Investigating the integration of cover cropping into vining pea rotations

Technical report for 1st round of trials, 2016-2019.

Processors & Growers Research Organisation
Green Pea Company

Tom Jelden
Dr. Lea Herold

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1 Background

Vining peas are vulnerable to poor soil conditions and soil borne pathogens. Cover crops can be used to improve soil structure and health. They also have the potential to mitigate disease risk from soil borne pathogens. These attributes in addition to the growing recognition of cover crop's environmental benefits render them a potential agronomic tool in vining pea production.

Cover cropping is a complex niche subject and their use in vining pea rotations is poorly documented. The purpose of this project is to investigate the effects of cover crops on vining pea development with reference to soil health and foot rot. Additionally, the effect of catch crops on following cereals is studied. Here cover cropping is defined as over-wintering vegetative cover (preceding peas) and catch crops as a fill between vining peas and the following crop.

This document presents the findings and analysis of three trials (out of nine) hosted by GPC growers. It is the first report in a series of three technical reports. The trials have assessed the use of a selection of common cover crops with numerous soil and plant criteria monitored. Cover crops were sown in 2016 prior to the 2017 vining pea season with 1st and 2nd wheats assessed in spring 2018 and 2019.

The ultimate objectives of these trials are to determine the suitability of cover cropping in vining pea rotations, to show how and where they may be employed with particular focus on improving our understanding of foot rot management.

The project was launched in 2016 sponsored by PGRO, Birdseye and The Green Pea Company, with funding awarded by the EIP-AGRI scheme and seed provided by Elsoms. All work was carried out by PGRO and GPC members Chris Byass, Tamara Hall, Andrew Falkingham and Richard Boldan.

Cover crop of black oats and phacelia (Universal)

2 Trial methods

Four cover crop mixes and three catch crop mixes were trialled alongside control measures and the field standard (Custom). The mixtures are detailed in table 2. The trial adhered to a simple strip trial layout. Cover crop strips were drilled parallel to then be partially overlapped by perpendicular catch crop strips later on (see figure 1). This resulted in field areas that had overlapping treatments. Where only catch crops are drilled, the treatments will be abbreviated with the prefix "*Post*" in this document (see table 2 for further clarification). It is important to note that this layout cannot completely distinguish field effects from treatment effects in some cases. The trials were repeated at three sites in the East Riding of Yorkshire with different soil types, foot rot pressures and drilling dates.

Table 1: Trial site summaries

Field name	Location	Drilling window	Foot rot pressure	Soil type
Molescroft 61B	Beverley	Late drilled	High foot rot risk conferred by *Aphanomyces* and *Didymella*	Poorly drained clay loam
Eastfield AR	Bainton	Mid season	No foot rot risk	Medium sandy clay loam with cover cropping and min-till history
Boxtree Bubwith	Asselby	Early drilled	Medium risk from *Fusarium* and *Didymella*	Free draining sandy loam with poor inherent structure

Table 2: Treatments / Species mixes

Name in text	Species mix	Rate
Control	Stubble	n/a
Vetch	100% Winter vetch (*Latigo*)	20kg/ha
Radish	100% Oil radish (*Defender*)	18kg/ha
Intensiv	80% Black oat (*Codex*), 20% Oil radish	30kg/ha
Universal	60% Black oat, 20% Phacelia (*Angelia*), 20% Berseem clover (*Otto*)	20kg/ha
Post control	Stubble	n/a
Post radish	90% Phacelia, 10% Oil radish	18kg/ha
Post buckwheat	10% Phacelia, 90% Buckwheat (*Hajnalka*)	20kg/ha
Post clover	38% Phacelia, 62% Berseem clover	12kg/ha
Control:Control	"Control" "Post control" overlap	-
Radish:Radish	"Radish" "Post radish" overlap	-
Intensiv:Buckwheat	"Intensiv" "Post buckwheat" overlap	-
Universal:Clover	"Universal" "Post clover" overlap	-

Numerous soil and plant parameters were assessed at various times throughout the rotation. Samples and assessments were made before cover crop drilling, prior to cover crop destruction, prior to pea harvest, shortly before catch crops were destroyed, and in the late spring in 1st and 2nd cereals. Through-out the text these time points are referred to as Pre-cc, Cover crop, Vining pea, Catch crop, 1st wheats and 2nd wheats respectively.

Soil properties examined included:

- SMN (soil mineral nitrogen) at various depths
- Macro-nutrients including phosphorus, potassium and magnesium
- Soil organic matter (LOI) and pH
- Soil moisture
- Compaction (penetrometer resistance)
- Assessment of soil condition (VESS)
- Inoculum pressure for foot rot pathogens *Fusarium solani* and *Didymella pinodella*

Assessments of plant health and responses included:

- Vining pea biomass
- Severity of foot rot development
- Estimates of straw and cereal yields

There were three relevant foot rot pathogens. *Fusarium solani*, *Didymella pinodella* and *Aphanomyces euteiches* which are referred to by their genus thought the text. *Fusarium* and *Didymella* were frequently monitored with *Aphanomyces* levels determined to be considered in analysis.

Note* - Clover had failed almost entirely to emerge in Post Clover treatments (Phacelia + clover). It is best, therefore, to consider the "Post Clover" treatment as predominantly phacelia. The name of the treatment is preserved to maintain consistency with accompanying reports.

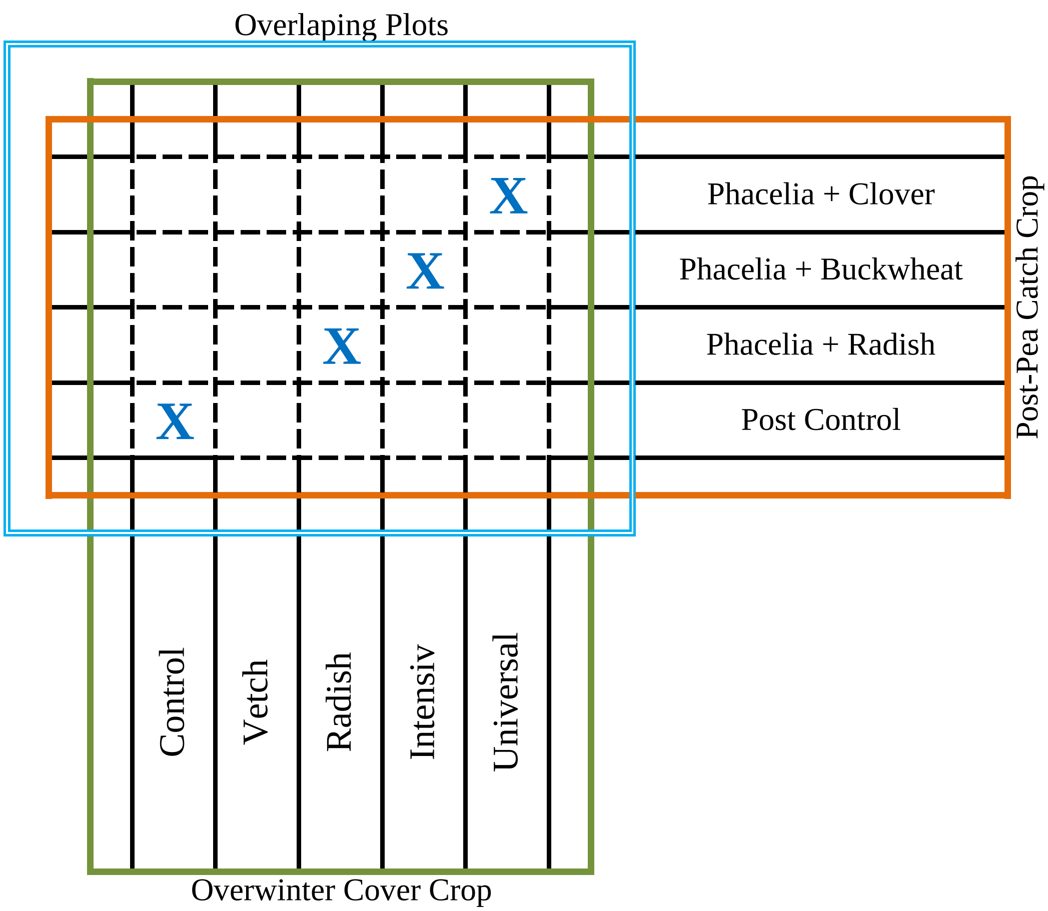


Figure 1: Schematic example of the strip plot layout employed

Details on methods, timings, analysis and replication are given in the appendix. All chemical analysis of soil samples was performed by Hillcourt Farm Research.

3 Results

3.1 Soil mineral nitrogen (SMN)

3.1.1 Cover crop

Values for soil mineral nitrogen, prior to vining pea drilling are shown in figures 2 and 3. Data from Molescroft 61B are not available due to failure to collect samples. A significant quantity of soluble nitrogen leached through the soil profile at Eastfield AR and Boxtree Bubwith in Control plots. This can be demonstrated by the greater amount of SMN in the deeper soil. Radish and Intensiv mixes had the least nitrogen at lower soil depths probably due to the deep rooting oil radish in the mixes intercepting nitrogen from greater depths. At Eastfield AR, Universal had a higher amount of free ammonium. At Boxtree Bubwith, Vetch appeared to have failed in taking up nitrogen (having figures similar to Control) perhaps due to the limited and shallow rooting of vetch, plus the readiness with which nitrogen would leach in this sandy soil. The high amount of SMN at 60-90cm in the Custom treatment was unexplained.

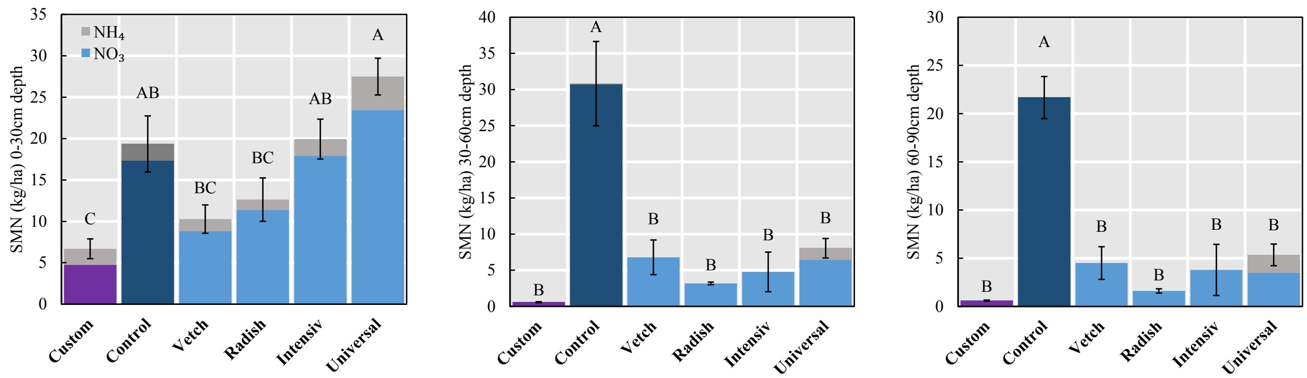


Figure 2: Mean soil mineral nitrogen at various depths at cover crop stage (January 2017). Eastfield AR.

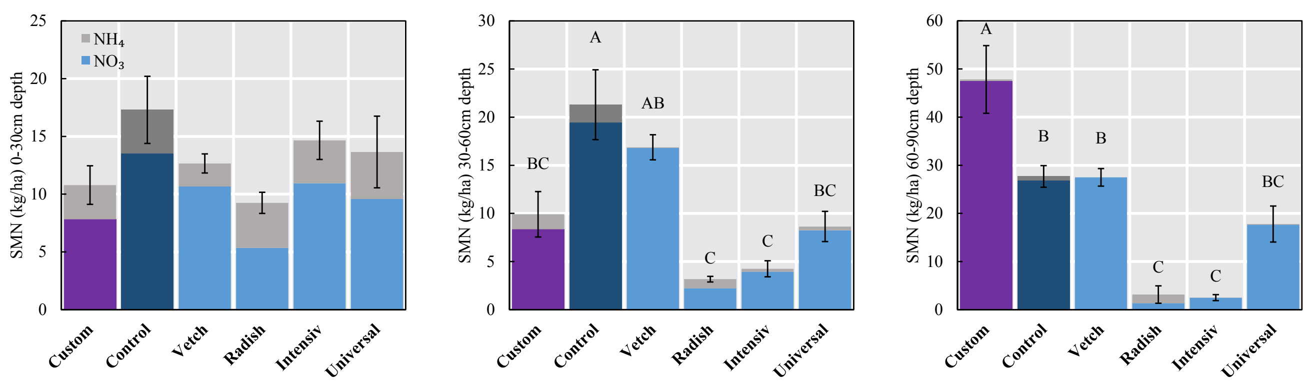


Figure 3: Mean soil mineral nitrogen at various depths at cover crop stage (January 2017). Boxtree Bubwith.

3.1.2 Vining pea

Values for soil mineral nitrogen at vining pea harvest (Post-pea) are shown in figures 4 and 5. Few significant differences were found at this sampling time. At Molescroft 61B, Control was lowest in SMN probably due to a lack of available nitrogen released from plant biomass. However, all treatments will have lost nitrogen to leaching over winter as a consequence of destroying cover crops at the beginning of winter (October 2016), allowing nitrogen to leach. Cover crops at the other sites were destroyed much later (January 2017). At Eastfield AR, SMN was highest in Vetch and Universal plots (30-60cm). Vetch was generally the highest in SMN at this time, possibly a result of fixed nitrogen released from destroyed vetch. Custom and Radish were lowest. Some differences in SMN were also present at Boxtree Bubwith. Control plots at both depths had the least SMN compared to other treatments. Likely due to loss of soluble nitrogen over winter and no nitrogen release from decaying biomass. This is not statistically supported. Overall, Vetch had the least amount of SMN (at vining pea stage) which contradicts findings observed at Eastfield AR. However, levels of SMN in the Vetch treatment appeared to have caught up with other treatments by September (see figure 6), a phenomenon also observed at Molescroft 61B.

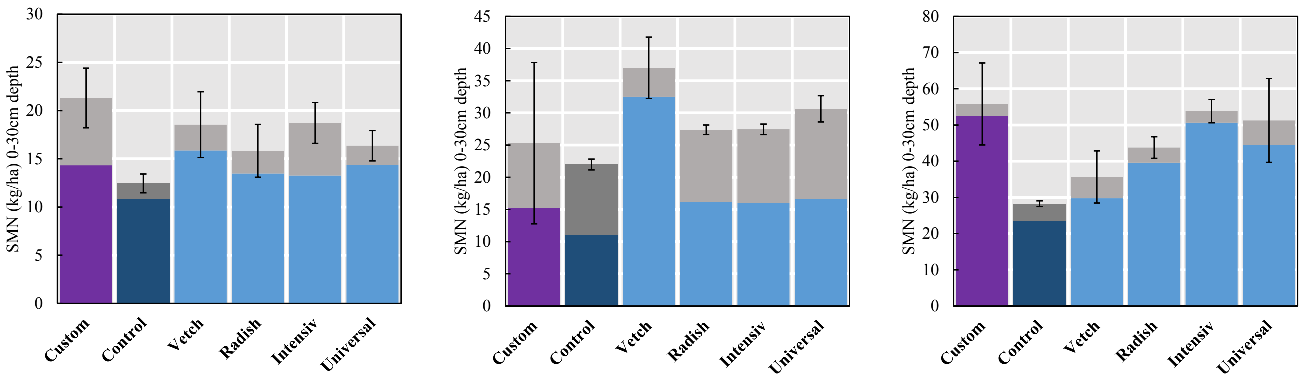


Figure 4: Mean soil mineral nitrogen to 30cm depth at vining pea stage (July 2017). Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right).

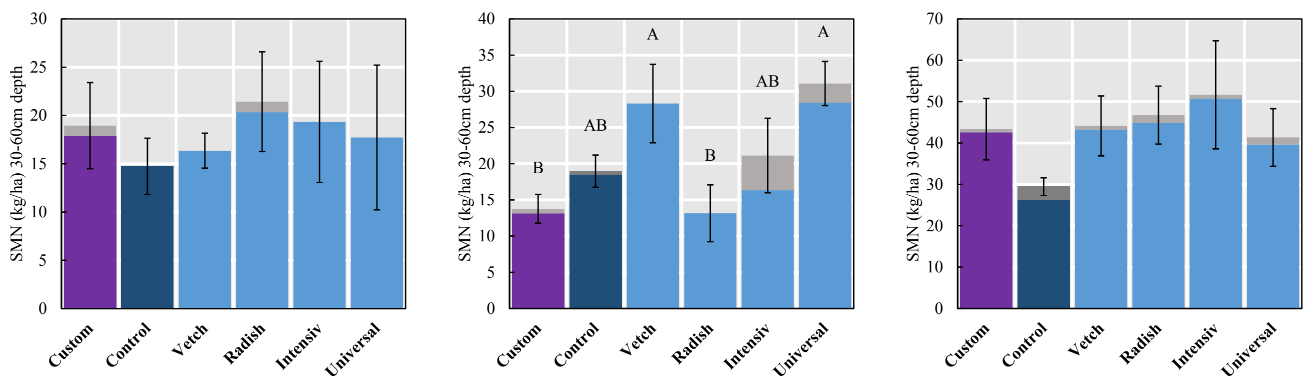


Figure 5: Mean soil mineral nitrogen from 30cm to 60cm depth at vining pea stage (July 2017). Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right).

3.1.3 Catch crop

At Molescroft 61B, SMN was lowest in the plots with catch crops. An expected result considering the nitrogen demand of the catch crops, between which there is negligible difference in SMN. Interestingly, Control and Radish plots measured considerably less in SMN compared to Vetch, Intensiv and Universal plots. This may be partially explained by the greater severity of foot rot in the Control and Radish treatments (see figure 35).

SMN was approximately 70-80% lower in catch cropped plots at Eastfield AR, with buckwheat dominant mixtures displaying a lesser appetite for nitrogen. These data demonstrate that catch crops have effectively used all the nitrogen generated by vining peas. The Control treatment had greatest SMN, gaining nearly 100 kg/ha since vining. Other cover cropped treatments have "accumulated" roughly 70 kg of SMN per hectare. This is an odd result considering the Control treatments yielded the least haulm biomass (figure 37) although the relatively high quantity of ammonium in the treatment suggests the explanation lies in the soil biology.

At Boxtree Bubwith, as with the other sites, SMN was lowest in the catch cropped plots. Curiously, Control and Control:Control treatments showed the least SMN whilst having supported the greatest amount of pea biomass during the summer, a result in complete contrast to cover cropped plots at Eastfield AR.

Missing explanations for unexpected SMN responses aside, these data all show the "catching" ability of catch crops, holding nitrogen suspected to benefit early cereal production in the following autumn.

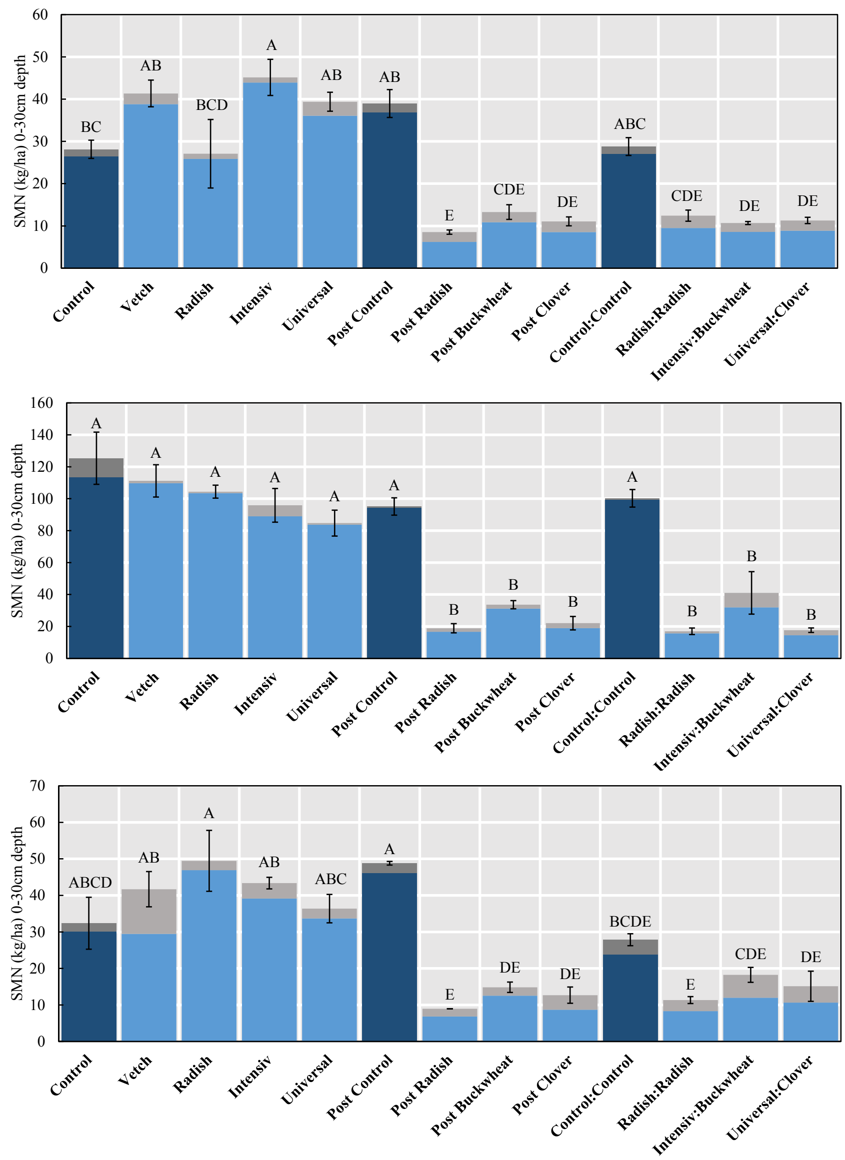


Figure 6: Mean soil mineral nitrogen to 30cm soil depth at catch crop stage (September 2017). Molescroft 61B (top), Eastfield AR (middle), Boxtree Bubwith (bottom).

3.1.4 1st wheats

No treatment effects on SMN could be confidently identified in the 1st wheats following catch crops. This is likely due in part to significant nitrogen applications before sampling. At Molescroft 61B, the levels of SMN were very similar between all treatments with the exception of a spike in the Post Control plots. SMN levels at Eastfield AR were very variable with no clear picture emerging. The Control and Control:Control measures were lowest but this was not a statistically supported difference. The grower had commented that the wheat in the Post Control strip appeared to be ”far greener” compared to the rest during the winter, thought to be a result of more readily available nitrogen. No SMN samples were taken then to examine the claim. Again, at the Boxtree Bubwith site no obvious treatment effects were discovered by statistical means. However, figure 7 shows that (with the exception of Post Radish) catch cropped areas were lower in SMN overall.

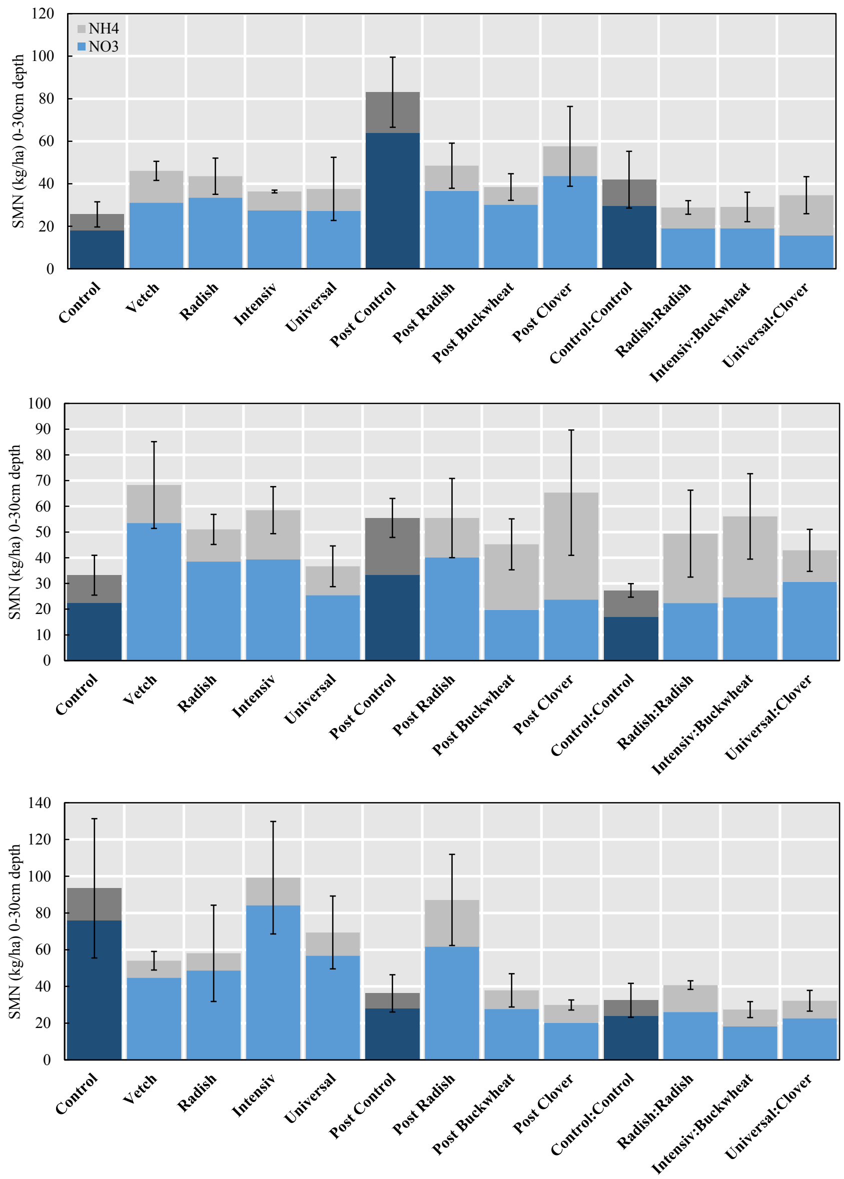


Figure 7: Mean soil mineral nitrogen to 30cm depth at 1st wheats stage (May 2018). Molescroft 61B (top), Eastfield AR (middle), Boxtree Bubwith (bottom).

3.1.5 2nd wheats

At both Molescroft 61B and Eastfield AR no treatment differences were identified on SMN availability in the second wheats. Unsurprising considering the year and half after the previous catch crop and the nitrogen inputs since. There are no data for Boxtree Bubwith as the site had changed ownership.

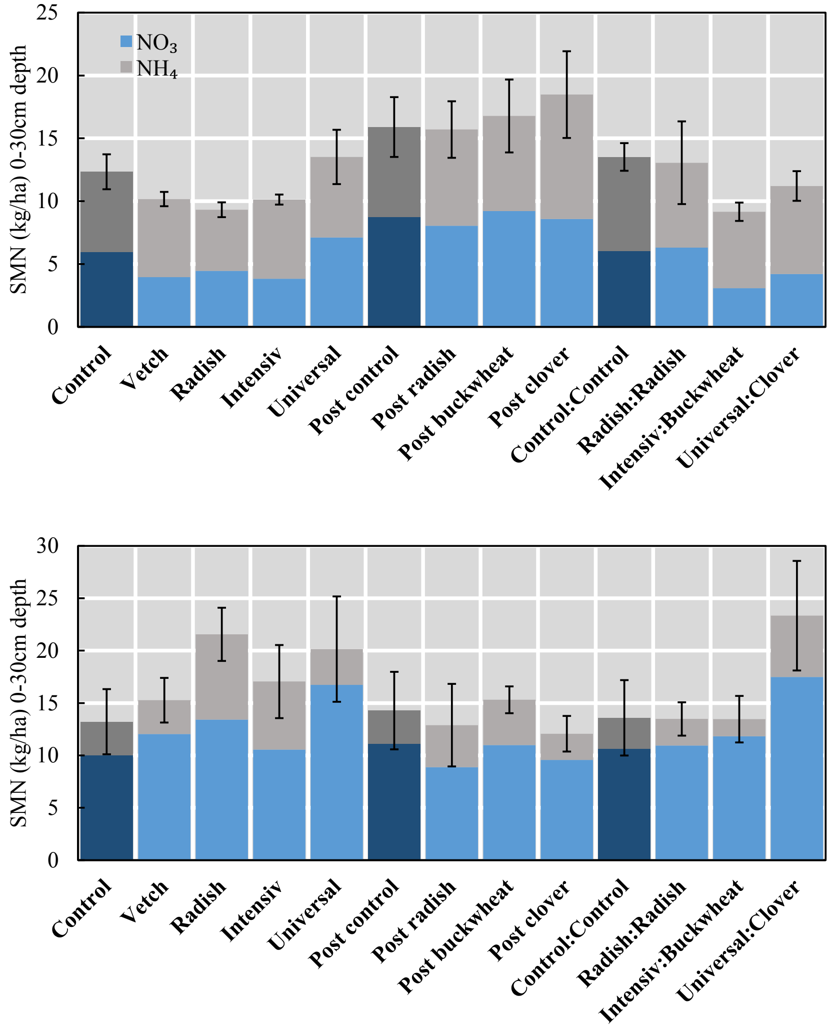


Figure 8: Mean soil mineral nitrogen to 30cm depth at 2nd cereals stage (May 2019), Molescroft 61B (top), Eastfield AR (bottom).

3.2 Soil nitrogen supply (SNS)

3.2.1 Vining pea

At Molescroft 61B, cover cropping had a significant impact on SNS measured at pea harvest. The Universal and Intensiv treatments had approximately twice the SNS compared the Control. This was mostly due to the greater haulm biomass accumulation in these these treatments (a result of arrested foot rot development).

Although not statistically significant, the Control treatment at both Eastfield AR and Boxtree Bubwith had the lowest SNS, probably due to a lack of residual nitrogen released gradually from incorporated cover crops.

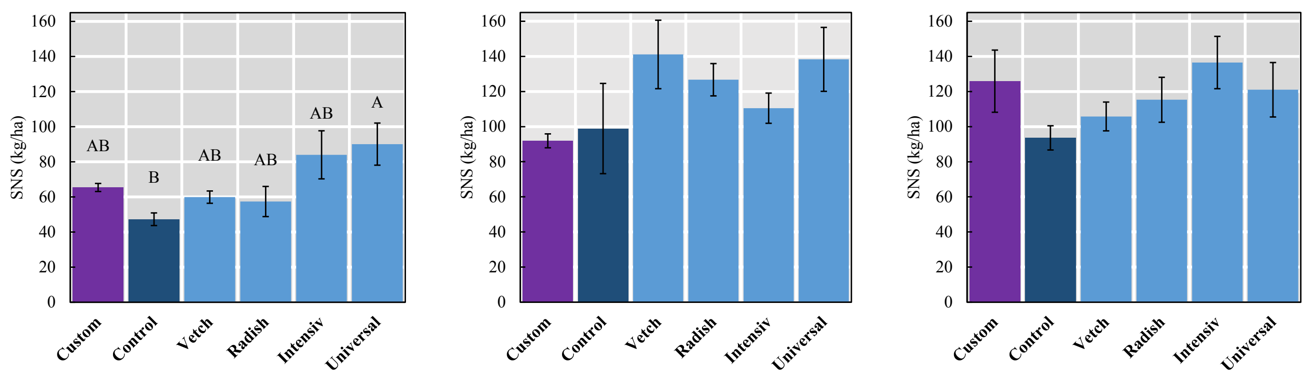


Figure 9: Mean soil nitrogen supply at vining pea stage (July 2017), Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right).

3.2.2 1st wheats

By May the following year (2018), total system nitrogen remained variable and difficult to interpret. However, a few patterns were present across all sites. Catch crop treatments containing oil radish have generally fared better in terms of nitrogen (compared to other catch crop treatments) which is expected due to the legacy of high biomass and nitrogen demand of oil radish. Buckwheat appears to be a poor candidate for retaining nitrogen into the first wheats, possibly a consequence of reducing wheat vigour which then exhibits poor nitrogen uptake efficiency. Lastly, on only one occasion did control measures show high SNS (Post Control and Control:Control at Molescroft 61B). Normally, total system nitrogen in control measures was relatively modest or low.

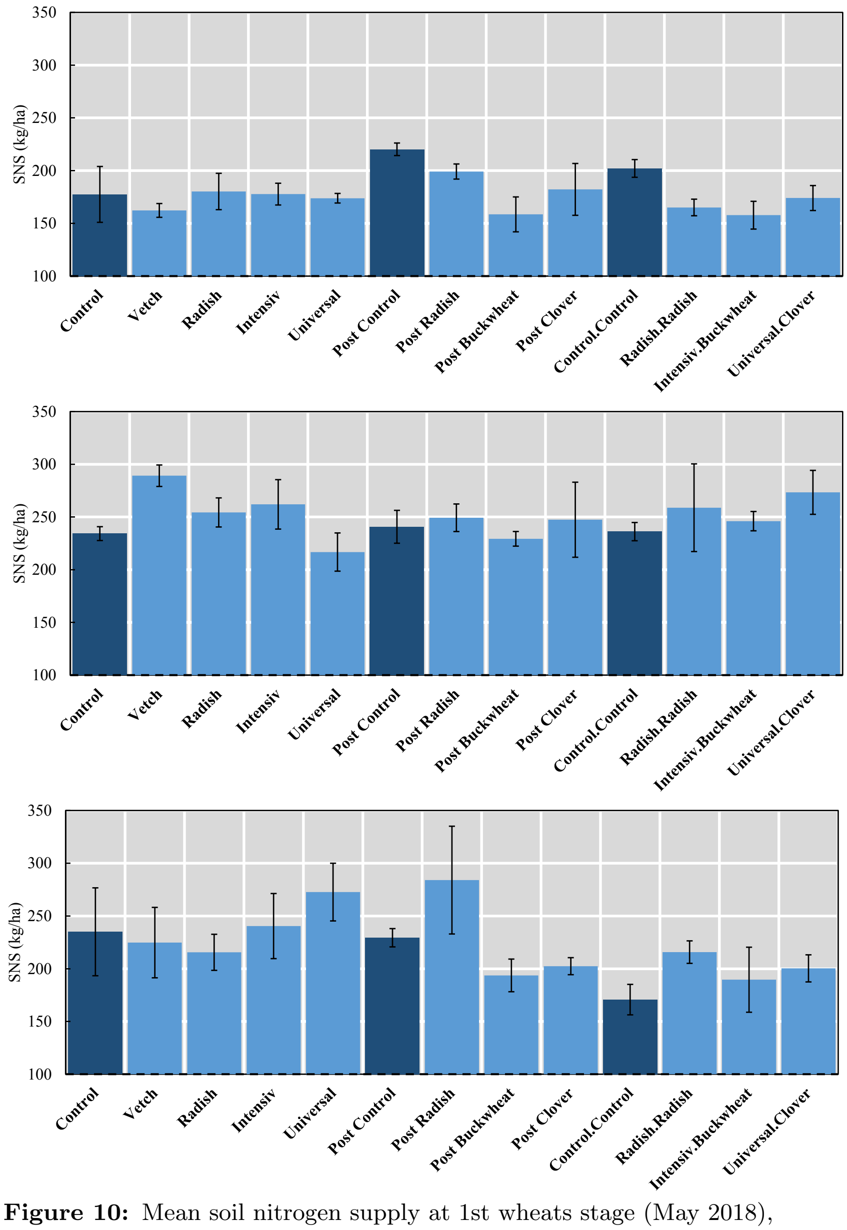


Figure 10: Mean soil nitrogen supply at 1st wheats stage (May 2018), Molescroft 61B (left), Eastfield (middle), Boxtree Bubwith (bottom).

3.3 Nutrient data

3.3.1 Cover crop

Phosphorus, Potassium, Magnesium

There were large differences between treatments concerning P, K, and Mg. Although the figures for nutrient "responses" are often statistically significant, they are suspected to be (partially) a result of the strip trial layout, and thus more likely a field effect rather than treatment effects. The data may however go some way in explaining pea and foot rot development discussed in a separate document, as components of a greater model describing soil interactions.

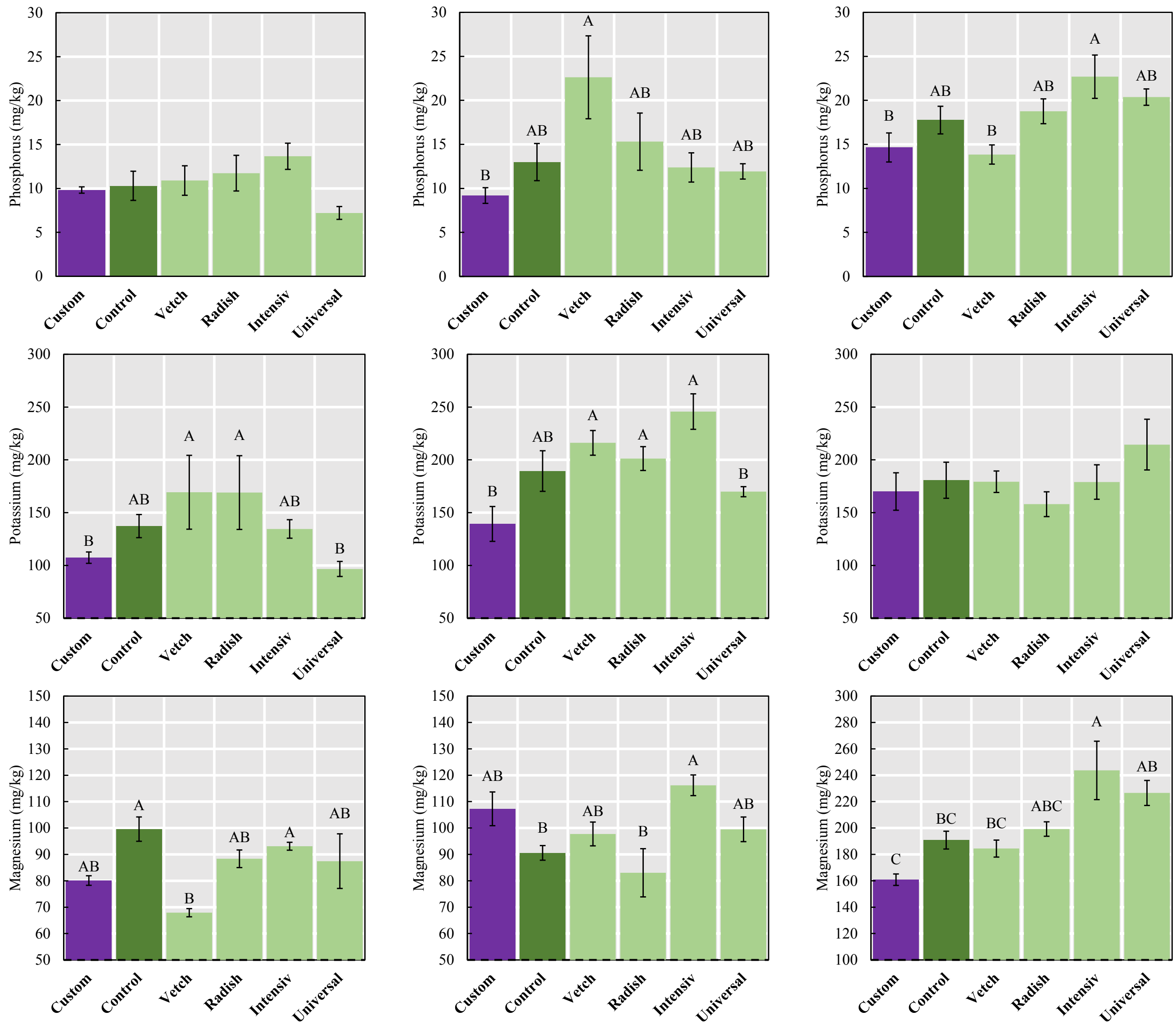


Figure 11: Mean macronutrient availability at cover crop stage (January 2017). Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right).

3.3.2 Vining pea

Phosphorus, Potassium, Magnesium

These data are again likely to have been influenced by field effects (as discussed previously). The available potassium and phosphorus at Molescroft 61B showed a strong negative correlation with pH, which may be a field attribute. Data from Eastfield AR were quite mixed. The nutrient data at Boxtree Bubwith roughly reflected those seen in the cover crop stage.

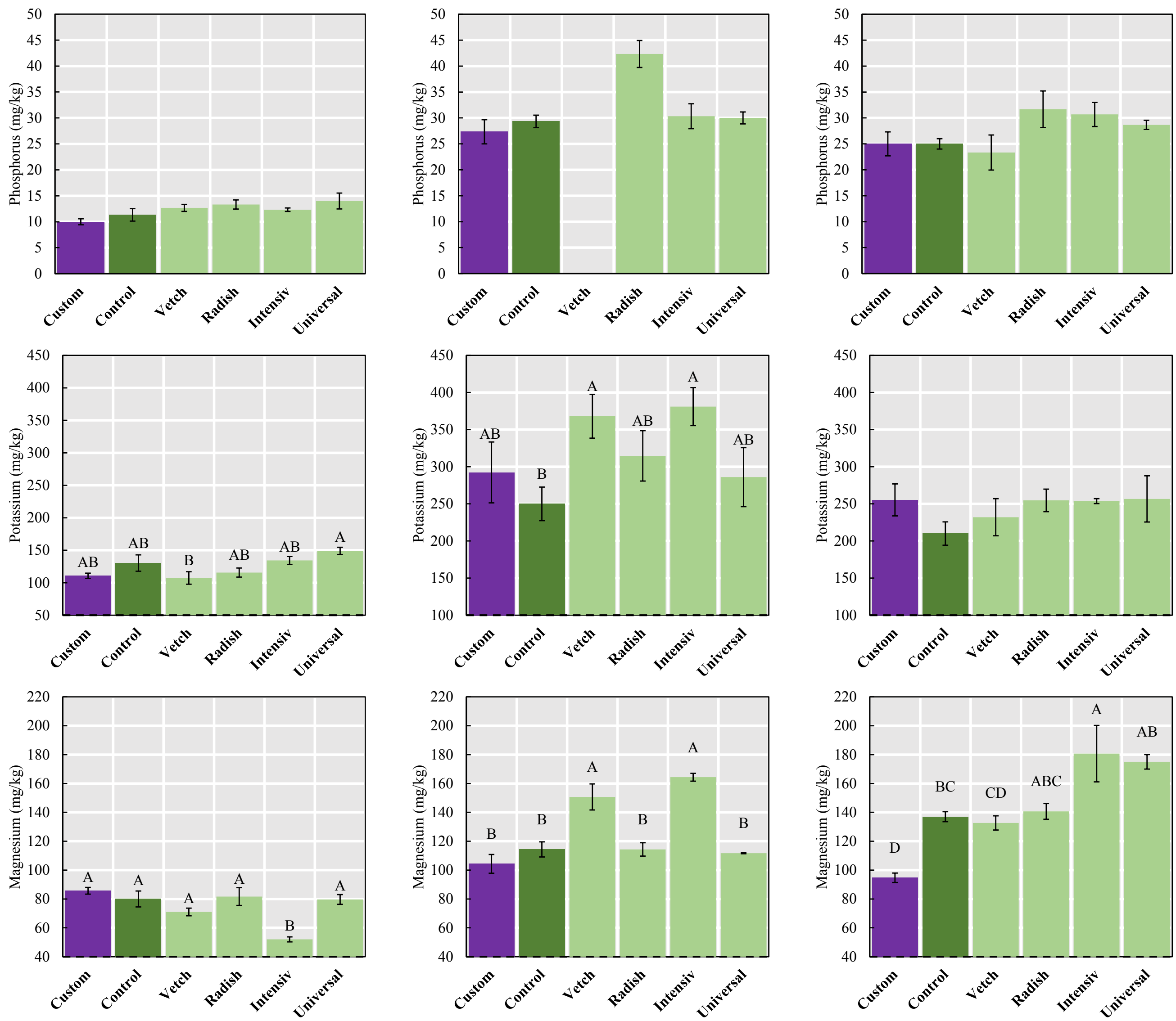


Figure 12: Mean macronutrient availability at vining pea stage (July 2017). Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right). *Vetch data not available in Eastfied AR phosphorus figure.

Cover crop soil pH

Figure 13 shows the soil pH at cover crop stage. pH at all sites straddled pH 7 with no extreme values. The values had not changed much since before cover crops were drilled (see appendix). The only significant difference was the higher pH in the Universal treatment at Molescroft 61B.

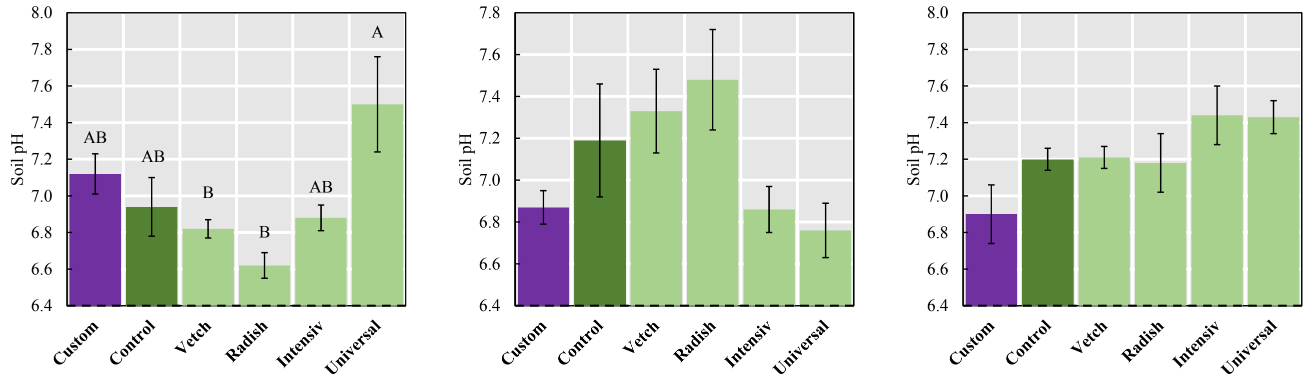


Figure 13: Mean soil pH at cover crop stage (January 2017). Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right).

Vining pea soil pH

By this stage, the pH had dropped to pH 6.2 from 7.3 five months prior in the Universal plots at Molescroft 61B whilst other treatments remained constant. Soil pH had dropped slightly during the season at Eastfield AR with the phacelia containing treatments (Custom & Universal) dropping below pH 6. At Boxtree Bubwith pH hovered around 7.5, only Custom was acidic. The pH here correlated strongly with potassium and magnesium availability.

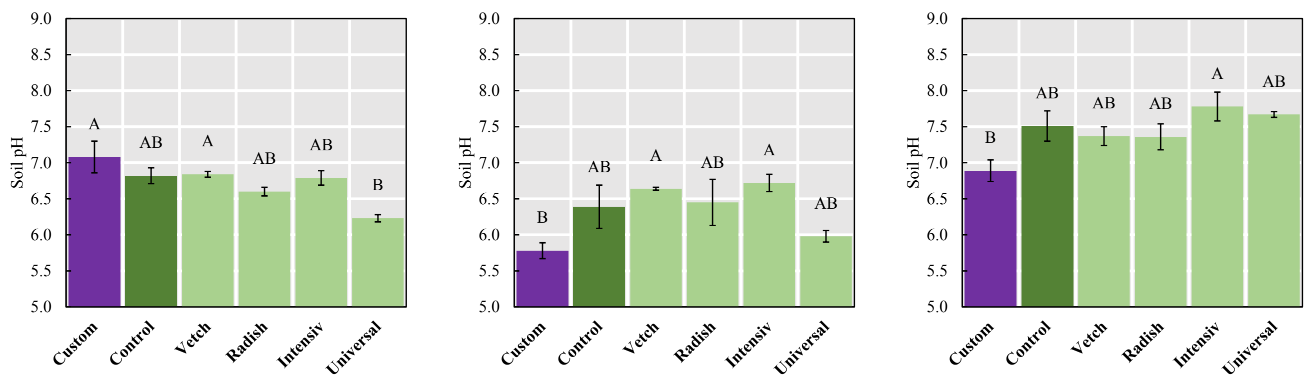
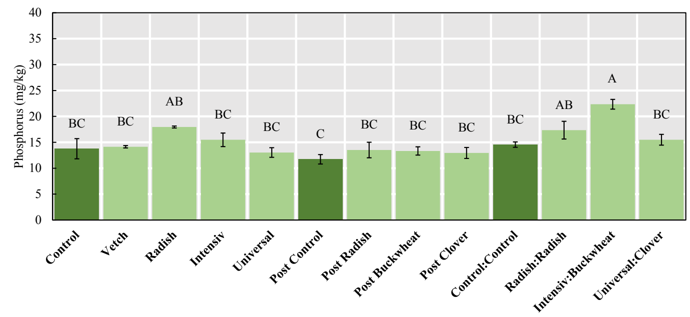


Figure 14: Mean soil pH at vining pea stage (July 2107). Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right).

3.3.3 1st wheats

Phosphorus

Phosphorus levels were quite variable at all sites with no clear patterns emerging other than perhaps slightly higher phosphorus in treatments containing oil radish at Boxtree Bubwith. At Molescroft 61B the level of phosphorus available in the Intensiv:Buckwheat treatments was almost twice that of the Control. Buckwheat is known to have phosphate mobilising attributes which could explain this spike although if that were the case it would also be expected in Post buckwheat. Phosphorus was higher in all plots that contained cover crops (except Vetch) at Boxtree Bubwith compared to control measures.



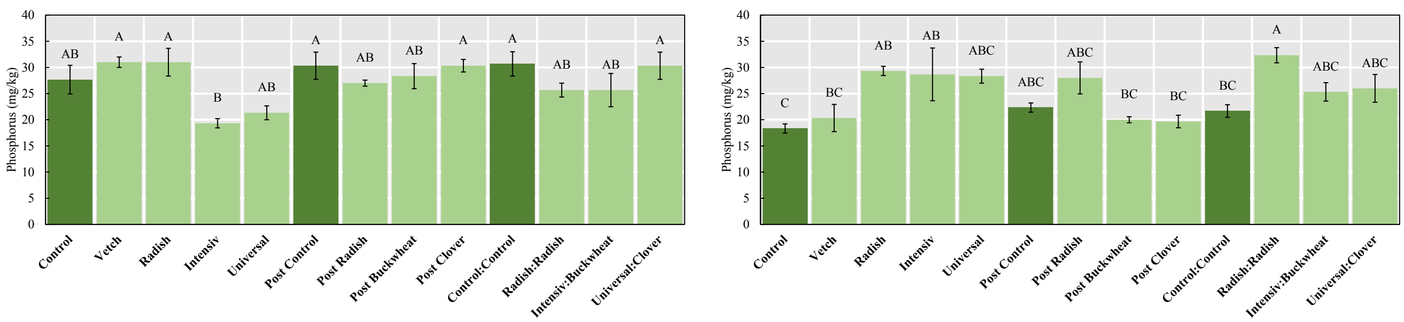
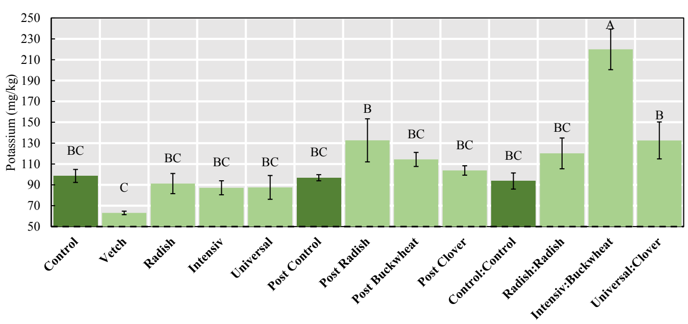


Figure 15: Mean phosphorus availability at 1st wheats stage (May 2018), Molescroft 61B (top right), Eastfield AR (bottom left), Boxtree Bubwith (bottom right).

Potassium



Potassium levels from Molescroft 61B and Eastfield AR were variable and probably showed no real treatment effects. At Boxtree Bubwith however, it could be suggested that, on the whole, available potassium was higher in cover cropped plots compared to controls.

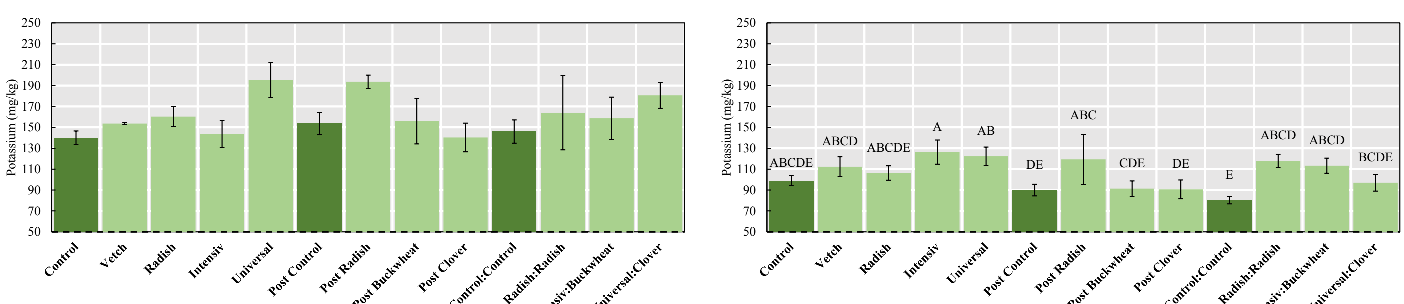
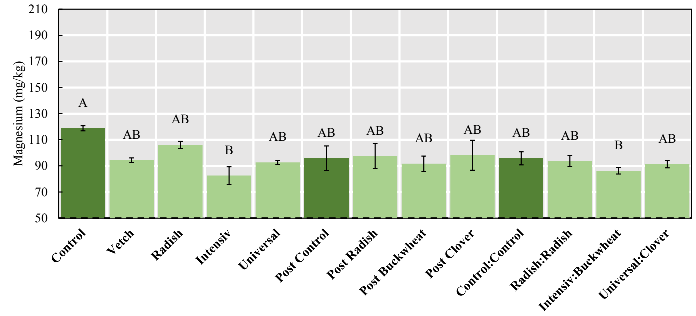
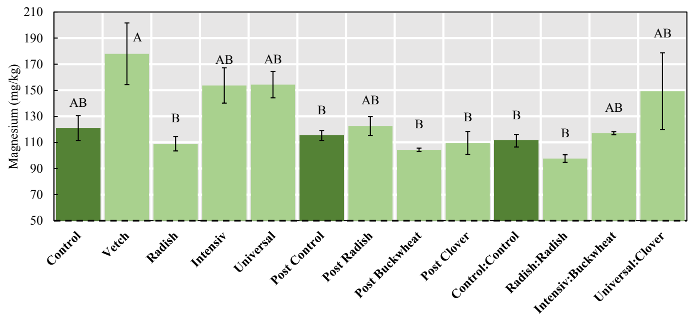


Figure 16: Mean potassium availability at 1st wheats stage (May 2018), Molescroft 61B (top left), Eastfield AR (bottom left), Boxtree Bubwith (bottom right).

Magnesium

Magnesium seemed to be coupled to soil pH. Interestingly, the values in catch cropped treatments at Eastfield AR were similar (in relative terms) to those of Boxtree Bubwith.





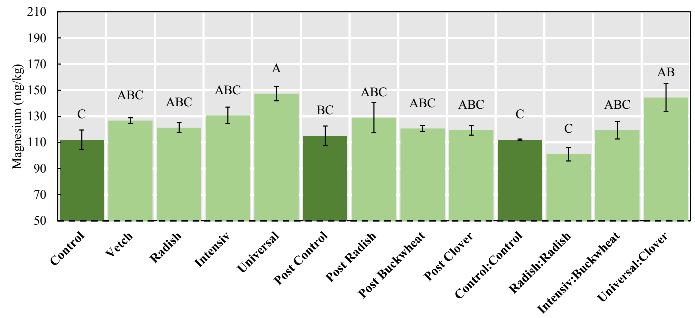
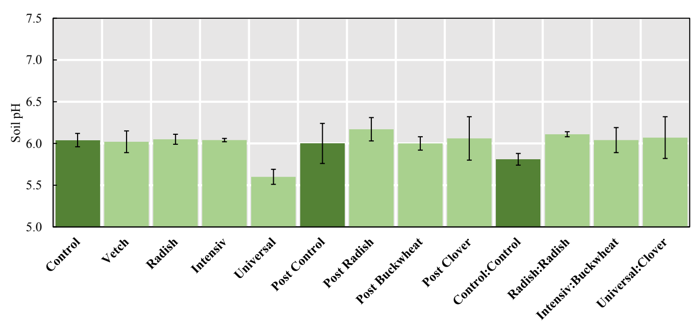
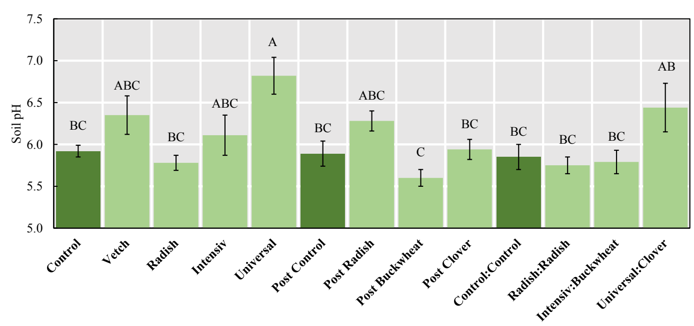


Figure 17: Mean magnesium availability at 1st wheats stage (May 2018), Molescroft 61B (top right), Eastfield AR (bottom left), Boxtree Bubwith (bottom right).

Soil pH



Soil pH at all sites had decreased to around pH 6-6.5 by the late spring in first wheats. No significant differences were found at Boxtree Bubwith nor Molescroft 61B, but in the latter, Universal plots had lowest pH by some margin. The pH values for this treatment so far have always been outstanding and may have some interaction with organic matter. At Eastfield AR, the pH values for Universal and Universal:Clover were also very pronounced, suggesting that phacelia based cover crops may influence soil chemistry for some time. Again organic matter might be implicated in these findings.



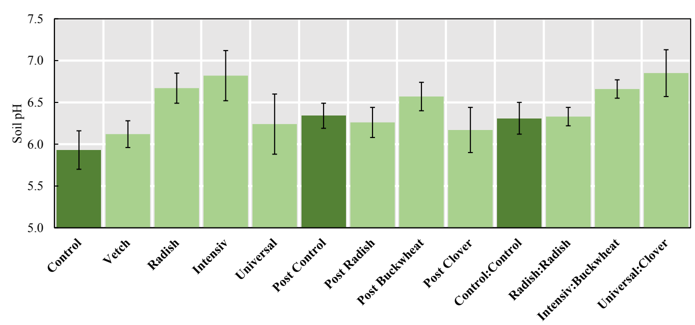


Figure 18: Mean soil pH at 1st wheats stage (May 2018), Molescroft 61B (top right), Eastfield AR (bottom left), Boxtree Bubwith (bottom right).

3.3.4 2nd wheats

Phosphorus

The levels of phosphorus in the 2nd cereal at Molescroft 61B roughly reflected the same treatment differences as observed a year prior in the first wheats. The strength of a field effect was suspected to be very high here, thus discrediting any initially apparent treatment effects on phosphorus. Again, echos of the previous spring 1st wheat results were seen at Eastfield AR.

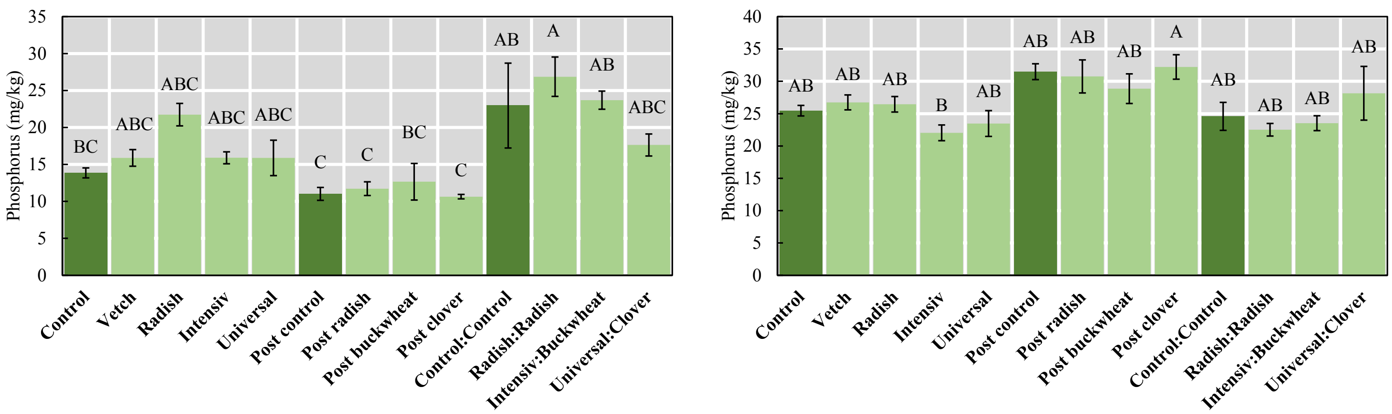


Figure 19: Mean phosphorus availability at 2nd wheats (May 2019), Molescroft 61B (left), Eastfield AR (right).

Potassium

There was an unusual spike in potassium levels in the Intensiv:Buckwheat overlap at Molescroft 61B that had previously been seen the year before. Probably not treatment related despite the statistical support. Other than that, potassium levels at Molescroft 61B were largely constant across all treatments.

Differences in potassium availability for Eastfield AR showed no obvious treatment effect. An east to west fertility gradient in the field is thought to have caused the differences highlighted in figure 20.

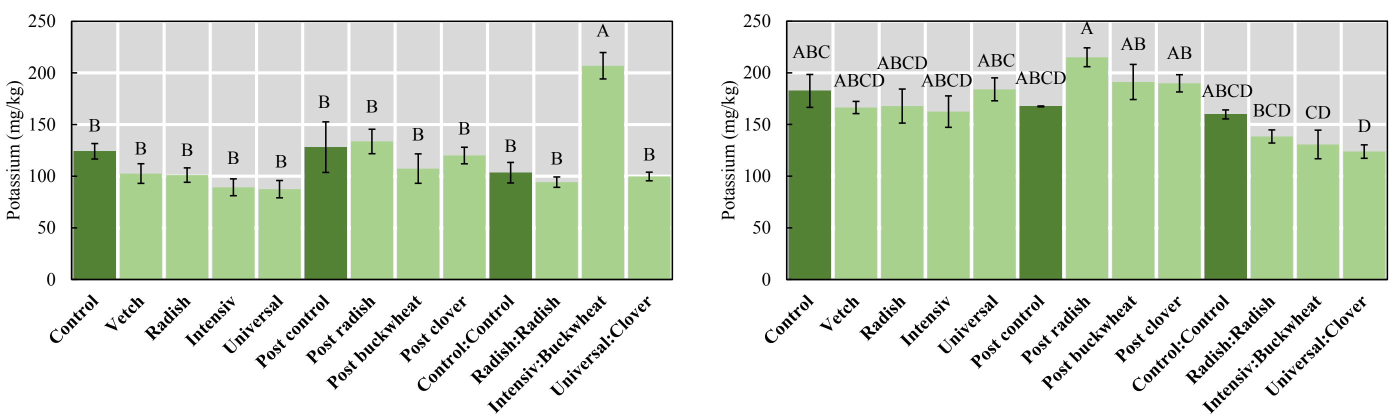


Figure 20: Mean potassium availability at 2nd wheats (May 2019), Molescroft 61B (left), Eastfield AR (right).

Magnesium

Molescroft 61B magnesium levels had not changed in relative terms since the 1st wheats sampling period. Similar comments can be made regarding magnesium at Eastfield AR, although there were no longer statistically supported differences. The availability of magnesium at Eastfield AR was roughly reflected by soil pH.

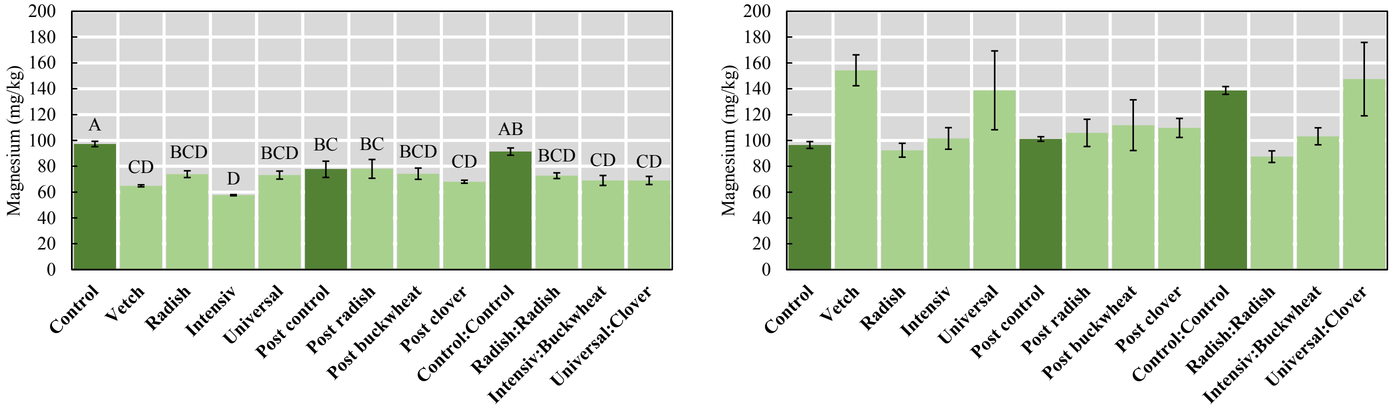


Figure 21: Mean magnesium availability at 2nd wheats (May 2019), Molescroft 61B (left), Eastfield AR (right).

Soil pH

Soil pH at Molescroft 61B showed little in terms of treatment effect and the differences present cannot be ruled out as field effects. At Eastfield AR, the most striking difference seen was the contrast between Intensiv:Buckwheat and Universal:Clover. These were adjacent plots in the field and differed significantly by nearly 1 pH. This gap has widened since the previous sampling a year prior.

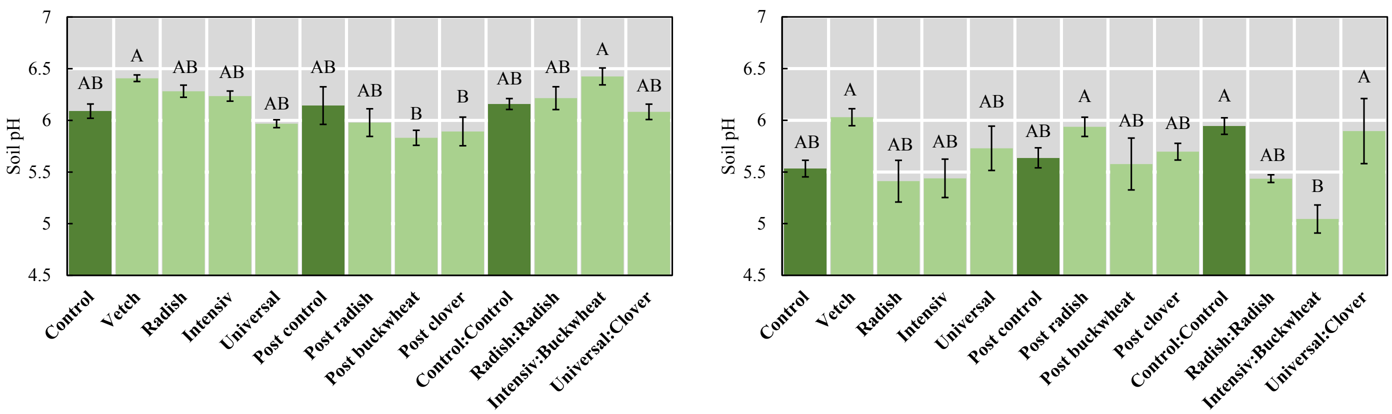


Figure 22: Mean soil pH at 2nd wheats cereals (May 2019), Molescroft 61B (left), Eastfield AR (right).

3.4 Soil organic matter

3.4.1 Cover crop

At Molescroft 61B, soil organic matter ranged between 3-3.4%. The organic matter was highest in the Radish plots, with lowest recorded in the Universal plots. No significant differences were present in organic matter at Eastfield AR. Soil organic matter at Boxtree Bubwith varied around 2-2.5%, where the Universal treatment had significantly higher organic matter than Custom. A field effect is suspected to have influenced organic matter here.

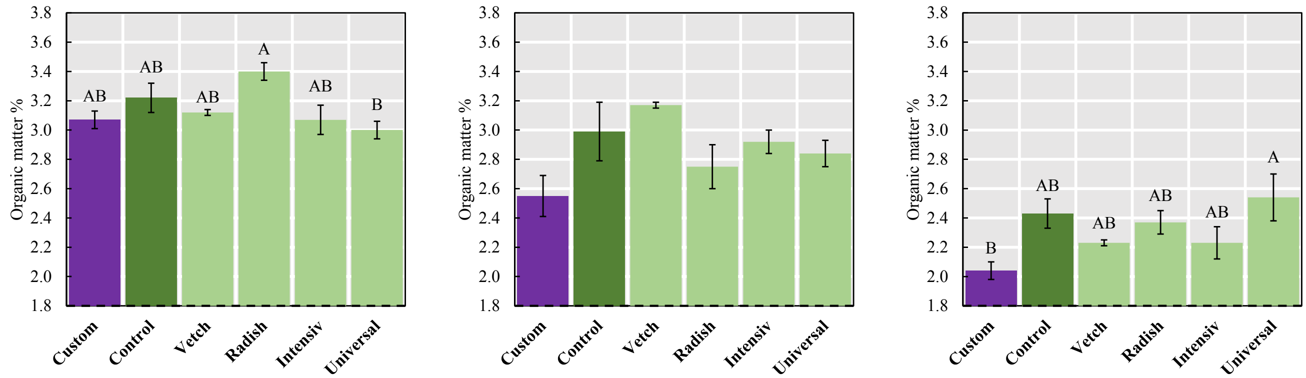


Figure 23: Mean soil organic matter at cover crop stage (January 2017), Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right).

3.4.2 Vining pea

The levels of soil organic matter at Molescroft 61B changed dramatically since the previous sampling period for the Custom and Radish treatments. Radish plots now had far less organic matter than before, where they had previously had the highest level of organic matter. The opposite is true for the Universal treatment.

Soil organic matter had increased by almost 1% at Eastfield AR for all treatments with the exception of Vetch which increased by 1.8% although this may be the consequence of an outlier.

At Boxtree Bubwith, soil organic matter levels have increased by roughly 0.25%. The difference between treatments follows the field gradient.

At both Eastfield AR and Boxtree Bubwith, organic matter levels remained similar in Control treatments between January and July. In cover cropped treatment however, soil organic matter increased over the same period suggesting a positive effect of cover crops on soil organic matter levels.

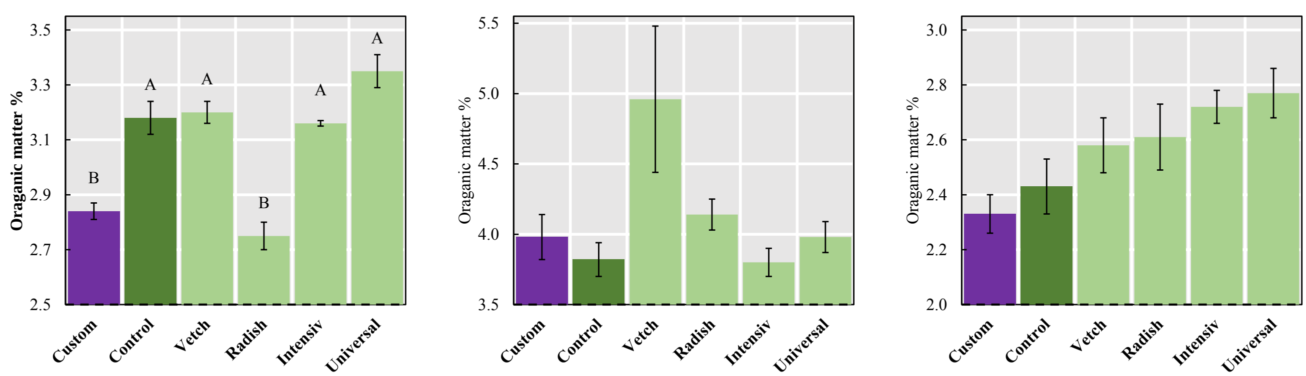


Figure 24: Mean soil organic matter at vining pea stage (July 2017), Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right).

3.4.3 1st wheats

At Molescroft 61B, the pattern of soil organic matter seen at the cover crop stage emerged again at the first wheats stage, with Radish treatments having significantly higher organic matter than Universal. Although not statistically significant, the treatments containing radish had the greatest organic matter at this stage compared to "competitor" treatments. Overall the levels of soil organic matter where slightly higher in overlapping treatments followed by catch cropped plots, with cover cropped only plots having the least soil organic matter. This was due if anything to the frequency and timing of vegetative cover.

The only significant difference in soil organic matter at Eastfield AR was between Radish and Post Buckwheat treatments. Soil organic matter at Eastfield AR was 3.2% before cover crops were drilled. Control plots did not deviate far from this value over the duration of the trial, whereas other treatments (except Post Buckwheat) accumulated a modest amount of soil organic matter in the same period.

Soil organic matter at Boxtree Bubwith at this stage no longer showed the suspected field effects seen earlier in the trial. No clear pattern emerged other than the Control measures showed the least soil organic matter. This is an expected result given the carbon contributions of cover/catch crops, but the only site where this was observed. Boxtree Bubwith started with an initial soil organic matter content of 2.6% before cover crops were sown, by this stage (1st wheats) some treatments had climbed very slightly above this point.

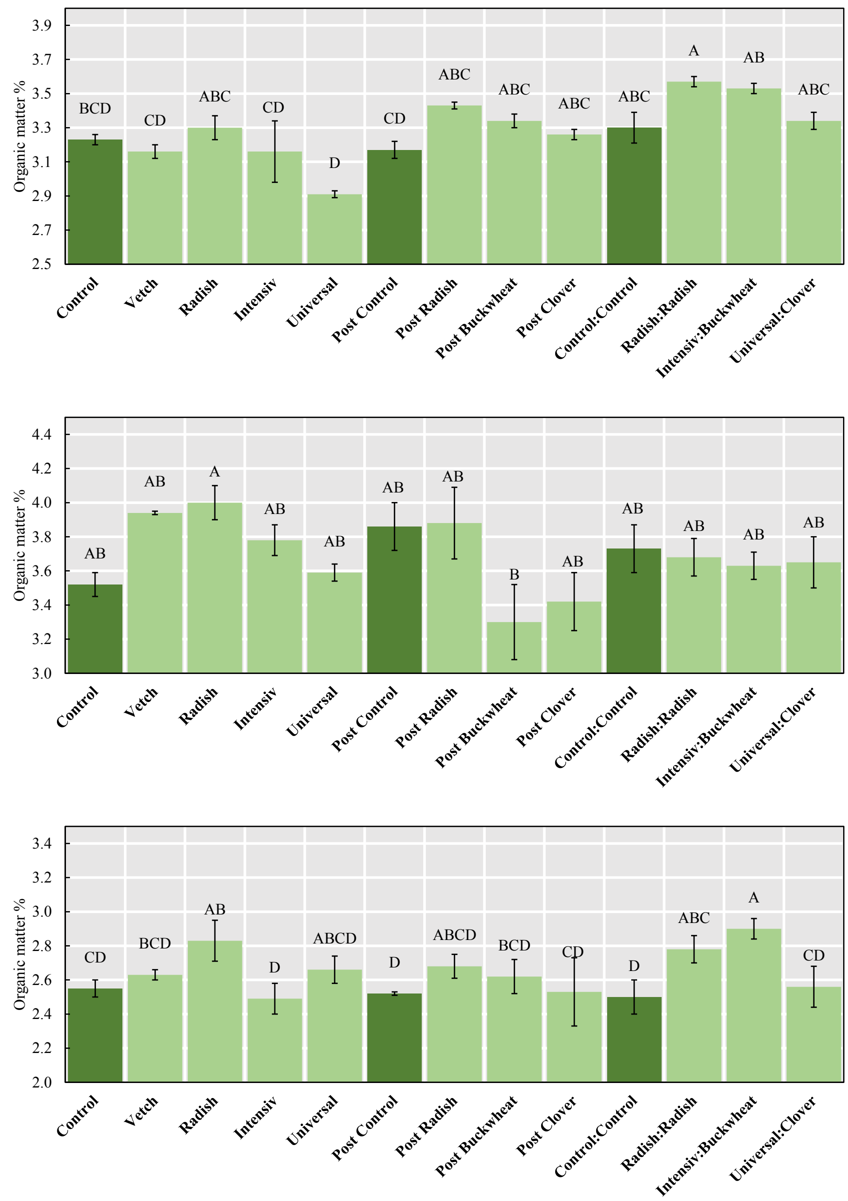


Figure 25: Mean soil organic matter at 1st wheats stage (May 2018), Molescroft 61B (top), Eastfield AR (middle), Boxtree Bubwith (bottom).

3.4.4 2nd wheats

At Molescroft 61B soil organic matter increased slightly in some treatments (Control, Vetch, Radish and Intensiv. Universal decreased considerably). The Post Control and Control:Control treatments had the lowest soil carbon compared to catch cropped treatments closely followed by Buckwheat mixes. The site had a background organic matter content of 3.5% before the trial started, by this point no treatment had any long lasting effect on soil organic matter.

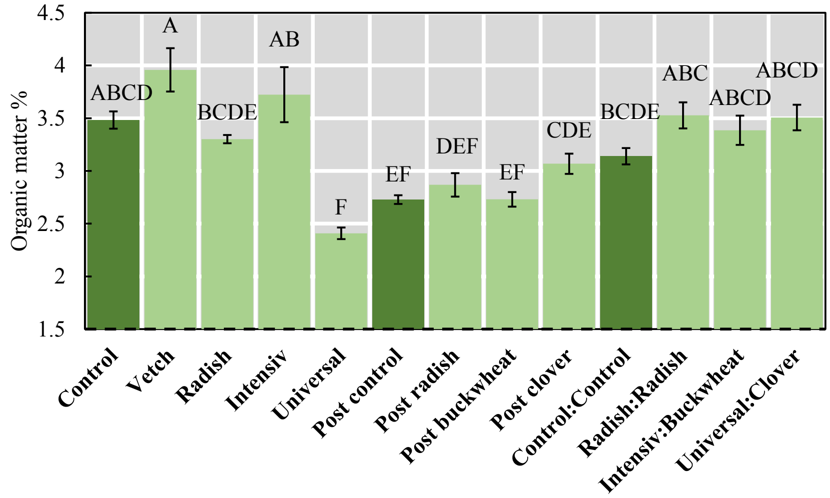


Figure 26: Mean soil organic matter at 2nd cereals stage (May 2019), Molescroft 61B.

Soil organic matter at Eastfield AR showed no difference in terms of treatment effects by this point.

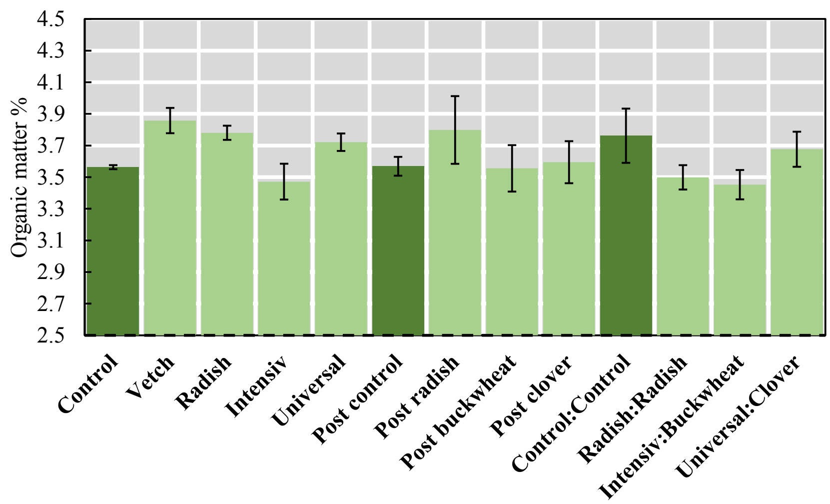


Figure 27: Mean soil organic matter at 2nd cereals stage (May 2019), Eastfield AR.

3.5 Foot rot risk

3.5.1 Cover crop and vining pea

Plate tests for pathogen presence (*Fusarium* + *Didymella*) in cover crop showed that Radish plots had the greatest risk of foot rot at Molescroft 61B prior to vining pea drilling, significantly higher risk than Vetch and Universal (figure 29). The *Didymella* pressure increased in Radish, Intensiv and Universal treatments by the summer, with Radish remaining the highest in *Didymella* pressure and Vetch the lowest (figure 30). *Fusarium* pressure was extremely low. *Aphanomyces euteiches* was also present at this site but no innoculum pressure was determined prior to drilling.

At Boxtree Bubwith, there was no significant difference in overall foot rot risk between treatments, at both cover crop and vining pea stages. However, Vetch remained low at both times. *Fusarium* abundance was lowest in Vetch at cover crop with Control harbouring most *Fusarium*, but by summer this difference had levelled out. *Didymella* inoculum decreased by over half in all treatments except Control between winter and summer. Foot rot was practically absent from Eastfield AR, thus the analysis is not presented.

Figure 28: PGRO in-house testing for determining foot rot pathogen risk.

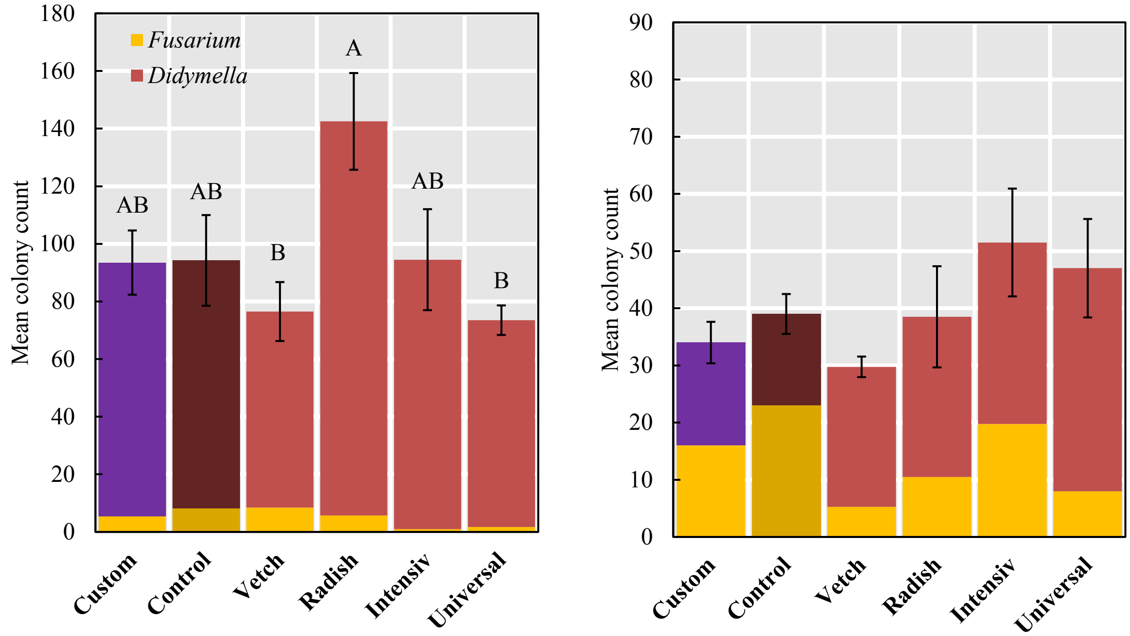


Figure 29: Foot rot risk assessment at cover crop stage (January 2017), Molescroft 61B (left), Boxtree Bubwith (right).

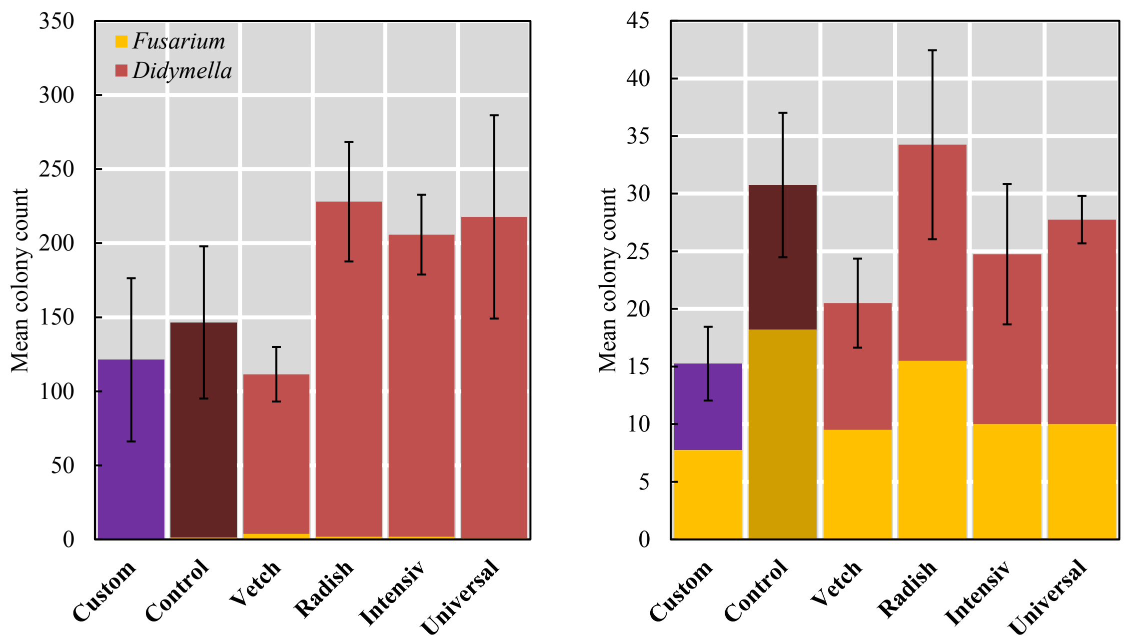


Figure 30: Foot rot risk assessment at vining pea stage (July 2017), Molescroft 61B (left), Boxtree Bubwith (right).

3.5.2 Catch crop

Plate tests from the catch crop sampling period at Molescroft 61B delivered very high numbers of *Didymella* colonies, almost 3-fold greater than at vining pea harvest (figure 31), a consequence of resting spore release from decaying roots. The highest counts derived from the Post Radish treatment, about 4 times greater than the Radish:Radish treatment. Levels of *Fusarium* were negligible. *Didymella* levels at Boxtree Bubwith were lower than at Molescroft 61B, but often still high in general terms. Custom stands out as the highest in *Didymella* at this point. Custom aside, Intensiv showed the highest level of *Didymella* pressure compared to other treatments which somewhat mirrors the effect in Molescroft 61B. Overlapping plots showed about two thirds less *Didymella* in soil compared to the overlapping Control treatment. Lowest levels of *Fusarium* were detected in the Control treatment where almost no *Fusarium* was detected. Highest levels were found in the Radish:Radish and Universal:Clover treatments.

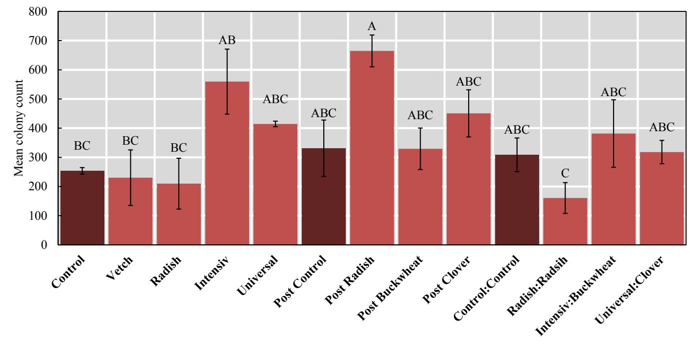
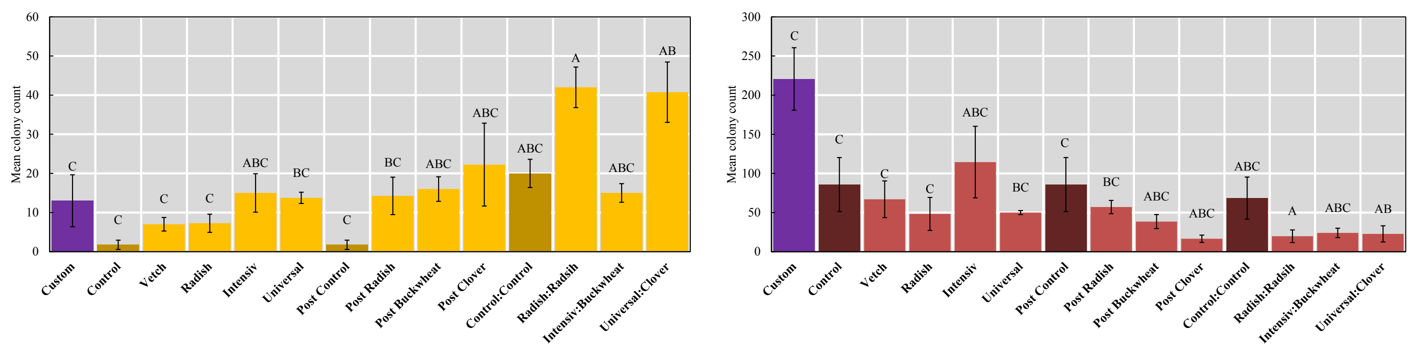


Figure 31: Foot rot risk assessment at catch crop stage (September 2017), Molescroft 61B (*Didymella*, above), Boxtree Bubwith (below (*Fusarium* left, *Didymella* right)).



3.5.3 1st wheats

The pathogen data from the 1st wheats timing at Molescroft 61B did not mirror what was observed 8 months earlier. Overall pathogen levels had generally decreased, however the Radish:Radish treatment was the highest in May 2018 where it was previously lowest risk in September 2017. The Intensiv and Post Radish treatments came down in pathogen level since to a similar level to most other treatments. *Fusarium* levels were negligible. At Boxtree Bubwith, the results did reflect what was previously observed in some treatments. Control, Radish, Post Radish and Control:Control have increased in pathogen level, specifically *Didymella*. Very bizarre results, but confirmed by glasshouse pot tests of the relevant soil samples (figure 34). Soil pathogen spore abundance can be patchy which may partially explain observed results. Every effort was made to uphold rigorous sampling technique.

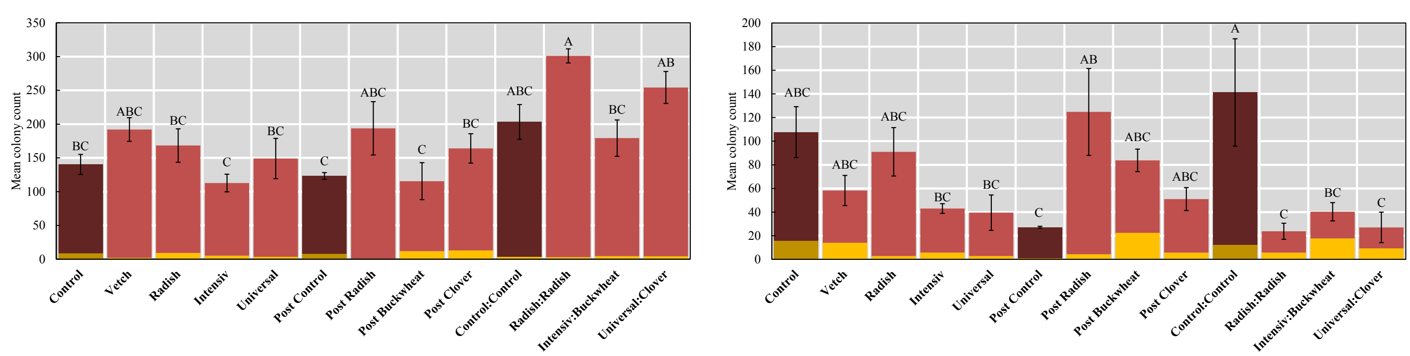


Figure 32: Foot rot risk assessment at 1st wheats stage (May 2018), Molescroft 61B (left), Boxtree Bubwith (right).

3.5.4 2nd wheats

Pathogen pressure decreased since the previous sampling period overall at Molescroft 61B. However, *Fusarium* inoculum increased somewhat. There were no significant treatment effects on individual pathogens although the low inoculum in Radish and Control:Control were notable.

Fusarium levels for Eastfield AR are shown in figure 33 (right). Although the foot rot risk remained negligible, some treatments did show unusual peaks in pathogen abundance. Also, there were similarities between the relative pathogen abundance in the different treatments between this assessment and that of Boxtree Bubwith at 1st wheats stage.

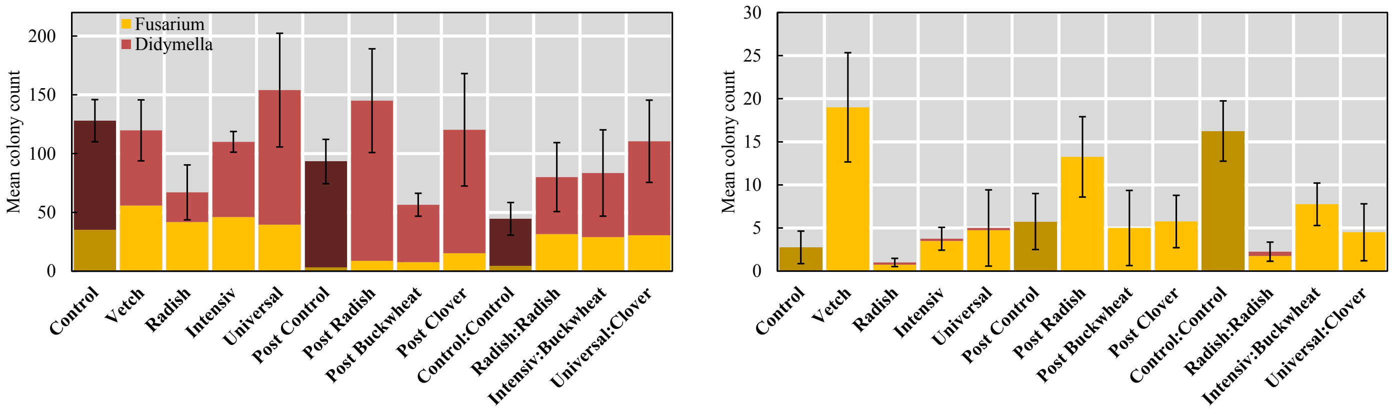


Figure 33: Foot rot risk assessment at 2nd cereals stage (May 2019), Molescroft 61B (left), Eastfield AR (right).

Figure 34: Contrast in foot rot development from glasshouse pot test of Boxtree Bubwith 1st wheats soil samples. Darkening of roots and stem base show infection with *Didymella pinodella*. Plants grown in Radish treatment soil had severely compromised roots and stem base.

3.6 Crop health and development

3.6.1 Foot rot development

Control and Radish treatments at Molescroft 61B had roughly double the rate of early foot rot infection compared to other vegetated treatments. At Boxtree Bubwith, the Custom plots showed higher initial foot rot compared to all others. Rates of early infection at Boxtree Bubwith were low. The data do not discriminate as to which pathogens were responsible for the foot rot, which included *Aphanomyces euteiches* at Molescroft 61B. As the season progressed, virtually all plants succumbed to foot rot at both Molescroft 61B and Boxtree Bubwith. Vetch did not increase foot rot development at any site. These data are the first that suggest oil radish may be deleterious in terms of foot rot development in peas.

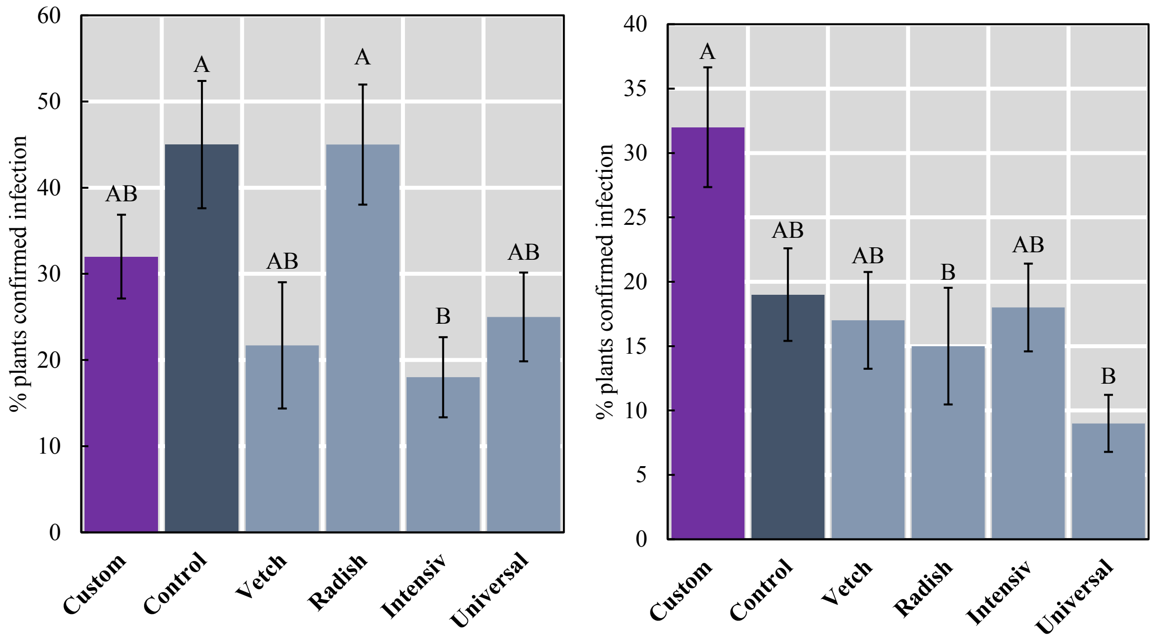


Figure 35: Severity of foot rot development in vining peas (June 2017), Molescroft 61B (left), Boxtree Bubwith (right).

Figure 36: Severe foot rot at Molescroft 61B, the catastrophic product of high *Didymella* and *Aphanomyces* pressure.

3.6.2 Haulm length and biomass

Plant biomass and haulm length were measured shortly prior to pea harvest. At Molescroft 61B, Custom plots showed shorter haulm lengths than other treatments with Universal having the greatest haulm length. Dry weight did not necessarily reflect haulm length, however, the Universal plants were the tallest and heaviest. The greater biomass in Intensiv and Universal treatments may have been a result of earlier foot rot mitigation, a potential residual effect of the blacks oats in those treatments. These plots could be seen as healthier "green islands" for some time.

Vetch and Intensiv had the tallest plants at Eastfield AR, significantly taller than Custom and Radish. Again this was not the case concerning biomass were Radish plots had greatest biomass.

At Boxtree Bubwith, haulm length and biomass were generally in accordance with Control showing the greatest height and biomass. This is thought to be a consequence of those peas establishing better in the spring for unknown reasons (soil moisture, slugs?).

There are no data measuring yield. The occurrence of green aphid and downy mildew were recorded, but levels were too variable and low to warrant analysis.

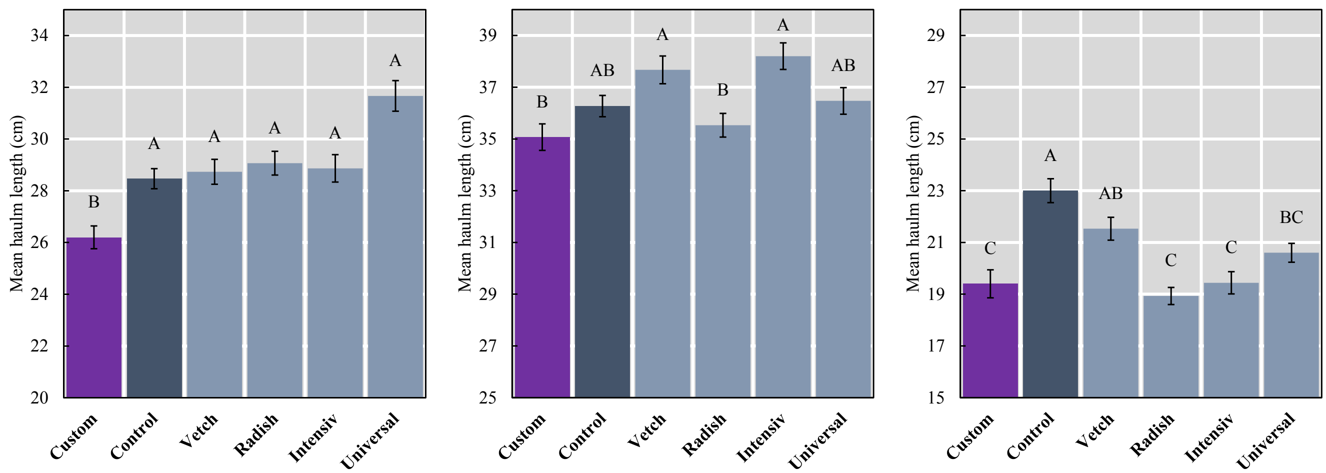


Figure 37: Mean haulm lengths (June 2017), Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right).

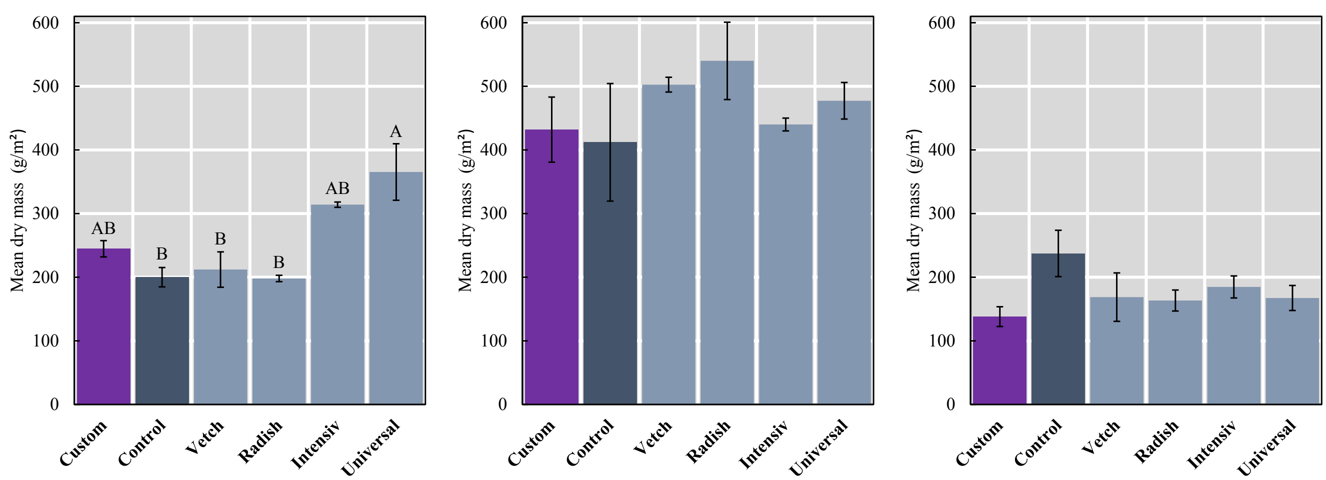


Figure 38: Mean haulm biomass (June 2017), Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right).

3.6.3 Wheat-straw and yield

The data for wheat development did not show very clear treatment effects. It is important to consider that by this point the soils had been further cultivated and had typical nitrogen inputs which will have somewhat levelled any effect of recent cover cropping. Figure 39 shows the straw yields in May 2018 and an estimate of yield compared to the Control:Control measure.

The only notable finding here concerns buckwheat. Treatments containing buckwheat had generally lower straw weights compared to control measures and other catch crop treatments. It performed un-remarkably in terms of yield compared to other catch crops also. Other studies have demonstrated the residual alleleopathy of buckwheat, suppressing early development of cereals and vegetables, which could explain what has been observed here.

Although not assessed, the legacy of cover crops could be seen in the 2nd wheats at Boxtree Bubwith. Plot boundaries were faintly distinguishable in late spring 2019, displaying variable green shades.

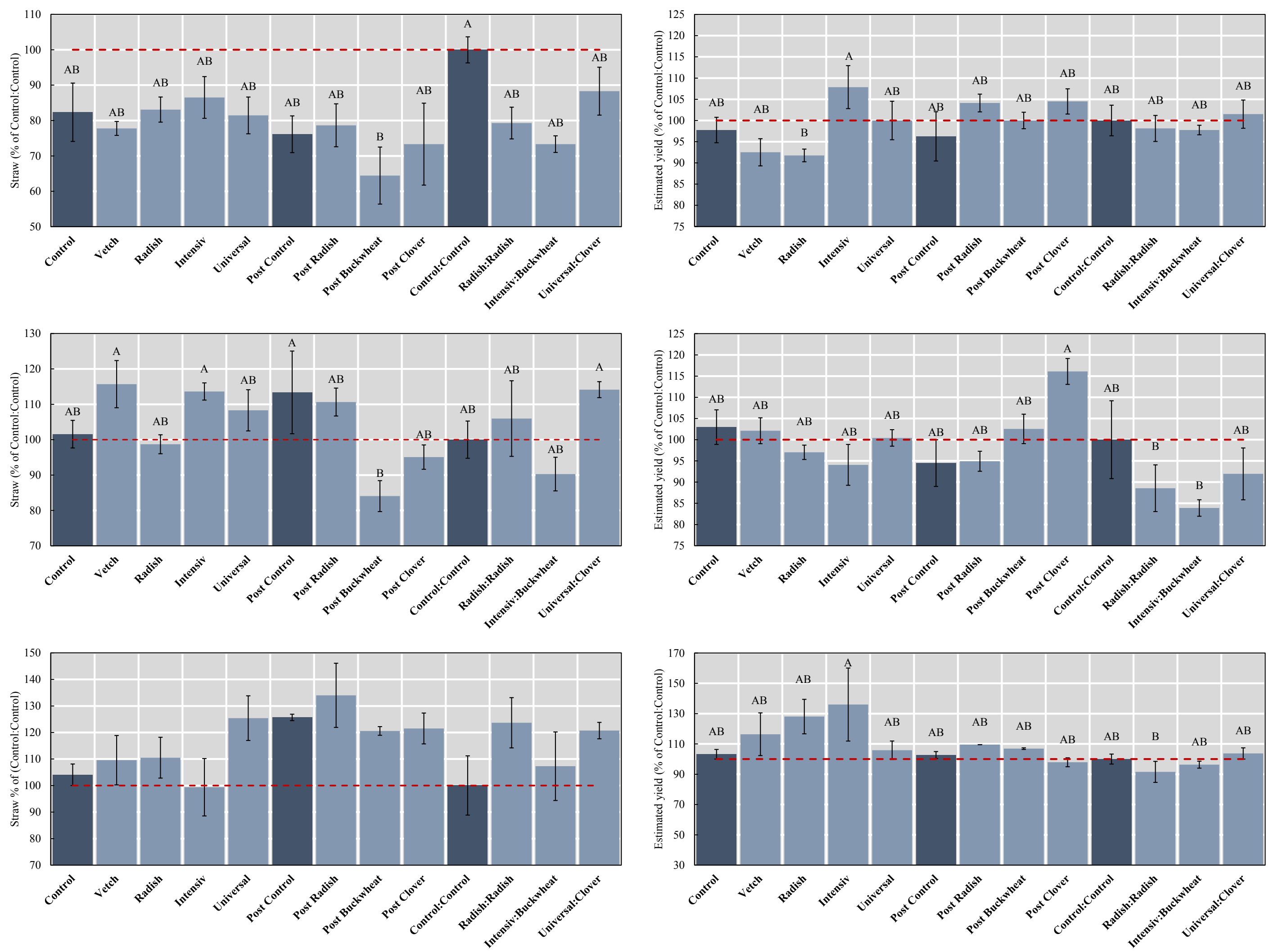


Figure 39: Relative estimated straw and grain yields in first wheats (May 2018), Molescroft 61B (top), Eastfield AR (middle), Boxtree Bubwith (bottom).

3.7 Soil health

Visual assessments of soil structure were made shortly prior to harvest. Table 3 shows that, in general, Intensiv and Universal (oat based mixtures) have given better structure and supported greater numbers of earthworms compared to other treatments at all three sites. An exception can be made for Custom treatments which had scored roughly equivalent to Intensiv and Universal. That this was observed at all sites is purely coincidental given they are different treatments for each site.

Figure 40 highlights the stark difference in soil condition between Control (left) and Universal (right) treatments at Boxtree Bubwith. The vegetated treatments had greater soil moisture at pod fill (section 3.8).

VESS assessments were also made at catch crop stage. No differences were discernible (see appendix).

Figure 40: Contrast in soil condition at vining pea stage Boxtree Bubwith. Control (left), Universal (right).

	Molescroft 61B		**Eastfield AR**		**Boxtree Bubwith**	
	SQ	Worms	SQ	Worms	SQ	Worms
Custom	1.33	0.05	1.00	2.00	2.00	1.33
Control	1.50	0.33	3.33	0.33	3.83	1.00
Vetch	1.67	0.33	2.00	1.33	2.83	0.30
Radish	1.50	1.00	1.67	1.67	3.00	1.33
Intensiv	1.00	0.67	1.50	2.33	2.33	2.33
Universal	1.00	0.33	1.33	2.33	2.50	1.33

Table 3: Structural assessments (SQ) and worm counts (per block) prior to vining (June 2017). Lower SQ scores denote better soil structure.

3.8 Soil moisture

Figures 41 and 42 below show how soil moisture (at 20cm depth) changed over 48 hours after selected rain events. The data have been statistically analysed although the measurements were not robustly repeated within the sites and thus not entirely legitimate. However, the graphs do give some insight into cover crop's effects on soil moisture. Instruments at Molescroft 61B had malfunctioned, thus no data presented.

Figure 41 suggests that, in moderately cohesive soil, cover cropped treatments assisted early season drainage compared to the control which could be readily exploited in spring cropping (i.e. drilling and spring cultivations).

Figure 42 (right) shows how, on light land in summer, water rapidly percolated through the soil profile to an ultimately drier state in the control compared to cover cropped treatments, which by comparison, seemed to better retain the moisture in the top soil after rain. Although yield data were not collected, the greater availability of soil moisture at a time coinciding with pod fill is assumed to protect yield.

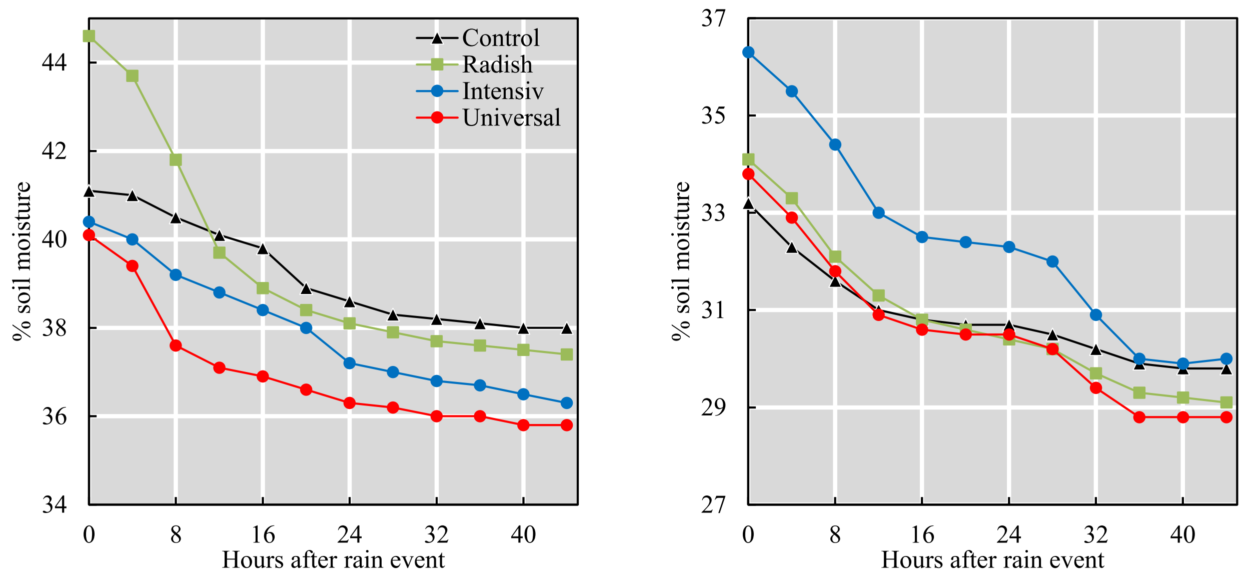


Figure 41: Soil moisture at Eastfield AR (Medium sandy clay loam). Early March 2017 (left) prior to drilling, Early June 2017 (right).

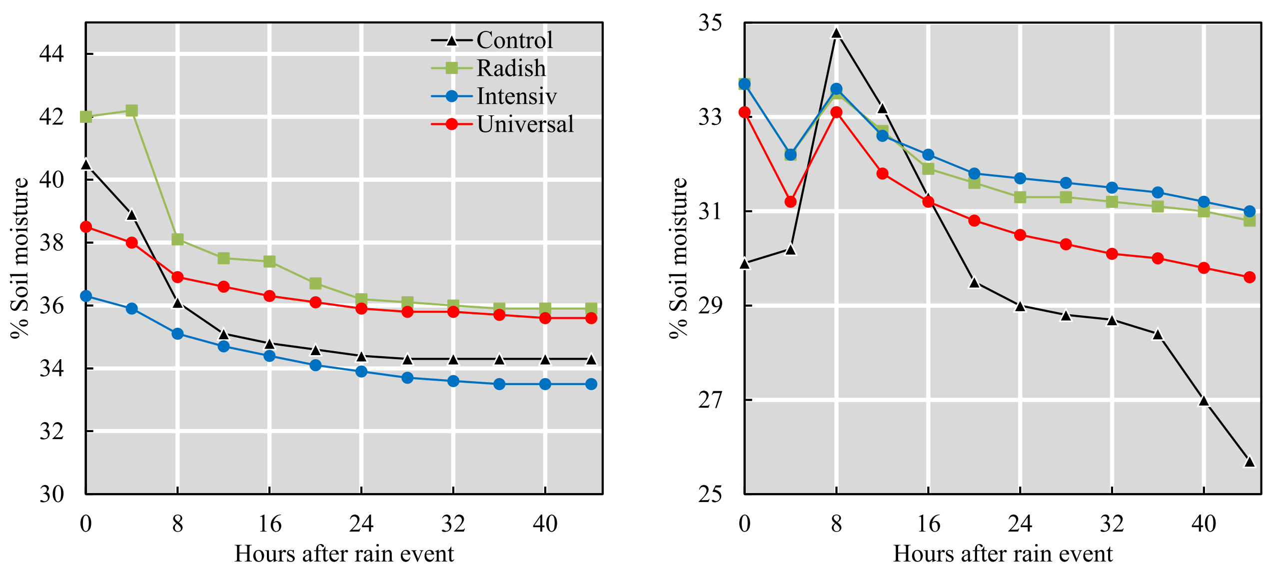


Figure 42: Soil moisture at Boxtree Bubwith (sandy loam). Early March 2017 (left) prior to drilling, Early June 2017 (right).

3.9 Compaction

3.9.1 Cover crop

At Eastfield AR, penetrometer resistance was highest in the Control treatment. This shows the alleviation of compaction by cover crops. The only other notable finding is the lesser resistance in deeper soil in Radish plots, a consequence of deep rooting oil radish.

Similar patterns were found at Boxtree Bubwith, where Control plots gave greatest resistance and Radish broke deep compaction. The overall sum resistance through the soil profile in the Radish treatment was higher than at Eastfield AR, probably a result of deep soil drying.

Data from Molescroft 61B are not available for this stage. The early ploughing and soil moisture saturation offered little resistance at the time of sampling.

It is important to note that these data are not corrected for moisture, and thus reflect both soil compaction and soil moisture.

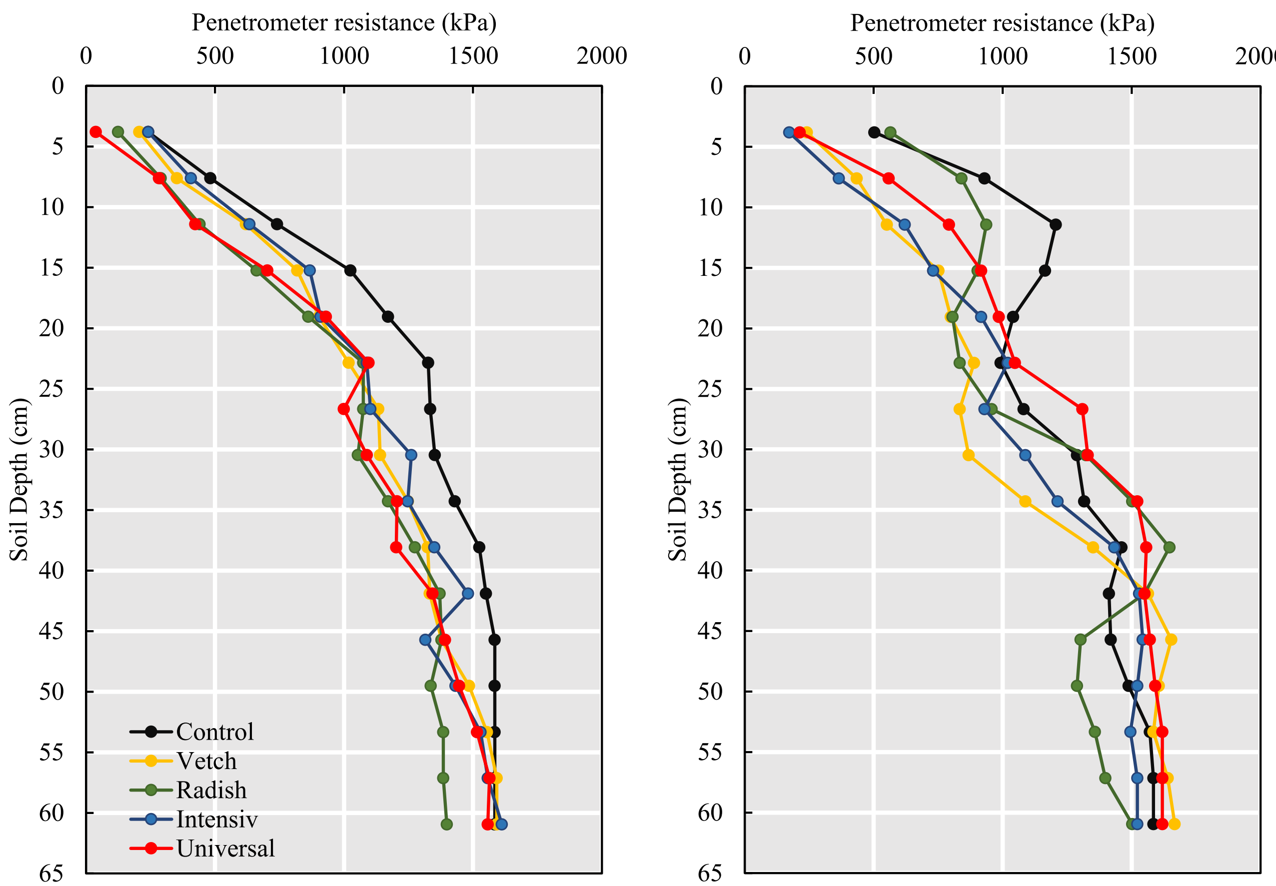


Figure 43: Compaction profiles at cover crop stage (January 2017), Eastfield AR (left), Boxtree Bubwith (right).

Treatment	**(ls) Mean resistance** Eastfield AR	Boxtree Bubwith
Control	1241 a	1254 a
Vetch	1100 b	1096 c
Radish	1012 c	1171 b
Intensiv	1122 b	1103 b
Universal	1139 b	1239 b

Table 4: Least square mean penetrometer resistance (kPa) through 60cm soil profile at cover crop stage (January 2017).

3.9.2 Vining pea

The compaction profile at Eastfield AR prior to vining generally mirrored that of the cover crop compaction profile. However, the sum resistance (see appendix) figures suggest that Radish plots were almost as compacted as the Control plots with the oat based mixtures showing least resistance through the entire profile.

Penetrometer resistance at Boxtree Bubwith was far greater in Vetch and Control treatments. This is likely a result of both the mixed effects of alleviated compaction and moisture retention in other treatments (as previously discussed). The soil below 25cm depth in Vetch and Control treatments is presumed to have been very compact as it was impossible to operate the penetrometer below that depth.

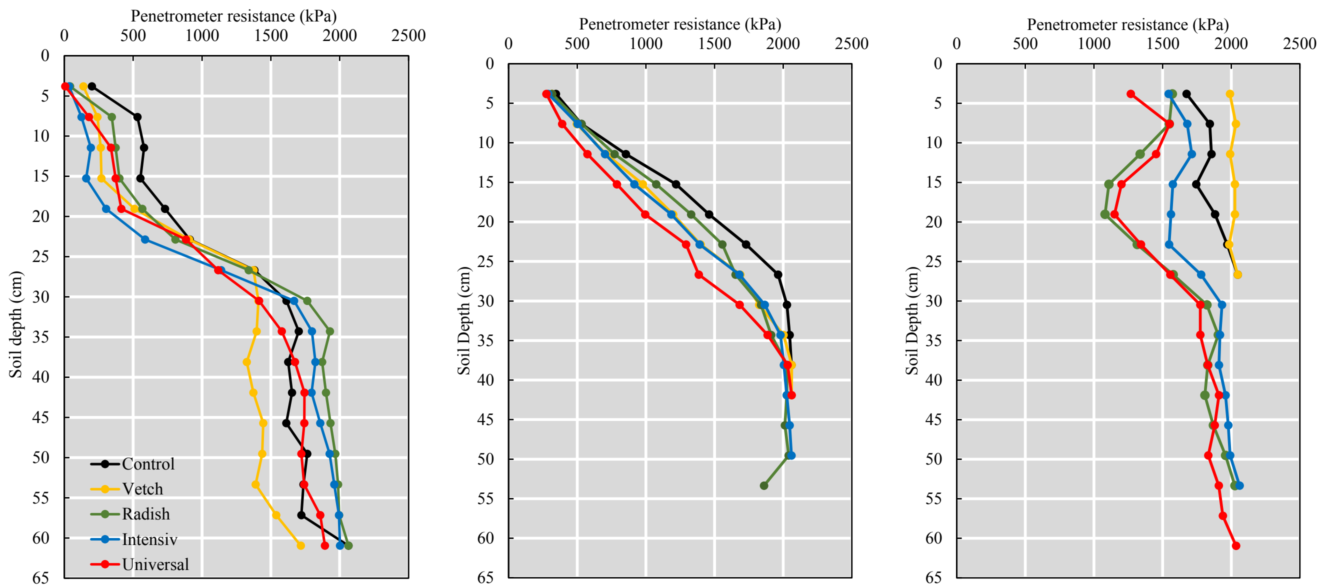


Figure 44: Compaction profiles at vining pea stage (June 2017). Molescroft 61B (left), Eastfield AR (middle), Boxtree Bubwith (right).

Treatment	(ls) Mean resistance		
	Molescroft 61B	Eastfield AR	Boxtree Bubwith
Custom	787 c	875 d	1886 c
Control	977 a	1415 a	1975 b
Vetch	910 abc	1178 b	2043 a
Radish	965 ab	1172 b	1682 d
Intensiv	800 bc	1137 b	1832 c
Universal	840 abc	995 c	1655 d

Table 5: Least square mean penetrometer resistance (kPa) through 60cm soil profile at vining pea stage (June 2017).

3.9.3 Catch crop

The assessment of compaction during the catch crop phase were extremely mixed and remain uncorrected for moisture. Here, a moisture correction is required but impossible given that no soil moisture data were collected. Nevertheless, the data are summarised in terms of accumulated resistance in the appendix.

3.9.4 2nd wheats

Penetrometer readings were impossible to make in the spring for 1st wheats due to the hard ground. They were taken at the 2nd wheats stage for Molescroft 61B and Eastfield AR.

Treatment	**(ls) Mean resistance**	
	Molescroft 61B	Eastfield AR
Control	1484_{abc}	4005_{de}
Vetch	1382_{bcd}	4115_{a}
Radish	1699_{ab}	4087_{bc}
Intensiv	1196_{e}	3936_{ab}
Universal	1450_{cde}	3771_{bcd}
Post Control	1372_{cde}	4132_{a}
Post Radish	1365_{cde}	4015_{bcd}
Post Buckwheat	1339_{de}	3956_{abc}
Post Clover	1273_{de}	n/a
Control:Control	1629_{a}	3761_{cd}
Radish:Radish	1575_{abc}	3780_{e}
Intensiv:Buckwheat	1580_{abc}	3815_{e}
Universal:Clover	1326_{cde}	3810_{bcd}

Table 6: Least square mean penetrometer resistance (kPa) through 60cm soil profile at 2nd cereals stage (May 2019). *Note - the pairwise value for Control at Eastfield AR appears at first to be out of place. However, this was due to a high point of resistance at 225-250mm soil depth that is "smoothed out" in the mean resistance figure. See methods section for details on analysis.

4 Conclusions

This round of trials has yielded a vast quantity of information. Cover crops most certainly effect the development of vining peas and following cereals respond to treatments also. There are few clear trends with regards to specific species/mixes but what can be confidently concluded from these three trials is listed below.

Nitrogen

Cover crops display big differences in their ability to intercept soil mineral nitrogen. Oil radish reliably mops up nearly all available nitrogen, even at depth, whilst less vigorous species like Vetch take up less nitrogen. A greater quantity of nitrogen provided by cover crop residue appears to have no impact on vining pea development or foot rot development.

Macronutrients

No obvious pattern of macronutrient availability with regards to cover cropping presents itself. The quantities of macronutrients are often interrelated and pH dependent. The data are precious as parameters of a greater model to describe foot rot and yield behaviours due at the end of this project.

Soil organic matter

Although there were soil organic matter responses to treatments, they were mixed. There were no concrete observations to suggest that a single ”round” of cover/catch cropping will increase soil organic matter. However, soil organic matter had increased very slightly in the short term at some sites. It must not be forgotten that carbon accumulation occurs in the long term alongside compatible cultivation and agronomic strategies. Cover/catch cropping is not a quick fix for restoring soil organic matter.

Foot rot

Foot rot risk does respond to cover and catch cropping. So far, it appears that oil radish may increase foot rot risk and development in certain cases. There are indications that foot rot is subdued somewhat by cover crop mixes where oat predominates. No negative effects of legume species could be observed.

Crop quality

Haulm length and biomass have responded to different cover crop treatments. The effects were mixed depending on the site. Wheat has also responded to treatments, particularly catch crops. Again the effects are mixed but there are early indications that buckwheat may arrest development of winter wheat.

Soil structure/health

Cover crops had strong, generally beneficial effects on soil structure, compaction and moisture retention. These effects seem to be dependent on soil type and are implicated in the development of vining peas and foot rot.

Agronomy

Growers reported that early drilling of cover crops and well timed destruction were critical. Earlier drilling allows the cover crop to achieve more of its potential before the winter ceases growth. Slugs were cited as a concern because of the shelter and green material provided by cover crops, thus it is important that the cover be destroyed early enough so that slug pressure declines before drilling peas. Early destruction also ensured that the majority of trash had ample time to deteriorate adequately for seed bed preparation. Oil radish left behind a lot of persistent woody trash that is of particular concern to a vining pea operation. The residue from this material reduces the quality of threshed peas. With the right conditions catch crops can accrue vast amounts of biomass. Flailing may be necessary.

5 Appendix

Methods

Soil mineral nitrogen (SMN) is a readily available soluble form of nitrogen. It is also easily leached. Three soil cores to various depths were taken per treatment. The cores were refrigerated to prevent mineral decay and SMN determined by laboratory analysis. Potentially mineralisable nitrogen was also determined from the same cores. PMN is a stable but only partially available form of nitrogen. Corresponding plant samples were taken to complement soil cores, used to quantify total nitrogen per unit area. Soil macronutrients were determined from soil samples taken from a soil depth of 5-20cm. P, K, Mg, pH and soil organic matter (loss on ignition) were determined by laboratory analysis. Three replications per treatment. Foot rot risk was determined from soil samples taken from a depth of 5-20cm replicated four times per treatments. Risk was determined by in-house methods at PGRO. Colony numbers (which reflect risk) are reported in this document. Risk is the product of both *Fusarium solani* and *Didymella pinodella*. Foot rot severity in crop was measured by noting percentage of plants exhibiting visible symptoms of foot rot. 100 plants per treatment were assessed. Haulm lengths were recorded shortly before vining. 75 plants per treatment were measured. Wheat development data was extrapolated from the crop nitrogen samples (straw) and yield determined by pre-harvest plot sampling replicated 3 times per treatment. Assessments of soil structure were carried out in three replicates per treatment according to VESS methods published by SRUC. SQ scores range from 1-5, where 1=excellent soil structure and 5=very poor/structure-less soil. Soil compaction was measured using an analogue cone penetrometer. Readings were taken at regular depth intervals. This showed how resistance to penetration (a measure of soil strength) varied throughout a soil profile. 8-12 insertions were performed per treatment. Later readings were taken using a digital penetrometer that achieves a similar but higher definition result. Soil moisture was recorded using SM150T probes (Delta-t technologies). Due to a limited number of probes the data were not replicated spatially. Field cultivations, drilling and crop maintenance were conducted by GPC project partners. Some details can be found in the diary. Drill specifications are not yet provided.

	Molescroft 61B	**Eastfield AR**	**Boxtree Bubwith**
Pre-cc Sampling	29/08/16	29/08/16	29/08/16
Cover crop drilled	30/08/16	29/08/19	10/9/16
Destruction	31/12/16 (plough)	14/02/17 (sprayed)	06/02/17 (sprayed)
Cover crop sampling	07/02/17	06/02/17	08/02/17
Peas drilled	15/04/17	13/04/17	27/03/17
Variety	Plover	?	Aloha
Crop assessments	08/06/17	08/06/17	08/06/17
Vining pea sampling	30/06/17	29/06/17	22/06/17
Vined	07/07/17	11/07/17	abandoned
Catch crop drilled	14/07/17	18/07/17	02/07/17
Catch crop sampling	14/09/17	13/09/17	12/09/17
Destruction		29/09/17 (Flail)	21/09/17 (sprayed)
1st wheat drilled			
1st wheat sampled	06/06/18	05/06/18	04/06/18
2nd wheat drilled			
2nd wheat sampled	14/05/19	15/05/19	n/a

Appendix notes

Most treatment effects are confirmed (or not) by standard ANOVA methods with appropriate pairwise comparisons (Tukey's HSD, Tukey-Kramer or Games-Howell) set at a default alpha of 0.05. Occasionally these methods are not appropriate and substitute methods are employed. These exceptions are highlighted in the appendix tables. VESS assessments are analysed using chi-squared independence of fit, and foot rot severity assessed using pseudo-binomial models.

P-value - Probability that null hypothesis holds (i.e. treatment effect). Values below 0.05 are generally considered to be significant.
Root MSE - Root mean squared error. A measure of variance. Similar to standard error which applies only to group means in the text.
CoEff var. - Co-efficient of variation. The ratio of the standard deviation of the sample data and the sample mean. Values exceeding 20 are thought to be too great to yield reliable analyses.

Soil compaction. Tables in text report "least squared mean resistance". This can be effectively interpreted as "average compaction" through the measured profile. The greater the LSM, the greater the penetration resistance. No moisture corrections have been made, thus penetration resistance may not reliably reflect soil compaction when soil moistures are extreme or very variable. Accumulated resistance was used to determine statistical differences between treatments. Briefly, it involves comparing the sum of all resistance readings for an insertion, taking soil depth into account during the analysis.

Mean soil mineral nitrogen (kg/ha). N=3. NO_3 - nitrate, NH_4 - ammonium.

	Molescroft 61B			**Eastfield AR**			**Boxtree Bubwith**		
	NO_3	NH_4	SMN	NO_3	NH_4	SMN	NO_3	NH_4	SMN
Pre-CC 0-30cm									
	28.7	6.1	34.8	32.4	7.9	40.4	19.5	5.3	24.8
Pre-CC 30-60cm									
	7.9	2.8	10.7	10.1	5.2	15.3	10.6	3.8	14.4
Cover crop 0-30cm									
Custom	-	-	-	4.76^{d}	1.93^{ab}	6.69^{c}	7.82^{ab}	2.97	10.79
Control	-	-	-	17.33^{abc}	2.02^{ab}	19.35^{ab}	13.51^{a}	3.79	17.3
Vetch	-	-	-	8.80^{cd}	1.47^{ab}	10.28^{bc}	10.66^{ab}	2	12.66
Radish	-	-	-	11.39^{bcd}	1.24^{b}	12.63^{bc}	5.35^{b}	3.89	9.25
Intensiv	-	-	-	17.94^{ab}	2.00^{ab}	19.94^{ab}	10.95^{ab}	3.71	14.66
Universal	-	-	-	23.44^{a}	4.06^{a}	27.49^{a}	9.57^{ab}	4.08	13.65
ANOVA									
p-value	-	-	-	< 0.001	< 0.001	< 0.001	0.009*	0.29	0.14
Root MSE	-	-	-	4.34	1.16	4.72	3.44	1.35	4.09
CoEff.Var	-	-	-	31.16	54.6	29.41	35.71	39.67	31.37
									*Welches ANOVA
Cover crop 30-60cm									
Custom	-	-	-	0.57^{b}	0.00^{b}	0.57^{b}	8.35^{b}	1.56	9.91^{bc}
Control	-	-	-	30.69^{a}	0.12^{b}	30.82^{a}	19.47^{a}	1.82	21.29^{a}
Vetch	-	-	-	6.78^{b}	0.00^{b}	6.78b	16.81^{a}	0.06	16.87^{ab}
Radish	-	-	-	3.17^{b}	0.00^{b}	3.17b	2.22^{b}	0.94	3.17^{c}
Intensiv	-	-	-	4.77^{b}	0.00^{b}	4.77b	3.95^{b}	0.29	4.25^{c}
Universal	-	-	-	6.42^{b}	1.62^{a}	8.04b	8.26^{b}	0.39	8.64^{bc}
ANOVA									
p-value	-	-	-	< 0.001	< 0.001	< 0.001	< 0.001	0.15	< 0.001
Root MSE	-	-	-	5.71	0.15	5.72	3.65	1.05	3.97
CoEff.Var	-	-	-	65.38	53.02	63.4	37.1	124.89	37.18
Cover crop 60-90cm									
Custom	-	-	-	0.61^{b}	0.00^{b}	0.61^{b}	47.52^{a}	0.31	47.83^{a}
Control	-	-	-	21.66^{a}	0.00^{b}	21.66^{a}	26.83^{b}	0.86	27.68^{b}
Vetch	-	-	-	4.50^{b}	0.00^{b}	4.50^{b}	27.49^{b}	0	27.49^{b}
Radish	-	-	-	1.61^{b}	0.00^{b}	1.61^{b}	1.35^{d}	1.79	3.14^{c}
Intensiv	-	-	-	3.79^{b}	0.00^{b}	3.79^{b}	2.50^{cd}	0.01	2.51^{c}
Universal	-	-	-	3.50^{b}	1.84^{a}	5.35^{b}	17.66^{bc}	0.13	17.79^{bc}
ANOVA									
p-value	-	-	-	< 0.001	< 0.001	< 0.001	< 0.001	0.21	< 0.001
Root MSE	-	-	-	3.32	0.35	3.26	6.92	1.11	7.09
CoEff.Var	-	-	-	55.79	113.31	52.21	33.65	213.37	33.65

	Molescroft 61B			Eastfield AR			Boxtree Bubwith		
	NO_3	NH_4	SMN	NO_3	NH_4	SMN	NO_3	NH_4	SMN
Vining pea 0-30cm									
Custom	14.32	6.99	21.31	15.23^{ab}	10.07	25.3	52.5	3.3	55.8
Control	10.82	1.63	12.45	10.98^{b}	11.01	21.98	23.49	4.77	28.26
Vetch	15.86	2.68	18.54	32.52^{a}	4.48	37.01	29.73	5.91	35.64
Radish	13.48	2.35	15.83	16.16^{ab}	11.22	27.38	39.58	4.19	43.77
Intensiv	13.27	5.45	18.72	15.99^{ab}	11.46	27.45	50.62	3.2	53.83
Universal	14.34	2.02	16.36	16.64^{ab}	14	30.64	44.45	6.81	51.26
ANOVA									
p-value	0.86	0.07	0.25	0.03	0.54	0.54	0.09	0.13	0.13
Root MSE	4.73	2.25	4.28	6.57	5.97	9.64	12.6	1.7	12.92
CoEff.Var	34.59	64.16	24.87	36.72	57.57	34.08	31.45	36.4	28.89
Vining pea 30-60cm									
Custom	17.87	1.08	18.95	13.12^{b}	0.66	13.78^{b}	42.57	0.79	43.36
Control	14.73	0	14.73	18.51^{ab}	0.46	18.97^{ab}	26.18	3.27	29.46
Vetch	16.36	0	16.36	28.31^{a}	0	28.31^{a}	43.26	0.88	44.14
Radish	20.33	1.1	21.43	13.15^{b}	0	13.15^{b}	44.79	1.96	46.75
Intensiv	19.34	0	19.34	16.34^{ab}	4.8	21.13^{ab}	50.72	0.93	51.65
Universal	17.72	0	17.72	28.44^{a}	2.63	31.08^{a}	39.63	1.71	41.34
ANOVA									
p-value	0.97	0.39	0.95	0.04	0.21	0.03	0.4	0.48	0.53
Root MSE	8.43	0.91	8.77	6.66	2.55	6.69	13.47	1.71	13.79
CoEff.Var	47.55	252.12	48.44	33.92	180.3	31.81	32.67	107.3	32.23
Catch crop 0-30cm									
Control	26.49^{bc}	1.64	28.13^{bc}	113.63^{a}	11.71	125.34^{a}	30.08^{abc}	2.3	32.38^{abcd}
Vetch	38.81^{ab}	2.53	41.34^{ab}	109.72^{a}	1.44	111.16^{a}	29.48^{abcd}	12.22	41.70^{ab}
Radish	25.87^{bc}	1.2	27.07^{bcd}	103.49^{a}	0.92	104.41^{a}	46.90^{a}	2.57	49.46^{a}
Intensiv	43.90^{a}	1.23	45.14^{a}	88.95^{a}	6.9	95.85^{a}	39.12^{ab}	4.25	43.36^{ab}
Universal	36.06^{ab}	3.32	39.38^{ab}	83.73^{a}	0.98	84.72^{a}	33.69^{ab}	2.68	36.37^{abc}
Post Control	36.84^{ab}	2.11	38.96^{ab}	94.26^{a}	0.86	95.12^{a}	46.15^{a}	2.65	48.80^{a}
Post Radish	6.19^{d}	2.34	8.53^{e}	16.64^{b}	2.24	18.88^{b}	6.85^{e}	2.1	8.97^{e}
Post Buckwheat	10.89^{cd}	2.38	13.27^{cde}	31.17^{b}	2.44	33.61^{b}	12.53^{cde}	2.31	14.84^{de}
Post Clover	8.53^{d}	2.55	11.07^{de}	18.94^{b}	3.11	22.05^{b}	8.68^{e}	4.01	12.69^{de}
Control:Control	27.10^{b}	1.68	28.78^{abc}	99.41^{a}	0.84	100.25^{a}	23.81^{bcde}	4.05	27.86^{bcde}
Radish:Radish	9.51^{d}	2.92	12.43^{cde}	15.71^{b}	1.27	16.98^{b}	8.33^{e}	3.01	11.34^{e}
Intensiv:Buck	8.59^{d}	2.09	10.68^{de}	32.00^{b}	9.02	41.01^{b}	11.99^{d}	6.25	18.24^{cde}
Universal:Clover	8.87^{d}	2.43	11.29^{de}	14.50^{b}	3.16	17.66^{b}	10.66^{e}	4.46	15.12^{de}
ANOVA									
p-value	<0.001*	0.09	0.006*	<0.001	0.13*	<0.001*	<0.001*	0.07	<0.001*
Root MSE	4.99	0.79	28.98	10	5.97	13.89	6.06	3.44	6.67
CoEff.Var	22.54	36.18	5.38	15.81	172.9	20.83	25.54	84.49	24.01

*Welches ANOVA

	Molescroft 61B			Eastfield AR			Boxtree Bubwith		
	NO_3	NH_4	SMN	NO_3	NH_4	SMN	NO_3	NH_4	SMN
1st wheats 0-30cm									
Control	18.03[b]	7.57	25.57	22.47	10.73	33.2	75.93	17.5	93.47
Vetch	31.10[ab]	14.97	46.07	53.47	14.8	68.3	44.77	9.23	54
Radish	33.53[ab]	10.03	43.53	38.5	12.5	51	48.63	9.4	58.07
Intensiv	27.40[ab]	8.97	36.4	39.33	19.17	58.53	84.23	14.97	99.17
Universal	27.17[ab]	10.43	37.63	25.47	11.2	36.7	56.8	12.6	69.4
Post Control	63.93[a]	19.13	83.03	33.37	22.1	55.47	28.03	8.2	36.23
Post Radish	36.67[ab]	11.83	48.5	40.2	15.23	55.43	61.67	25.43	87.1
Post Buckwheat	30.17[ab]	8.3	38.43	19.73	25.47	45.23	27.67	10.2	37.9
Post Clover	43.67[ab]	13.93	57.6	23.7	41.6	65.3	20.1	9.8	29.87
Control:Control	29.63[ab]	12.3	41.93	17.03	10.27	27.27	23.93	8.5	32.47
Radish:Radish	19.07[b]	9.8	28.87	22.37	27	49.37	26.07	14.67	40.73
Intensiv:Buck	19.07[b]	10.03	29.07	24.67	31.4	56.03	18.23	9.17	27.4
Universal:Clover	15.77[b]	18.87	34.63	30.63	12.23	42.87	22.73	9.47	32.17
ANOVA									
p-value	0.02	0.12	0.06	0.08	0.36	0.56	0.11	0.38	0.08
Root MSE	13.77	4.92	18.21	13.18	15.46	22.26	29.15	7.99	31.98
CoEff.Var	45.28	40.98	42.94	43.82	79.2	44.88	70.34	65.28	59.57
2nd wheats 0-30cm									
Control	6.0	6.4	12.3	10.0	3.2	13.2	-	-	-
Vetch	4.0	6.2	10.2	12.0	3.2	15.3	-	-	-
Radish	4.5	4.9	9.3	13.4	8.1	21.6	-	-	-
Intensiv	3.8	6.3	10.1	10.6	6.5	17.1	-	-	-
Universal	7.1	6.4	13.5	16.7	3.4	20.2	-	-	-
Post Control	8.8	7.1	15.9	11.1	3.2	14.3	-	-	-
Post Radish	8.0	7.7	15.7	8.9	4.0	12.9	-	-	-
Post Buckwheat	9.2	7.6	16.8	11.0	4.3	15.3	-	-	-
Post Clover	8.6	9.9	18.5	9.6	2.5	12.1	-	-	-
Control:Control	6.0	7.5	13.5	10.6	3.0	13.6	-	-	-
Radish:Radish	6.3	6.8	13.1	10.9	2.5	13.5	-	-	-
Intensiv:Buck	3.1	6.1	9.2	11.8	1.6	13.5	-	-	-
Universal:Clover	4.2	7.0	11.2	17.5	5.8	23.3	-	-	-
ANOVA									
p-value	0.06	0.16	0.06	0.67	0.25	0.32	-	-	-
Root MSE	2.50	1.61	3.50	5.10	2.70	5.67	-	-	-
CoEff.Var	40.70	23.30	2.70	43.10	68.70	35.80	-	-	-

Mean soil pH, organic matter % and soil nitrogen supply (SNS). N=3.

	Molescroft 61B			Eastfield AR			Boxtree Bubwith		
	pH	OM%	SNS	pH	OM%	SNS	pH	OM%	SNS
Pre-CC									
	7.3	3.5	73.6	6.9	3.2	92.7	7	2.6	69.6
Cover crop									
Custom	7.1^{ab}	3.1^{ab}	-	6.9	2.6	-	6.9	2.0^{b}	-
Control	6.9^{ab}	3.2^{ab}	-	7.2	3	-	7.2	2.4^{ab}	-
Vetch	6.8^{b}	3.1^{ab}	-	7.3	3.2	-	7.2	2.2^{ab}	-
Radish	6.6^{b}	3.4^{a}	-	7.5	2.8	-	7.2	2.4^{ab}	-
Intensiv	6.9^{ab}	3.1^{ab}	-	6.9	2.9	-	7.4	2.2^{ab}	-
Universal	7.5^{a}	3.0^{b}	-	6.8	2.8	-	7.4	2.5^{a}	-
ANOVA									
p-value	0.007	0.017	-	0.066	0.051	-	0.061	0.031	-
Root MSE	0.28	0.15	-	0.36	0.26	-	0.24	0.2	-
CoEff.Var	4.02	4.69	-	5.18	8.89	-	3.39	8.48	-
Vining Pea									
Custom	7.1^{a}	2.8^{b}	65.4^{ab}	5.8^{b}	4	91.9	6.9^{b}	2.3	125.9
Control	6.8^{ab}	3.2^{a}	47.3^{b}	6.4^{ab}	3.8	98.9	7.5^{ab}	2.4	93.6
Vetch	6.8^{a}	3.2^{a}	59.9^{ab}	6.6^{a}	5	141.1	7.4^{ab}	2.6	105.8
Radish	6.6^{ab}	2.8^{b}	57.4^{ab}	6.5^{ab}	4.1	126.7	7.4^{ab}	2.6	115.3
Intensiv	6.8^{ab}	3.2^{a}	84.0^{ab}	6.7^{a}	3.8	110.5	7.8^{a}	2.7	136.5
Universal	6.2^{b}	3.4^{a}	90.1^{a}	6.0^{ab}	4	138.3	7.7^{ab}	2.8	121
ANOVA									
p-value	0.011	<0.001	0.03	0.011	0.083	0.22	0.045	0.061	0.323
Root MSE	0.21	0.07	14.8	0.27	0.45	27.8	0.29	0.17	22.9
CoEff.Var	3.14	2.24	29.4	4.32	11	25.7	3.93	6.54	20.6
Catch crop									
Control	-	-	28.1	-	-	125.3^{a}	-	-	32.4^{ab}
Vetch	-	-	41.3	-	-	111.2^{ab}	-	-	41.7^{ab}
Radish	-	-	27.1	-	-	104.4^{abc}	-	-	49.5^{ab}
Intensiv	-	-	45.1	-	-	95.9^{abc}	-	-	43.3^{ab}
Universal	-	-	39.4	-	-	84.7^{abc}	-	-	36.7^{ab}
Post Control	-	-	39.0	-	-	95.1^{abc}	-	-	48.8^{ab}
Post Radish	-	-	38.4	-	-	56.4^{c}	-	-	46.5^{ab}
Post Buckwheat	-	-	34.3	-	-	61.3^{c}	-	-	42.5^{ab}
Post Clover	-	-	46.1	-	-	64.1^{bc}	-	-	54.7^{ab}
Control:Control	-	-	28.8	-	-	100.2^{abc}	-	-	27.9^{b}
Radish:Radish	-	-	49.7	-	-	58.1^{c}	-	-	52.5^{ab}
Intensiv:Buck	-	-	42.0	-	-	81.2^{abc}	-	-	58.5^{a}
Universal:Clover	-	-	43.3	-	-	60.9^{c}	-	-	58.4^{a}
ANOVA									
p-value	-	-	0.06*	-	-	0.001*	-	-	0.007
Root MSE	-	-	8.39	-	-	16.6	-	-	9.35
CoEff.Var	-	-	21.7	-	-	19.6	-	-	20.5

*Welche's ANOVA

	Molescroft 61B			Eastfield AR			Boxtree Bubwith		
	pH	OM%	SNS	pH	OM%	SNS	pH	OM%	SNS
1st wheats									
Control	6	3.2^{bcd}	197.3	5.9^{bc}	3.5^{ab}	274.7	5.9	2.6^{cd}	265.9
Vetch	6	3.2^{cd}	190.6	6.4^{abc}	3.9^{ab}	338.9	6.1	2.6^{bcd}	260.1
Radish	6.1	3.3^{abc}	211.9	5.8^{bc}	4.0^{a}	283.1	6.7	2.8^{ab}	247.5
Intensiv	6	3.2^{cd}	213.7	6.1^{abc}	3.8^{ab}	305.5	6.8	2.5^{d}	278.3
Universal	5.6	2.9^{d}	209.7	6.8^{a}	3.6^{ab}	267.2	6.2	2.7^{abcd}	325.2
Post Control	6	3.2^{cd}	263.4	5.9^{bc}	3.9^{ab}	274.9	6.3	2.5^{d}	262.1
Post Radish	6.2	3.4^{abc}	233.4	6.3^{abc}	3.9^{ab}	311	6.3	2.7^{abcd}	319.6
Post Buckwheat	6	3.3^{abc}	192.7	5.6^{c}	3.3^{b}	264.5	6.6	2.6^{bcd}	224.8
Post Clover	6.1	3.3^{abc}	227	5.9^{bc}	3.4^{ab}	279	6.2	2.5^{cd}	243.1
Control:Control	5.8	3.3^{abc}	227.5	5.9^{bc}	3.7^{ab}	281.3	6.3	2.5^{d}	199.3
Radish:Radish	6.1	3.6^{a}	216.6	5.8^{bc}	3.7^{ab}	294.7	6.3	2.8^{abc}	289.6
Intensiv:Buck	6	3.5^{ab}	199.7	5.8^{bc}	3.6^{ab}	281.5	6.7	2.9^{a}	241.2
Universal:Clover	6.1	3.3^{abc}	231	6.4^{ab}	3.7^{ab}	321.5	6.9	2.6^{cd}	230.8
ANOVA							**Duncan's multiple range test, α = 0.1*		
p-value	0.487	<0.001	0.12	<0.001	0.035	0.45	0.156	0.069*	0.19
Root MSE	0.26	0.11	26.6	0.27	0.23	38.1	0.39	0.16	51.1
CoEff.Var	4.25	3.43	12.3	4.47	6.23	13.1	6.08	6.11	19.6
2nd Wheats									
Control	6.1^{ab}	3.5^{abcd}	-	5.5^{ab}	3.6	-	-	-	-
Vetch	6.4^{a}	3.9^{a}	-	6.0^{a}	3.9	-	-	-	-
Radish	6.3^{ab}	3.3^{bcde}	-	5.4^{ab}	3.8	-	-	-	-
Intensiv	6.2^{ab}	3.7^{ab}	-	5.4^{ab}	3.5	-	-	-	-
Universal	6.0^{ab}	2.4^{f}	-	5.7^{ab}	3.7	-	-	-	-
Post Control	6.1^{ab}	2.7^{ef}	-	5.6^{ab}	3.6	-	-	-	-
Post Radish	6.0^{ab}	2.9^{def}	-	5.9^{a}	3.8	-	-	-	-
Post Buckwheat	5.8^{b}	2.7^{ef}	-	5.6^{ab}	3.6	-	-	-	-
Post Clover	5.9^{b}	3.1^{cde}	-	5.7^{ab}	3.6	-	-	-	-
Control:Control	6.2^{ab}	3.1^{bcde}	-	5.9^{a}	3.8	-	-	-	-
Radish:Radish	6.2^{ab}	3.5^{abc}	-	5.4^{ab}	3.5	-	-	-	-
Intensiv:Buck	6.4^{a}	3.9^{abcd}	-	5.0^{b}	3.5	-	-	-	-
Universal:Clover	6.1^{ab}	3.5^{abcd}	-	5.9^{a}	3.7	-	-	-	-
ANOVA									
p-value	0.003*	<0.001*	-	0.009*	0.2	-	-	-	-
Root MSE	0.16	0.22	-	0.28	0.2	-	-	-	-
CoEff.Var	2.66	6.75	-	5.02	5.4	-	-	-	-

*Welche's ANOVA

Mean soil macronutients Phosphorus, Potassium and Magnesium (kg/ha). N=3.

	Molescroft 61B			Eastfield AR			Boxtree Bubwith		
	P	K	Mg	P	K	Mg	P	K	Mg
Pre-CC									
	12.1	174.6	95.6	32.8	222.1	101.9	25.3	187.9	184.6
Cover crop									
Custom	9.82^{a}	107.34^{b}	80.1^{ab}	9.19^{b}	139.3^{c}	107.3^{ab}	14.65^{b}	170	160.8^{c}
Control	10.3^{ab}	137.25^{ab}	99.59^{a}	12.99^{ab}	189.4^{abc}	90.57^{a}	17.76^{ab}	180.69	190.8^{bc}
Vetch	10.9^{ab}	169.3^{a}	67.91^{b}	22.62^{a}	216.1^{ab}	97.75^{ab}	13.85^{b}	179.28	184.4^{bc}
Radish	11.74^{a}	169^{a}	88.35^{ab}	15.31^{ab}	201.2^{abc}	83.03^{b}	18.76^{ab}	157.99	199.2^{abc}
Intensiv	13.66^{a}	134.53^{ab}	93.1^{a}	12.38^{ab}	245.78^{a}	116.2^{ab}	22.69^{a}	178.99	243.7^{a}
Universal	7.21^{b}	96.64^{b}	87.45^{ab}	11.93^{ab}	169.8^{bc}	99.5^{ab}	20.37^{ab}	214.46	226.6^{ab}
ANOVA									
p-value	0.039*	0.013*	0.018*	0.03	0.001	0.009	0.008	0.32	0.003*
Root MSE	2.89	42.6	9.92	5.26	28.4	11.2	3.19	33.59	21.84
CoEff.Var	24.28	31.4	11.52	37.41	14.68	11.34	17.7	18.64	10.87
Vining pea									*Welches ANOVA
Custom	10	110.7^{ab}	85.7^{a}	27.3^{b}	292.3^{ab}	104.3^{b}	25	255.3	94.7^{d}
Control	11.3	130.3^{ab}	80.0^{a}	29.3^{b}	250.0^{b}	114.3^{b}	25	210	137.0^{bc}
Vetch	12.7	107.3^{b}	71.0^{a}	147.7^{a}	368.0^{a}	150.7^{a}	23.3	232	132.7^{cd}
Radish	13.3	115.7^{ab}	81.7^{a}	42.3^{ab}	314.7^{ab}	114.3^{b}	31.7	254.7	140.7^{abc}
Intensiv	12.3	134.3^{ab}	52.0^{b}	30.3^{b}	381.0^{a}	164.3^{a}	30.7	253.7	180.7^{a}
Universal	14	149^{a}	79.7^{a}	30.0^{b}	286.0^{ab}	111.7^{b}	28.7	256.7	175.0^{ab}
ANOVA									
p-value	0.153	0.038	0.001	0.028	0.008	<0.001	0.107	0.481	<0.001
Root MSE	1.73	14.5	6	40.8	35.7	8.9	3.78	33.4	14.8
CoEff.Var	14.08	11.68	8	79.68	11.33	7	13.82	13.69	10.29
1st wheats									
Control	13.8^{bc}	98.6^{bc}	118.8^{a}	27.7^{ab}	140	121.0^{ab}	18.3^{c}	99^{abcde}	112.0^{c}
Vetch	14.1^{bc}	63.1^{c}	94.3^{ab}	31.0^{a}	153.7	178.0^{a}	20.3^{bc}	112^{abcd}	126.7^{abc}
Radish	18.0^{ab}	91.3^{bc}	106.2^{ab}	31.0^{a}	160.3	109.0^{b}	29.3^{ab}	106^{abcde}	121.3^{abc}
Intensiv	15.5^{bc}	87.2^{bc}	82.6^{b}	19.3^{b}	143.7	153.7^{ab}	28.7^{ab}	126^{a}	130.7^{abc}
Universal	13.0^{bc}	87.6^{bc}	92.7^{ab}	21.3^{ab}	195.3	154.3^{ab}	28.3^{abc}	122^{ab}	147.3^{a}
Post Control	11.7^{c}	96.9^{bc}	95.9^{ab}	30.3^{a}	153.7	115.3^{b}	22.3^{abc}	90de	115.0^{bc}
Post Radish	13.5^{bc}	132.7^{b}	97.6^{ab}	27.0^{ab}	193.7	122.7^{ab}	28.0^{abc}	119^{abc}	129.0^{abc}
Post Buckwheat	13.3^{bc}	114.4^{bc}	91.7^{ab}	28.3^{ab}	156	104.3^{b}	20.0^{bc}	91^{cde}	120.7^{abc}
Post Clover	12.9^{bc}	103.8^{bc}	98.2^{ab}	30.3^{a}	140.3	109.7^{b}	19.7^{bc}	91de	119.3^{abc}
Control:Control	14.6^{bc}	93.7^{bc}	95.8^{ab}	30.7^{a}	146	111.3^{b}	21.7^{bc}	80^{e}	112.0^{c}
Radish:Radish	17.3^{ab}	120.2^{bc}	93.7^{ab}	25.7^{ab}	164	97.7^{b}	32.3^{a}	118^{abcd}	101.0^{c}
Intensiv:Buck	22.3^{a}	219.9^{a}	86.2^{b}	25.7^{ab}	158.7	117.0^{ab}	25.3^{abc}	113^{abcd}	119.3^{abc}
Universal:Clover	15.5^{bc}	132.6^{b}	91.3^{ab}	30.3^{a}	180.7	149.3^{ab}	26.0^{abc}	97^{bcde}	144.3^{bc}
ANOVA									
p-value	<0.001	<0.001	0.017	0.008	0.25	0.002	<0.001	0.059*	<0.001
Root MSE	1.85	19.64	9.35	3.67	27.69	20.84	3.43	17.54	10.1
CoEff.Var	12.3	17.7	9.76	13.3	17.3	16.49	13.9	16.7	8.19

**Duncan's multiple range test, α = 0.1*

	Molescroft 61B			Eastfield AR			Boxtree Bubwith		
	P	K	Mg	P	K	Mg	P	K	Mg
2nd Wheats									
Control	13.9[bc]	124.1[b]	97.3[a]	25.5[ab]	182.5[abc]	96.5	-	-	-
Vetch	15.9[abc]	102.6[b]	64.8[cd]	26.7[ab]	166.4[abcd]	154.3	-	-	-
Radish	21.7[abc]	101.1[b]	73.9[bcd]	26.4[ab]	167.8[abcd]	92.4	-	-	-
Intensiv	15.9[abc]	89.3[b]	57.6[d]	22.0[b]	162.5[abcd]	101.6	-	-	-
Universal	15.9[abc]	87.4[b]	73.2[bcd]	23.5[ab]	184[abc]	138.8	-	-	-
Post Control	11.0[c]	128.2[b]	77.6[bc]	31.5[ab]	167.5[abcd]	101.1	-	-	-
Post Radish	11.7[c]	133.6[b]	78.0[bc]	30.8[ab]	215.0[a]	105.9	-	-	-
Post Buckwheat	12.7[bc]	107.4[b]	74.2[bcd]	28.9[ab]	191[ab]	111.8	-	-	-
Post Clover	10.6[c]	120.0[b]	68.0[cd]	32.2[a]	189.9[ab]	109.7	-	-	-
Control:Control	23.0[ab]	103.4[b]	91.3[ab]	24.6[ab]	159.7[abcd]	138.7	-	-	-
Radish:Radish	26.9[a]	94.3[b]	72.7[bcd]	22.5[ab]	138.4[bcd]	87.5	-	-	-
Intensiv:Buck	23.7[ab]	207.0[a]	69.0[cd]	23.5[ab]	130.7[cd]	103.2	-	-	-
Universal:Clover	17.6[abc]	99.7[b]	68.9[cd]	28.2[ab]	123.8[d]	147.5	-	-	-
ANOVA									
p-value	<0.001*	0.011*	<0.001*	0.036*	<0.001	<0.001*	-	-	-
Root MSE	3.78	19.5	6.29	3.39	19.5	24.5	-	-	-
CoEff.Var	22.3	16.9	8.46	12.7	11.6	21.4	-	-	-

*Welches ANOVA

Mean foot rot risk. Colony counts of *Fusarium solani* and *Didymella pinodella* from laboratory plate tests. N=4.

	Molescroft 61B			Boxtree Bubwith		
	Fusarium	*Didymella*	Total	*Fusarium*	*Didymella*	Total
Pre-cc	7.9	37.5	45.4	33.9	42.5	76.4
Cover crop						
Custom	5.50^{ab}	88^{ab}	93.5^{ab}	16	18^{b}	34
Control	8.25^{a}	86^{ab}	94.25^{ab}	23	16^{b}	39
Vetch	8.50^{a}	68^{b}	76.5^{b}	5.25	24.5^{ab}	29.75
Radish	5.75^{ab}	136.75^{a}	142.5^{a}	10.5	28^{ab}	38.5
Intensiv	1.00^{b}	93.5^{ab}	94.5^{ab}	19.75	31.75^{ab}	51.5
Universal	1.75^{b}	71.75^{b}	73.5^{b}	8	39^{a}	47
ANOVA						
p-value	0.005	0.022	0.03	0.31	0.019	0.2554
Root MSE	2.87	26.38	26.98	12.32	8.7	13.41
CoEff.Var	60	29.09	28.16	89.64	33.18	33.57
Vining pea						
Custom	0.5	120.75	121.25	7.75	7.5	15.25
Control	1.5	145	146.5	18.25	12.5	30.75
Vetch	3.75	107.75	111.5	9.5	11	20.5
Radish	1.75	226.25	228	15.5	18.75	34.25
Intensiv	1.75	204	205.75	10	14.75	24.75
Universal	0.75	217	217.75	10	17.75	27.75
ANOVA						
p-value	0.087	0.337	0.342	0.35	0.29	0.19
Root MSE	1.51	93.66	93.38	7.47	7.33	10.73
CoEff.Var	90.55	55.05	54.35	63.1	53.5	42.03
Catch crop						
Control	-	253.75^{bc}	-	13^{c}	220.75^{a}	234**
Vetch	-	230.25^{bc}	-	1.75^{c}	85.75^{bc}	87.5
Radish	-	209.75^{bc}	-	7^{c}	67^{bc}	74
Intensiv	-	559.5^{ab}	-	7.25^{c}	48.25^{bc}	55.5
Universal	-	414.5^{abc}	-	15^{abc}	114.5^{b}	129.5
Post Control	-	331.25^{abc}	-	13.75^{bc}	50^{bc}	63.75
Post Radish	-	664.75^{a}	-	14.25^{bc}	57^{bc}	71.25
Post Buckwheat	-	329.25^{abc}	-	16^{abc}	38.5^{bc}	54.5
Post Clover	-	450.75^{abc}	-	22.25^{abc}	16.5^{c}	38.75
Control:Control	-	308.5^{abc}	-	20^{abc}	68.5^{bc}	121.75
Radish:Radish	-	160.5^{c}	-	42^{a}	19.75^{c}	61.75
Intensiv:Buck	-	381.5^{abc}	-	15^{abc}	24^{c}	39
Universal:Clover	-	318^{abc}	-	40.75^{ab}	22.75^{c}	63.5
ANOVA						
p-value	-	<0.001	-	<0.001	<0.001	<0.001
Root MSE	-	112.62	-	66.72	33.45	36.8
CoEff.Var	-	43.72	-	10.2	78.39	62.06

	Molescroft 61B			Boxtree Bubwith		
	Fusarium	*Didymella*	Total	*Fusarium*	*Didymella*	Total
1st wheats						
Control	8.8^{abcd}	131.5^{bc}	140.3^{bc}	16	91.7^{abc}	107.7^{abc}
Vetch	2.0^{cd}	190.0^{abc}	192.0^{abc}	14	44.3^{abc}	58.3^{abc}
Radish	9.3^{abc}	159.0^{bc}	168.3^{bc}	2.8	88.3^{abc}	91.0^{abc}
Intensiv	5.3^{abcd}	107.5^{c}	112.8^{c}	5.8	37.3^{bc}	43.0^{bc}
Universal	3.5^{bcd}	145.5^{bc}	149^{bc}	2.8	36.8^{bc}	39.5^{bc}
Post Control	8.3^{abcd}	115.0^{c}	123.3^{c}	1	26.3^{c}	27.3^{c}
Post Radish	0.8^{d}	193.0^{abc}	193.8^{abc}	4.3	120.5^{ab}	124.8^{ab}
Post Buckwheat	11.8^{ab}	103.8^{c}	115.5^{c}	22.5	61.3^{abc}	83.8^{abc}
Post Clover	13.0^{a}	151.0^{bc}	164^{bc}	5.8	45.3^{abc}	51.0^{abc}
Control:Control	3.5^{bcd}	199.8^{abc}	203.3^{abc}	12.3	129.0^{a}	141.3^{a}
Radish:Radish	3.0^{cd}	298.0^{a}	301.0^{a}	5.8	18.0^{c}	23.8^{c}
Intensiv:Buck	4.5^{bcd}	174.8^{bc}	179.3^{bc}	17.8	22.5^{c}	40.3^{bc}
Universal:Clover	4.3^{bcd}	250.0^{ab}	254.3^{ab}	9.3	17.8^{c}	27.0^{c}
ANOVA						
p-value	<0.001	<0.001	<0.001	0.047	<0.001	<0.001
Root MSE	3.36	47.4	46.9	9.33	36.1	37.7
CoEff.Var	56.22	27.78	26.56	101.4	63.6	57
2nd Wheats					**Eastfield AR**	
Control	35.5	92.5	128.0	2.75	0	-
Vetch	55.8	64.0	119.8	19	0	-
Radish	41.8	25.3	67.0	0.75	0.25	-
Intensiv	46.0	64.0	110.0	3.5	0.25	-
Universal	39.5	114.5	154.0	4.75	0.25	-
Post Control	3.3	90.0	93.3	5.75	0	-
Post Radish	8.8	136.3	145.0	13.25	0	-
Post Buckwheat	7.8	48.8	56.5	5	0	-
Post Clover	15.3	105.0	120.3	5.75	0	-
Control:Control	4.5	40.0	44.5	16.25	0	-
Radish:Radish	31.5	48.5	80.0	1.75	0.5	-
Intensiv:Buck	29.0	54.5	83.5	7.75	0	-
Universal:Clover	30.5	80.0	110.5	4.5	0	-
ANOVA						
p-value	0.1	0.3	0.3	-	-	-
Root MSE	24.5	57.8	61.4	-	-	-
CoEff.Var	91.3	78.0	61.9	-	-	-

Mean foot rot severity observed in crop. N=100.

	Molescroft 61B	**Boxtree Bubwith**
Custom	32[ab]	32[a]
Control	45[a]	19[ab]
Vetch	28[ab]	17[b]
Radish	45[a]	15[b]
Intensiv	18[b]	18[ab]
Universal	25[ab]	9[b]
Generalized LM		
p-value (Wald's)	0.036	0.005
χ^2 (Wald's)	11.9	16.7

Mean haulm lengths (cm) and dry weights (g/m²) of pea plants prior to harvest. N=100 (haulm), N=3 (biomass).

	Molescroft 61B		**Eastfield AR**		**Boxtree Bubwith**	
	Haulm Length (cm)	Dry Weight (g/m²)	Haulm Length (cm)	Dry Weight (g/m²)	Haulm Length (cm)	Dry Weight (g/m²)
Custom	26.2[b]	244.7[ab]	35.1[b]	432	19.4[c]	138
Control	28.5[a]	200[b]	36.3[ab]	412	23[a]	237.3
Vetch	28.7[a]	212[b]	37.7[a]	502.7	21.5[ab]	168.7
Radish	29.1[a]	198[b]	35.5[b]	540	18.9[c]	163.3
Intensiv	28.9[a]	314[ab]	38.2[a]	440	19.4[c]	184.7
Universal	31.7[a]	365.3[a]	36.5[ab]	477.3	20.6[bc]	167.3
ANOVA						
p-value	< 0.001	0.005	< 0.001	0.521	-	0.213
Root MSE	3.89	48.76	4.29	89.08	-	44.54
CoEff.Var	13.7	19.07	11.8	19.06	-	22.22
Kruskal-Wallis						
p-value	-	-	-	-	< 0.001	-
χ^2 value	-	-	-	-	56.45	-

Mean straw and estimated crop yields of 1st wheats. N=3.

	Molescroft 61B			**Eastfield AR**			**Boxtree Bubwith**		
	Straw Fresh (g/m²)	Straw Dry (g/m²)	Yield	Straw Fresh (g/m²)	Straw Dry (g/m²)	Yield	Straw Fresh (g/m²)	Straw Dry (g/m²)	Yield
Control	3524	865^{ab}	97.8^{ab}	3967^{ab}	1044^{ab}	103.0^{ab}	3163^{b}	1033	103.2^{ab}
Vetch	3147	817^{ab}	92.5^{ab}	4284^{ab}	1189^{a}	102.1^{ab}	3369^{b}	1088	116.4^{ab}
Radish	3309	873^{ab}	91.8^{b}	3921^{ab}	1015^{ab}	97.0^{ab}	3344^{b}	1097	128.0^{ab}
Intensiv	3825	909^{ab}	107.9^{a}	4349^{a}	1168^{a}	94.1^{ab}	3279^{b}	987	136.0^{a}
Universal	3504	856^{ab}	100.0^{ab}	4108^{ab}	1113^{ab}	100.4^{ab}	4159^{ab}	1245	105.8^{ab}
Post Control	3255	800^{ab}	96.3^{ab}	4308^{a}	1165^{a}	94.5^{ab}	3749^{ab}	1248	102.7^{ab}
Post Radish	3259	827^{ab}	104.1^{ab}	4297^{ab}	1137^{ab}	94.9^{ab}	5533^{a}	1331	109.5^{ab}
Post Buckwheat	2705	677^{b}	100.0^{ab}	3239^{b}	864^{b}	102.5^{ab}	3857^{ab}	1197	106.9^{ab}
Post Clover	3048	771^{ab}	104.5^{ab}	3795^{ab}	977^{ab}	116.1^{a}	3868^{ab}	1207	97.9^{ab}
Control:Control	3981	1051^{a}	100.0^{ab}	3876^{ab}	1028^{ab}	100.0^{ab}	2993^{b}	993	100.0^{ab}
Radish:Radish	3212	833^{ab}	98.1^{ab}	4039^{ab}	1089^{ab}	88.6^{b}	3780^{ab}	1228	91.5^{b}
Intensiv:Buck	2984	771^{ab}	97.8^{ab}	3628^{ab}	928^{a}b	83.9^{b}	3339^{b}	1065	96.3^{ab}
Universal:Clover	3640	928^{ab}	101.5^{ab}	4392^{a}	1173^{a}	91.9^{ab}	3744^{ab}	1199	103.7^{ab}
ANOVA									
p-value	0.103	0.076	0.042	0.05	0.019	0.013	0.002	0.139	0.03
Root MSE	451	111	4.65	391	109	6.4	710	147	8.79
CoEff.Var	15.3	13.1	5.25	9.74	10.2	8.34	19.2	12.8	13

**Tukeys parwise, α=0.1.*

Mean VESS SQ (1-5) scores, quality of soil structure declines with increasing score. Mean Earthworm counts. N=3.

	Molescroft 61B		Eastfield AR		Boxtree Bubwith	
	SQ	Worm no.	SQ	Worm no.	SQ	Worm no.
Vining pea						
Custom	1.33	0.05	1	2	2	1.33
Control	1.5	0.33	3.33	0.33	3.83	1
Vetch	1.67	0.33	2	1.33	2.83	0.3
Radish	1.5	1	1.67	1.67	3	1.33
Intensiv	1	0.67	1.5	2.33	2.33	2.33
Universal	1	0.33	1.33	2.33	2.5	1.33
Catch crop						
Control	2.3	0.7	2.2	3	2.7	0.3
Vetch	3	0	2	5.3	2.8	1
Radish	2.8	0.7	2	3.7	2.2	1.3
Intensiv	1.7	0.3	2	2.3	2.3	3.7
Universal	2.8	1.3	2	2	2.8	1.3
Post Control	2.2	0.7	2	2.7	2.2	2
Post Radish	1.5	0	1.8	0.7	1.7	2
Post Buckwheat	2.2	0.3	2.3	1	1.8	3.7
Post Clover	1.7	1	2.7	1.7	1.8	4.3
Control:Control	2.3	0.7				
Radish:Radish	2.2	1	2.8	2.7	2.7	1.3
Intensiv:Buck	1.8	1	2.3	3	2.5	3.7
Universal:Clover	2	0.3	2.3	2.3	2.8	1.3

Least squared means from accumulated compaction ANCOVA procedure. N=8.

	Molescroft 61B	Eastfield AR	Boxtree Bubwith
Cover crop (psi)			
Control	-	1392.25^{a}	1461.7^{a}
Vetch	-	1169.5^{b}	1113.3^{c}
Radish	-	1068.7^{c}	1346.3^{b}
Intensiv	-	1210.3^{b}	1154.5^{c}
Universal	-	1242.7^{b}	1347.9^{b}
ANCOVA			
p-value	-	< 0.001	< 0.001
Root MSE	-	212.6	265.8
CoEff.Var	-	17.6	20.7
Vining pea (psi)			
Custom	-	1356^{d}	2302.9^{c}
Control	-	1832^{a}	2522.3^{b}
Vetch	-	1660^{b}	2647.1^{a}
Radish	-	1792^{a}	2013.7^{d}
Intensiv	-	1641^{b}	2272.6^{c}
Universal	-	1509^{c}	2010.8^{d}
ANCOVA			
p-value	-	< 0.001	< 0.001
Root MSE	-	240.5	317.1
CoEff.Var	-	14.7	13.9
Catch crop (psi)			
Control	1241.1^{efg}	1421^{d}	1295.1^{abc}
Vetch	1485.2^{b}	1372.6^{d}	1243.7^{bc}
Radish	1311^{ef}	1370.9^{d}	1206.4^{c}
Intensiv	1159.6^{g}	1694.6^{c}	1344.7^{abc}
Universal	1361.8^{cde}	1357.4^{d}	1310.2^{abc}
Post Control	1255.5^{efg}	1477.2^{d}	1257.4^{abc}
Post Radish	1347.9^{def}	1760^{c}	1295.8^{abc}
Post Buckwheat	1493.7^{b}	1443.3^{d}	1390.5^{ab}
Post Clover	1462.6^{b}	2004.1^{b}	1337.3^{abc}
Control:Control	1166.5^{g}	1423.5^{d}	1292.8^{abc}
Radish:Radish	1646.2^{a}	2149^{a}	1430.5^{a}
Intensiv:Buck	1427.1^{bc}	1971.4^{b}	1421.8^{ab}
Universal:Clover	1299.4^{ef}	2193.5^{a}	1303^{abc}
ANCOVA			
p-value	< 0.001	< 0.001	< 0.001
Root MSE	267.8	272.6	406.1
CoEff.Var	19.7	16.4	30.8

Least squared means from accumulated compaction ANCOVA procedure. N=8.

	Molescroft 61B	Eastfield AR	Boxtree Bubwith
2nd wheats (kPa)			
Control	5994[abc]	35812[de]	-
Vetch	5626[bcd]	40532[a]	-
Radish	6582[ab]	38472[bc]	-
Intensiv	4636[e]	39273[ab]	-
Universal	5405[cde]	37917[bcd]	-
Post Control	5356[cde]	40692[a]	-
Post Radish	5325[cde]	37776[bcd]	-
Post Buckwheat	4957[de]	38692[abc]	-
Post Clover	4990[de]	-	-
Control:Control	6663[a]	36497[cd]	-
Radish:Radish	6059[abc]	34231[e]	-
Intensiv:Buck	5941[abc]	36335[d]	-
Universal:Clover	5061[cde]	37482[bcd]	-
ANCOVA			
p-value	<0.001	<0.001	-
Root MSE	1495	4709	-
CoEff.Var	26.9	12.5	-