Northern Farming Systems site—Emerald

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Research Question: *What are the long-term impacts on systems performance (e.g. productivity, profitability and soil health) when six strategically different 'farming systems' are applied to one geographic location over a five year period?*

Key findings

1. *Higher soil fertility* was the most profitable and highest yielding system for the 2018 sorghum crop.
2. *Higher legume* is cumulatively the most profitable system thus far.
3. The *Baseline* system is falling behind four of the six systems in the trial on most comparisons.

Background

In early 2015, the project developed six locally relevant farming systems to investigate in Emerald that were consistent with those being studied by the Northern Farming Systems Initiative. A range of agronomic practices (i.e. row spacing, plant populations), crop types and rotations, crop frequency, planting time/windows, tillage practices, fertiliser rates and planting moisture triggers were adopted and strategically used to develop the following six farming system treatments:

1. **Baseline** is a conservative zero tillage system targeting one crop/year. Crops include wheat, chickpea and sorghum, with nitrogen rates on cereals targeting median seasonal yield potential.
2. **Higher legume** increases the frequency of pulses (i.e. 1 pulse every 2 years) to assess the impact of more legumes on profitability, soil fertility, disease and weeds.
3. **Higher crop intensity** increases cropping intensity to 1.5 crops/year when water allows. Crops include wheat, chickpea, sorghum, mungbean and forage crops/legumes.
4. **Higher nutrient supply** examines the economic and agronomic implications of increased nitrogen and phosphorus rates targeting 90% of yield potential based on soil moisture in an environment of variable climate. Crops and other practices are the same as the *Baseline* system.
5. **Higher soil fertility** repeats the *Higher nutrient supply* system but with the addition of 60 t/ha of manure. Designed to see if higher initial soil fertility can be maintained with greater nutrient inputs (targeting 90% of yield potential based on soil moisture).

Table 1. Crop rotations used for all treatments since 2015 to winter 2019.

Treatment	Winter 2015	Summer 2015/16	Winter 2016	Summer 2016/17	Winter 2017	Summer 2017/18	Winter 2018	Summer 2018/19	Winter 2019
Baseline	Wheat EGA GregoryⓅ	Fallow	Chickpea KyabraⓅ	Fallow	Wheat SunguardⓅ	Sorghum MR-Buster	Fallow	Fallow	Wheat MitchⓅ
Higher crop intensity	Wheat EGA GregoryⓅ	Mungbean Jade-AUⓅ	Wheat CondoⓅ	Fallow	Wheat SunguardⓅ	Sorghum MR-Buster	Fallow	Fallow	Chickpea KyabraⓅ
Higher legume	Chickpea Kyabra	Fallow	Wheat CondoⓅ	Fallow	Chickpea SeamerⓅ	Sorghum MR-Buster	Fallow	Fallow	Chickpea KyabraⓅ
Higher nutrient	Wheat EGA GregoryⓅ	Fallow	Chickpea KyabraⓅ	Fallow	Wheat SunguardⓅ	Sorghum MR-Buster	Fallow	Fallow	Wheat MitchⓅ
Higher soil fertility	Wheat EGA GregoryⓅ	Fallow	Chickpea KyabraⓅ	Fallow	Wheat SunguardⓅ	Sorghum MR-Buster	Fallow	Fallow	Wheat MitchⓅ
Integrated weed management	Wheat EGA GregoryⓅ	Fallow	Chickpea KyabraⓅ	Fallow	Wheat SunguardⓅ	Sorghum MR-Buster	Fallow	Fallow	Wheat MitchⓅ

6. **Integrated weed management** is a minimum tillage system focused on one crop/year but employing a wide range of practices to reduce reliance on traditional knockdown herbicides in Central Queensland (CQ) farming systems. Crops include wheat, chickpea, sorghum and mungbean.

What was done

2018 summer crop

The site received 363 mm of rainfall between the 2017 winter crop harvest and planting sorghum on 23 January 2018. All treatments were planted to MR-Buster, with the *Integrated Weed Management* treatment planted on a 50 cm spacing; all other treatments were planted on 1 m spacing. The sorghum received an additional 212 mm of rainfall in-crop (200 mm fell before the end of February). Physiological maturity was at the end of April, with an additional 11 mm falling prior to harvest.

Winter 2018 to now

No further rainfall was received until late June (18 mm), which was insufficient for any winter crop plantings. The next significant rainfall was received mid-October (82 mm), however no cropping window was open at this time. Isolated showers and storms over the summer did increase accumulated rainfall totals, however high temperatures and low humidity quickly negated any benefit these provided.

Results

Early in-crop rainfall helped the sorghum to establish and develop quickly, with 196 mm of rain received in the first month post-planting. However, only 15 mm was received in-crop from 25 February until physiological maturity around 10 May. Temperatures were above average for February and April 2018; 36 °C (long-term average 33.4 °C) and 31.5 °C (long term average 29.5 °C), respectively.

Despite good starting plant available water (PAW) and significant early in-crop rainfall, the crop showed signs of moisture stress during the flowering/grain fill period and senesced quickly after filling as much grain as it could. Grain yields and qualities highlighted differences between the treatments. *Higher soil fertility* produced the highest yield and lowest screenings (still quite high). *Baseline*, *Higher legume* and *Higher nutrient supply* produced lower yields and higher screenings than *Higher soil fertility*, but were similar to each other. *Higher intensity* had the lowest starting PAW resulting in lowest yield and highest screenings. (Figure 1). For most systems, screenings decreased as grain yield increased (Figure 1).

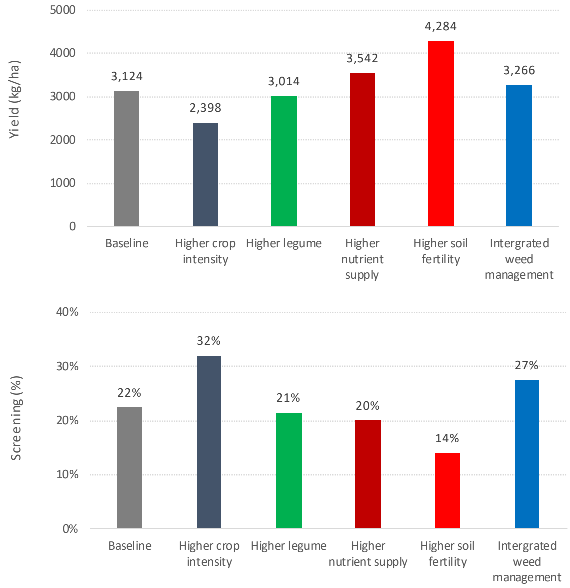

Figure 1. Grain yield (kg/ha) and screenings (%) for 2018 sorghum crop in all systems.

Pre-plant and post-harvest PAW measurements (Figure 2) show the *Higher crop intensity* treatment, had the lowest PAW at planting (at least 26 mm less) compared to any of the other systems that had come out of wheat), despite having the same cropping regime as *Baseline* since winter 2016. The *Higher legume* treatment, where the previous crop was chickpea, also had lower PAW than *Baseline*, but had on average 10 mm more PAW at planting than the *Higher crop intensity* system.

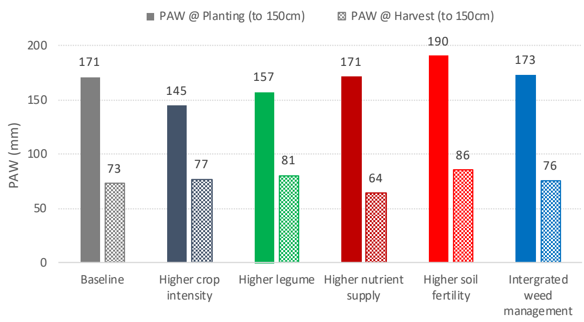

Figure 2: Average planting and harvest PAW for the 2018 sorghum crop for all treatments.

The PAW spread at planting was 45 mm between treatments. The spread at harvest was still 22 mm; the *Higher nutrient supply* had the largest variation between starting and finishing PAW at 107 mm, and *Higher intensity* had the lowest spread at 68 mm.

Crop water use efficiency (WUE) mirrored grain yield; the *Higher soil fertility* system had the best conversion of available water to grain (13.4 kg of grain per ha for every mm of water used by the crop). The lowest yielding system, *Higher crop intensity*, also had the lowest WUE (8.6 kg/ha/mm) (Figure 3).

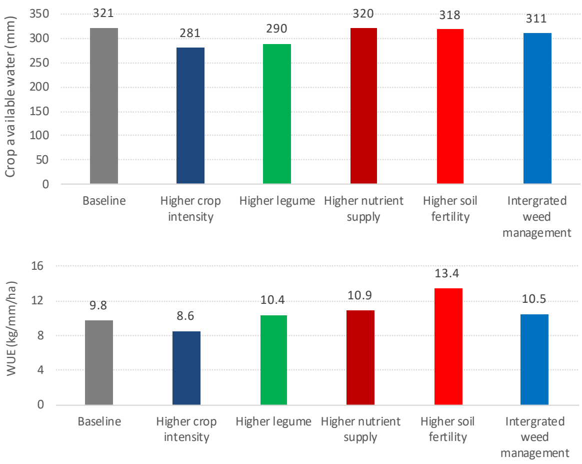

Figure 3. Crop available water and the WUE (kg/ha/mm) of each of the treatments.

Nitrogen and phosphorous removal by grain mirrored yield, as expected (Figure 4). However, when total biomass production is considered, it is highly probable that nutrient stratification on the surface over time may be higher in the *Integrated weed management* treatment. The narrower row spacing and higher established populations in this system allowed it to grow considerably more biomass, but with the dry finish it was not able to convert this biomass into a yield advantage.

Planting the 2018 sorghum treatments.

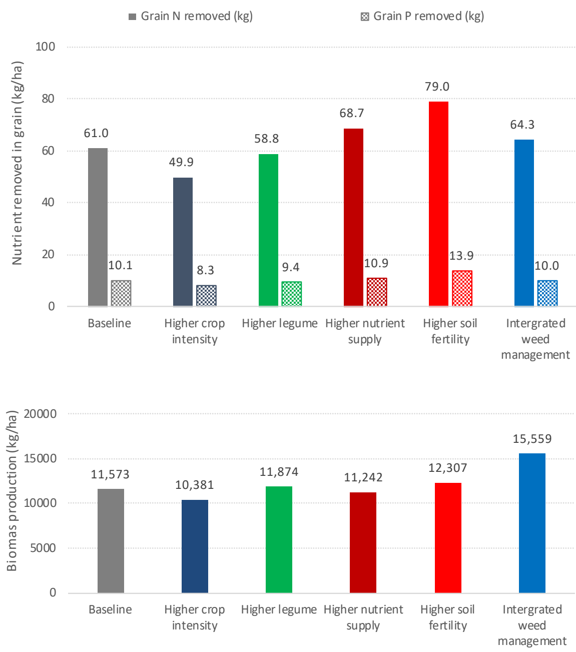

Figure 4. Grain nutrient removal (kg/ha) and crop biomass production (kg/ha).

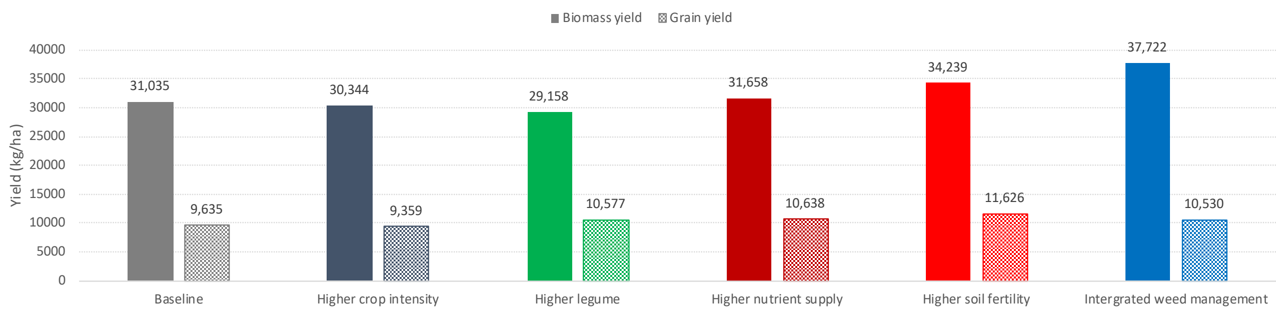

Figure 5. Cumulative biomass and grain yield production since 2015 for all six treatments.

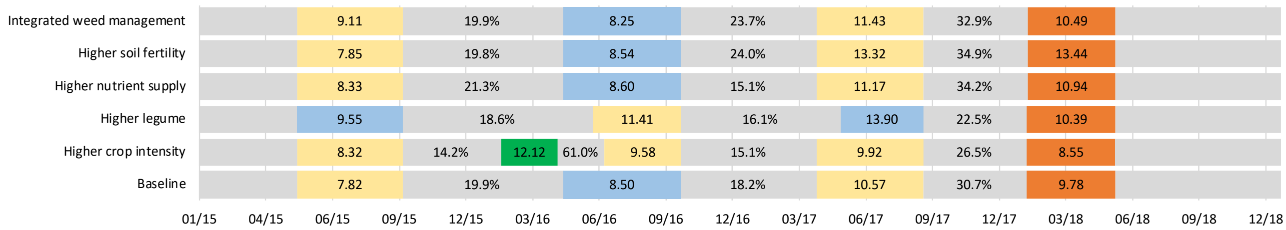

Figure 6. Water use efficiency (kg/ha/mm) and fallow efficiency (%) since the start of the trial in 2015. WUE indicates grain produced by the crop in each treatment per mm of water available to it.
Yellow bars represent wheat, blue bars are chickpea, orange bars are sorghum and the green bar is mungbean. The percentage number indicates how much of the fallow rainfall was captured and available at the next planting event.

Project life analysis

Now into the fifth year of the project, we are able to make some longer-term system observations. Total biomass and grain produced for each system (Figure 5) indicates that the *Integrated weed management* system stands out for having produced the greatest amount of biomass, most likely due to the narrower row spacing and higher plant establishment over time. However, the *Higher soil fertility* system has produced the highest overall grain yield.

Water use efficiency (kg/mm/ha) and fallow efficiency, is an interesting way to compare differences between systems over time. The rotations for each of the farming systems have varied (Figure 6).

Early in the trial, the *Higher legume* system produced the highest WUE, however as the manure treatments started to take effect, the *Higher soil fertility* system has now pushed slightly ahead (Figure 6). Despite producing significantly more biomass (and therefore ground cover) than any other system over the duration of the trial, the *Integrated weed management* system has not been able to beat the *Higher soil fertility* or *Higher nutrient supply* systems for fallow efficiency.

When cumulative gross margins are calculated for all systems/crops and compared to WUE (Figure 7), the highest return per mm/ha to date has been for the *Higher legume* system. The cumulative gross margin for each system (Figure 8), shows very little margin between the top two systems; all systems except the *Higher crop intensity* have outperformed the *Baseline*.

While implementing a *Higher legume* system has produced the highest cumulative gross margin and the highest cumulative $/mm/ha return to date, there are downsides when nutritional balances are considered.

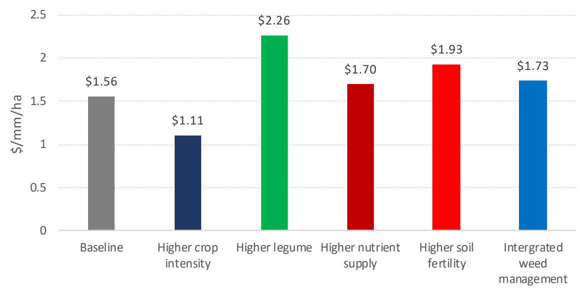

Figure 7. Gross margin of $ per mm available to the crop over the growing season.

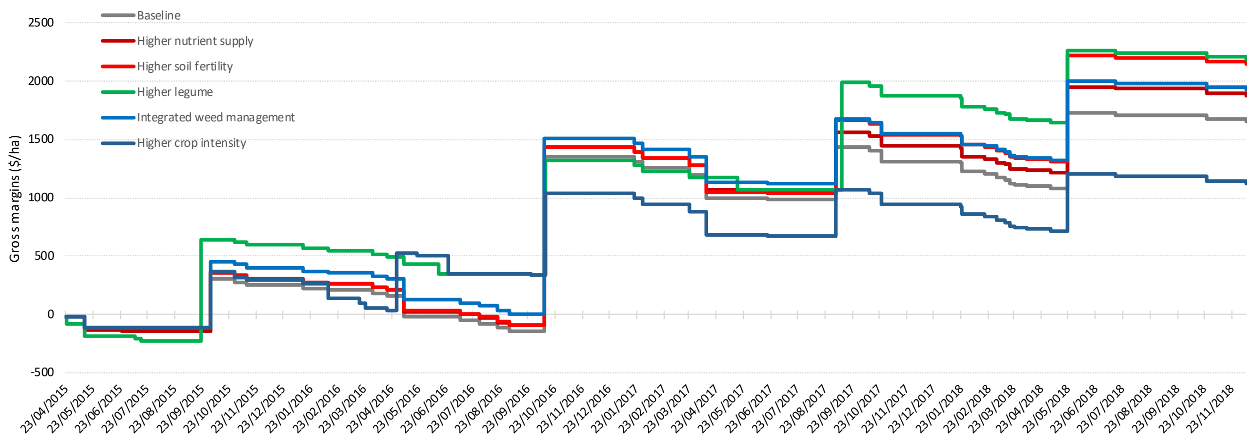

Figure 8. Cumulative gross margin for each of the treatments over the trial duration.

Only the *Higher nutrient supply* system is matching grain phosphorus (P) removal with application rates of starter fertiliser (Figure 9). *Higher legume* had the highest deficit of 14.72 kg/ha of P (equivalent to 70 kg/ha of MAP fertiliser) by the end of 2018. It should be noted that the initial manure application in the *Higher soil fertility* system added 422 kg P/ha, which has not included in these P balance calculations.

Removal of nitrogen (N) by grain (Figure 10) also shows that we have exported considerably more N in grain than what has been applied to the systems. Again, *Higher legume* has the greatest deficit with 280 kg/ha of N removed (equivalent to 609 kg/ha of urea). However this does not take into consideration mineralisation of organic carbon in the soil, nor any N produced by legume crops.

Organic carbon soil tests compare how much draw down has occurred from the organic carbon pool over the life of the project. Starting organic carbon levels in 2015 on-site were already lower than ideal, on average 0.8% in the top 10 cm (Figure 11). These levels have dropped by as much as 0.16% since then, with only the *Higher soil fertility* system showing an increase in the top 30 cm over the past five years, (a result of 10.6 t/ha of carbon added in the first year when it received 60 t/ha of manure). *Higher legume* has utilised the greatest amount in the top 10 cm (and overall), closely followed by the *Baseline* system. Interestingly, the *Higher nutrient supply* system maintained its organic carbon in the 0–10 cm increment, but has drawn more at the 10–30 cm increment.

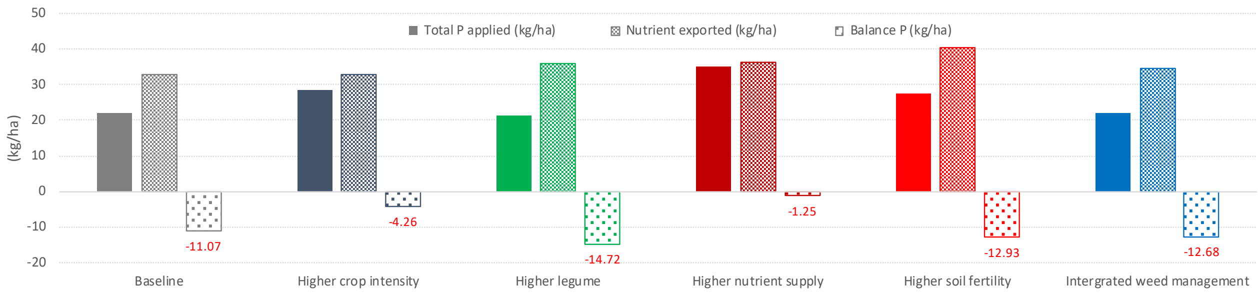

Figure 9. Phosphorous (P) application and removal (kg/ha) over the duration of the trial.

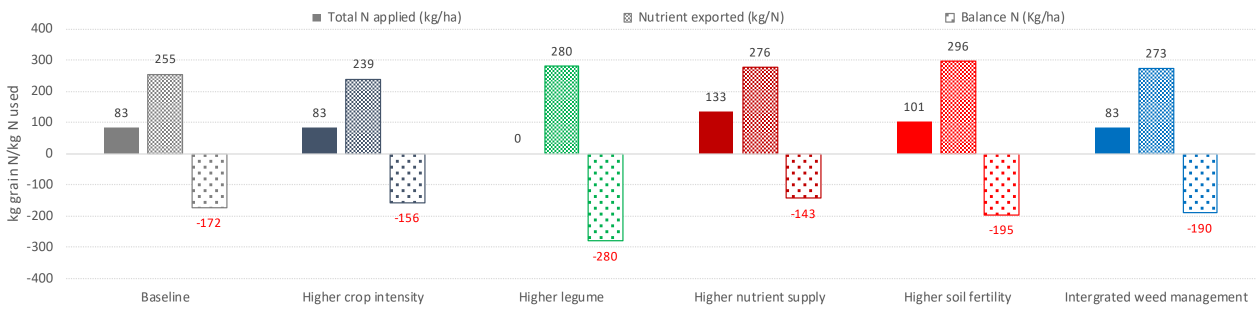

Figure 10. Nitrogen (N) application and removal (kg/ha) over the duration of the trial.

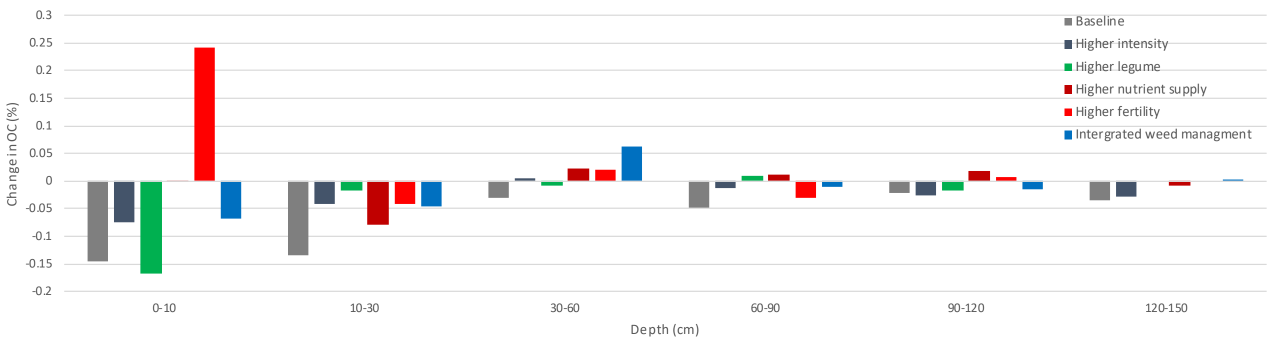

Figure 11. The change in organic carbon levels for all soil increments tested over the life of the trial to date.

Implications for growers

The six systems are now starting to show differences across various parameters due to modifications in the rotation, nutrition and agronomic management. The *Baseline* system has slipped behind most systems on most indices, showing a conservative nutrient approach may not be ideal for CQ. The *Higher legume* system has benefited significantly from the two chickpea crops in 2015 and 2018. The manure applied in the *Higher soil fertility* system has resulted in the system leading in most indices.

Integrated weed management has the highest nutritional demand as a direct result of the higher target plant populations and improved establishment due to the narrower row spacing. Yield response has been good to date because of the improved populations. Weed densities have been low; however, this has been similar for most systems.

From a sustainability point of view, only the *Higher nutrient supply* system is holding ground with respect to nutrient run-down. All other treatments (except *Higher soil fertility*) are seeing declines in P, N and organic carbon. This raises a number of questions, particularly about the sustainability of both the *Higher legume* system, because of the nutrient removal in the grain, but also the *Integrated weed management* system with the significantly higher biomass productions for no extra grain to date.

Acknowledgements

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Trial details

Location:	Emerald Research Facility	
Soil type:	Cracking, self-mulching, Grey Vertosol, >1.5 m deep, estimated plant water holding capacity of approx. 240 mm	
In-crop rainfall:	212 mm	
Row spacing (cm) 2018:	Baseline	100
	Higher crop intensity	100
	Higher legume	100
	Higher nutrient supply	100
	Higher soil fertility	100
	Integrated weed management	50
Phosphorus applied with seed (kg/ha) for 2018:	Baseline	5.5
	Higher crop intensity	5.5
	Higher legume	7.9
	Higher nutrient supply	7.9
	Higher soil fertility	5.5
	Integrated weed management	50

Integrated weed management's narrow row treatment running out of water while still trying to fill grain.