Field lab: Intercropping and Companion Cropping in Arable Systems
2019 report

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Summary

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1 Field lab aims

The field lab aims to explore opportunities for intercropping and companion cropping in arable systems including:

- Identifying beneficial combinations and their impact on key indicators selected for testing by farmers, e.g. weed burden, plant health, pest and disease damage and yield, in different contexts.
- Enabling farmers to share knowledge and experiences of working with different plant teams. Including peer to peer exchange on practical considerations, e.g. crop competition, establishment, machinery, harvest, separation and finding markets.

In 2018/19 three trials were drilled on two farms (T1 and T2 on Bockhanger Farm and T3 on Roundhill Farm). Each trial had a different objective as outlined below:

- **T1**: Test the effectiveness of oats in reducing linseed loss during establishment via reduction of pest pressure.
- **T2 (A):** Test the effectiveness of oats in reducing spring oil seed rape (OSR) losses (in a crop which is also intercropped with peas) via reduction in pest and disease pressure.
- **T2 (B):** Test the effectiveness of OSR in supporting the pea crop and reducing lodging.
- **T3:** Test whether intercropping beans with wheat reduces the weed burden in the bean crop and increases the protein content in wheat.

Furthermore, for trials 1 and 2, different seed rates of the intercrop (oats for T1 and OSR for T2) were tested to determine what differences there are in the effect, and in yield, in relation to this factor.

2 Background (200-400 words)

Intercropping has been shown to be beneficial for pest, disease and weed management, preventing lodging, improving water quality, soil fertility and biodiversity as well as increasing resilience to climatic and agronomic shocks (Brooker et al, 2015). With the decreasing efficacy of chemical control and concern over negative repercussions of the use of pesticides on beneficial insect populations, there is increasing interest among farmers and policy makers in the potential for intercropping in arable systems.

Much of the innovation is happening in farmer’s fields and on-farm trials are an important step towards enhancing understanding of the benefits and challenges of working with different plant teams in a variety of contexts.

In 2018/19 different group members tried out different mixtures and shared their experiences on WhatsApp and at field events. The main challenges they were seeking to overcome were:

- Weeds;
- Lodging;
- Pests and disease.

Two members decided to utilise the research fund to help them address important issues they were facing on farm. These were:

Andy Howard, Bockhanger Farm, Kent
T1, Linseed and oats: The 2017/18 linseed crop at Bockhanger Farm suffered from low establishment which was identified to most likely be the result of high levels of flax flea beetle (FFB) damage. FFB attack the linseed when it is emerging and damage the stems before it can establish. However, Andy observed that in areas of the field where there were wild oats there were much lower levels of damage. He was therefore keen to see if oats could act as a temporary nurse crop to help reduce FFB attack and aid linseed establishment.

T2, Pea, oilseed rape and oats: Pea-oilseed rape 'Peola' mixtures have been grown with success in previous years on Bockhanger Farm. OSR provides structural support to the peas. This trial tested different seed rates to find an optimum for scaffolding support in the peas. Furthermore, in the previous year the spring OSR did not establish well which Andy suspected may have been due to cabbage stem flea beetle (CSFB) or slug damage to young plants. He had seen evidence that oats are good at repelling CSFB and potentially other pests. He therefore trialled Peola with and without oats within the same trial.

James Hares, Roundhill Farm, Wiltshire
T3, Wheat and beans: Problematic levels of wild oats in certain fields at Roundhill Farm were causing huge yield losses. James was looking for an alternative method to get on top of them within the arable part of the rotation - particularly in the bean crop in which weed control is particularly challenging. In 2017/18 intercropping wheat and beans anecdotally enabled 74% reduction in weed biomass between samples taken in the intercropped field versus a bean monocrop but saw a yield penalty in the beans. James was therefore keen to alter the seed rate to see if he could achieve a similar level of weed control with reduced yield loss in a different year.

3 Methodology

Trial set up and data collection
T3 was drilled in winter 2018 and T1 and T2 in spring 2019 as per the trial plans below (Figures 1 -3). Each trial had different data collection priorities to address the different objectives outlined above, which are summarised in the tables below (Tables 1 – 3 summarise the completed data collection activites).

Data collection challenges
T1 was successfully completed with the oats being killed with herbicide in late spring once the linseed had established so no separation was necessary to obtain target crop yields. Unfortunately, however, T2 and T3 encountered problems. Although pest/disease damage assessments were completed in T2, the OSR did not establish well and thus it was not possible to complete the lodging assessments to assay the scaffolding potential of the OSR for the pea. Separation of the final crop was also not necessary. For T3, the farmer took the urgent decision to mow the monoculture control before harvesting due to the heavy burden of wild oats. Yield data was therefore not collected for the monocrop.

T1: Linseed and oats, Bockhanger Farm

Objective: Test the effectiveness of oats in reducing linseed loss during establishment via reduction of pest pressure.

Farm Context: No till arable on varied soil types. Low input system with a 50% reduction in inputs over the last 5 years.

Establishment: Using a cross slot drill the linseed and oats were drilled on 27/03/19 in one pass. Linseed was drilled at a seed rate of 700 seeds/m2 with and without an oat companion. The treatments were the oat seed rates of 0 seeds/m2, 70 seeds/m2 and 140 seeds/m2. These were replicated three times in strips across the field.

Assessments: A transect of seven samples moving up each strip was completed to assay crop establishment and pest damage. The linseed pest damage score was assayed on a scale of 0-5 (0 = 0% leaf surface area damage, 1 = 1-10%, 2 = 11- 20%, 3 = 21-30%, 4 = 31-40%, 5=41%+). Two pan traps were placed in each strip for five hours to assay pest abundance.

Figure 1 – T1 field plan showing location of treatments and replicates across the field.

Table 1 – Overview of T1 data collection that was completed in all treatments.

Target crop	Measurements	Method	Number of reps sampled	Samples per rep	Date completed
Linseed	Crop establishment	Plant counts for surviving plants % in metre squared quadrat	3	7	25 /04/19
Linseed	Linseed pest damage score	Plant pest damage score estimate (FFB, slugs, pigeons, etc) for all plants in quadrat	3	7	25 /04/19
Linseed	FFB abundance	Pan traps placed in field strips and number of individuals caught per trap in 5 hours counted	3	2	25 /04/19

Linseed	Linseed yield	Calibrated yield from combine monitor	3	1	26/8/19

T2: Peas, OSR and oats, Bockhanger Farm

Objectives: a) Test the effectiveness of oats in reducing spring oil seed rape (OSR) losses (in a crop which is also intercropped with peas) via reduction in pest and disease pressure; b) Test the effectiveness of OSR in supporting the pea crop and reducing lodging.

Establishment: Marrowfat peas were drilled at a seed rate of 70 seeds/m2 with and without OSR and an oat companion on 30/03/19. The treatments were: monoculture peas; 2: peas plus OSR at 35 seeds/m2; peas plus OSR at 50 seeds/m2; and, peas plus OSR at 50 seeds/m2 plus oats at 70 seeds/m2. These were replicated two times in strips across the field with the monocrop being replicated three times to assay in-field heterogeneity.

Assessments: Sampling was conducted as above except five samples were taken per strip rather than seven, and the pan traps were left out for four hours instead of five (Table 2).

Treatment	Plot	Area (ha)	Peas (seed /m2)	SOSR (seed / m2)	Oats (seed / m2)
1	1	0.78	70	0	0
2	2	0.8	65	35	0
3	3	0.79	65	50	0
4	4	0.71	65	50	70
1	5	0.63	70	0	0
2	6	0.53	65	35	0
3	7	0.53	65	50	0
4	8	0.54	65	50	70
1	9	0.54	70	0	0

Figure 2 – T2 field plan showing location of treatments and replicates across the field.

Table 2 – Overview of T2 data collection that was completed in all treatments.

Target crop	**Measurements**	**Method**	**Number of reps sampled**	**Samples per rep**	**Date completed**
OSR and Pea	Crop establishment	Plant counts for surviving plants % in metre squared quadrat	2	5	25/04/19
OSR and Pea	OSR pest and disease damage score	Plant pest/disease damage score estimate (CSFB larvae and adults, slugs, pigeons, fungal infection etc) for all plants in m2 quadrat	2	5	25/04/19

OSR and Pea	CSFB abundance	Water traps placed in field strips and number of individuals caught per trap in 4 hours counted	2	1	25/04/19
OSR and Pea	OSR and Pea tissue sampling	Samples sent to NRM for standard tissue analysis (N, P, K, etc)	1	1	21/06/2019
OSR and Pea	Total yield (OSR and Pea, but little OSR)	Yield from combine monitor	2	1	03/08/19

T3: Wheat and beans, Roundhill Farm

Objectives: Test whether intercropping beans with wheat reduces the weed burden in the bean crop and increases the protein content in wheat.

Farm context: Mixed organic farm (beef and arable) in Wiltshire. Oxford clay, heavy clay loam (non-calcareous).

Establishment: Field split with 1 ha of monoculture beans (Tundra variety) drilled at 200kg/ha and 5.3 ha additive design intercrop with 200kg/ha beans plus 100kg/ ha wheat (Mulika variety). The drilling date was the 30/10/18 for the beans and 31/10/18 for the wheat. No replicates were included as this not practical for the farmer this year. Drilled in two passes with a weaving drill. A monocrop of Mulika wheat in a separate field was used for protein/Hagberg Falling Number (HFN) comparison.

Assessments: Sampling was completed by a walking 'W' transect up the length of the strip with samples at regular pacing intervals. Leaving at least 10m from the headlands and field edges. All biomass to ground level within a 0.5m2 quadrat was cut and removed. Weeds were then separated from crop in the lab, dried and weighed to give dry weight biomass. Dominant weed species were also identified at each sample point. Wheat grain samples were taken at harvest from different sections of the combine for the intercrop and monocrop. Harvest date was 22/08/19.

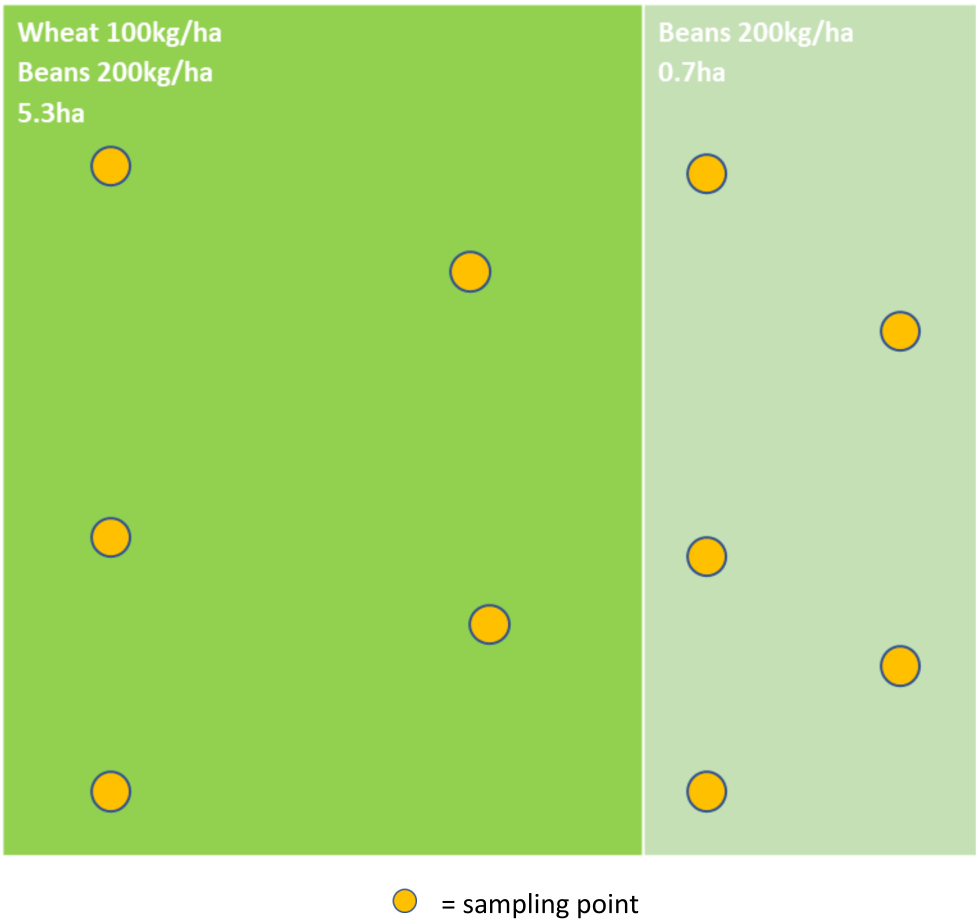

Figure 3 – T3 field plan showing sampling across the two treatments.

Table 3 – Overview of T3 data collection that was completed.

Trial	Target crop	Measurements	Method	Number of reps sampled	Samples per rep	Date completed
T3	Bean	Weed biomass	Quadrat cut, dry and weigh at ORC	1	6	18/06/2019
T3	Bean	Wheat protein and HFN	Lab test of inter and mono wheat	1	1	19/09/2019

Data analysis

T1 was analysed via Analysis of Variance (ANOVA) following a randomised block design with the blocking factor being each replicate group of strips moving across the field. An analysis to compare blocks to one another within a treatment, to determine differences in relation to spatial position of a strip (and proximity to the woodland; see Figure 1), was also completed via ANOVA of samples within each treatment separately.

For T2, a two-sample *t*-test was performed to firstly examine the pest/disease damage observed in the OSR crop at the 50 OSR seeds/m2 seed rate with and without oats (strips 3 and 7 versus 4 and 8), as well as the establishment and yield of these strips. Secondly, ANOVA was performed on the full data set of 8 strips to assess whether there were any differences in pest numbers found in pan traps across the treatments and, finally, in pea plant establishment and yield. OSR yield was not analysed due to the OSR crop failure and in turn part b of T2 (assessment of OSR as a scaffold for the peas) was not completed.

It was not possible to complete any advanced data analysis on T3 due to the lack of replicates in the dataset.

4 Results and discussion

T1: Linseed and oats, Bockhanger Farm

Establishment

Linseed plant establishment was higher in the highest oat seed rate treatment (Figure 4) but this was not found to be significant (F = 2.90, d.f. = 1, 5, P = 0.15).

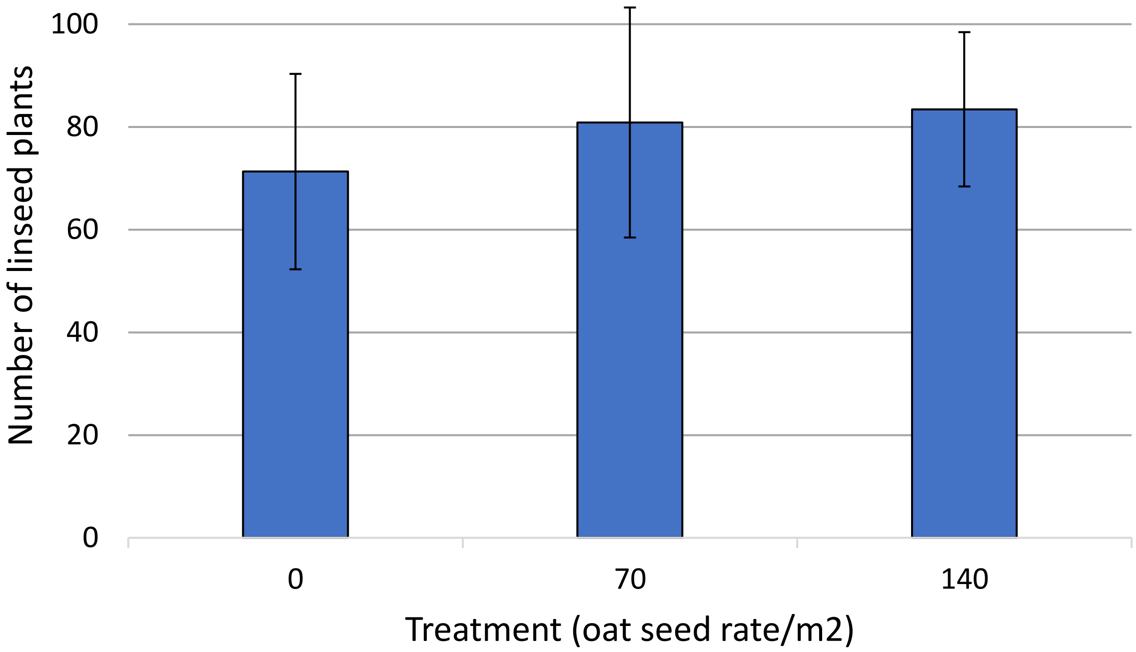

Figure 4 – Average number of linseed plants (+/- one standard deviation) for each oat seed rate treatment across the three strips, counted in T1 near to establishment.

Image 1: Linseed and oats at 70 oat seeds/m2

Impact of oats on linseed establishment across the field
The farmer's observations suggested a spatial difference in the effectiveness of oats in supporting plant establishment – with those closest to the woods seeing a greater effect. Analysis of spatial differences across the field found no effect on linseed plant count of strip position for the 0 and 70 seeds/m2 treatments (F = 1.33, d.f. = 2, 18, P = 0.29 and F = 0.49, d.f. = 2, 18, P = 0.62 respectively), but there was a significant spatial effect for the 140 seeds/m2 treatment (Figure 5; F = 8.59, d.f. = 2, 18, P = 0.002). There was a lower abundance of linseed plants furthest away from the woodland (strip number 3) versus those closer to the woods (strip number 9; also see Figure 1).

This may indicate that the oats were of most benefit when nearest to a potential source of pests (woodland), however across the whole trial no significant difference in linseed establishment in relation to the different seed rates of oats was observed (Figure 4). It is also important to note that it is not possible to determine whether the differences in plant abundance relates directly to losses due to predation or other factors, especially in light of the pan trap results described below. More extensive pan trapping as well as plant counts over time (to determine losses) would be necessary to thoroughly explore the impact of the woodland as a potential source of pests and in turn the potential benefits of the companion.

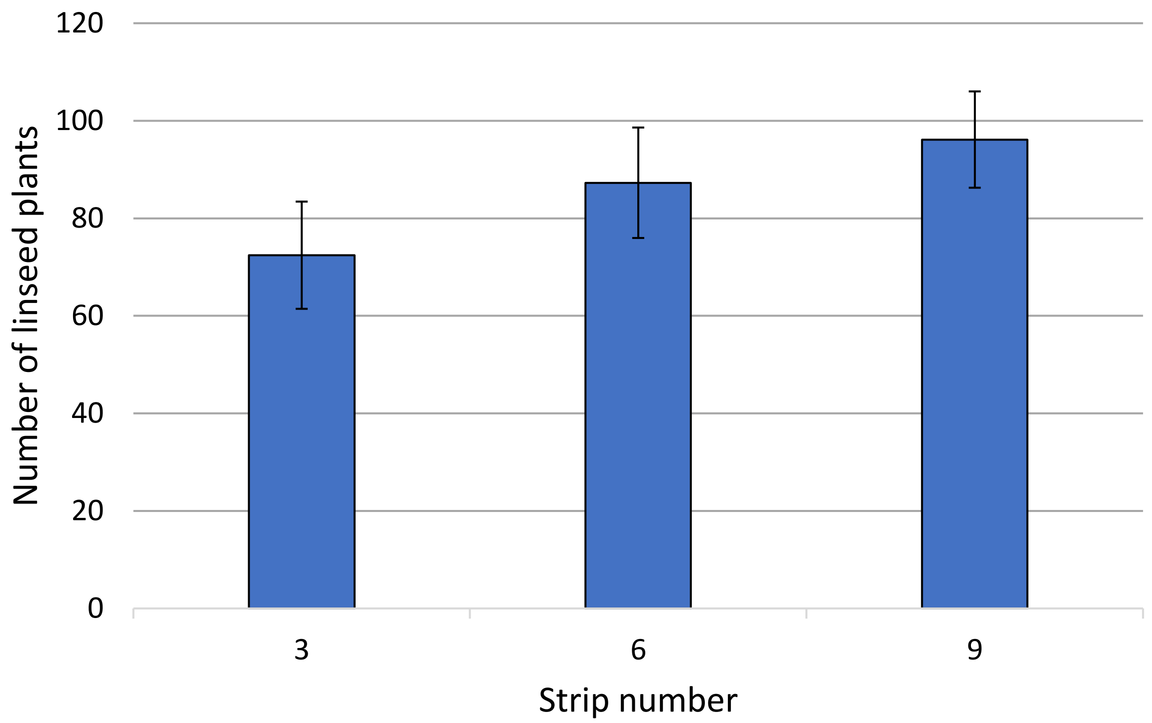

Figure 5 – The average number of linseed plants (+/- one standard deviation) increased in the 140 oat seeds/m2 treatment in strips closer to the woods (see Figure 1 for key to strip numbers).

Pest damage
Figure 6 (below) summarises the average pest damage score under the different seed rate treatments (oat seed rates of 0 seeds/m2, 70 seeds/m2 and 140 seeds/m2). There were no significant differences between the three seed rate treatments in the level of pest damage according to the pest damage score (F = 1.58, d.f. = 1, 5, P = 0.26).

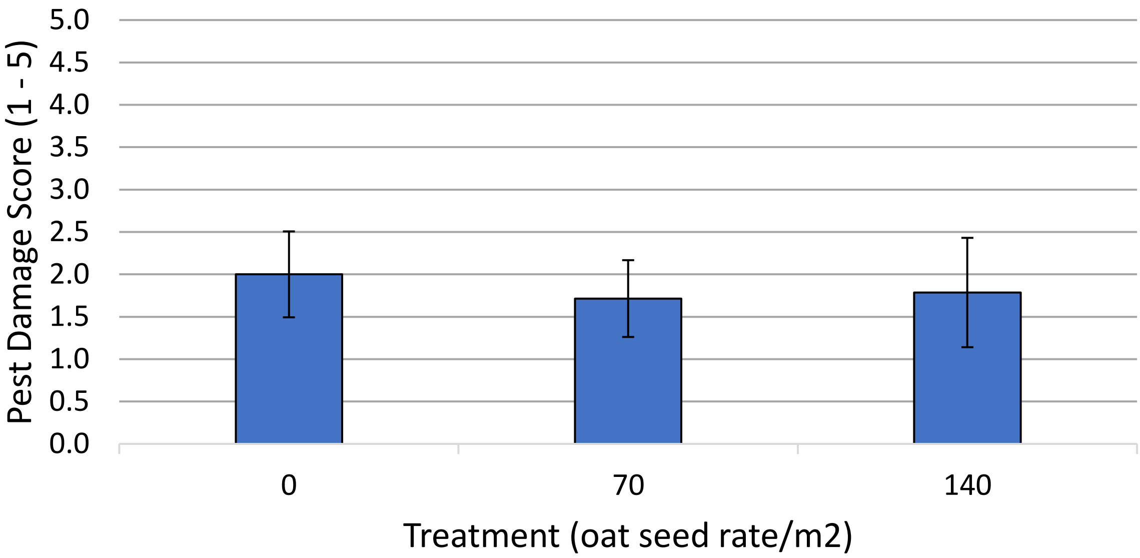

Figure 6 – No difference in average pest damage score (+/- one standard deviation) on linseed in T1 for each oat seed rate treatment across the three strips.

Insect presence and abundance

The traps captured a range of insects – mostly beneficials (including hoverflies and bees) and flax flea beetles (identification of which was supported by flea beetle specialist Dr Sam Cook (Rothamsted) and Jessica Hughes (John Innes Centre)). In terms of abundance the most flax flea beetles were in the 70 seeds/m2 treatment at an average of 7 individuals (+/- 4) and the least were found in the treatment without oats at an average of 6 individuals (+/- 3) (F = 0.004, d.f. = 1, 5, P = 0.95). There were no significant differences between the three seed rate treatments and flax flea beetle pest abundance (F = 0.004, d.f. = 1, 5, P = 0.95). An increased number of pest traps and longer sampling period would be required to enable more accurate data on the abundance of flax flea beetle within and between treatments.

Linseed yield

Significant differences in linseed yield were found (Figure 7; F = 6.59, d.f. = 1, 5, P = 0.05); with both treatments containing oats yielding more than the monocrop. The 70 oat seeds/m2 treatment showed a slightly higher linseed yield, suggesting that there is a balance of the facilitative and competitive effects between the two crops.

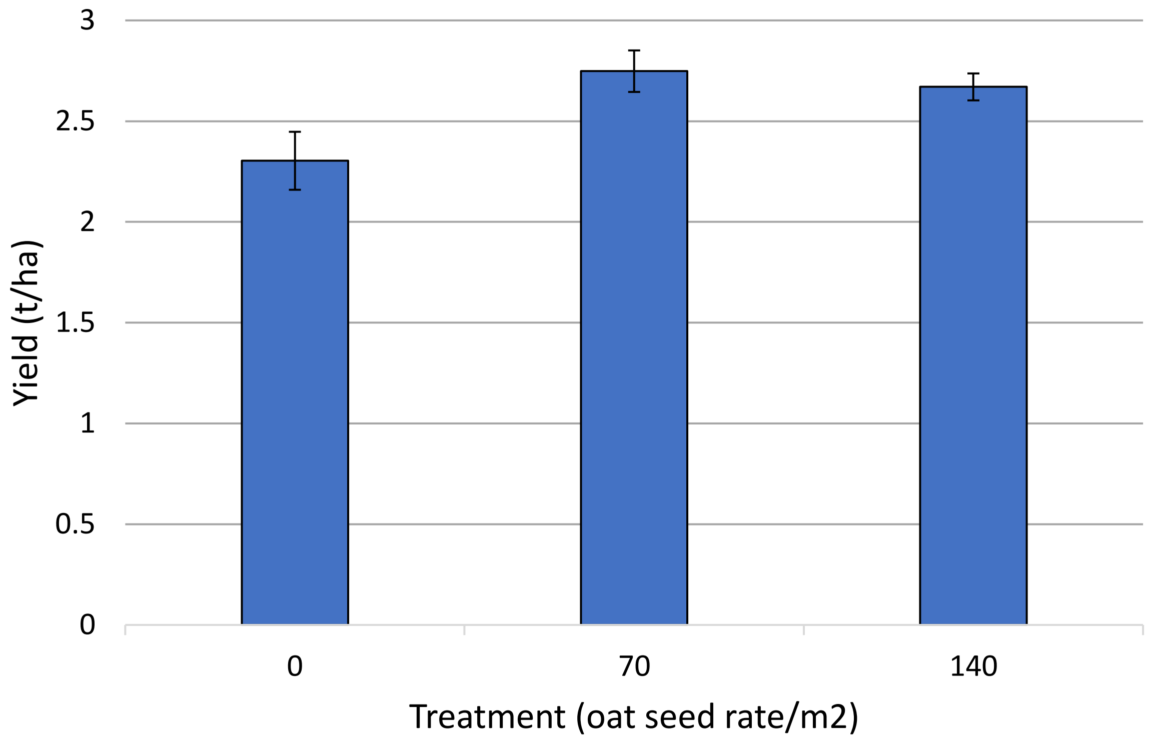

Figure 7 – A higher average linseed yield (+/- one standard deviation) was found in T1 in the treatments with oats across the three strips.

The increased yield with the oat companion was also satisfying to Andy: "From what I can work out the oats has given a yield boost of between 17-19% which was a great result". However, due to low linseed crop price, he reported that linseed is not a profitable crop for him to grow despite the advantages conferred by intercropping with oats.

T2: Peas, OSR and oats, Bockhanger Farm

Plant counts

The OSR had very poor establishment in the trial. In turn the OSR plant counts showed very little difference between the two treatments with an average of 3.1 individuals (+/- 0.3) in the strips without oats and 3.45 individuals (+/- 0.75) in the strips with oats (t = -0.43, df = 1.36, P = 0.31). Pea establishment (plant counts) did not differ across all the different treatments either, indicating that the OSR and oats did not provide any competition with the peas (F = 0.94, d.f. = 3, 3, P = 0.52).

Pest and disease damage

Shotholing from CSFB was found on the OSR in the trial, but it was difficult to completely distinguish between pest and disease damage in this case. Pest and disease damage score for the OSR averaged 2.85 (+/- 0.35) in strips without oats and 3.45 (+/- 0.15) in the strips with oats (Figure 8). The difference in the means was not found to be significant (t = -1.58, df = 1.36, P = 0.31). Considering the overall context of the experiment, and the poor establishment of the OSR within the trial, we would read all these results with caution and would have to consider the experiment insufficient to test the hypothesis that oats can reduce spring OSR losses (in a crop which is also intercropped with peas) via reduction in pest and disease pressure. Furthermore, no difference in pest abundance was observed across all the trial strips (*F* = 1, d.f. = 3, 3, *P* = 0.5), and only two cabbage stem flea beetle pests were trapped across the entire trial.

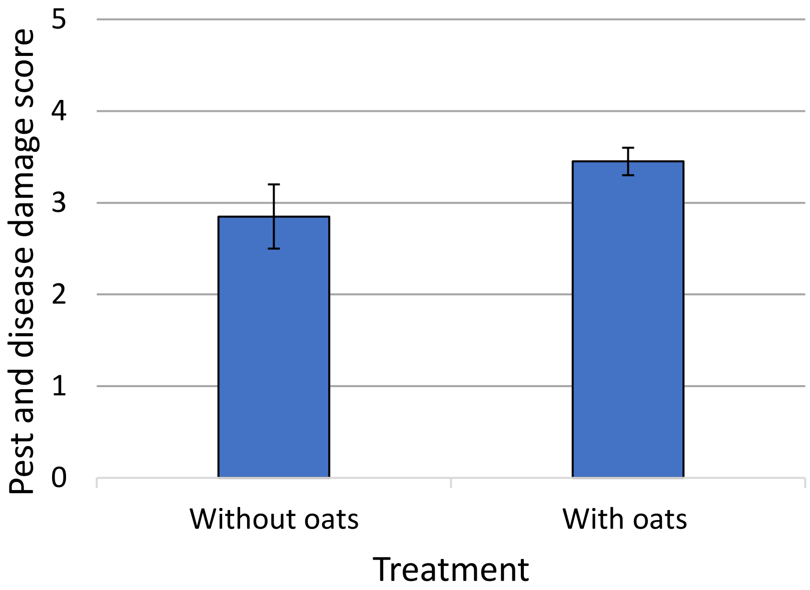

Figure 8 – Average pest and disease damage score (+/- one standard deviation) on OSR in T2 'Peola' was higher in strips without oats but this was not significant.

Plant N (OSR and Pea)

Plant tissue nutrient testing of the peas and OSR in the intercrop was completed by the farmer to see if the OSR was able to take up enough nitrogen with the pea companion, and with no N fertiliser application. The tests show that despite receiving no N fertiliser there was sufficient N in the plant tissue of both crops. There was however a deficiency of potassium – as peas have high a potassium need it is possible this deficiency is due to crop competition. The tissue test results for peas in monocrop were however very similar – reflecting what the farmer has seen previously that intercropping does not seem to be to the detriment of pea nutrition.

Yield

There was no significant difference in pea yields found in strips with v without oats (Figure 9; *t* = -0.8, df = 1.07, *P* = 0.56). This was also reflected in differences in the pea yields across all strips (*F* = 0.86, d.f. = 3, 3, *P* = 0.56). The OSR was not brought to harvest and thus there is no yield data. At the end of the day the farmer running the trials reflected that: "Yields look consistent. Maybe…slightly more OSR survived with the oats is something we may have gleamed from this trial. The main learning from this is don't grow spring OSR!".

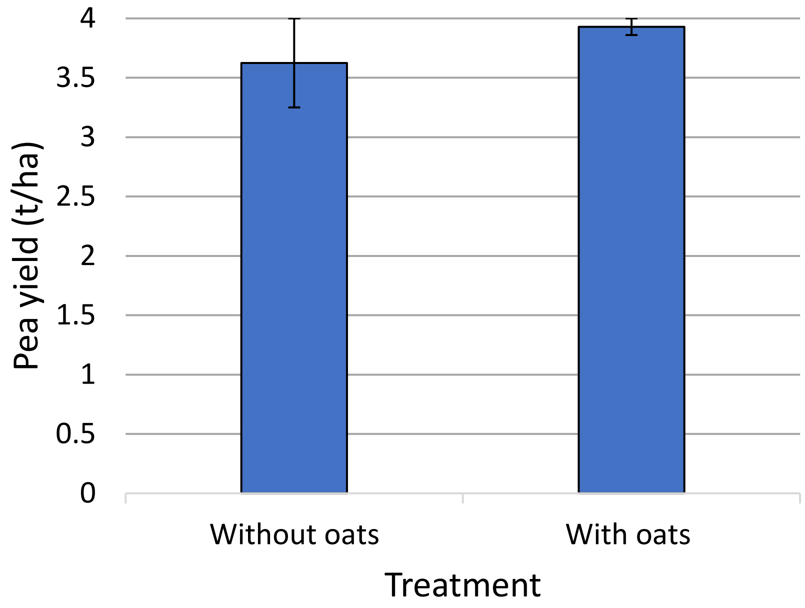

Figure 9 – The presence of oats in T2 'Peola' did not result in a significant difference in the average pea yield (+/- one standard deviation).

T3: Wheat and beans, Roundhill Farm

Weed Biomass

Weed biomass was generally higher in the monocrop area than the intercrop area but there was a large degree of in field heterogeneity (Figure 10). On average across the six samples there was 74.83% less weed biomass (dry weight) in the intercrop in comparison to the monocrop. This reflected the results in 2018/19 (73% less dry weight weed biomass), however this year there was a greater diversity of weeds – with more blackgrass and charlock.

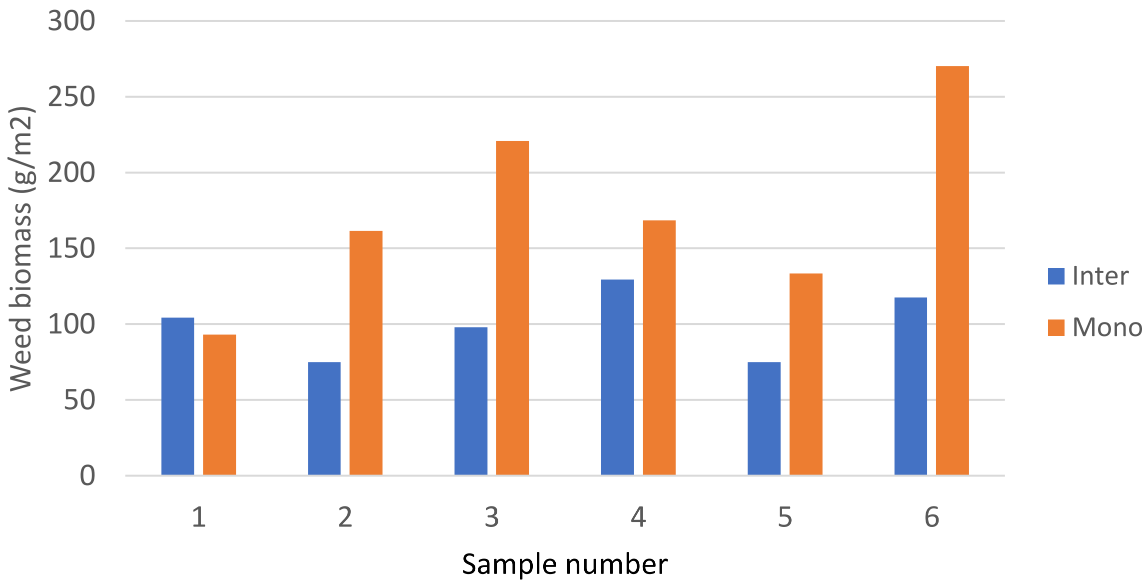

Figure 10 – Weed biomass (dry weight in g per m2 quadrat) in intercrop versus monocrop samples.

Yield
Due to the excessive weed burden the farmer took the decision to destroy the monocrop beans to prevent the wild oats going to seed. As such there is no yield comparison data between bean monocrop and intercrop. The combined yield of the intercrop was 2.5 tonnes/ha mixed beans and wheat with a ratio of approximately 25:75 beans: wheat. This compares to the combined yield of 1.7 tonnes/ha in the mixed intercrop in the previous year with the higher wheat seed rate (175kg/ha wheat and 125kg/ha beans). As such the farmer is happy with the decision to lower the wheat seed rate and increase the bean seed rate this year (100kg wheat and 200kg/ha beans) which has enabled the same (slightly higher) level of weed control with less yield penalty. However, these results should be read with some caution. It is not possible for us to distinguish the effect of the intercrop/monocrop treatment, and change in seed rates, at this stage as the change in yield could relate to a number of other factors such as the condition of the field that the crop was grown in this year, or the weather.

James plans to repeat this again next year. Although a yield comparison with this year's monocrop was not possible, the farmer felt this was of less interest as they did not intend to grow monocrop beans anymore and were more interested in the weed suppression effects and finding a good seed ratio. If the trials were to be repeated and more rigour required, it would be recommended that a small area of the monocrop should be preserved in order to enable yield comparisons. Also strips of monoculture wheat should ideally be in the same field as the intercrop and replicates of the treatments should be split across the field to seek to address infield heterogeneity. However, the farmer did not feel this was practical this year and he felt that his questions were answered from the observations of the field. For him the fact that he had to destroy the monocrop and not the intercrop was enough evidence of its efficacy! Our ability to determine the reproducibility of these results and make general recommendations is however limited.

Wheat Protein and Hagberg Falling Number
A sample was taken through the heap of the intercrop and the monocrop. Lab tests show that the intercropped wheat protein content was 10.94 and 10.67 in the monocrop sample. The HFN of the intercrop sample was 411 compared to 384 in the monocrop sample. Due to the lack of replicates in the trial it is not possible to determine whether this result is chance or represents a real difference in protein content and HFN of the wheat as a result of intercropping with beans. It does however indicate that improved wheat quality could be another benefit of intercropping with beans on this farm and this merits further investigation.

Image 2: Anecdotal differences in wild oat size were observed again this year

5 Conclusions/Recommendations (500 to 800 words)

T1: Linseed and Oats

The results showed a significantly **increased linseed yield in strips with oat companion**. This suggests that there could be some mechanism through which oats aid establishment and yield of the linseed. Further investigation into the mechanism (allelopathy/distraction/repulsion) would allow for more general guidelines to be developed. **Pan traps were able to confirm the presence of certain pests in the field**, however, to understand their impacts further, more extensive pan trapping as well as plant counts over time (to determine losses) would be necessary.

It is also worth noting that this was the only trial where significant differences between a treatment were detected which may be a result of the **increased number of replicates and higher sampling effort.** This highlights the value of including replicates in a trial when hoping to attain robust conclusions and general recommendations. The optimal number of replicates and samples will depend on the size of the effect that is being tested, however in complex farming systems with a lot of random variation e.g. from the environment, including at least three replicates is recommended.

T2: OSR, Peas and Oats

Although the OSR did not make it through to harvest there were still some insights harvested from this trial. Firstly, the tissue tests suggested that the **intercropped OSR's nutrient levels were sufficient despite no artificial N being applied**. This could suggest a facilitative effect between the pea and the OSR, which could be investigated further in future studies. At the same time there was **no difference between the pea in intercrop versus monocrop** suggesting that intercropping did not have a competitive effect on pea nutrition. This was also reflected in the pea yields - there was no significant difference between treatments which suggest there was no competitive effects of companion cropping with oats/OSR.

On a practical note – intercropping did provide **insurance** as although the OSR crop failed, the farmer was still able to harvest something. It has also highlighted the challenges of growing OSR on this farm and encouraged the farmer to consider taking it out of the rotation.

T3: Wheat and Beans

The results of this trial were consistent with last year with a **much lower weed biomass in the intercrop versus the monocrop** – 73% and 74% respectively. Furthermore, this year's intercrop resulted in a higher total yield compared to last year's intercrop, which the farmer feels is in part due to the lower wheat seed rate and higher bean seed rate. It seems that in very high wild oat infestations intercropping beans with wheat could enable the wheat to fill the niche of the wild oats, competing for nutrients and light and thus reducing weed abundance. These trials have provided the farmer with confidence in changing their practice although it is difficult to make general recommendations due to the limited trial design. However, the consistency in effect from one year to the next, alongside the theoretical background and support of past research, indicates that the reduced weed abundance is the result of intercropping.

6 Knowledge Exchange and Communications Activities

It is worth noting that this Field Lab also engaged in a significant number of Knowledge Exchange and Communications activities over the year. As well as the Whats App group where members regularly share photos and updates, we organised several events and published materials including:

- Field Lab meeting at Roundhill Farm (April 2019)
- Agricology Field Day at Bockhanger Farm – including other group members sharing their experiences (June 2019)
- ORC Field Day at Sonning – including Bean and Triticale trials and a follow-up video with David Casebow to be published on Agricology (June 2019)
- Session at Groundswell with members of the group (June 2019)
- Direct Driller magazine article (November 2019 issue)
- Agricology blog (Published December 2019)
- ORC Bulletin (Winter 2019 Issue)
- Presentation in Pulses Session at ORFC (January 2020)

7 Further reading

Brooker, R.W., Bennett, A.E., Cong, W.F., Daniell, T.J., George, T.S., Hallett, P.D., Hawes, C., Iannetta, P.P., Jones, H.G., Karley, A.J. and Li, L., 2015. Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology. *New Phytologist*, *206*(1), pp.107-117.