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GRAINS RESEARCH & DEVELOPMENT CORPORATION

## Final Technical Results Report

# 2023
# Increasing the profitability of the double break rotation in the MRZ of WA Wheatbelt through incorporation of an early sown high value pulse

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REPORT SENSITIVITY

Does the report have any of the following sensitivities?

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| Intended for journal publication | YES ☐ NO ☒ |
| Results are incomplete | YES ☐ NO ☒ |
| Commercial/IP concerns | YES ☐ NO ☒ |
| Embargo date | YES ☐ NO ☒<br>If Yes, Date: <Choose date> |

# Contents





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# ABSTRACT

The effectiveness of a double break crop rotation was evaluated across 6 sites and three years in the Western Australian Wheatbelt region. A double break, consisting of canola or fallow (depending on rainfall zone) was followed by a high value legume and then a cereal crop on a wide range of soil types that are prevalent across the region. The impact of early vs late sowing for the high value legume was also investigated. Crop growth was monitored along with grain yield and the Gross Margin was calculated to give a return on the three-year crop sequence. It was found that incorporating canola or fallow, followed by an early-sown high value legume (chickpea, lentil) was a profitable crop sequence that increased grain yield of the following cereal crop. Interestingly, chickpea were a consistent performer at most sites on a range of soil types (deep sands, sandy loams) as well as clay soils. This indicates that the area suitable for chickpea production may now be greater following the successful amelioration of soil constraints in this region. The inclusion of chickpea or lentil in the crop sequence did lead to an increase in weed populations, however this did not cause any management issues in the following cereal crop.




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## EXECUTIVE SUMMARY


Break crops are widely acknowledged as being necessary to manage the biological constraints that reduce cereal crop production. However, one of the constraints in the use of break crops is that the Gross Margin of the commonly used break crops are generally less than growing a cereal crop. To combat severe biological constraints to crop production (high weed population and/or soil pathogens) break crops have traditionally been used as a single crop in rotation. The use of two break crops in sequence has been shown to improve the effectiveness of this approach, particularly as shifts in disease presence, and increases herbicide resistance in weeds has reduced the effectiveness of a single break crop. However, the use of break crops is limited to situations where the biological constraint has a greater impact on profitability relative to the lower profitability (Gross Margin) of the break crop.

The most desired traits of a break crop are to be highly effective in controlling weeds and soil pathogens while also being highly profitable. Current highly effective break crop options of canola and lupin are rated as moderate to low profitability (respectively) by growers, while pasture phases or fallow period generally result in a low or negative Gross Margin.

This study investigated the profitability of growing canola (with effective weed control options) followed by a high value legume (with higher economic value) as an effective and profitable double break crop sequence. The contribution of an early sowing date versus a traditional sowing date to further increase the profitability of the high value legume was also evaluated.

The double break crop sequence was evaluated at 6 demonstration style sites (with no replication) over three years in the Western Australian Wheatbelt region. An existing paddock of canola or fallow (depending on rainfall zone) was selected to grow a high value legume and then follow this with a cereal crop on a wide range of soil types that are prevalent across the region. Crop growth was monitored along with grain yield, and the Gross Margin was calculated to give an overall return on the three-year crop sequence. Rainfall at most sites had a combination of a below and above average seasonal rainfall that impacted on the growth and grain yield of either the double-break crop or the following cereal crop, but not both.

There was large variation in the Cumulative Gross Margin of the double-break crop sequence of Canola (or Fallow) followed by a legume and a cereal crop and was reflective of the range of annual rainfall and grain yield potential for each site. Within each site, a strong trend was that the inclusion of a double-break crop led to a similar or greater cumulative Gross Margin. Within the double-break legume phase, the early time of sowing tended to give an increase in grain yield for chickpea and this was a significant driver of the increase in Gross Margin. Some sites were discontinued after the high value legume year following poor crop growth and this resulted in a lower two-year Cumulative Gross Margin compared to growing wheat after a single break.

The was a trend that the Gross Margin of cereal crops was improved in the third phase of the crop sequence following a double break crop sequence. There was no consistent trend in the effect of time of sowing for chickpea on subsequent cereal grain yield, however, the Gross Margin and grain yield were increased by the preceding legume crop when the legume grain yield was low, independent of the time of sowing.

There was also a trend that the total weed population in the third-year cereal or second-year legume were higher after the double break crop sequence compared to standard practice of growing two cereal crops following canola or fallow (when measured at GS.30 growth stage





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for cereals). The use of canola or fallow as the first crop in the double break sequence appeared effective at lowering weed numbers, while weed populations tended to be higher in the high value legume year. Weed control in the cereal crop year appeared effective in ensuring that weed populations do not get out of control as total weed population was around 50 plants/m$^2$ for double break crop sequences.

The impact of double break crop sequences on the four main soil pathogens in WA was not clear in this study. The level of soil pathogen varied between sites and years, with the major soil pathogens being P.*neglectus* and R. *solani* AG8. Within each site, there was evidence that each crop sequence had a greater impact on changing the relative proportions of soil pathogens rather than an overall reduction in pathogen levels. The structure of this study limited the collection of soil pathogen data prior to the double break being implemented.

While by no means conclusive, the data collected in this study indicates that weed populations are likely to increase in the legume phase of the double break sequence, but this does not cause a weed 'blowout' in the subsequent cereal crop. A barrier to successful weed control was encountered in this project where we found very limited knowledge among agronomic advisors on how to successfully grow high value legumes, especially in applying effective herbicide packages using the new chemical options now available.

This study has shown that a double break crop sequence can be more profitable than a single break where a high value legume (chickpea) can be successfully grown across the Wheatbelt of WA. This was shown across a range of soil types and rainfall zones in this study, with a key outcome being that chickpea were successfully grown in soil types and regions that were not considered to be suited to growing this legume crop. The early seeding of a high value legume in Mid-April rather than Mid-May was an effective practice to increase grain yield and drive profitability of the legume compared to the late sowing timing for every paired sowing date. It appears that the potential for chickpea to be a profitable break crop is underestimated in WA with the current agronomy packages and genetic material available.

Profitable growth of high value legumes in WA is likely to require a similar need to store and market the grain to maximise the high value nature of these legumes, and this will need to be a consideration for growers when considering adoption of growing a high value legume.


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# BACKGROUND

Break crops are widely acknowledged as being necessary to manage the biological constraints that reduce cereal crop production. While break crops have traditionally been used as a single crop in rotation, the use of two break crops in sequence has been shown to greatly increase cereal crop production and profitability, particularly as shifts in disease presence, and increases herbicide resistance in weeds has reduced the effectiveness of a single break crop.
One of the constraints in the use of a single or double break crop sequence is that the Gross Margin of the most commonly used break crops are generally less than growing a cereal crop. Growers need to balance the short-term decrease in economic return from growing a break crop with the longer-term benefits of decreased production costs and increased productivity of cereal crops for many years following. As a result, break crops are used sparingly by growers in crop rotations with the aim of maintaining the most profitable sequence of crops while maintaining reasonable control of weeds and diseases.
The most desired traits of a break crop are to be highly effective in controlling weeds and disease while also being highly profitable. Current highly effective break crop options of canola and lupin are rated as moderate to low profitability (respectively) by growers, while pasture phases or fallow period generally result in a low or negative Gross Margin.

The integration of high value legumes such as chickpea or lentil have been successful in medium to low rainfall environments of Eastern Australia to improve crop rotation profitability while maintaining effective weed control. Recent studies in WA found that profitable grain yields of both chickpea and lentil are achievable in the medium rainfall zone (MRZ) of the WA Wheatbelt. The impact of earlier sowing of these pulses has also been demonstrated to significantly increase in the profitability of these high value legumes. The downside of high value legumes is that potentially these break crop options have less developed (and therefore less effective) weed management packages for the WA environment.


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# PROJECT OBJECTIVES

The objective of this trial is to demonstrate that growing canola (with effective weed control options) followed by a high value legume (with higher economic value) can lead to an effective and profitable double break crop sequence. The contribution of an early sowing date versus a traditional sowing date to increase the profitability of these crops will also be evaluated.

This project will determine the economic value of growing canola followed by a high value legume, and the impact of this rotation on the grain yield and profitability of a cereal crop in the first year following the double break crop sequence.


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# METHODOLOGY

Six sites were established across medium and low rainfall zone (MRZ) of the WA wheatbelt covering the main soil types and regions where high value legumes can be grown, and where there was considered a reliable rainfall pattern for legume production. Each site was managed by a local grower group who were responsible for co-ordinating the activities of the site with the host farmer, data collection, and communication of outcomes of the project in their local region. These groups included: the Liebe group, Corrigin Farm Improvement Group (CFIG), Facey group, along with the West Midlands Group (WMG).

Each site was set up as a demonstration style site in paddocks that grew canola in 2019 or 2020, or fallow in 2020, to form the first year of the double break crop sequence. The demonstration site of a range of high value legumes at differing sowing times was established in the first year of the study, being the second year of a double break phase. Each demonstration strip fit in with the host growers' current practices and were either 200m long by the width of the harvester, or 100m long by the width of the sprayer and with no replication. All sites were sown, sprayed, and harvested with grower scale equipment.

At each site there was a comparison of a high value legume (chickpea or lentil, depending on the soil type and species suitability) against standard grower practice of growing a cereal crop following canola. There were two times of sowing (TOS) for the high value legume: early (aim for mid-April) and late (mid-late May). The control treatment (cereal crop) was sown on the farmer determined date that maximised grain yield for the region (current grower practice). A comparison treatment of a second alternative break crop option available to the host grower was also included at some sites. In the second year of the project (third year of the break crop sequence), a cereal crop was sown across the whole site to determine the effect of varying crop sequences on crop growth and grain yield.

Soil nutrient, moisture, and PredictaB tests were collected at the beginning of the season to a depth of 50cm to inform the host grower of the depth of seeding for the chickpea and lentil, and to assess the nutrient requirements and presence of any chemical barriers in the soil (eg. Acidity, nutrient toxicity). Where the soil was dry to a depth of 12 cm, the chickpea and lentil were to be sown at 5cm and this was considered as dry seeding of the legume. Where soil moisture was present at a soil depth of <12 cm, the chickpea and lentil seed were to be sown at a depth of up to 12 cm to allow for early establishment of the crop. Deep seeding of legumes was to be achieved by using the deep banding boot of the seeder and placing the fertiliser through the seed boot. The second time of sowing was to occur 2-4 weeks after the break of the season into adequate soil moisture to allow for immediate germination of the crop. The cereal crop comparison treatment and the current legume comparison crop will be sown using current grower practices.

The collection of in-season crop production data was completed by each local grower group using standardised sampling procedures to enable the data to be aggregated for analysis across the MRZ. The agronomic plan for each crop at each site was determined by grower groups in consultation with local agronomists and in conjunction with the WMG.

**Table 1. Study years for the eight sites in this study that denote the The Cuballing and Latham sites were discontinued after the first year due to poor double break crop growth, while the Dandaragan site was sown to a third break crop in 2022.**

| Site | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| Cuballing | Canola | Discontinued | | |
| Latham | Canola | Discontinued | | |
| Moora | Canola | Double Break | Cereal | |


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|---|---|---|---|---|
| Wadderin | Canola | Double Break | Cereal | |
| Wickepin | | Canola | Double Break | Cereal |
| Dandaragan | | Canola | Double Break | Discontinued |
| Dalwallinu | | Fallow | Double Break | Cereal |
| Narembeen | | Fallow | Double Break | Cereal |

**Table 2. Soil pH at each site to a depth of 50 centimetres at the start of this study. Note: Dalwallinu site subsoil was tested in *10-20cm and *20-30cm layers.**

| Site | 0-10 cm | 10-30 cm | 30-50 cm |
|---|---|---|---|
| Moora | 6.6 | 4.4 | 5.3 |
| Latham* | 6.0 | 5.5 | 5.4 |
| Cuballing | 4.9 | 5.5 | 5.8 |
| Wadderin | 5.5 | 7.1 | 7.7 |
| Dalwallinu | 8.7 | 8.7* | 8.9** |
| Dandaragan | 4.9 | 4.6 | 5.0 |
| Narembeen | 6.6 | 9.2 | 7.9 |
| Wickepin | 5.3 | 5.8 | 7.6 |

**Table 3. Sowing date for each double-break legume treatment at each site. Na=treatment not applied at this site.**

| Site | Cereal | Early Sown | Late Sown | Alternate Crop |
|---|---|---|---|---|
| Moora | 5 June | 14 May | 5 June | na |
| Latham | 7 April | 7 April | 28 May | 28 May |
| Cuballing | 20 May | 20 May | 15 June | na |
| Narembeen | 31 May | 1 June | 22 June | 1 June |
| Dalwallinu | 13 May | 17 April | 7 June | 7 June |
| Wadderin | 1 June | 1 June | 22 June | 1 June |
| Dandaragan | 5 May | 10 May | 26 July | na |
| Wickepin | 18 May | 24 April | 18 May | na |

# LOCATION

Where field trials have been conducted, provide the following location details in the table below: latitude and longitude, or nearest town. (Add additional rows as required.)

| Site # | Latitude (decimal degrees) | Longitude (decimal degrees) | Nearest town |
|---|---|---|---|
| Trial Site #1 | -30.744275° | 116.102268° | Moora |
| Trial Site #2 | -30.653000° | 115.724662° | Dandaragan |
| Trial Site #3 | -32.146914° | 118.186633° | Narembeen |
| Trial Site #4 | -30.29394° | 116.65131° | Dalwallinu |
| Trial Site #5 | -32.72927438° | 117.21615217° | Cuballing |
| Trial Site #6 | -29.460327S° | 116.235133° | Latham |


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| Site # | Latitude (decimal degrees) | Longitude (decimal degrees) | Nearest town |
|---|---|---|---|
| Trial Site #7 | -32.705055° | 117.774879° | Wickepin |
| Trial Site #8 | -32.0633886° | 118.2936525° | Wadderin |

If the research results are applicable to a specific GRDC region/s (e.g. North/South/West) or GRDC agro-ecological zone/s, indicate which in the table below:

| Research | Benefiting GRDC region (select up to three) | Benefitting GRDC agro-ecological zone | |
|---|---|---|---|
| Increasing the profitability of the double break rotation in the MRZ of WA Wheatbelt through incorporation of an early sown high value pulse | Western Region<br>Choose an item.<br>Choose an item. | ☐ Qld Central<br>☐ NSW NE/Qld SE<br>☐ NSW Vic Slopes<br>☐ Tas Grain<br>☐ SA Midnorth-Lower Yorke Eyre<br>☒ WA Northern<br>☐ WA Eastern<br>☐ WA Mallee | ☐ NSW Central<br>☐ NSW NW/Qld SW<br>☐ Vic High Rainfall<br>☐ SA Vic Mallee<br>☐ SA Vic Bordertown-Wimmera<br>☒ WA Central<br>☐ WA Sandplain |


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# RESULTS

## Rainfall and Time of Sowing (TOS)

Annual and monthly rainfall varied across all sites and years in this study, typical of the range expected for any growing environment in Western Australia (WA)(Table 4). Most notably, the 2020 season was below average for all sites established in that year, while the 2021 was above average for all sites and 2022 season was near average (above or below) depending on the site (Table 5). To aid interpretation of this impact, most sites had the combination of a below and above average season that impacted on the growth and grain yield of either the double-break crop or the following cereal crop, but not both. Crop emergence for each time of sowing was impacted by monthly rainfall in each season, with very low rainfall received in April 2020, and as a consequence, emergence from the early time of sowing was achieved in May and late time of sowing in June 2020 for the double-break legume crops (Table 3). Sites that were established in the 2021 season to a double-break legume received 21mm to 35mm rainfall in April and this enabled a true ‘early’ time of sowing to be completed. The Dandaragan site received 122 mm rainfall in July 2021 and this caused transient waterlogging which reduced the growth of the early sown chickpea and delayed the completion of the late time of sowing. Rainfall was closer to the monthly average (data not presented) for the remaining months at Dandaragan and this allowed the late sown chickpea to escape the effects of transient waterlogging and this contributed to a higher grain yield from the late versus early sown chickpea.

**Table 4. Monthly rainfall received at each site commenced in 2020 and sites continuing into 2021 compared to the long-term average (1971-2020) (Climate Data Online, BOM, 2023).**

| | 2020 | | | | 2021 | |
|---|---|---|---|---|---|---|
| Month | Moora | Latham | Cuballing | Wadderin | Moora | Wadderin |
| Jan | 0 | 13 | 0 | 0 | 0 | 0 |
| Feb | 45 | 93 | 43 | 49 | 13 | 28 |
| Mar | 6 | 7 | 25 | 8 | 56 | 38 |
| Apr | 6 | 6 | 3 | 6 | 70 | 21 |
| May | 29 | 26 | 52 | | 43 | 25 |
| Jun | 41 | 20 | 55 | 37 | 60 | 47 |
| Jul | 25 | 34 | 35 | 26 | 58 | 46 |
| Aug | 68 | 56 | 47 | 34 | 139 | 101 |
| Sep | 25 | 4 | 49 | 18 | 45 | 39 |
| Oct | 3 | 4 | 8 | 0 | 19 | 39 |
| Nov | 38 | 17 | 46 | 40 | 14 | 46 |
| Dec | 1 | 4 | 0 | 23 | 0 | 0 |
| Total Annual | 287 | 284 | 363 | 241 | 518 | 430 |
| Mean Annual | 445 | 303 | 491 | 332 | 445 | 332 |


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**Table 5. Monthly rainfall at each site commenced in 2021 and continuing in 2022 compared to the long-term average (1971-2020) (Climate Data Online, BOM, 2023).**

| | 2021 | | | | 2022 | | |
|---|---|---|---|---|---|---|---|
| Month | Dalwallinu | Narembeen | Wickepin | Dandaragan | Dalwallinu | Narembeen | Wickepin |
| Jan | 3 | 5 | 4 | 1 | 13 | 0 | 0 |
| Feb | 34 | 11 | 37 | 71 | 6 | 26 | 6 |
| Mar | 97 | 57 | 49 | 24 | 26 | 32 | 19 |
| Apr | 33 | 21 | 35 | 33 | 21 | 28 | 14 |
| May | 83 | 89 | 116 | 75 | 15 | 30 | 52 |
| Jun | 39 | 48 | 28 | 41 | 34 | 42 | 67 |
| Jul | 107 | 113 | 146 | 122 | 46 | 48 | 52 |
| Aug | 25 | 35 | 59 | 50 | 94 | 110 | 72 |
| Sep | 6 | 18 | 20 | 18 | 34 | 44 | 36 |
| Oct | 35 | 45 | 39 | 64 | 4 | 36 | 30 |
| Nov | 0 | 1 | 0 | 13 | 13 | 13 | 10 |
| Dec | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| Total Annual | 462 | 443 | 533 | 511 | 306 | 414 | 358 |
| Mean Annual | 351 | 334 | 405 | 479 | 351 | 334 | 405 |

## Cumulative Gross Margin of Double-Break crop sequences

There was large variation in the Cumulative Gross Margin of the double-break crop sequence of Canola (or Fallow) followed by a legume and a cereal crop (Figure 1) and is reflective of the range of annual rainfall and grain yield potential for each site. This variability was also reflected in the average Gross Margin for each rotation at each site (Figure 2). Within each site, a strong trend was for that the inclusion of a double-break crop led to a similar or greater cumulative Gross Margin at all sites except for Dalwallinu. Within the double-break legume phase, the early time of sowing tended to give an increase in grain yield (Table 7) for chickpea and this was a significant driver of the increase in Gross Margin.


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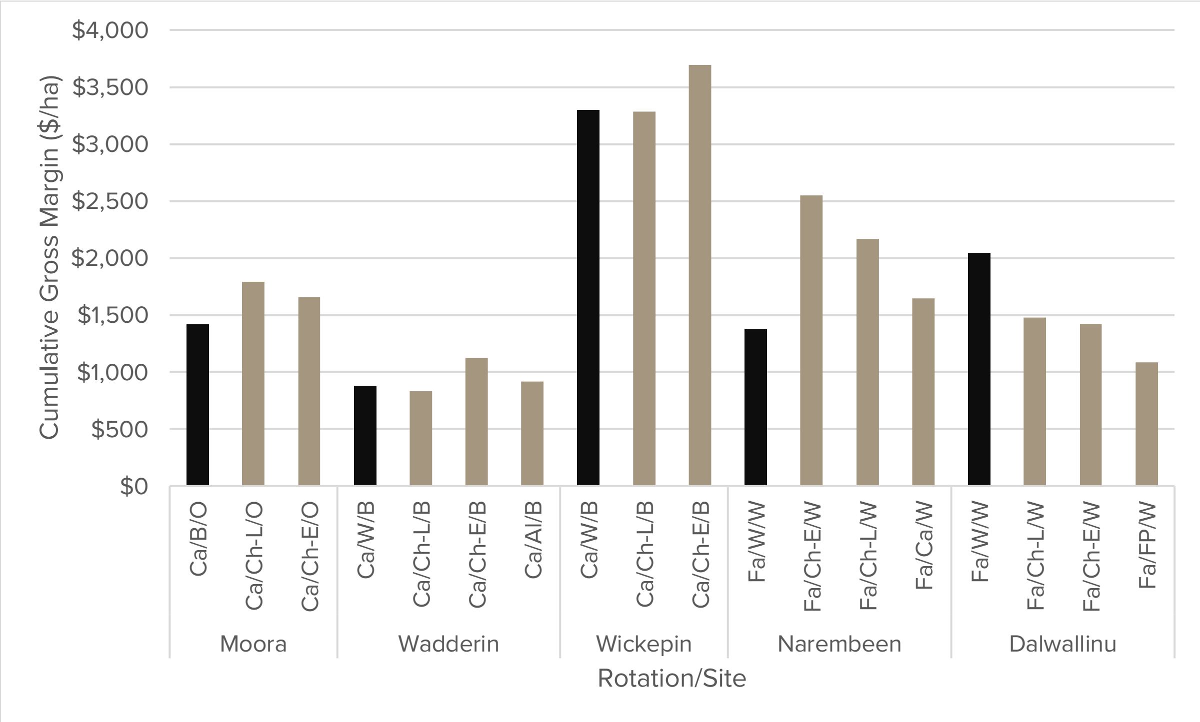


**Figure 1. Cumulative Gross Margin over three years for each double-break crop rotation at each site compared to current practice (dark bars) in this study. Sites presented contained 3 years of data to include the first and second break crop, followed by cereal. Ca=Canola, Ch-L=Chickpea-Late sown, Ch-E=Chickpea-Early sown, L-L=Lentil-Late sown, AL=Albus Lupin, FP=Fieldpea, Fa=Fallow, W=Wheat, B=Barley, O=Oats**

At sites that were discontinued following poor crop growth in the double-break year, the result for two-year Cumulative Gross Margin was quite variable (Figure 3). The use of a double-break legume such as lentil or chickpea led to a negative Gross Margin for the crop (Table 6) and this impacted on the Cumulative Gross Margin compared to growing wheat after a single break. The exception to this was the Latham site, where a severe hailstorm rendered all treatments un-harvestable and no yield result could be obtained. However, visual observations during the growing season indicated that wheat following canola would have yielded significantly higher than chickpea (early or late sown) in the absence of storm damage.



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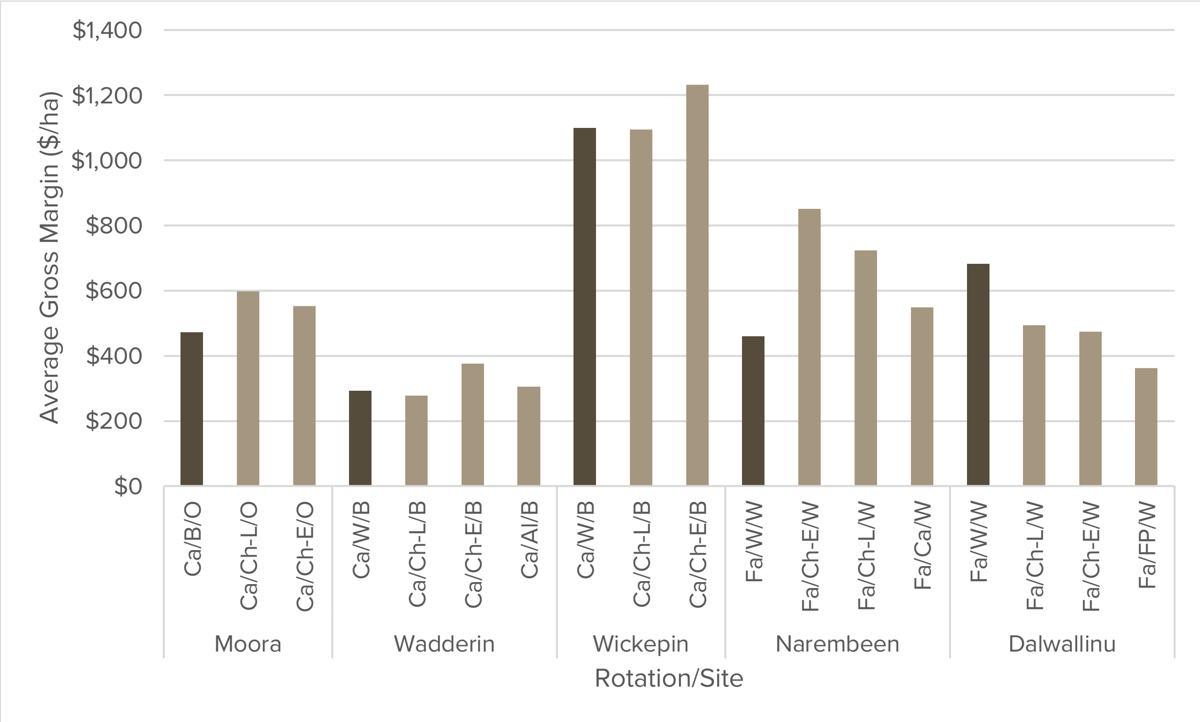


**Figure 2. Average Gross Margin over three years for each double-break crop rotation compared to district practice (denoted by dark bar) at each site in this study. Sites presented contained 3 years of data to include the first and second break crop, followed by cereal. Ca=Canola, Ch-L=Chickpea-Late sown, Ch-E=Chickpea-Early sown, L-L=Lentil-Late sown, AL=Albus Lupin, FP=Fieldpea, Fa=Fallow, W=Wheat, B=Barley, O=Oats**

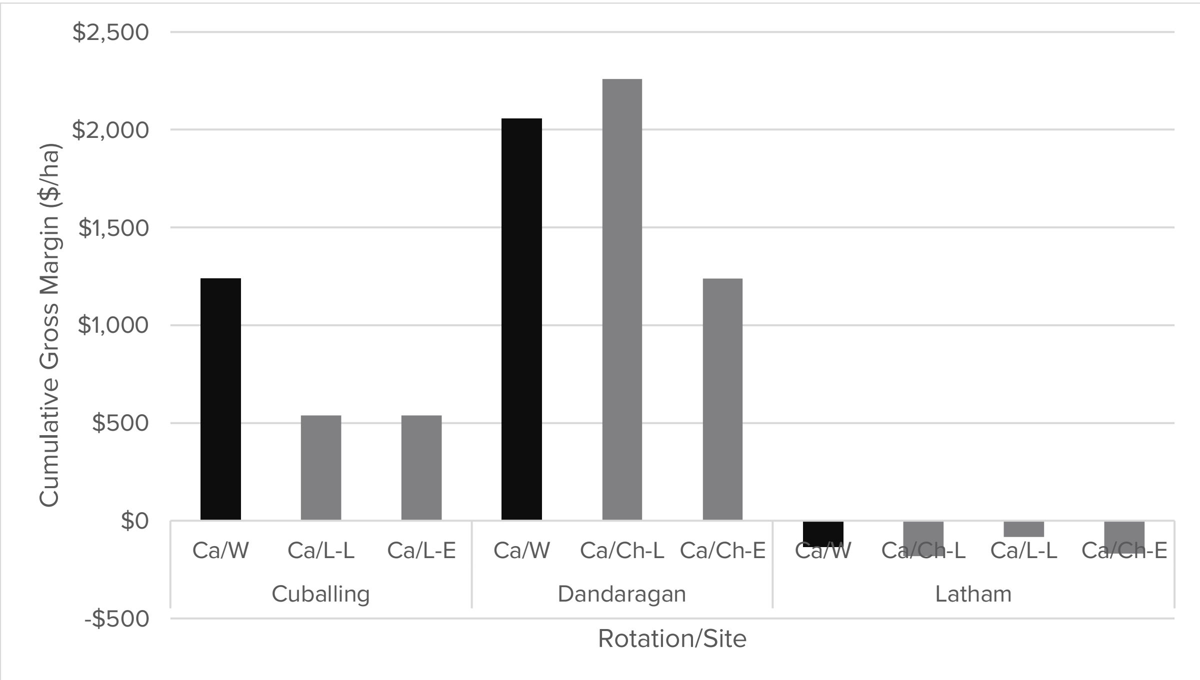


**Figure 3. Cumulative Gross Margin for two years at sites where the break-crop failed and the site was abandoned. District practice is denoted by the dark bar for each site.**



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The was a general trend that the Gross Margin of cereal crops was improved in the third phase of the crop sequence following a double break crop sequence (Figure 4). There was no consistent trend in the effect of time of sowing for chickpea on subsequent cereal grain yield, however, the Gross Margin (Figure 4) and grain yield (Table 7) were increased by the preceding legume crop when the legume grain yield was low, independent of the time of sowing. This is exemplified by wheat following field pea and chickpea (late sown) at Dalwallinu where these crops yielded 0.7 and 1.1 t/ha respectively but were the highest yielding crop sequences.

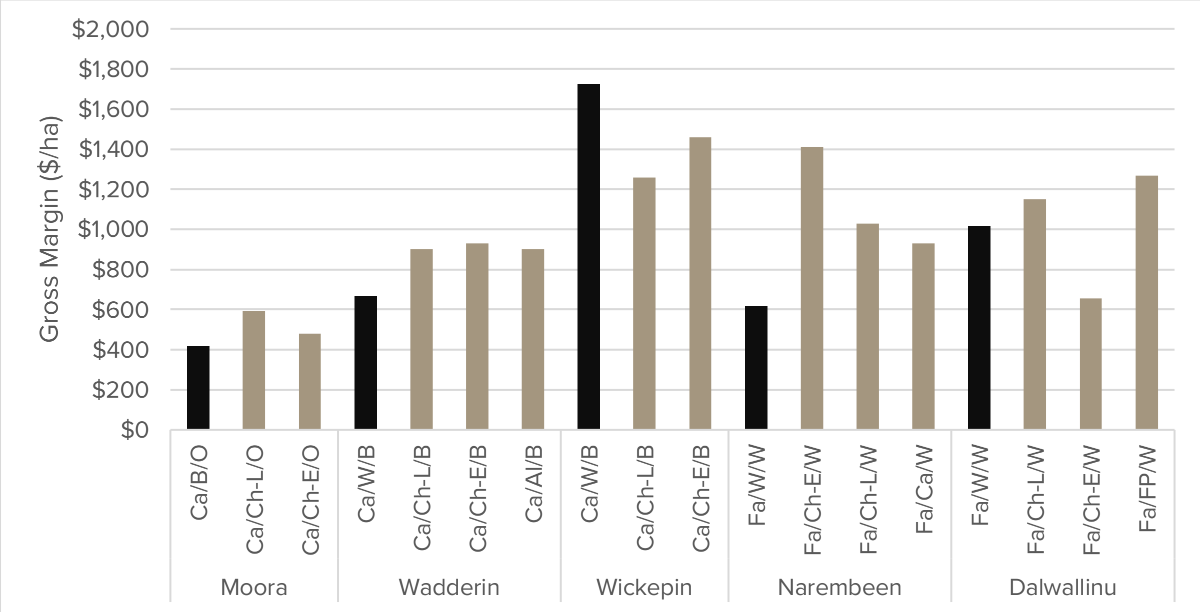


**Figure 4. Gross Margin of cereal crops following a double-break for all sites that completed the 3-year crop sequence. Dark bars denote current practice for each site. Sequence abbreviations: Ca=Canola, Ch-L=Chickpea-Late sown, Ch-E=Chickpea-Early sown, L-L=Lentil-Late sown, AL=Albus Lupin, FP=Field pea, Fa=Fallow, W=Wheat, B=Barley, O=Oats**

**Figure 5. Comparison of early sown (left) versus late sown (right) chickpea at Wickepin on the 17th August, 2021. The alternate plot can be seen in each photo for reference as well as tree in left of both pictures. Photo: Amy Bowden (Facey Group).**

**Table 6. Summary of Grain yield of each crop in the Double-Break crop sequence at each site. Shading denotes crop type: yellow=canola, orange=fallow, green=legume, blue=cereal crop.**

| Site | Break Crop | Time of Sowing | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Cuballing | Canola | Standard | 1.8 | | | |
| | Lentil | Early | | 0.0 | | |
| | | Late | | 0.0 | | |
| | Wheat | Early | | 2.4 | | |
| Latham | Canola | Standard | 0.9 | | | |
| | Chickpea | Early | | 0.0 | | |
| | | Late | | 0.0 | | |
| | Lentil | Late | | 0.0 | | |
| | Wheat | Early | | 0.0 | | |
| Moora | Canola | | 1.4 | | | |
| | Barley | Standard | | 2.9 | | |
| | Chickpea | Early | | 1.5 | | |
| | | Late | | 1.5 | | |
| | Oats | Early | | | 3.8 | |
| | | Late | | | 4.3 | |
| | | Standard | | | 3.5 | |
| Wadderin | Canola | | 0.8 | | | |
| | Albus Lupin | Alternate | | 0.4 | 3.9 | |
| | Chickpea | Early | | 0.6 | 4.0 | |
| | | Late | | 0.2 | 3.9 | |
| | Wheat | Standard | | 1.1 | 3.1 | |
| Dandaragan | Canola | Standard | | 2.1 | | |
| | Chickpea | Early | | | 1.0 | |
| | | Late | | | 2.4 | |
| | Wheat | Early | | | 4.5 | |
| Narembeen | Canola | Standard | | Fallow | 2.0 | 3.6 |
| | Chickpea | Early | | | 2.2 | 5.1 |
| | | Late | | | 2.2 | 3.9 |
| | | Wheat | | | 3.6 | 2.7 |
| Dalwallinu | Chickpea | Early | | Fallow | 1.8 | 3 |
| | | Late | | | 1.1 | 4.5 |
| | Field pea | Alternate | | | 0.7 | 4.9 |
| | Wheat | Standard | | | 4.4 | 4.1 |
| Wickepin | Canola | Standard | | 0.9 | | |
| | Chickpea | Early | | | 3.4 | 6.4 |
| | | Late | | | 3.1 | 5.6 |
| | Wheat | Standard | | | 5.3 | 4.9 |


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Impact of Double-Break on weed populations and soil pathogens

There was a trend that the total weed population in the third-year cereal or second-year legume were higher after the double break crop sequence compared to standard practice of growing two cereal crops following canola or fallow (Figure 6). Total weed population refers to the total number of all weeds present at GS.30 for cereals and flowering stage of legumes and includes all grasses and broadleaf weeds. The use of canola or fallow as the first crop in the double break sequence appeared effective at lowering weed numbers as weed populations were relatively low for the cereal crop sequences. Weed control in the cereal crop year appears effective in ensuring that weed populations do not get out of control as total weed population was around 50 plants/m$^2$ for double break crop sequences, whether it is in the second-year legume or third-year cereal crop. The type of agronomy package available for weed control may have an impact on weed control as weed populations increased significantly following Albus Lupin at the Wadderin site, which has few registered herbicide options. In contrast, the Narembeen and Latham sites highlight that effective weed control is achievable and comparable to cereal crop production.

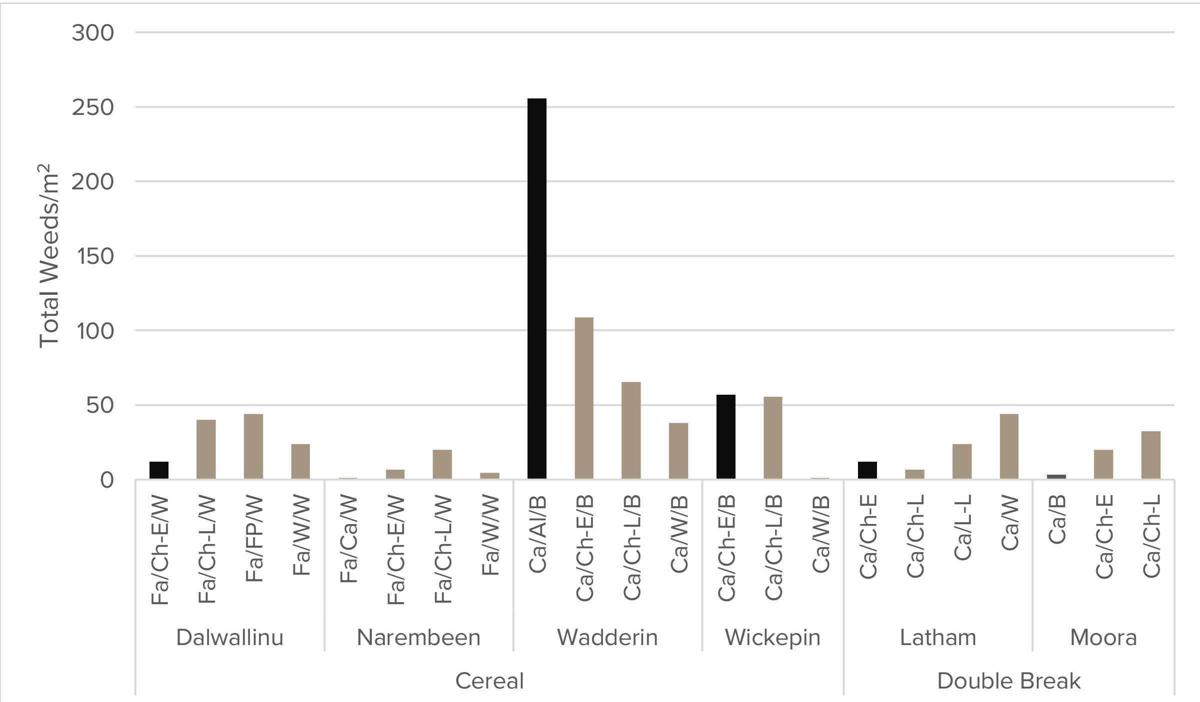


**Figure 6. Total number of weeds present in each treatment at the end of July for each site after the application of all herbicides for the growing season. Dark bars denote current practice at each site. Sites denoted by 'Cereal' had weed counts taken in the cereal crop (i.e. third crop) in the crop rotation, while 'Double Break' sites had weed counts taken in the Double Break (i.e. second crop) year. Ca=Canola, Ch-L=Chickpea-Late sown, Ch-E=Chickpea-Early sown, L-L=Lentil-Late sown, AL=Albus Lupin, FP=Fieldpea, Fa=Fallow, W=Wheat, B=Barley, O=Oats**

The impact of double break crop sequences on the four main soil pathogens in WA was not clear in this study. The level of soil pathogen varied between sites and years (Figure 7), with the major soil pathogens being P.neglectus and R. solani AG8. Within each site, there was evidence that each crop sequence had a greater impact on changing the relative proportions of soil pathogens rather than an overall reduction in pathogen levels. The structure of this study limited the collection of soil pathogen data prior to the double break (i.e. in the canola


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or fallow year) being implemented and so the full impact of the double break cannot be presented.

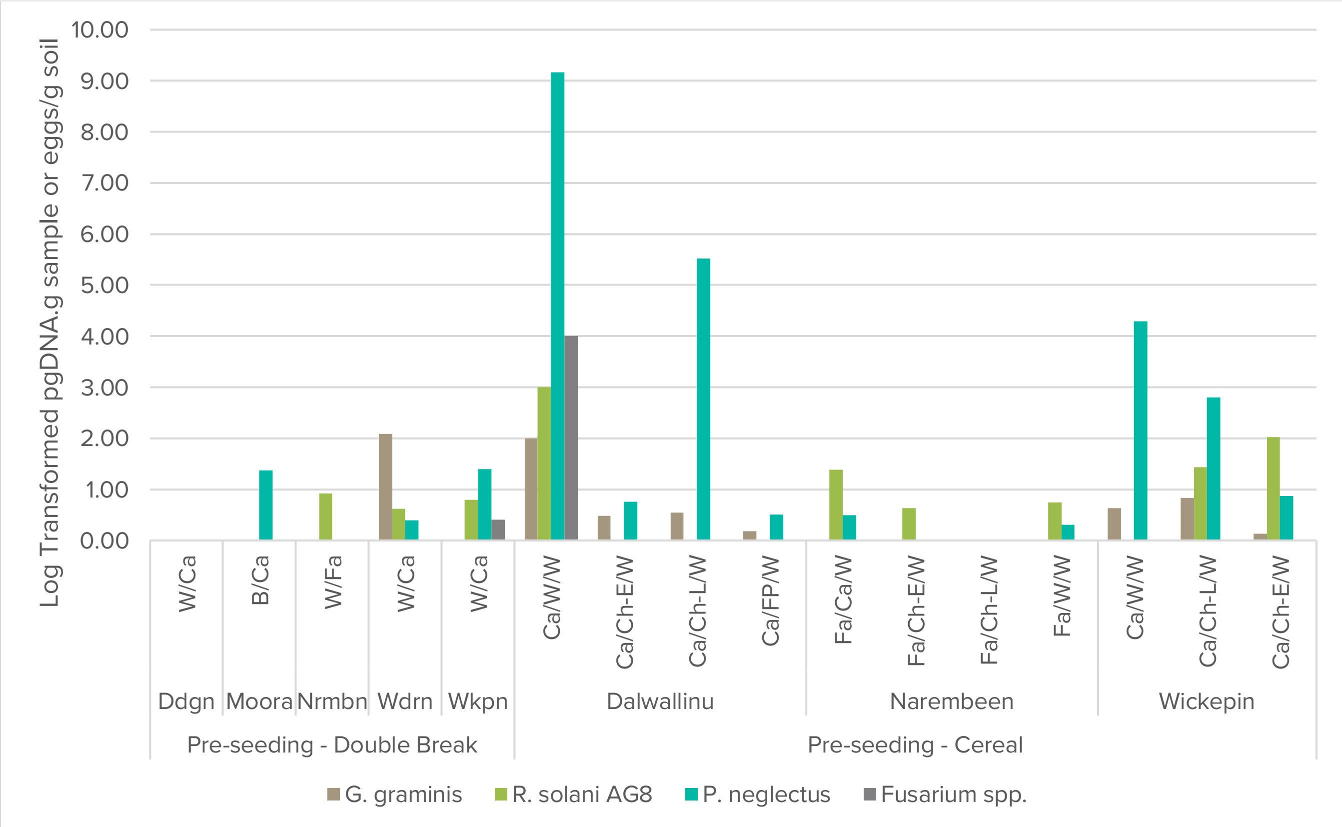


**Figure 7. Profile of the four most common soil pathogens at sites either at the commencement of the project (start of the double break) or in the cereal phase (3rd year of rotation). Site abbreviations: Ddgn=Dandaragan, Nrmbn=Narembeen, Wkpn=Wickepin. Rotation abbreviations: Ca=Canola, Ch-L=Chickpea-Late sown, Ch-E=Chickpea-Early sown, FP=Fieldpea, Fa=Fallow, W=Wheat.**

## DISCUSSION OF RESULTS

This study has shown that a double break crop sequence can be more profitable than a single break where a high value legume (chickpea) can be successfully grown across the Wheatbelt of WA. This was shown across a range of soil types and rainfall zones in this study, with a key outcome being that chickpea were successfully grown in soil types and regions that were not considered to be suited to growing this legume crop. While the positive benefits of growing a cereal crop following a single year of break crop have been widely researched, this study has highlighted that a well-managed three-year crop sequence is the driver of profit, rather than just a large increase in grain yield of the subsequent cereal crop. The two main drivers of profitability of the double break crop sequences evaluated were the Gross Margin of chickpea and the increase in grain yield of the cereal following chickpea. Within this, profitable chickpea production was based on the use of early seeding to maximise biomass production and grain yield for soil types that are not traditionally used for growing chickpea. A limitation of this study is that sites were discontinued where high value legumes could not be successfully grown, and the subsequent impact on the production and profitability of the cereal crop is not known.

The early seeding of a high value legume in Mid-April rather than Mid-May was an effective practice to increase grain yield across the Wheatbelt of WA. The practical application of early seeding in a wide range of environments meant that a wide range of seeding dates were achieved, and this was relative to the amount of soil moisture that was available at seeding in each year. Where seasonal conditions were below average and crop establishment was sub-optimal, large financial losses were sustained by growing a high value legume, and this was not able to be compensated by the following cereal crop. However, where the season was below average and good crop establishment was achieved, it was possible to still grow a profitable legume crop, and this contributed to a three-year double break crop sequence that was equal or better than growing canola followed by two cereal crops (current farmer practice). In each comparison, grain yield of early sown legume was similar or greater than late sowing for every paired sowing date. This indicates that while maximum grain yield probably occurs where the legume emerges in Mid-April, high value legumes and in particular, chickpea, are best sown first when moisture is available to lower risk. There is little grain yield and plant growth data available on chickpea sown earlier than Mid-April in WA, and this is an opportunity for future research as there is much interest in plant options for early sowing opportunities, such as long season wheat varieties. A limitation of this project is that grain yield was measured using hand harvest techniques to measure the maximum amount of grain produced, without the impact of harvest losses. To reduce the risk of growing chickpea further, growers will need to have confidence to manage harvest losses, which can account for 0-55% of total grain yield and reducing the potential for harvest grain losses will have significant benefits for the profitability of a double break crop sequence that includes high value legumes.


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**Figure 8. Comparison of excessive early chickpea growth from an early sowing on a heavy soil type (right) compared to late sowing (left) at the Dalwallinu site on the 9th September 2021. Photo: N Craig (West Midlands Group).**

There were situations where early sowing did not increase the grain yield of the high value legume. At the Dalwallinu site on a heavy red clay soil that is typically suited to growing chickpea, mid-April sowing led to excessive early growth of chickpea, with the total height of the crop being close to 1 metre tall at maturity (Figure 8). This excessive growth in a high rainfall year led to increased vegetative growth compared to the mid-May sowing did not increase grain yield, but increased the requirement for fungicide use which is consistent with Eastern States Best Practice guidelines. Good early growth is not necessarily a bad outcome from early sowing, as growing chickpea on non-traditional, sandy soil types benefit from the extra growth that leads to an increased grain yield (Figure 5).
Early sowing at the Dandaragan site also did not lead to higher grain yield as transient waterlogging occurred from heavy rainfall after sowing chickpea in May (early sowing timing). The later sowing was timed after the waterlogging had subsided and this allowed for better establishment and growth of chickpea. Early sowing did not increase the grain yield of lentil at the Cuballing site (which was discontinued after the legume phase) due to the impact of soil acidity on crop growth. The need for due diligence in selecting where to grow lentil (and chickpea) revolves around adequate soil testing to determine current soil acidity levels, and the longer-term deployment of soil amelioration strategies (for example: liming, deep ripping, mouldboard ploughing) that have successfully addressed these constraints. These paddock traits appear a strong indicator that alternate legumes can be successfully grown on these soil types.

It appears that the potential for chickpea to be a profitable break crop is underestimated in WA with the current agronomy packages and genetic material available. A large driver of this profitability is early sowing of chickpea (mid-April) to allow greater growth of the chickpea during the season. This is in contrast to best practice chickpea production in the Eastern States of Australia, where early sowing leads to excessive vegetative growth and increased risk of disease infection, especially Ascochyta blight (G Lendon, Pers. Comm, 2022). Other studies of time of sowing for chickpea in the West Midlands region on a sandy soil, atypical of where chickpea would be normally grown, highlights the consistent advantage in biomass and grain yield production for chickpea through early sowing (West Midlands Group 2019, 2020, 2021, 2022). The main soil type traditionally used for growing chickpea in WA has been the heavier loam and clay soil types that are dispersed throughout the grain growing region. Successful chickpea crops have been achieved in WA using early sowing on deep, light, sandy soil types that are conducive to long-term crop rotations (coloured sands).

These sandy soils have typically had soil constraints that have reduced the growth and grain yield of chickpea, such as soil acidity (surface and sub-soil), compaction, and soil water repellence. The successful adoption of soil amelioration strategies for these soils to overcome these physical and biochemical constraints means that chickpea can now be successfully grown in these soils. Further research is required to determine the extent of area that will now support the growth of chickpea in WA outside of the traditional soil types. While the grain yield advantage in these atypical soils has been highlighted in previous studies (West Midlands Group 2019, 2020, 2021, 2022), the mechanism of how this occurs is not clear, but appears related to greater biomass growth achieved through a longer growing season and the relationship between legume biomass, nitrogen fixation, and grain yield.

This study sought to determine the grain yield and profitability of a double break crop sequence and did not have a strong focus on the weed and soil pathogen control impact of a double break crop sequence. Previous studies have given strong conclusions in these aspects and this study sought to demonstrate the application of the double break approach to grain growers in WA. The limited data in this study highlighted gave a glimpse of the application of the double break in WA, with previous studies largely being conducted in Eastern Australia on differing soil types found in WA. While by no means conclusive, the data collected in this study indicates that weed populations are likely to increase in the legume phase of the double break sequence, but this does not cause a weed 'blowout' in the subsequent cereal crop. A barrier to successful weed control was encountered in this project where we found very limited knowledge among agronomic advisors on how to successfully grow high value legumes, especially in applying effective herbicide packages using the new chemical options now available. This was evident with growing Albus lupin at one site, where lack of herbicide options (likely partly through lack of local herbicide knowledge) meant that weeds increased significantly compared to chickpea. Limited knowledge had an impact on the success of growing chickpea (and lentil) in this study, as more generic herbicide packages had to be used in lieu of locally developed herbicide packages that could effectively control weeds in these legume crops. Further research and information will need to be generated to support capacity building to drive the successful growth of high value legume production in WA, irrespective of the crop sequence deployed by farmers.

The impact of a double break crop sequence on soil pathogen levels was not clear in this study. There was a trend that the profile of soil pathogens at each site changed as a result of deploying a double break crop sequence. This contrasts with a total reduction in soil pathogens that was expected, and highlights that differing crops host different soil pathogens, and success in a double break crop sequence would mean ensuring that the profile of soil pathogens is favourable for the growth of the successive crop(s). In WA, this would mean a reduction in cereal diseases such as rhizoctonia, crown rot, and P. neglectus. However, this study indirectly highlights how responsive the profile of soil pathogens are in the soil to each crop, and it is likely that the soil pathogen profile will change with each successive crop. From this, it can be postulated that long-term success with crop rotations to reduce soil pathogens will be dependent on growing a diverse range of crop types in succession so that the current soil pathogen profile does not have a negative affect on the growth of the next crop. In reality in WA, the dominance of cereal crops being grown (Harries et al, 2014) means that the soil will return to a dominance of pathogens that have a negative impact on cereal crop production in the longer term.

A significant factor for the profitability of chickpea and lentil in a double break crop sequence is the value of grain produced, and indirectly, the marketing options available for growers at harvest time. The most common strategy for improving the profitability of chickpea in Eastern Australia is to utilise on-farm storage and to market the grain independently to the harvest process (Seymour, 2021). This approach is not used to any large extent in WA due to the highly effective co-operative-based grain handling system which handles 87% of the state's grain crop (CBH, 2023). While this works for the main commodities (wheat, barley, canola, lupin), it currently does not handle significant volumes of chickpea and so this is a limiting factor for farmers. The calculation of Gross Margins for chickpea in this study was based on a 5-year average price of $700 per tonne, however, can vary between $400 and $1700 per tonne (Seymour, 2022) and this can significantly impact on the profitability of the crop. Profitable growth of high value legumes in WA is likely to require a similar need to store and market the grain to maximise the high value nature of these legumes.

## CONCLUSION

Double break crop sequences can increase the profitability of cropping programs in the WA Wheatbelt by being profitable crop options and by contributing to an increase in grain yield and profitability of the following cereal crop. While weed control can represent a challenge in legume crops like chickpea and lentil, the successful growth of the high value legume to boost profitability in the second year, and the ability of the first break crop to significantly reduce any weed populations, are a good combination of break crop species. Successful growth of the high value legume was largely continent on taking advantage of early sowing opportunities to improve plant growth, harvestability, and grain yield. The grain yield benefit of the double break crop to the successive wheat crop yield was consistent across all sites and of a magnitude that was expected from following a break crop.

There was a noticeable impact on the weed population and soil pathogen levels from implementing a double break crop rotation. Weed control was most effective where canola or fallow were used in the first year and this is based on well-developed herbicide packages for these crop sequence options. A challenge in this study was to find local knowledge that would guide the development of an effective herbicide package for chickpea and lentil, and this is an area for further industry support as successive research trials have highlighted that effective weed control can be achieved in these crops. Nonetheless, an increase in weed populations in chickpea and lentil did not translate into high weed levels in the following cereal crop as there are effective herbicide packages available. The double break crop rotation did not significantly reduce soil pathogen levels at each site in readiness for the successive cereal crop but did alter the species of soil pathogens present at each site. This indicates that the successful combination of break crop species does need consideration when tackling specific soil pathogens.


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## IMPLICATIONS

A double break crop sequence can be a profitable option for growers in the Wheatbelt region of WA to boost the both the following cereal crop and be profitable in each year of the crop rotation. This benefit to the productivity of cropping in this region is based on the amelioration and removal of soil constraints that have previously impeded the growth of chickpea on soils other than heavy clay types. Strategies have been employed by growers over the past 10 years to remove soil compaction (deep ripping), soil water repellence (rotary spading, mouldboarding), and soil acidity (lime application). The result is a soil that is no longer inhospitable for chickpea and lentil growth. It is, however, difficult to estimate the amount of land that has been effectively ameliorated in the past 10 years where all constraints are now removed. While the focus of soil amelioration has been on the impact of these practices on wheat production, perhaps the most significant benefit for grain production from the removal of soil constraints may be the ability of growers to now diversify their crop options to further improve profitability with a lower risk of failure. Through this study and other related projects, chickpea production on other soil types has been de-risked for adoption by the practice of early sowing, which has been shown to increase grain yield on a range of soils in the Wheatbelt region, from deep coloured sands to sandy loam and clay soils.


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# RECOMMENDATIONS

The use of double break crop sequences is dependent on three factors: effective weed control as the first break crop, a profitable grain legume, and an increase in grain yield of the following cereal crop. The agronomy of canola production is very well established in Australia and with the increased inclusion of a greater range of herbicide tolerance genes into new canola varieties, canola as the first break crop for effective weed control is recommended. The use of fallow has also been shown to be effective in reducing weed populations. The agronomy package of wheat following the double break crop is also well established and this project has demonstrated that weeds can be effectively controlled and that there is a benefit to crop production.

The control of weeds in the second break crop, being a legume, is a harder challenge and relies on effective weed control from the first break crop (canola). The range of weed control options is limited in legume crops and varies widely between species. Chickpea were identified in this study as a highly profitable break crop option for the WA Wheatbelt where soil constraints have been ameliorated. However, the challenge was to implement a successful herbicide package to ensure adequate weed control, and this was influenced by two factors. Firstly, the range of herbicide options available for chickpea in WA is less than lupin or canola, and secondly, the industry knowledge of how to effectively use these herbicides as an effective weed control package was very low. A significant barrier to the delivery of this trial program was finding local knowledge on effective herbicide options for each environment, and further extension and communication is needed for agronomists and consultants to support farmers as they consider growing high value legumes such as chickpea and lentil. Further work to demonstrate effective herbicide packages across the WA Wheatbelt that compare herbicide effectiveness with lupin would be beneficial to increase confidence, as this has been a successful approach in the West Midlands region where the chickpea herbicide package provided better weed control than the best practice lupin herbicide package.

While addressing the herbicide package for high value legumes such as chickpea and lentil will go a long way in supporting an increase in grower and agronomist/consultant confidence of growing chickpea, the achilles heel for alternate legume production is market availability to realise the high value of these legumes. The development of a stable, long-term market is dependent on volume and market access/negotiation and is a larger topic for discussion. It is noted here in this report as a large barrier that will need to be overcome for a successful and sustainable high value legume industry in WA.

The use of a Double Break crop rotation should be considered by growers in WA as a way of increasing the profitability of crop sequences rather than as a break crop phase to reduce weeds and disease. Disease and weed control are often the first reasons for implementing a break crop into the crop sequence, however effective management practices such as early sowing of high value legumes can greatly increase the profitability of break crops. It is recommended that growers commit to trialling both double break and high value legumes into the crop rotation over a series of years to 'learn' how to get the best out of these crop sequence options. A community of practice around best practice legume production may also be of benefit to support the adoption of these practices.


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# **APPENDIX A:** Annual Gross Margin for all Crop sequences

**Table 7. Annual Gross Margin for three-year crop sequences at sites where a cereal crop has been sown following the respective double break crop rotations across the Wheatbelt of WA. Sites were following either canola or fallow as the first-year break crop. Gross Margin indicates the annual value of production (gross income minus herbicide, fertiliser, fungicide, insecticide, machinery, and seed costs). TOS=Time of Sowing.**

| Site | Crop | Year 1 | Crop | TOS | Year 2 | Crop | Year 3 |
|---|---|---|---|---|---|---|---|
| Cuballing | Canola | $785 | Wheat | Standard | $455 | | $0 |
| | | | Lentil | Late | -$246 | | $0 |
| | | | Lentil | Early | -$246 | | $0 |
| Dandaragan | Canola | $964 | Wheat | Standard | $1,093 | | $0 |
| | | | Chickpea | Late | $1,297 | | $0 |
| | | | Chickpea | Early | $275 | | $0 |
| Latham | Canola | $149 | Wheat | Standard | -$283 | | $0 |
| | | | Chickpea | Late | -$332 | | $0 |
| | | | Lentil | Late | -$231 | | $0 |
| | | | Chickpea | Early | -$317 | | $0 |
| Moora | Canola | $465 | Barley | Standard | $536 | Oats | $415 |
| | | | Chickpea | Late | $736 | Oats | $591 |
| | | | Chickpea | Early | $709 | Oats | $481 |
| Wadderin | Canola | $116 | Wheat | Standard | $95 | Barley | $668 |
| | | | Chickpea | Late | -$185 | Barley | $900 |
| | | | Chickpea | Early | $82 | Barley | $929 |
| | | | Albus Lupin | Alternate | -$101 | Barley | $900 |
| Wickepin | Canola | $164 | Wheat | Standard | $1,409 | Barley | $1,724 |
| | | | Chickpea | Late | $1,861 | Barley | $1,259 |
| | | | Chickpea | Early | $2,071 | Barley | $1,460 |
| Narembeen | Fallow | -$108 | Wheat | Standard | $867 | Wheat | $619 |
| | | | Chickpea | Early | $1,247 | Wheat | $1,411 |
| | | | Chickpea | Late | $1,247 | Wheat | $1,029 |
| | | | Canola | Standard | $823 | Wheat | $930 |
| Dalwallinu | Fallow | -$108 | Wheat | Standard | $1,136 | Wheat | $1,018 |
| | | | Chickpea | Late | $437 | Wheat | $1,150 |
| | | | Chickpea | Early | $895 | Wheat | $490 |
| | | | Field pea | Alternate | -$73 | Wheat | $1,268 |



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