Trial Report

Technical Summary

NGN – N Banking strategies to manage variable and unpredictable nitrogen demand in the LRZ of the Southern Region

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Key Messages

- 2022 was the first season comparing the N bank management strategy on different soil types to more conventional methods.
- Multiple years are needed for a valid comparison – at the moment they are just N rate experiments.
- At the N responsive sites Yield Prophet® treatments resulted in more applied fertiliser than N bank treatments in a favourable (>decile 7) season and thus outperformed N bank treatments.
- Post harvest soil sampling indicated that soil mineral N either remained the same or increased under the increasing rates of N fertiliser applied.

Background

Australian wheat yields are only half what they could be for the rainfall received (Hochman *et al.* 2017). Nitrogen (N) deficiency is the single biggest factor contributing to this yield gap. This is also likely to be true for other non-legume crops (barley, canola and oats) and this reduces farm profitability. Alleviating N deficiency has the potential to increase national wheat yields by 40 per cent (Hochman and Horan 2018).

On farms with no legume pastures, most of the crop N supply must come from N fertiliser. Grain legumes do not provide enough N to support yield of subsequent crops at the intensity at which they are currently grown. N fertiliser is a costly input, and its use increases the cost of production and value-at-risk for growers. Growers fear over-fertilisation will result in 'haying off', which reduces both yield and quality. There is also concern that overapplied fertiliser not used by crops is lost to the environment through leaching, volatilisation, and denitrification. Consequently, efforts are made to match N fertiliser inputs to seasonal yield potential. This is difficult in southern Australia due to the lack of accurate seasonal forecasts for rainfall. The difficulty in matching N supply to crop demand and a tendency for growers to be conservative in their N inputs is responsible for a large proportion of the yield gap explained by N deficiency.

In 2022, as part of the GRDC's NGN process, growers identified that current approaches utilised to determine tactical N applications utilise N crop demand (i.e., yield potential) to estimate N supply. This has a high level of uncertainty linked with it due to errors associated with prediction of August to October rainfall. The GRDC thus invested in a one-year research project across six different sites within the low rainfall zone (LRZ) to evaluate the potential for different N management systems to simplify the approach to N management and profitably close the yield gap for non-leguminous crops, with the view that work around N management approaches will continue to be pursued through the National Risk Management Initiative.

The N banking approach aims to maintain a base level of soil mineral N that is topped up each season to a target N bank level that is most appropriate for a given location to achieve the water-limited yield potential in most seasons. Through previous work undertaken by Hunt et al. (2022) this strategy has been identified as a promising approach to manage N in crop production areas with low environmental losses (i.e., leaching, denitrification).

Aim

To validate a range of 'N banking targets' (and respective N budget scenarios) and compare to traditional 'N crop demand driven strategies' to establish potential profits and risks associated with both.

Trial Details

Table 1. GPS coordinates, crop type, sowing and harvest dates for the six LRZ trial sites.

Site	GPS Coordinates	Crop Type	Variety	Sow Date	Harvest Date
Birchip	-35.777879, 142.852193	Barley	MaximusCL	15/05/2022	28/11/2023
Carwarp	-34.496576, 142.208837	Barley	Compass	22/04/2022	19/12/2022
Cootra	-33.22763, 135.94484	Wheat	Scepter	30/04/2022	9/12/2022
Curyo	-35.800844, 142.685156	Wheat	RazorCL	19/05/2022	7/12/2022
Walpeup Constrained* (East)	-35.125686, 141.974851	Barley	CommodusCL	22/05/2022	29/12/2022
Walpeup Unconstrained (West)	-35.125552, 141.971262	Barley	CommodusCL	22/05/2022	27/12/2022

**Note the constrain at the Walpeup site is soil compaction*

Trial Inputs

These experiments were kept free of weeds, pests and diseases as per current best management practices.

Nitrogen fertiliser at each site was applied as per table 2.

Table 2. Nitrogen fertiliser (starter and top-dressed urea) applied to different treatments in 2022 across the six LRZ sites.

	Total N fertiliser applied (kg N/ha)					
Treatment	**Birchip***	**Carwarp**	**Cootra**	**Curyo**	**Walpeup Constrained (East)**	**Walpeup Unconstrained (West)**
Nil N	0	3	14	7	0	0
District Practice	0	26	70	-	80	80
YP Lite Decile 1	0	82	14	-	115	98
YP Lite Decile 2-3	17	106	50	-	176	159
YP Lite Decile 5	61	142	78	-	263	246
YP Lite Decile 7-8	181	194	126	-	367	350
YP Lite BoM	181	194	126	-	367	350
N Bank Conservative	0	3	14	-	76	59
N Bank Optimal Profit	18	26	14	-	130	113
N Bank Optimal Yield	43	51	34	-	185	167
Replacement	-	-	-	42	-	-
National Average	-	-	-	45	-	-
100% YP	-	-	-	13	-	-
75% YP	-	-	-	62	-	-
50% YP	-	-	-	88	-	-
25% YP	-	-	-	38	-	-
N Bank 100kg/ha	-	-	-	68	-	-

N Bank 125kg/ha	-	-	-	130	-	-
N Bank 150kg/ha	-	-	-	136	-	-

**Note 80 kg/ha urea was applied in season by the grower at the Birchip site prior to trial establishment. This N was accounted for in the soil test data and not in the nitrogen fertiliser applied.*

Method

The five experiments (Birchip, Walpeup Constrained (East), Walpeup Unconstrained (West), Carwarp and Cootra) established in 2022 used a randomised complete block design to evaluate the performance of the different N management systems. The three systems being tested are below and within systems one and two there were different treatments targeting different yield potentials:

1. Matching N fertiliser to seasonal yield potential (Yield Prophet® (YP) Lite)
    - YP Lite Decile 1
    - YP Lite Decile 2-3
    - YP Lite Decile 5
    - YP Lite Decile 7-8
    - YP Lite BoM (BoM forecast at the time of N application decision making)
2. Maintaining a base level of fertility using N fertiliser (N banks)
    - N Bank Conservative (25 kg N/ha less than Optimal Profit)
    - N Bank Optimal Profit
    - N Bank Optimal Yield (25 kg N/ha more than Optimal Profit)
3. Current average N application rate for a specific region (District practice)

The N Bank targets were determined by the average economic yield for each specific location and the average annual rainfall using the equation from Meier et al. (2021). A few different targets to evaluate if the relationship was correct (e.g., The N Bank Conservative and N Bank Optimal Yield) were also added. The +/- 25 kg N/ha difference was selected due to what has worked well at the longer-term N Bank trial located at Curyo.

The one ongoing experiment (Curyo) established in 2018 also used a randomised complete block design to evaluate the performance of the different N management systems. The four different systems being tested are below and within systems one and two there were different treatments targeting different yield potentials:

1. Matching N fertiliser to seasonal yield potential (Yield Prophet® and Yield Prophet® (YP) Lite)
    - 100% YP: yield with lowest yielding season finish on record (YP Lite Decile 1)
    - 75% YP: yield with lower yielding season finish (YP Lite Decile 2-3)
    - 50% YP: yield with medium season (YP Lite Decile 4-7)
    - 25% YP: yield with higher yielding quartile season finish (YP Lite Decile 8-9)
2. Maintaining a base level of fertility using N fertiliser (N banks)
    - N Bank 100 kg N/ha
    - N Bank 125 kg N/ha
    - N Bank 150 kg N/ha
3. Replacing the amount of N removed in grain each year with fertiliser in the next season (replacement)
4. Applying national average N fertiliser rate (45 kg/ha) each season (NA)

All systems were compared to a nil control which received only starter fertiliser except the Birchip site which had received some in season N in 2022 (this occurred as result of all trials being established in grower sown crops and site selection occurring in late autumn/early winter). For the N bank treatments there were different target levels of N fertility (N bank targets). N fertiliser rates in these treatments were calculated as the N bank target value minus soil mineral N (kg/ha) measured prior to in-season urea application (Table 3).

Table 3. N Bank targets for the six LRZ experimental sites.

	N Bank Target (kg N/ha)					
Treatment	**Birchip**	**Carwarp**	**Cootra**	**Curyo**	**Walpeup Constrained (East)**	**Walpeup Unconstrained (West)**
N Bank Conservative	100	55	90	-	90	90
N Bank Optimal Profit	125	80	115	-	115	115
N Bank Optimal Yield	150	105	140	-	140	140
N Bank 100	-	-	-	100	-	-
N Bank 125	-	-	-	125	-	-
N Bank 150	-	-	-	150	-	-

All gross margins were calculated assuming a N fertiliser cost of $1.60/kg N, grain prices as per the 5-year averages in the 2022 SAGIT Gross Margin Guide as well as the total variable costs for APW wheat, canola – Clearfield hybrid and feed barley as per the 2022 SAGIT Gross Margin Guide (SAGIT 2022).

Results

There was a positive relationship between N rate and yield response across the LRZ sites, except for the Birchip site (Figure 1). Grain yield was generally consistent across applied N rate treatments at the Birchip site, suggesting that yield at this site is limited by a factor other than N, and likely affected, at least in part, by the severe waterlogging that occurred in spring 2022 (See Appendix 1, Figure 5). The Walpeup Constrained (E) site District Practice treatment appears to be a bit of an outlier with higher yields in comparison to other treatments with similar fertiliser N applied rates. This difference in yield could be due to the spatial variability of the soil at the site as it is located on a sand hill.

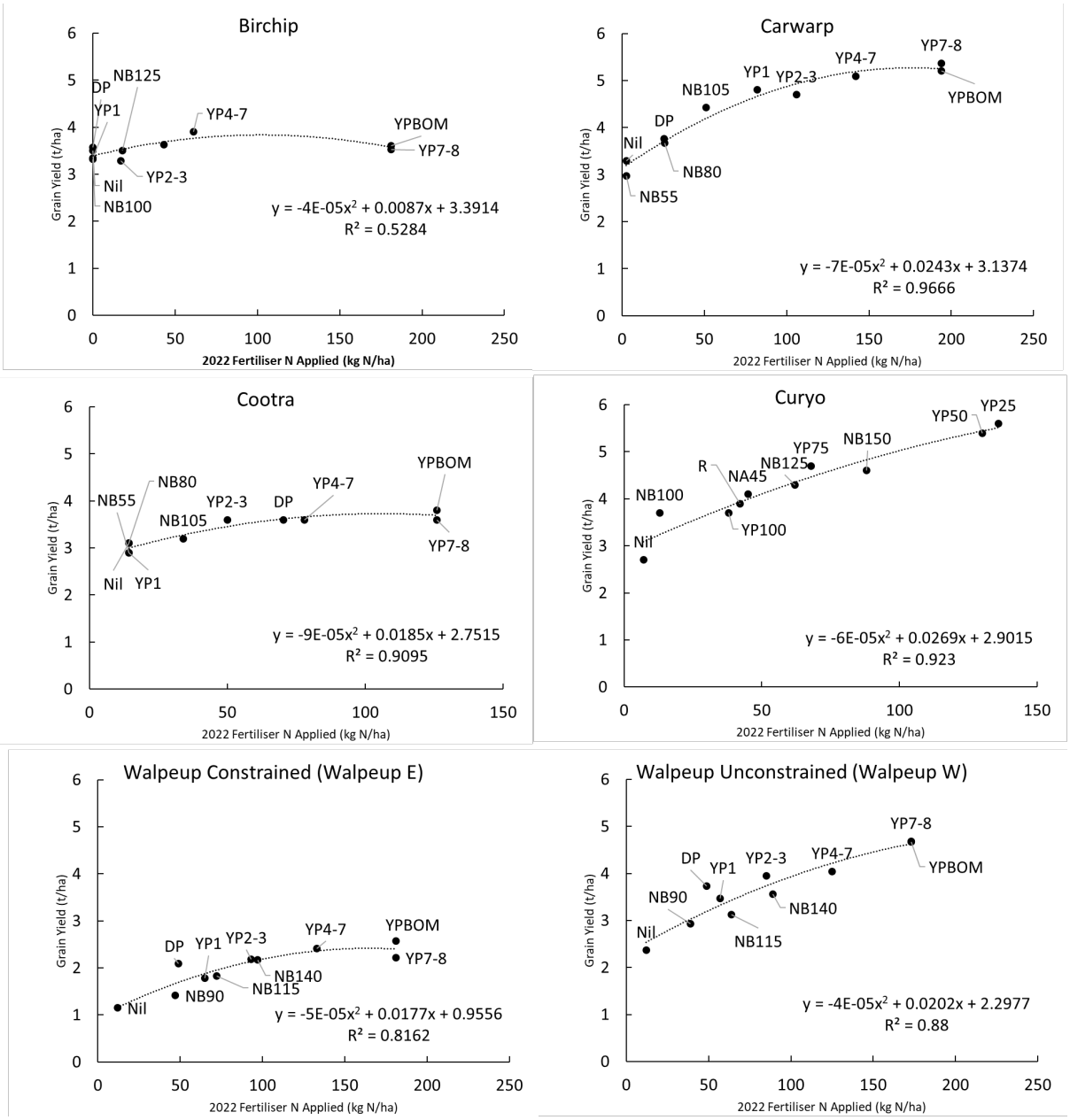

Figure 1. Grain yield (t/ha) response from the different N management strategies (Nil = Nil N, DP = District Practice, YPx = Yield Prophet Lite Decile x (or for Curyo YPx = Yield Prophet x%), YPBOM = Yield Prophet Lite BoM Forecast, NBx = N Bank Target x, R = replacement, NA45 = national average) at Birchip, Carwarp, Cootra, Curyo, Walpeup Constrained (Walpeup E) and Walpeup Unconstrained (Walpeup W), 2022.

A positive relationship was observed between N application rate and grain protein for all sites. The high N applied treatments, Yield Prophet Lite BoM and Yield Prophet Lite Decile 7-8 (and for the Curyo site Yield Prophet 25% and 50%) resulted in higher grain protein (Figure 2).

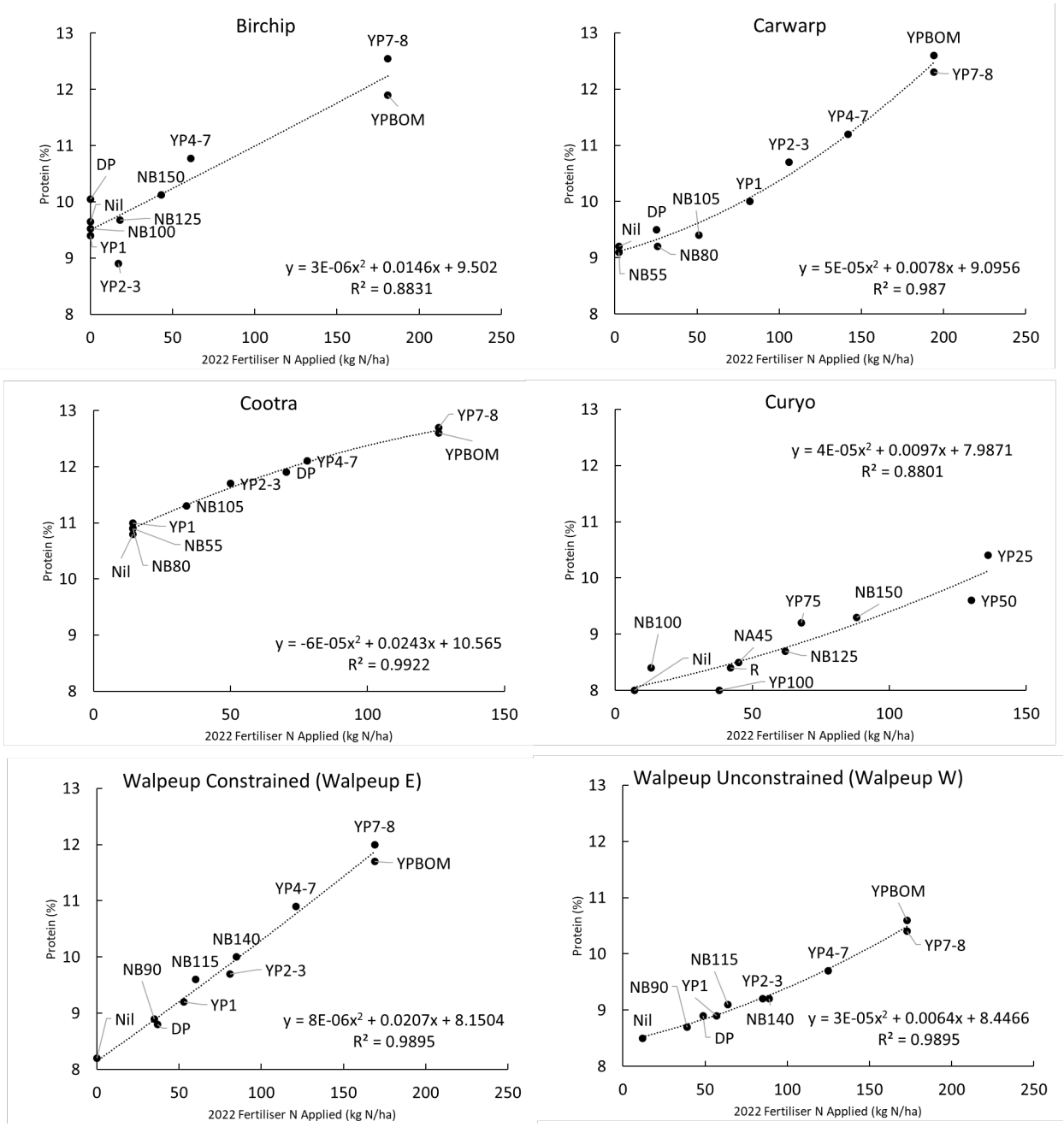

Figure 2. Protein (%) response from the different N management strategies (Nil = Nil N, DP = District Practice, YPx = Yield Prophet Lite Decile x (or for Curyo YPx = Yield Prophet x%), YPBOM = Yield Prophet Lite BoM Forecast, NBx = N Bank Target x, R = replacement, NA45 = national average) at Birchip, Carwarp, Cootra, Curyo, Walpeup Constrained (Walpeup E) and Walpeup Unconstrained (Walpeup W), 2022.

Despite all sites being N responsive in terms of yield, except Birchip in 2022, not all were as profitable from the increasing rates of N applied in season. The Curyo and Walpeup Unconstrained sites were more profitable with more N applied, Birchip was less profitable with increasing N applied and for Carwarp and Cootra, N applied at rates of 100-150 and 50-100 kg N/ha respectively were generally more profitable than those at 200 and 100-150 kg N/ha, respectively (Figure 3). At the Walpeup Constrained site, unlike the other sites where all treatments were profitable, the low and high applied N fertiliser rates would have cost the grower money. The District Practice treatment again stands out at this site with it being more profitable than other treatments with the same amount of fertiliser applied N. This difference would be largely driven by the higher yields achieved in this treatment.

Interestingly at the sites established in 2022 the Yield Prophet Decile 4-7 treatment was near the top of the curve (most profitable) which will be fascinating to see how it continues to perform over several seasons.

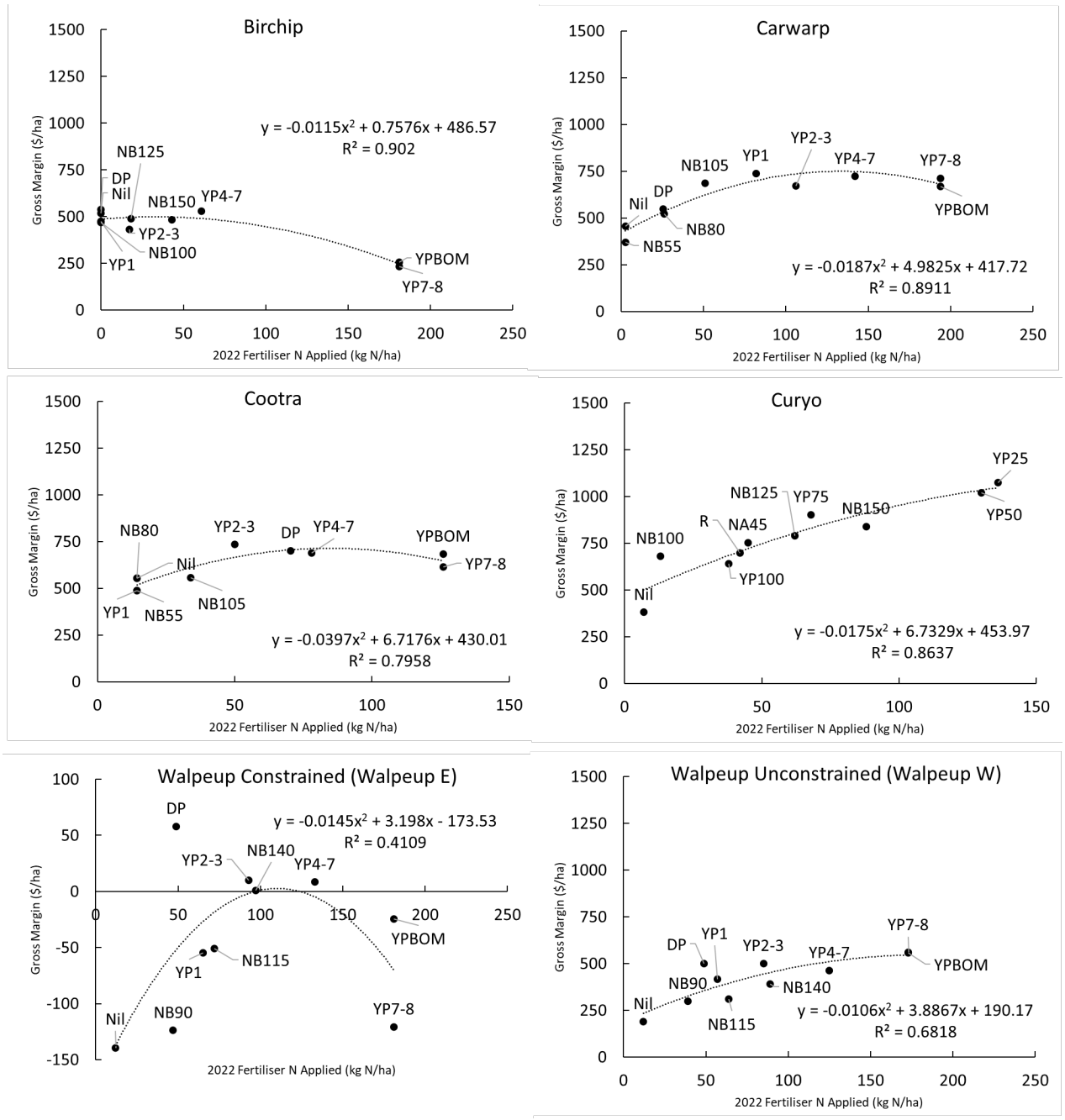

Figure 3. Gross margin ($/ha) impact from the different N management strategies (Nil = Nil N, DP = District Practice, YPx = Yield Prophet Lite Decile x (or for Curyo YPx = Yield Prophet x%), YPBOM = Yield Prophet Lite BoM Forecast, NBx = N Bank Target x, R = replacement, NA45 = national average) at Birchip, Carwarp, Cootra, Curyo, Walpeup Constrained (Walpeup E) and Walpeup Unconstrained (Walpeup W), 2022.

Post harvest soil sampling showed that at the Curyo, Walpeup Constrained and Walpeup Unconstrained sites there was a low correlation between soil mineral N and the amount of N fertiliser applied in the 2022 season (Figure 4). This is surprising and requires further investigation. At Birchip, Carwarp and Cootra however, there was a positive correlation between increasing N applied fertiliser rates and increasing soil mineral N (Figure 4).

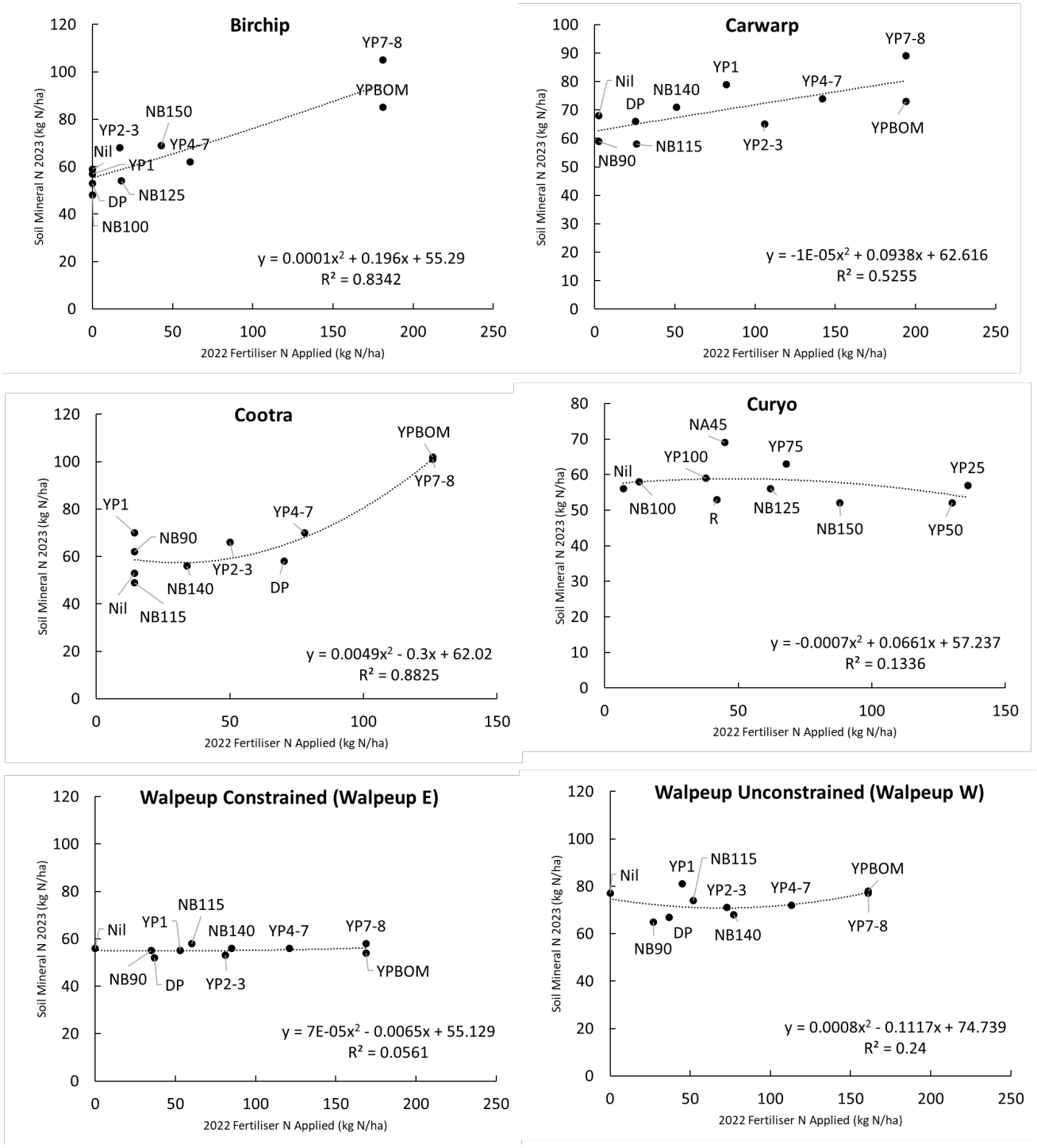

Figure 4. Soil mineral N (kg N/ha) post-harvest in 2023 to depth of 1m under the different N management strategies (Nil = Nil N, DP = District Practice, YPx = Yield Prophet Lite Decile x (or for Curyo YPx = Yield Prophet x%), YPBOM = Yield Prophet Lite BoM Forecast, NBx = N Bank Target x, R = replacement, NA45 = national average) at Birchip, Carwarp, Cootra, Curyo, Walpeup Constrained (Walpeup E) and Walpeup Unconstrained (Walpeup W), 2022.

Discussion

2022 was the first season comparing the N bank management strategy to more traditional approaches across several locations in the LRZ of the Southern region. Across all sites the season was very favourable for crop production with above average rainfall in the lead up to sowing as well as during the grain filling period in spring (see Appendix 1 for individual site rainfall information). All sites received decile 10 rainfall for the growing season (April to October) and the crop year (November to October).

Overall, the N bank approach performed as expected during year one of these experiments in a favourable season. As water was not limiting, the trials became N rate response experiments and it was those treatments that applied more N fertiliser i.e., Yield Prophet Lite Decile 7-8 and Yield Prophet Lite BoM (Yield Prophet 25% and Yield Prophet 50% at Curyo) that outperformed the N Bank treatments in terms of yield and protein, at the N responsive locations (Carwarp, Cootra, Curyo, Walpeup Constrained and Unconstrained). Interestingly this however didn't necessarily translate into profitability with the Yield Profit Decile 4-7 in the 2022 season appearing to be consistently more profitable (Figure 4).

The N bank approach is however a long-term strategy thus these experiments need to be run over multiple seasons to effectively assess this N management approach. The 2022 season results suggest that crop N demand is not meet under the N banks in very wet (> decile 7) seasons, this strategy however aims to meet the N needs of the crop in most but not all seasons thus how the N bank approach performs under a range of different seasons at these locations and soil types needs to be determined. Further analysis is also needed at the non-N responsive site (Birchip) to better understand the potential drivers behind its lack of response.

References

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Acknowledgments

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We thank all growers who have hosted these experiments.

Appendix 1

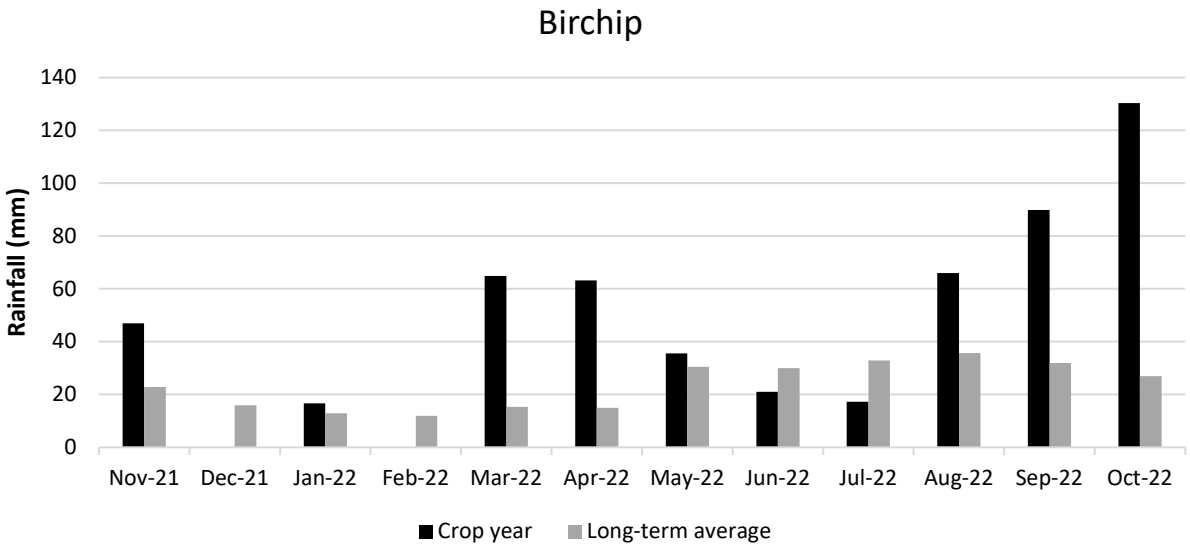

Figure 5. Crop year and long-term average rainfall (mm) for Birchip, 2021-2022.

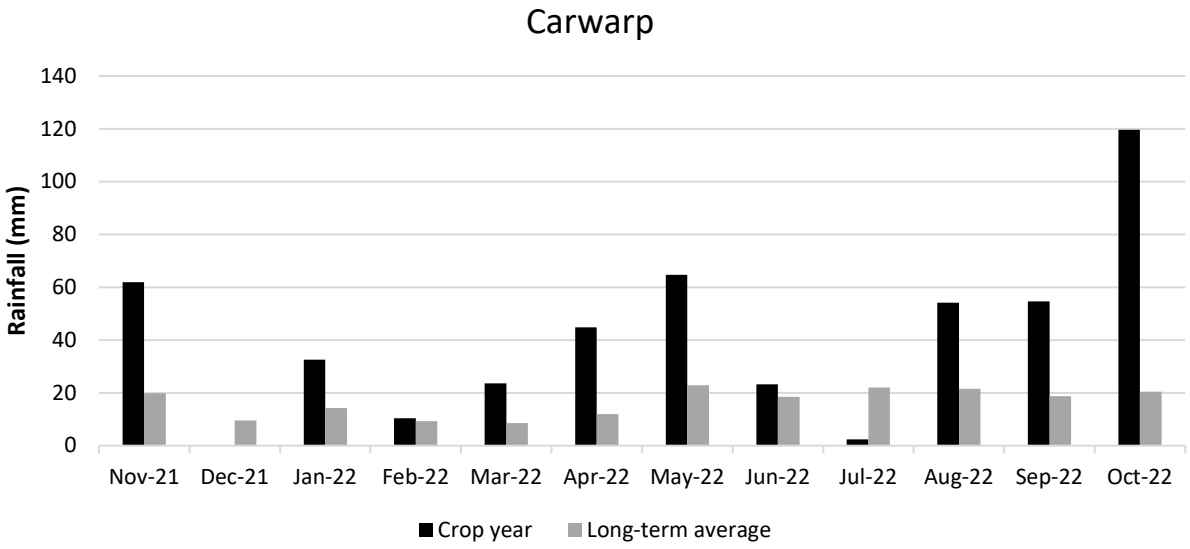

Figure 6. Crop year and long-term average rainfall (mm) for Carwarp, 2021-2022.

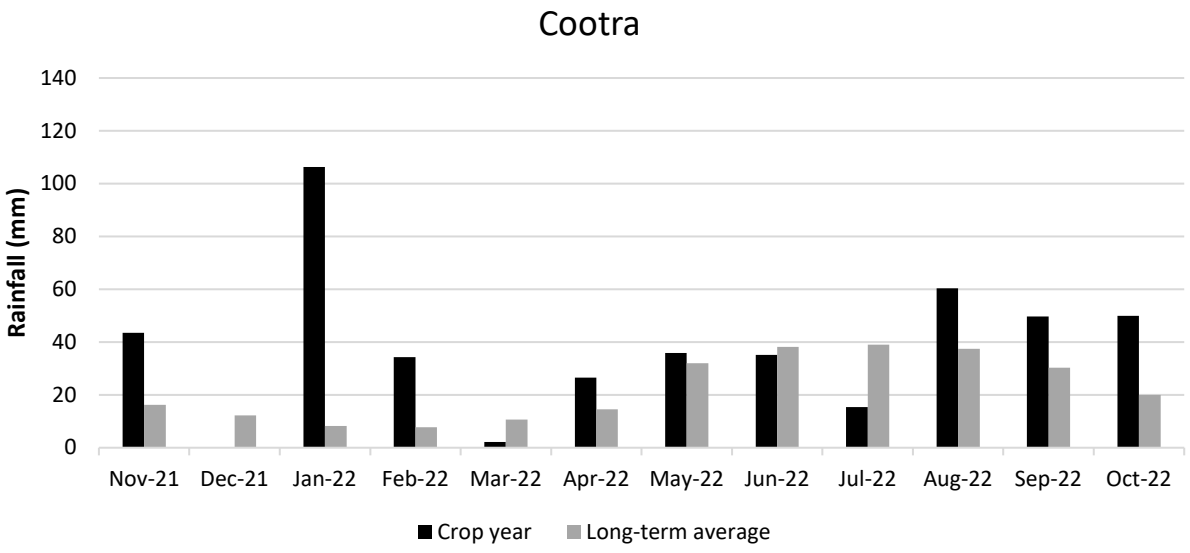

Figure 7. Crop year and long-term average rainfall (mm) for Cootra, 2021-2022.

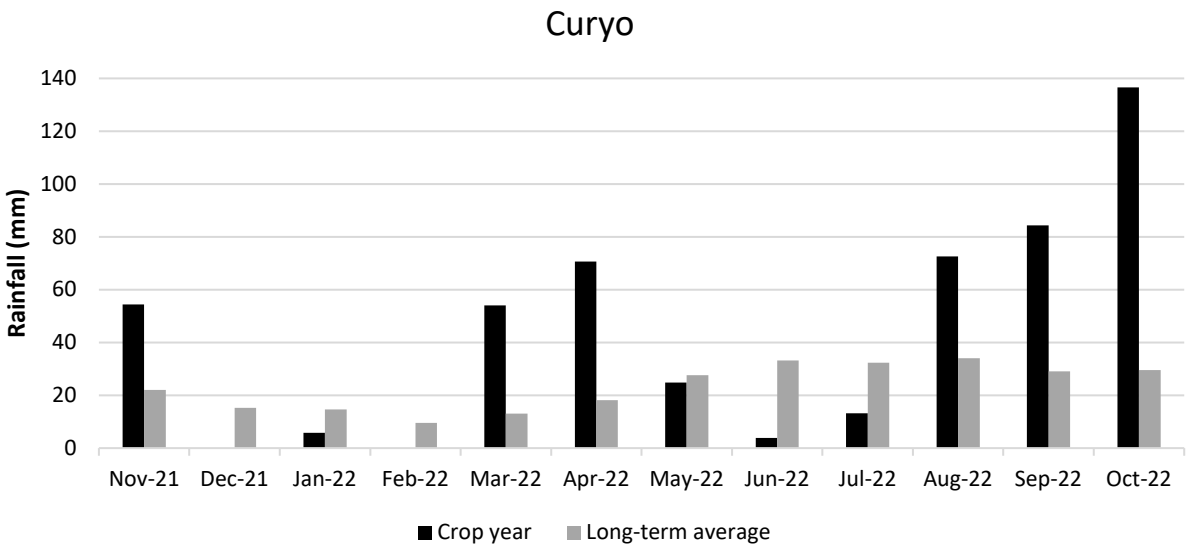

Figure 8. Crop year and long-term average rainfall (mm) for Curyo, 2021-2022.

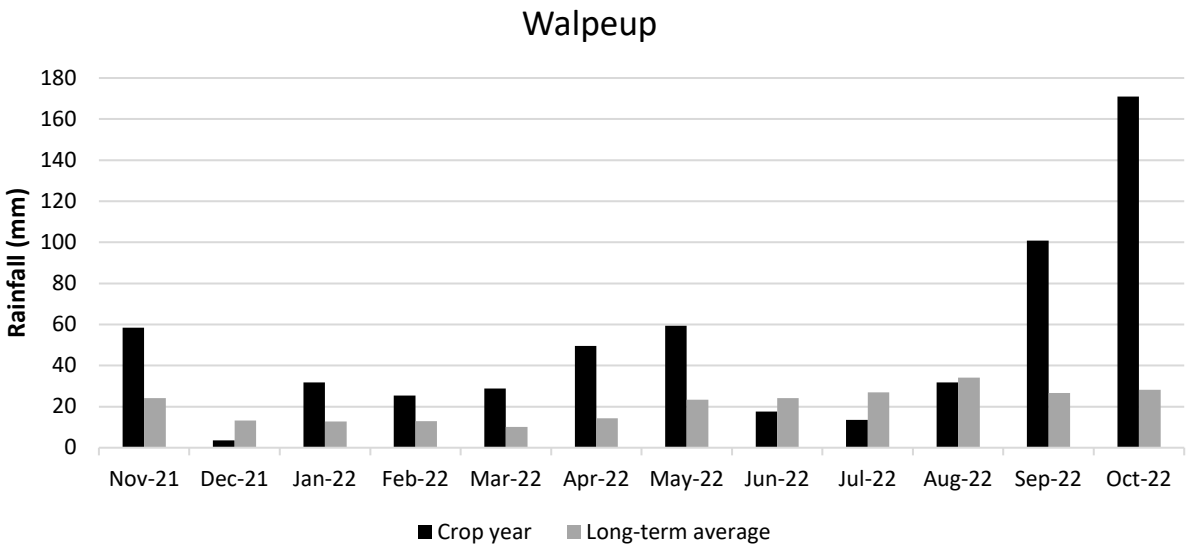

Figure 5. Crop year and long-term average rainfall (mm) for Walpeup, 2021-2022.