum crop in the same season. A similar economic return to dryland cotton can be generated via a sorghum-chickpea double crop, but this opportunity may not be available in all years.

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 (Tabled 2). 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 2. 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 3). 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 3. 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 1). 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).

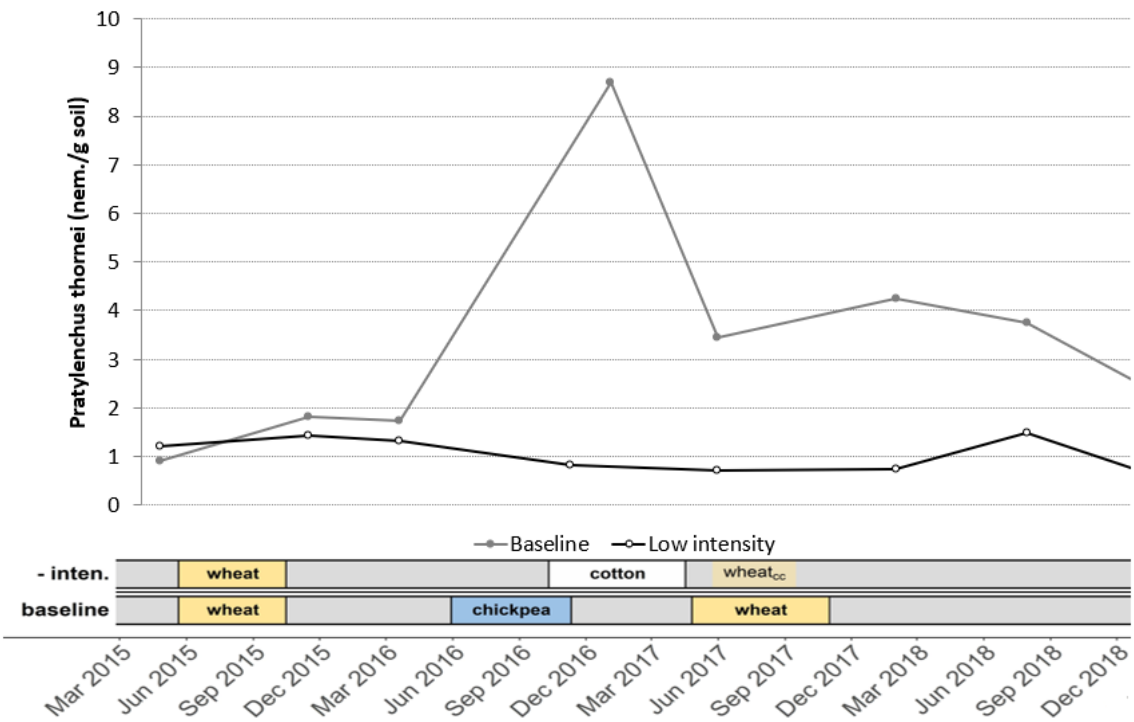

Figure 1. *P thornei* levels at Narrabri between 2015 and 2018. Baseline = Baseline, - inten. = Low intensity.

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 compared to waiting for planting 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 the 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 there are likely significant yield penalties (up to 60%) for such crops following a summer crop (especially cotton). However, when conditions are favourable the opportunity to utilise a double crop of chickpea in combination with sorghum can perform favourably compared to other crop sequences and dryland cotton.

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