Four decades of crop sequence trials in Western Australia

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KEY MESSAGES

A database that collates crop sequence trial data from over 160 trials is now available.

On average, wheat after lupin out yielded wheat after wheat by 0.5 t/ha. Greater increases in wheat yields following lupin occurred after the availability and widespread use of good, selective herbicides coinciding with the uptake of no-till seeding in the 1990s.

AIMS

Collate all of the available trial results from crop sequence experiments conducted in WA and use the database to quantify the rotational benefits of break crops. In addition determine the need for crop sequence research in the future.

METHOD

Over 150 crop sequence experiments have been conducted throughout WA since the 1960s to determine the rotation effects of leguminous or oilseed crops in cereal based rotations. The vast majority of these experiments have been conducted by the DAFWA. The results of these experiments and the limited number conducted by other organisations are available in various formats, but have never been collated in the one place in a uniform way. This paper briefly describes the production of a Microsoft Access database that collates the available information and provides a summary of break crop effects in WA.

The database currently holds 10 191 records consisting of trial x year x this year's crop x previous crop(s) x nitrogen combinations. The results of 167 trials appear in the database, around 165 are DAFWA experiments, one trial had CSIRO as the lead agency with DAFWA input and the remaining experiment is the rotation trial run by the Facey Group at Wickepin.

The database is available for DAFWA staff at \\Agessrdc01\users\Seymour\Break crop rotation database. People outside of DAFWA should contact the Mark Seymour (mseymour@agric.wa.gov.au) for copies.

Notation for crop sequences and rotations used in this paper and on occasions in the database are as follows:

- Abbreviations for major crops are—wheat (W), barley (B), canola (N), lupin (L), field pea (Fp), linseed (Li), oats (O), fallow (Fa), vetch (V), chickpea (K), faba bean (H), and mustard (Mu).
- Crop sequences are listed in order, e.g. LWW refers to lupin followed by wheat followed by wheat.
- Reference to the particular part or year of the crop sequence uses the notation/n. For example, for a LWW sequence LWW/1 refers to the first crop, lupin. LWW/2 refers to the first wheat after lupin and LWW/3 refers to the third crop, which in this case is the second wheat after lupin.

The base data

Fields that appear in the main database include trial information such as trial number, major personnel involved, site (farmer's name), location (nearest town), agzone, soil type, year(s) of experiment, the current year's crop and sometimes which variety was used, nitrogen application rate (kg N/ha), details of the previous 6 crops if available, some coding for rotation types and phase (incomplete), general comments, and some brief information on other treatment applied such as: ripping, fertiliser, time of sowing.

Crop traits in the database include grain yield, grain yield of previous crop if available, dry matter—usually peak or harvest biomass (noted if otherwise) and grain protein. Plants include: barley, canola, cereal rye, chickpea, faba bean, fallow, field pea, lentil, lathyrus, linseed, narrow-leafed lupin, albus lupin, yellow lupin, oats, serradella, sub. clover, medic, volunteer pasture, summer crops, triticale, vetch and wheat. Distinctions are made between harvest, green or brown manured, ploughed in, not harvested or stubble removed treatments, mixes of species and other variations.

Additional information linked to the database include rainfall records for the nearest meteorological station to the experiment from which annual rainfall, growing season rainfall (May to October) and stored water have been calculated. Stored water is estimated by using the formula: 10% of the previous November and December rainfall plus 20% of January and February rainfall, plus 55% of March rainfall plus 75% of April rainfall. Total water available to the plant (mm) was then estimated as rain falling during the growing season plus stored water.

RESULTS

As part of the GRDC project "Increasing the Profitability of Cropping Systems in Western Australia using Lupins, Oats, Oilseeds and Pulses" a detailed report is being prepared which summarises some of the database results. An extract of the section of this report that deals with narrow-leafed lupin is given below.

Wheat after narrow-leafed lupin

Narrow-leafed lupin has been the most widely examined break crop species with over 150 trials x year combinations available in the database. If we look at the raw data from all of the trials (Figure 1) we can see the range of yields obtained in the trials. The majority of wheat on wheat (WW/2) yields are less than 2.5 t/ha indicating that in the trials conducted to date it has been difficult to achieve yields higher than 2.5 t/ha with wheat sown after wheat.

In general it is also noticeable that the majority of wheat after lupin responses above the 1:2 ratio line occur when wheat on wheat yields are below 1.5 t/ha, indicating an agronomic issue with wheat-wheat which the inclusion of lupin helps to remediate. Invariably these issues have been identified in individual trials to be the presence of Take-all or high levels of annual ryegrass or brome grass. The outlier on the y-axis of yields of lupin-wheat at or above 4 t/ha when wheat-wheat yields less than 1.0 t/ha are from the trial 91KA111 at West Katanning in which Take-all was a factor that severely limited the yield of wheat on wheat and a wide range of break crops such as lupin, field pea and canola provided a good break from the disease. Similarly the outlier where WW/2 yields close to zero and LW/2 yields 2.5 t/ha is from a trial at South Carrabin in 1995 where brome grass became very difficult to control in the wheat on wheat plots.

Similarly there are occasions where the lupin sequence fails. For example, the outlier on the x-axis where WW/2 yields 1.8 t/ha and LW/2 yields close to zero are from a trial in 1983 at Nabawa (78C1) where wild radish was not able to be controlled in the lupin phase and the weeds swamped the following cereal crop. In later years the availability of diflufenican solved this issue, although in recent times wild radish has again become harder to control in the lupin year with selective herbicides.

Overall though wheat sown after lupin out yields wheat sown after wheat. A linear relationship can be fitted to the response of wheat after lupin compared to wheat after wheat over a wide range of wheat on wheat yields. If the outliers discussed earlier are removed this relationship is: GY of LW/2 = 0.9 (GY of WW/2) + 0.6, $r^2 = 0.58$, $P < 0.001$, GY = grain yield. If we were to constrain the regression through the origin the regression would become: GY of LW/2 = 1.34(GY of WW/2), $r^2 = 0.45$, $P < 0.001$.

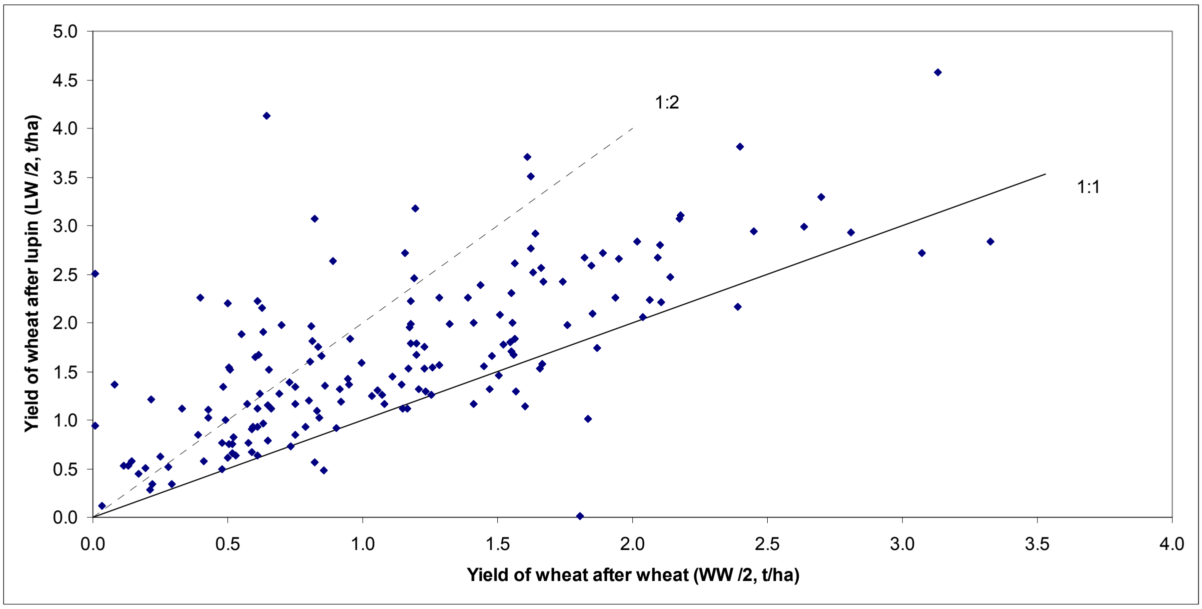

Figure 1 Relationship between the yield of wheat sown after wheat (WW/2) and the yield of wheat sown after lupin (LW/2) in 88 trials (167 trial x year combinations) in experiments conducted throughout WA since 1974. Linear curves indicate 1:1 and 1:2 ratios.

Another way to look at the data set is to consider the magnitude of the difference in yield (Ydiff) between WW/2 and LW/2 and the frequency in which various levels of Ydiff occur. In the first instance we will look at Ydiff averaged across all rates of nitrogen applied to the second year of wheat. Figure 2 shows that whilst there are relatively few instances where Ydiff is more than 1.5 t/ha, in 10% of instances Ydiff is less than or equal to 0 t/ha, and the distribution is centred around 0–500 kg/ha range with the mean increase in yield being 540 kg/ha.

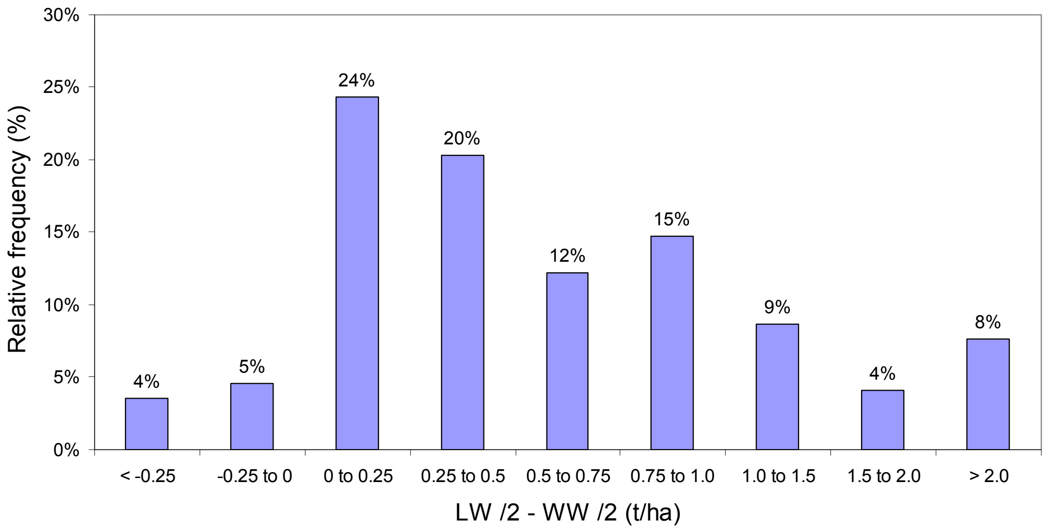

Figure 2 Relative frequency (%) in which the difference in yield (Y diff, t/ha) between wheat following lupin (LW/2) and wheat following wheat (WW/2) falls into 9 yield categories. Data are from 167 trials x year combinations in 86 trials conducted in WA since 1974.

As seasons influence the magnitude of any break effect it can be useful to compare the upper limit of the water use efficiency of the different rotations. To do this we calculated modified French and Shultz figures for the two rotations. We then fitted by eye a boundary line encompassing most of the data points (data not shown). Using this method the potential water use efficiency for wheat after lupin was 19 kg/ha/mm and was 15 kg/ha/mm for wheat after wheat.

Response to nitrogen

It is widely known that one of the major effects of lupin will be the residual nitrogen they supply to the following crop. Results discussed so far have been averaged across all the nitrogen fertiliser rates applied to the following wheat crop. In order to evaluate the effect of residual nitrogen on Ydiff we first grouped rates of applied nitrogen fertiliser into five groups labelled 0N, 25N, 50N, 100N, 150N, where 0N = all treatments where no nitrogen fertiliser was applied, 25N = where up to 25 kg N/ha was applied, 50N = 25 to 50 kg N/ha, 100N = 50 to 100 kg N/ha, and 150N = more than 100 kg N/ha. We then restricted the dataset to the 31 trials that included at least four of these five groups so that n = 67 for all N groups except 150N which had 44 observations. Residual maximum likelihood (REML) models were then fitted using Genstat 10 with N group as the fixed effect and Trial.Year as the random effect.

Overall nitrogen applied as fertiliser had a significant ($P < 0.001$) but small effect on Ydiff (data not shown). The largest Ydiff was 556 kg/ha and occurred when no nitrogen fertiliser was applied. Ydiff decreased as the rate of nitrogen fertiliser increased so, the highest nitrogen fertiliser group (150N) produced a Ydiff of 396 kg/ha.

Do changes over time affect the response to nitrogen?

The difference in yield between wheat after wheat and wheat after lupin appears to change over time with a gradual rising trend from 1974 up to 1990 when the difference in yield between LW/2 and WW/2 increases dramatically and then drops off again after 1993 (Figure 3).

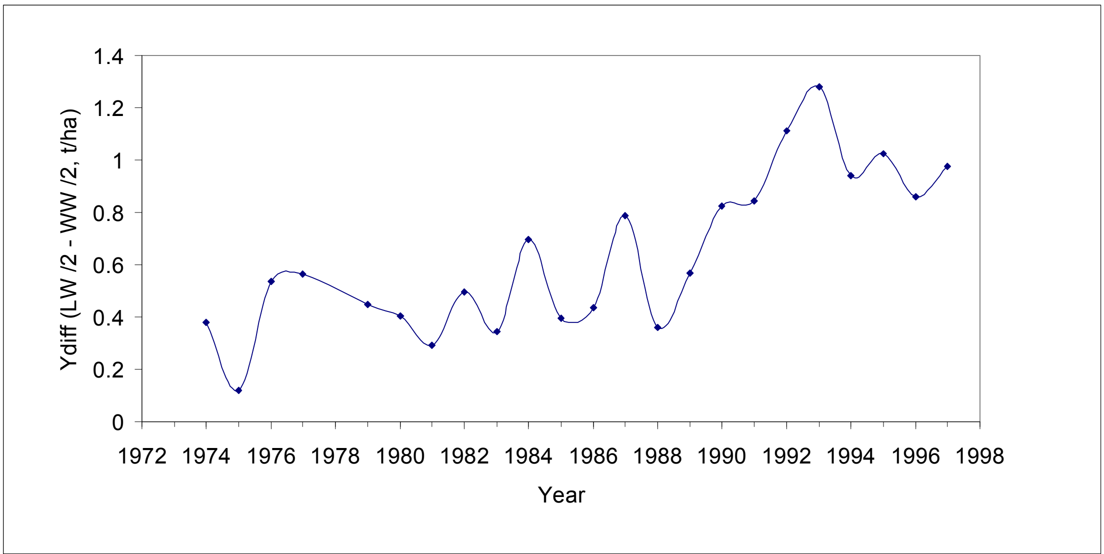

Figure 3 The difference in yield between wheat after wheat (WW/2) and wheat after lupin (LW/2) over time.

To investigate this observation further we restricted the data set to the years when the most number of lupin Agzones had trials, which was the period 1983 to 1995. This showed a relatively flat period from 1983 to 1991 and then an increase in the period following. We then considered the changes in the 1990s that led to this unprecedented increase in the difference in yield between LW/2 and WW/2. Was it environmental, such that we had a run of years that suited wheat after lupin more so than wheat after wheat? Or were there changes in agronomic practices that were of benefit to wheat after lupin or made lupin a better break crop?

To separate the effect of rainfall from management we compared the water use efficiency of the two sequences (data not shown). This showed that the difference between the WUE of LW/2 and WW/2 was, for the first time, consistently above 3 kg/ha/mm from 1990. Around that period of time there was a shift to no-till machinery both on farms and for experimental purposes. There was also a wider use of more effective herbicides for in-crop control of grass and broadleaf weeds in lupin crops, and rotations shifted to more continuous cropping as sheep numbers declined throughout WA. In general, comments from trials in the period 1990–95 indicated that the lupin plots were generally free from weeds and there were few reports of poor lupin growth in the trials. Thus these changes seemed to be of benefit both for the lupin crop and the following cereal.

This is further demonstrated if we group the data into two periods: ‘1983–89’ and ‘1990–95’. The Ydiff was 0.4 t/ha in the 1983–89 period and 0.9 t/ha 1990–95 period ($P < 0.001$) and this difference remained even when the peak year of 1993 was removed from the analysis. Of interest then was to see if the agronomic changes also changed the response to fertiliser nitrogen. To do this we had to further reduce the dataset because there were few trials that included rates of fertiliser nitrogen above 100 kg/ha (n = 6).

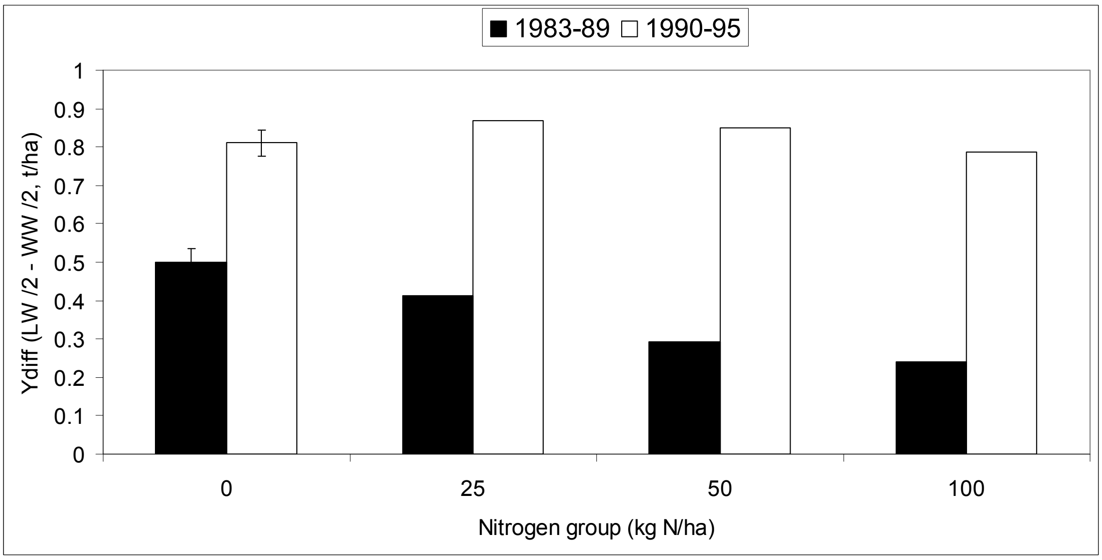

Figure 4 Response of Ydiff (LW/2–WW/2 in t/ha) to nitrogen fertiliser application in the wheat year for the periods prior to and after 1990.

Prior to 1990, as the rate of nitrogen increased the difference in yield between LW/2 and WW/2 decreased (Figure). However, since 1990 nitrogen has no effect ($P > 0.05$) on the difference in yield. It appears that since 1990 wheat after lupin continues to respond to increasing rates of nitrogen whereas in the previous period wheat after lupin did not respond to increasing rates of nitrogen whilst wheat on wheat did.

CONCLUSION

A database has been collated from all of the available crop sequence experiments conducted in WA. Over 10 000 records representing the results of over 160 experiments conducted since 1966 appear in the database, allowing for rigorous interrogation of rotation effects over a long period of time. In the experiments conducted to date continuous wheat was rarely as productive or economically viable as rotations that included either a pasture or break crop, regardless of amount of nitrogen fertiliser applied.

In general terms, since 1990, both the yield of wheat on wheat and the likelihood of a response to lupin in the following year have increased at all levels of applied nitrogen. This corresponds to a period where more effective herbicides were used, rotations shifted to more continuous cropping and trials were more likely to be sown with no-till machinery

If changes to crop management in the past have influenced the size of the break crop effect then we need to consider the implications of even more recent changes to crop management. In particular the benefits of break crops are likely to be influenced by the modern use of more effective fungicides, inter-row seeding to avoid last years crowns and roots, metering out of nutrition throughout the growing season, and the reduced effectiveness of weed control.

KEY WORDS

crop sequence, break crop, lupin

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