# Benefits to wheat and canola from upfront nitrogen fertiliser even when following a legume

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**Abstract**
Despite recent increases of nitrogen (N) inputs and one of the highest levels of adoption of soil-specific inputs of N fertiliser, a crop yield gap attributable to N remains on sandy soils. Over a 5 year period inclusive of decile 1 through to decile 9 seasons we have explored the effects of the source, rate and timing of N for increased productivity and reduced economic risk in low rainfall wheat and canola crops. While N application at the optimal rate is a primary driver of productivity and can reduce risk, we have identified that the N input for both wheat and canola is relatively insensitive to the timing of application. Utilising legumes in the sequence does increase the supply of N in the system, but the best productivity outcomes came from feeding wheat and canola with N from both legumes and fertiliser. A hybrid canola option has been shown to offer further yield gains per unit N input.

**Key Words**
Fertiliser timing, sequence, N use efficiency

**Introduction**
Inadequate N supply has been identified as a key driver of yield gaps in the rainfed crops in different agricultural regions of Australia. Fertiliser N input is critical for crop productivity in wheat and canola crops in low fertility sandy soils where N use efficiency remains at less than 50 % recovery of N in fertiliser in the year of application (Angus and Grace 2017). While fertiliser N is a key input, identifying options that increase N use efficiency to either reduce the inputs required or increase the productivity gain from inputs applied are critical to managing the risk of the investment in N. Legumes can supply significant quantities of N to subsequent cereal and canola crops (McBeath et al. 2015). As cropping systems have intensified and legume benefits are increasingly derived from grain legumes, the ability to sustainably reduce N inputs in crops subsequent to legumes has not been fully explored. Canola in the crop rotation can be an effective tool to manage soil borne diseases and control grass weeds, but the risk and profitability of canola is vulnerable to high input costs including N fertiliser and establishment failure in poor seasons. Optimising N use efficiency in canola could offer the ability to trade-off some of the risks associated with low rainfall canola production.

Delayed timing of fertiliser N inputs until more is known about the yield potential of the season has often been proposed as the key to reducing the risk of input costs (Ma and Herath 2016). However, ensuring adequate early N supply remains critical to the ability to attain crop yield potential in sandy soils with low N supply capacity, particularly in stubble retained systems with higher N immobilisation capacity. A delay in N inputs at sowing is not feasible where inadequate N is available to supply the crop through to tillering/bolting, or where there are not adequate opportunities to broadcast N across the farm and have it incorporated by rainfall. If there is no yield repsonse to timing of N supply, growing cultivars that can convert N into grain yield more efficiently may be a better strategy and (Svecnjak and Rengel 2006) could provide an option that reduces the level of fertiliser N required to achieve a target yield. The aim of this set of experiments was to identify strategies in low rainfall canola and wheat that increase N use efficiency and reduce the risks associated with N fertiliser inputs.

**Methods**
A series of small plot (1.8 x 20 m) experiments were established in the 2015-2018 growing seasons to test a range of hypotheses (Table 1) that were used to develop strategies for enhanced N use efficiency in low rainfall cropping systems. All crops were sown in May after opening rains of at least 10 mm and weeds and

disease were managed to minimise their effect on the results. All key nutrients that were not target treatments were managed to supply a non-limiting amount of that nutrient (e.g. phosphorus supplied at sowing, potassium sulfate to eliminate effects of potassium and sulfur and in-season foliar applications of copper, manganese and zinc). Measurements were made of pre-sowing mineral N and water to 1 m depth. At harvest, yield was measured using a plot harvester and a sub-sample of grain was analysed for protein and oil (for canola) using NIR.

**Table 1. A description of the hypothesis, site, season of experiment, crops and soils that were tested to inform strategies for increased N use efficiency in low rainfall wheat and canola crops.**

| Hypothesis | Site | Season | Crops | Soil Types |
|---|---|---|---|---|
| Legumes in the cropping sequence reduce the requirement for fertiliser N application in subsequent crops. | Karoonda, Ouyen | 2015-2017 | wheat or canola following legumes or cereals | deep sand, sand over clay, clay loam. |
| The rate of N fertiliser is more important than timing of application in wheat and canola. | Karoonda, Ouyen, Loxton, Minnipa | 2015-2017 | wheat, canola | deep sand, sand over clay, clay loam. |
| Hybrid canola has a lower fertiliser N requirement per unit yield than open pollinated canola. | Karoonda | 2018 | canola | sand over clay, clay loam |

## Results and Discussion

*Nitrogen from legumes and/or fertiliser*

Experiments with wheat in 2015 and 2016 indicated that wheat yield was independently responsive to both residue type (legume vs. non-legume) and N fertiliser (Muschietti-Piana et al. 2019). More detailed experimentation in 2016 revealed a 1.6 t/ha (+ 17%) wheat grain yield response to legume vs. wheat residue which was associated with increased supply of N at sowing, increased crop N uptake and a disease break in crops following legume. The wheat grain yield also independently responded (+1.4 t/ha or +46 %) to inputs of N fertiliser up to 40 kg N/ha applied at sowing regardless of residue type (Muschietti-Piana et al. 2019). These results were indicative of the level of demand for N input in this low fertility sand. The concept of using legumes residues with and without N fertiliser was extended to canola in 2017 where again yield was responsive to both residue type (+29-39%) and N fertiliser input (+31-53%, response of 4.4-10.6 kg grain/kg N) on the sandy soil types (Table 2).

**Table 2. 2017 Karoonda canola grain yield (t/ha) in response to residue type and N fertiliser input (where the residue x fertiliser interaction was not significant).**

| | Sand | Sand over clay | Clay loam |
|---|---|---|---|
| | | *Residue Type* | |
| Wheat | 0.79 | 0.70 | 0.78 |
| Lupin | 1.29 | 0.98 | 0.86 |
| P=0.05 LSD | 0.11 | 0.09 | NSD |
| N (kg/ha) | | *N fertiliser input (kg/ha)* | |
| 5 | 0.70 | 0.74 | 0.79 |
| 30 | 0.92 | 0.71 | 0.79 |
| 80 | 1.50 | 1.07 | 0.88 |
| P=0.05 LSD | 0.24 | 0.11 | NSD |

NSD-no significant difference, LSD- least significant difference

A site near Ouyen had canola sown into a broader range of residue types. The different residues resulted in variation in pre-sowing soil mineral N of 39-85 kg N/ha where vetch had the most pre-sowing mineral N (85 kg N/ha) and barley the least (39 kg N/ha). This range in mineral N was found to closely relate to canola grain yield with a response of 13.3 kg grain/ kg mineral N (Figure 1).

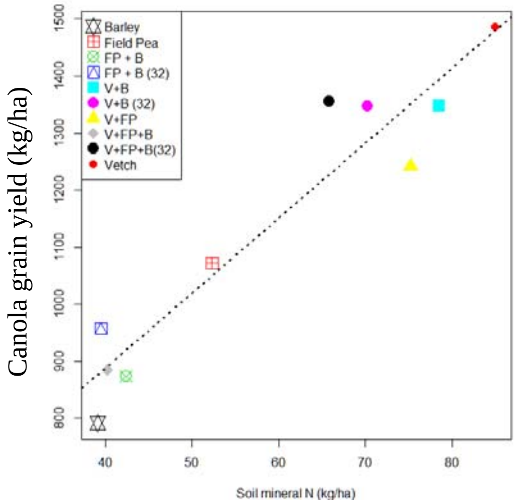


**Figure 1. Relationship between pre-sowing soil mineral N (kg/ha) and grain yield (kg/ha) at Ouyen in 2017 with $R^2$=0.90, P=0.05, where yield=13.3 kg grain/ kg soil mineral N. Residues were barley, field pea, field pea and barley (FP+B), vetch and barley (V+B), vetch and field pea (V+FP), V+FP+B without and with 32 kg N/ha as fertiliser N (32).**

*Rate and Timing*

Analysis of 14 site-years of data where rate and timing effects were measured across decile 1-9 season types, clearly demonstrates that the amount of N applied is the most critical and consistent factor in grain yield response relative to timing (Table 3).

**Table 3. Wheat and canola response to rate represented as kg grain/kg N when significant (P=0.05) and timing represented as % yield gain or penalty due to timing when significant (P=0.05). Where there was an effect of timing, the % response is annotated with the growth stage of bolting for canola and first node (GS31) for wheat.**

| Site | Year | Crop | Soil | Rate Response (kg grain/kg N) | Response to late N application (% yield gain or penalty) |
|---|---|---|---|---|---|
| Karoonda | 2016 | Canola | Sand | 9 | +24 bolting |
| | 2016 | Canola | Sand over clay | 11 | +26 bolting |
| | 2016 | Canola | Loam | 10 | NSD |
| Loxton | 2015 | Canola | Sand | 13 | NSD |
| | 2016 | Wheat | Sand | 18 | NSD |
| | 2017 | Wheat | Sand | 9 | -17 GS31 |
| | 2017 | Wheat | Sand over clay | 12 | NSD |
| | 2017 | Wheat | Loamy Sand | 12 | -8 GS31 |
| Minnipa | 2015 | Canola | Loam | NA | NSD |
| | 2016 | Canola | Loam | 9 | -6 bolting |
| Ouyen | 2015 | Canola | Sand | NA | -15 bolting |
| | 2016 | Canola | Sand | 9 | NSD |
| | 2017 | Wheat | Sand | 16 | NSD |
| | 2017 | Wheat | Sand over clay | 18 | NSD |

NSD-no significant difference. Dose response is calculated as the grain yield generated in the yield maximising treatment over and above minimum (5kg N/ha) or no N input. NA- not available as variation in dose was not tested. The yield maximising rate was 40-60 kg N/ha for wheat and 70-90 kg N/ha for canola.

There was variation between sites, soils and seasons in the level of response to N fertiliser but the responses were considerably lower than the benchmark of 25 kg grain/kg N. With respect to timing, the effects were largely seasonal. The wet spring of 2016 at Karoonda generated a positive response to bolting applications of N fertiliser in canola while the dry seasons of 2015 and 2017 generated negative responses to late applications of N in wheat and canola (Table 3.) In general, where the opportunity to topdress substantive areas ahead of adequate rainfall for incorporation are more limited in low rainfall environments, it would appear that optimising the rate upfront or early in the growing season will be important for the closure of yield gaps.

*Cultivar based differences in N use efficiency*

The 2018 growing season (April-October) had just 123 mm of rainfall at Karoonda, but yields in excess of 1 t/ha were achievable with the hybrid canola on sands at the higher levels of N input. On all soil types there was significantly more canola grain yield at each level of N input for the hybrid (Fig. 2). The hybrid N use efficiency was always higher than OP on sands but had limited response to the relatively high input of 90 kg N/ha on the heavier loam in a dry season.

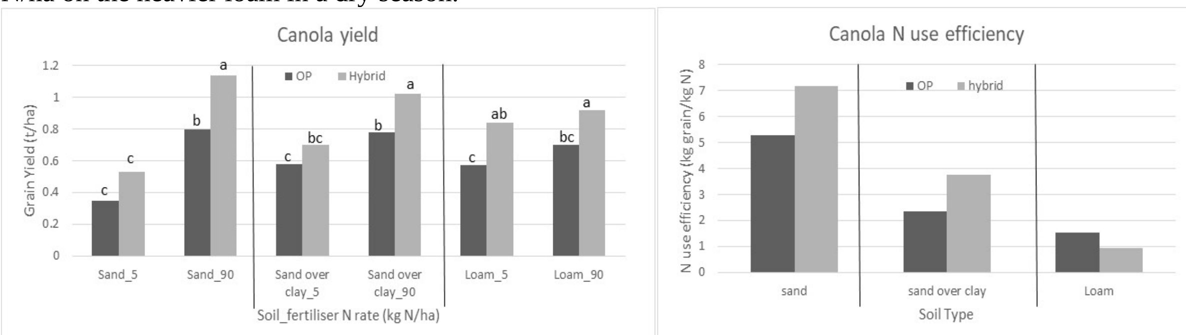


**Figure 2. Yield (t/ha) (left) of hybrid and open pollinated (OP) canola (cultivars 43Y92 cl and ATR Stingray) to inputs of 5 and 90 kg N/ha on three soil types at Karoonda in 2018. The N use efficiency (kg grain/kg N) of the cultivars is represented on the right. Within a soil type a significantly different result is annotated with a different letter (P=0.05).**

The hybrid (43Y92 cl®) required a lower level of N input per unit yield when compared to OP (ATR Stingray®). This is a critical benefit given the higher cost of hybrid seed. A broader range of N rates on the responsive soil types in a diverse set of season types is required to ascertain the yield and profit maximising levels of input.

## Conclusion

The efficient use of N remains a critical requirement for closing yield gaps and managing risk in low rainfall and sandy environments. Manipulation of the rate of N from both legume and fertiliser sources provides substantive productivity gains in both canola and wheat. Manipulation of the timing of N input is of lesser importance, making upfront a potentially attractive management option on these soils. The potential for a higher N use efficiency in new cultivars of canola offers a promising avenue for either reducing N inputs for a target yield or producing more yield per unit N input.

## Acknowledgements

The authors acknowledge the funding provided by the GRDC (Projects MSF0003, CSP00186, CSP00187). We are grateful to the host landowners and the technical input of Bill Davoren, Willie Shoobridge, Stasia Kroker, Marcus Hicks, Moodie Agronomy and the SARDI New Variety Agronomy group.

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