Investigating the integration of cover cropping into vining pea rotations

Technical report for 4th round of trials, 2020.

Processors & Growers Research Organisation
Green Pea Company

Tom Jelden
Dr. Lea Herold

Contents

This report details all findings from four cover crop trials beginning August 2019 as part of a greater project investigating the compatibility of cover and catch cropping in vining pea rotations. The project is sponsored by Birdseye, The Green Pea Company and HMC, with seed provided by Elsoms. All work was carried out by PGRO, GPC members Chris Byass, Tamara Hall, Andrew Falkingham and Richard Boldan and Proctor Brothers Ltd on behalf of HMC.

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 and the wider environmental benefits provided by cover crops 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.

This document presents the findings and analysis of four trials hosted by GPC and HMC growers. It is the forth report in a series of technical reports accompanying a summary report outlining current recommendations. The trials have assessed the use of a selection of common cover crops with numerous soil and plant criteria monitored.

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.

2 Trial methods

Three cover crop mixes were trialled alongside control measures. The mixtures are detailed in table 2. The trial adhered to a replicated random strip trial layout (3 reps). The trials were repeated at three sites in the East Riding of Yorkshire and one in Holbeach Marsh on different soil types, under different foot rot pressures and drilling dates.

Table 1: Trial sites

Field name	Location	Drilling window	Foot rot pressure	Soil type
Molescroft 6	Beverley	Mid-late	Medium	Sandy clay loam
Eastfield Flint	Bainton	Mid-late	Little to none	Medium sandy clay loam, min-tilled
Vicarage Railway	Asselby	Early	Low to medium	Free draining sandy loam with poor inherent structure
Russells	Wisbech	Early	Medium	Exceptional deep silt

Table 2: Treatments / Species mixes

Name in text	Species mix	Rate
Control	Stubble	n/a
Oat + phacelia	80% Black oat (*Pratex*), 20% Phacelia (*Angelia*)	25 kg/ha
Oat + vetch	70% Black oat, 30% Winter vetch (*Latigo*)	30 kg/ha
Oat + mustard	70% Black oat, 30% White mustard (*Albatross)*	30 kg/ha

Numerous soil and plant parameters were assessed at various times through-out the trial. Samples and assessments were made before cover crop drilling, prior to cover crop destruction, and through-out the vining pea season.

Soil properties examined included;

- Macro-nutrients including phosphorus, potassium, magnesium and calcium
- Soil organic matter (LOI) and pH
- Soil moisture
- Compaction (penetrometer resistance)
- Assessment of soil structure (VESS)
- Innoculum pressure for foot rot pathogens *Fusarium solani*, *Didymella pinodella* and *Aphanomyces euteiches*

Assessments of crop health and responses included;

- Vining pea yield
- Severity of foot rot development

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

Weather

Cover crops were drilled in good time into reasonable moisture. The autumn and winter of 2019/20 was extremely wet and mild, delaying field operations well into March. Beyond March rainfall ceased, severely compromising emergence. Conditions returned to a relative seasonal norm by late May.

2.1 Trial progress

Despite the prompt drilling and available moisture at drilling, the cover crops this year generally achieved only a modest biomass. This was perhaps due to the cool and wet autumn. The biomass/cover was considerably greater at sites where a small amount of starter nitrogen had been applied (around 25 kg/ha at Eastflid Flint and Russells) but the greater biomass did not necessarily translate into greater treatment effects.

Vining pea development was highly variable in the 2020 season. Yield was very low at Vicarage and Eastfield, satisfactory at Russells and quite good at Molescroft. The trial at Vicarage was severely compromised due to pigeon damage and irregular weed pressure. Foot rot pressure was quite low at all sites this year.

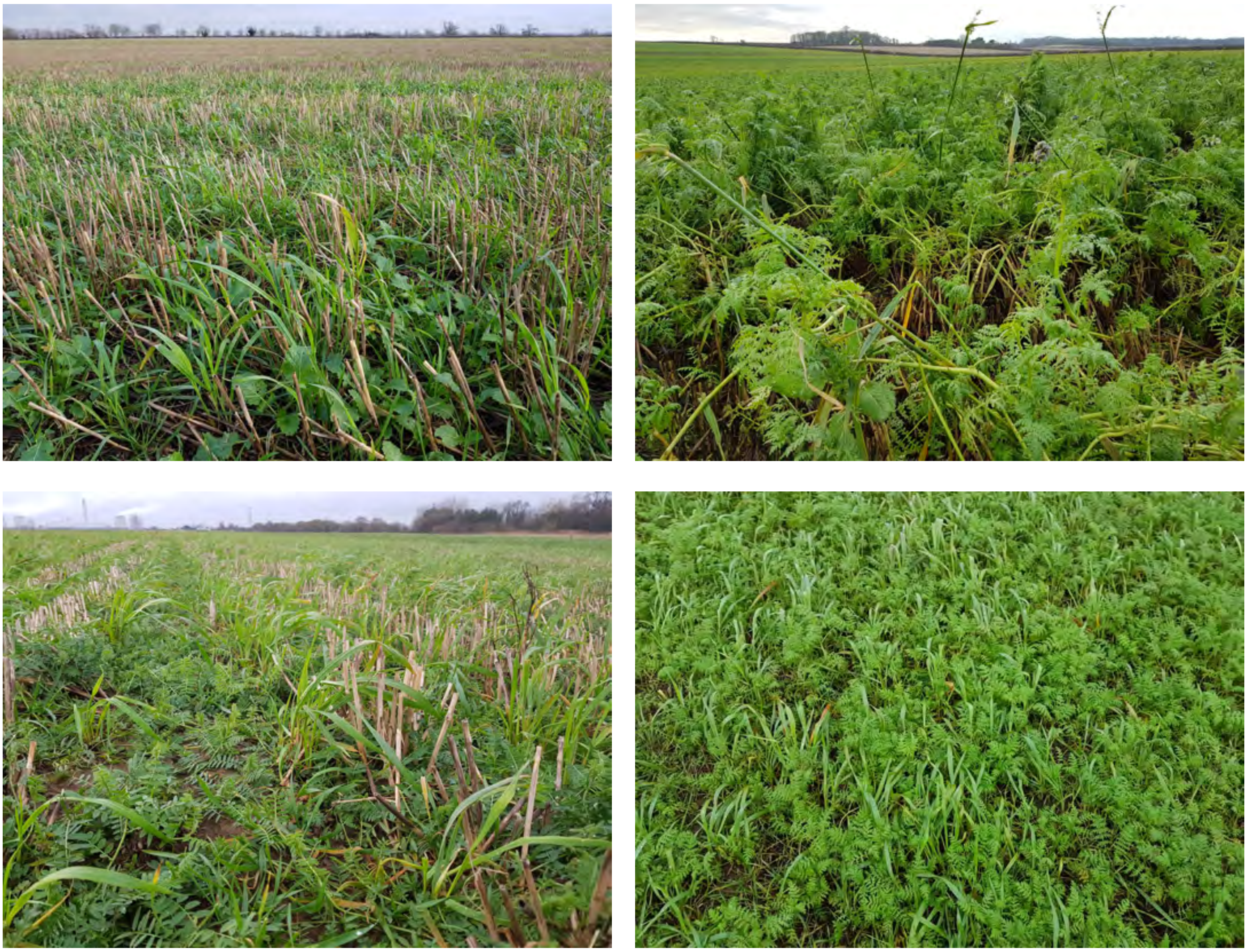

Figure 1: Final biomass achieved by cover crops. Clockwise starting top left, Molescroft 6, Eastfield Flint, Russells and Vicarage Railway.

3 Results

3.1 Soil nutrients

The tables below show the average change in available macronutrients, pH and soil organic matter between cover crop emergence and destruction. See appendix for concentrations. At all sites it was common for macronutrient and soil organic matter concentrations to decline between cover crop establishment and vining pea drilling. Soil pH increased. It is difficult to explain these changes. Most sites (except Vicarage) received some fertilizer input prior to vining pea drilling and all sites were cultivated somehow (see appendix) prior to peas. Lock-up of nutrients into deteriorating and/or buried cover residues may explain some of the apparent decline in nutrients but does not correlate with site dependant cover crop biomass.

Table 3: Molescroft 6. Mean change in nutrient availability (mg/kg), pH or soil organic matter percentage between drilling of cover crop and drilling of vining peas. *Welche's AVOVA.

Treatment	P	K	Mg	Ca	pH	OM%
Control	-18.3	-107	-2.2	8.7	0.52	-0.28
Oat + phacelia	-29.9	-123	-7.4	-118	0.46	-0.40
Oat + mustard	-21.9	-173	-8.4	-124	0.34	-0.47
F statistic	2.62	1.35	1.60	1.39	1.20	2.93*
p-value	0.11	0.29	0.23	0.28	0.38	0.11*

Table 4: Eastfield Flint. Mean change in nutrient availability (mg/kg), pH or soil organic matter percentage between drilling of cover crop and drilling of vining peas. *Welche's AVOVA.

Treatment	P	K	Mg	Ca	pH	OM%
Control	-14.7	-148	-46.1	-1.6	0.48	-0.91
Oat + phacelia	-13.2	-151	-33.1	-335	0.26	-1.07
Oat + mustard	-13.9	-119	-22.8	-111	0.74	-0.78
F statistic	0.14	0.29	2.36*	0.84	2.41	0.27
p-value	0.87	0.75	0.15*	0.45	0.12	0.77

Table 5: Vicarage Railway. Mean change in nutrient availability (mg/kg), pH or soil organic matter percentage between drilling of cover crop and drilling of vining peas.

Treatment	P	K	Mg	Ca	pH	OM%
Control	-2.5	1.6	-37.8	-96.7	0.28	-0.23
Oat + phacelia	1.5	-7.4	-38.3	-48.3	0.37	-0.27
Oat + vetch	-3.8	22.1	-53.0	-252	0.0	-0.29
F statistic	2.32	1.40	0.75	1.23	2.06	0.27
p-value	0.13	0.28	0.48	0.32	0.16	0.77

Table 6: Russells. Mean change in nutrient availability (mg/kg), pH or soil organic matter percentage between drilling of cover crop and drilling of vining peas.

Treatment	P	K	Mg	Ca	pH	OM%
Control	5.1	-116	-35.4	-368	0.0	-0.06
Oat + phacelia	-0.71	-141	-39.7	-324	0.1	-0.04
Oat + vetch	2.1	-112	-30.6	-540	0.1	-0.2
F statistic	1.56	0.86	0.31	2.88	0.79	1.63
p-value	0.23	0.51	0.86	0.05	0.55	0.21

3.2 Foot rot

3.2.1 Foot rot risk

Inoculum levels of soil borne foot rot pathogens were low or absent at all sites. Consequently, levels of foot rot that developed in crop were also low. Levels of *Fusarium solani* inoculum did not change significantly between cover crop drilling and vining pea drilling with the exception at Vicarage Railway, where *Fusarium* presence declined by a small but meaningful amount across all treatments. At Molescroft 6, the highest increase in *Fusarium solani* was observed in the control. *Didymella pinodella* inoculum was unaffected by cover cropping at three sites. At Russells, inoculum levels dropped between cover crop drilling and vining pea drilling in all treatments. The lowest decline, however, was observed in the oat + phacelia cover crop. *Aphanomyces euteiches* risk in spring was not significantly affected by cover cropping. However, the control measures appeared to have shown the lowest *Aphanomyces* pressure.

Table 7: Molescroft 6. Mean change in colony abundance of foot rot pathogens *Fusarium solani* and *Didymella pinodella* between drilling of cover crop and drilling of vining peas, plus mean *Aphanomyces euteiches* score at vining pea drilling.

Treatment	*Fusarium*	*Didymella*	*Aphanomyces* score
Control	15.6	1.3	0.24
Oat + phacelia	3.3	2.3	0.52
Oat + mustard	3.3	0.8	0.57
F statistic	2.49	1.98	0.55
p-value	0.12	0.17	0.59

Table 8: Eastfield Flint. Mean change in colony abundance of foot rot pathogens *Fusarium solani* and *Didymella pinodella* between drilling of cover crop and drilling of vining peas, plus mean *Aphanomyces euteiches* score at vining pea drilling. *Welches ANOVA.

Treatment	*Fusarium*	*Didymella*	*Aphanomyces* score
Control	4	-0.7	0.04
Oat + phacelia	0.8	-1.3	0
Oat + mustard	3.1	-0.2	0.17
F statistic	4.87*	1.40*	0.76
p-value	0.04*	0.29*	0.48

Table 9: Vicarage Railway. Mean change in colony abundance of foot rot pathogens *Fusarium solani* and *Didymella pinodella* between drilling of cover crop and drilling of vining peas, plus mean *Aphanomyces euteiches* score at vining pea drilling.

Treatment	*Fusarium*	*Didymella*	*Aphanomyces* score
Control	-11.3	-8.8	0.34
Oat + phacelia	-14.3	-5.3	1.6
Oat + vetch	-17.2	-6.3	0.85
F statistic	0.32	0.17	2.40
p-value	0.73	0.84	0.12

Table 10: Russells. Mean change in colony abundance of foot rot pathogens *Fusarium solani* and *Didymella pinodella* between drilling of cover crop and drilling of vining peas, plus mean *Aphanomyces euteiches* score at vining pea drilling.

Treatment	*Fusarium*	*Didymella*	*Aphanomyces* score
Control	0.7	-54.5_{a}	0.0
Oat + phacelia	-0.5	-22.0_{b}	0.1
Oat + vetch	0.50	-46.5_{ab}	0.0
F statistic	0.86	4.23	0.62
p-value	0.51	0.03	0.66

3.2.2 Foot rot development

Foot rot was generally light in this years trials. A combined effect of *Fusarium* and *Aphanomyces* was seen at Molescroft 6 where the oat + phacelia treatment displayed a modest but statistically significant reduction of foot rot infection. In contrast, at Russells where *Didymella* was the causal pathogen, the oat + phacelia treatment showed a similar amount of foot rot to the control but the oat + vetch treatment had significantly lower foot rot infection than the control. At Eastfield foot rot was nearly absent. At Vicarage, *Didymella* and *Aphanomyces* were the cause of foot rot but disease levels were low and none of the treatments had any any effect. Winter vetch and white mustard did not increase foot rot incidence in any of these trials. Cover cropping with oat + phacelia generally decreased foot rot incidence, albeit by a small amount.

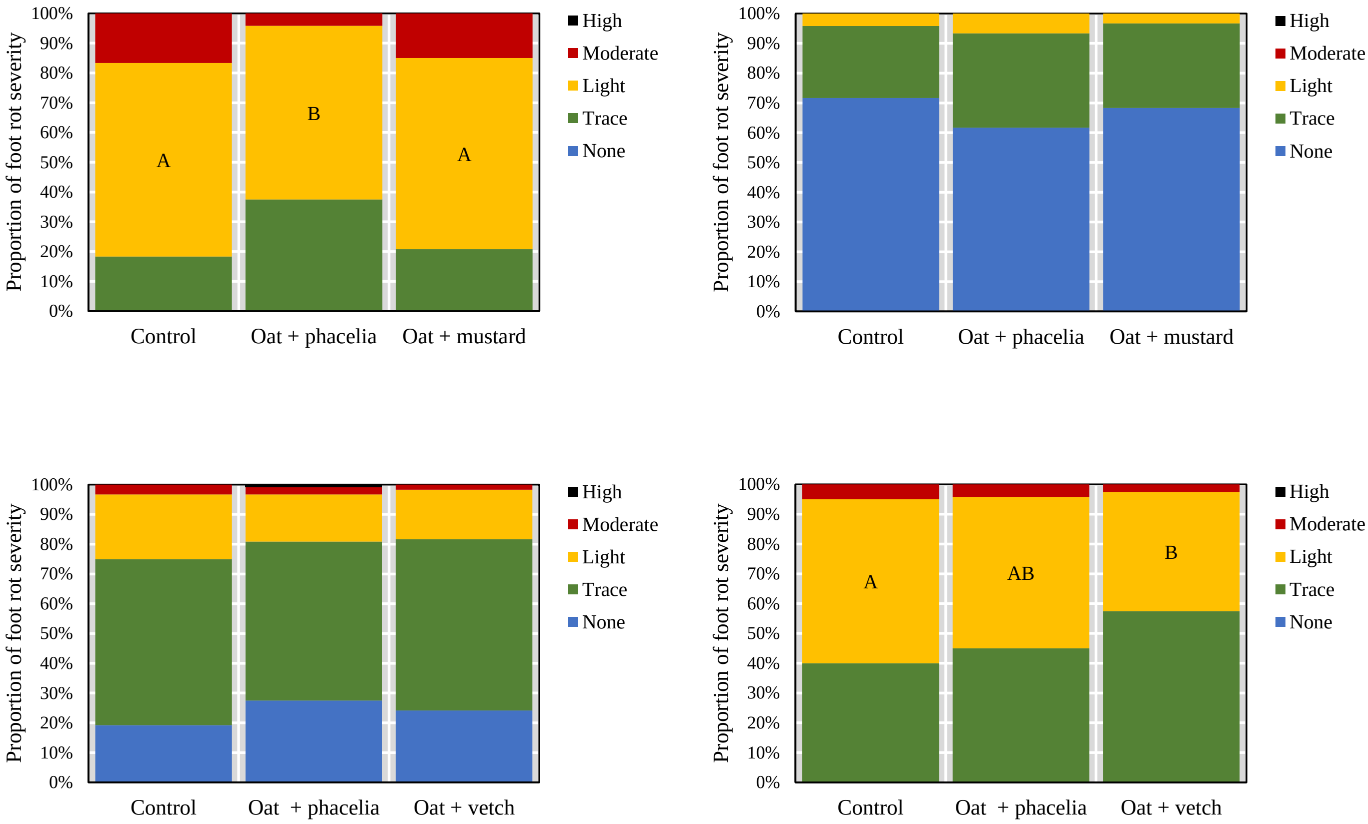

Figure 2: Proportion of foot rot severities developed in crop at flowering. Clockwise starting top left, Molescroft 6, Eastfield Flint, Russells and Vicarage Railway.

3.3 Yield

Vining pea yield was not significantly affected by cover cropping at any trial this year. The crop at Eastfield Flint was very poor, suffering from poor emergence and early drought. Vining peas at Vicarage Railway were heavily damaged by pigeons in one quarter of the trial area, with the remaining trial area erratically plagued by colt's-foot and thistles. The trial was yielded but the data heavily reflect the pigeon and weed pressure, and thus not presented here.

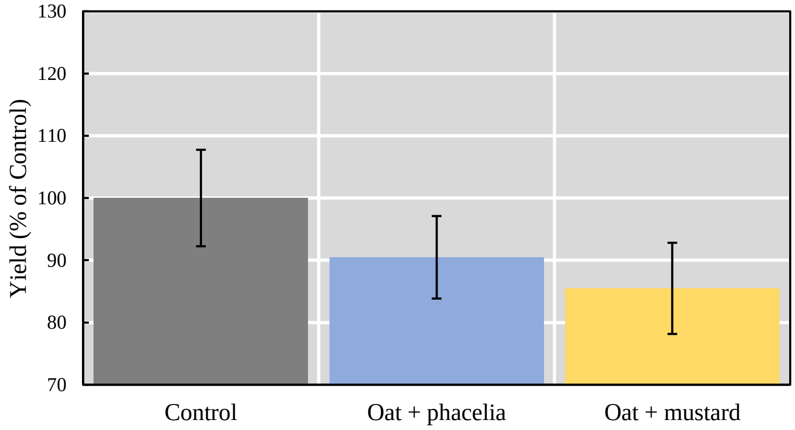

Figure 3: Mean vining pea yield (% of control), Molescroft 6.

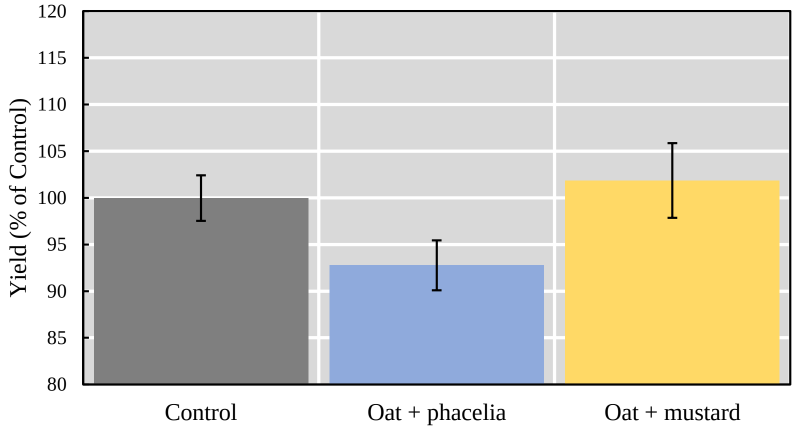

Figure 4: Mean vining pea yield (% of control), Eastfield Flint.

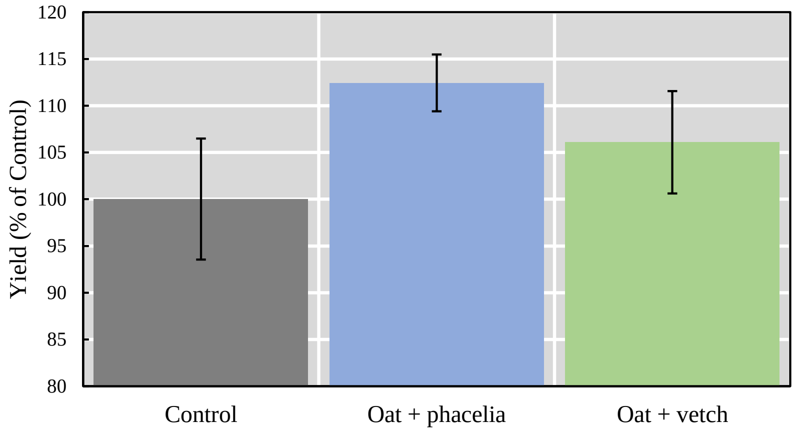

Figure 5: Mean vining pea yield (% of control), Russells.

3.4 Soil moisture

Cover cropping seems to have been generally advantageous to soil moisture retention in these trials. At Eastfield Flint, soil moisture change was recorded from cover crop destruction until vining pea harvest. Figure 6 demonstrates that cover cropped land remained slightly drier in the late winter and early spring compared to the control. Once drilled (end of April), cover cropped areas tended to retain a slightly greater amount of soil moisture for the remainder of the growing period. This was not, however, advantageous enough to affect vining pea yield in this trial. At both Vicarage Railway and Russells, an oat + phacelia crop resulted in greater soil moisture retention through-out the entire vining pea growing period, compared to the control. An oat + vetch cover crop resulted in more variable soil moisture retention which mirrored the phacelia mix towards the later half of the growing period. The improved soil moisture retention at Vicarage Railway was expected to improve yield given the spring drought on light land. Unfortunately, the yield data were compromised due to pigeon damage and weed pressure thus no solid conclusion can be made on the effect of soil moisture retention on this occasion.

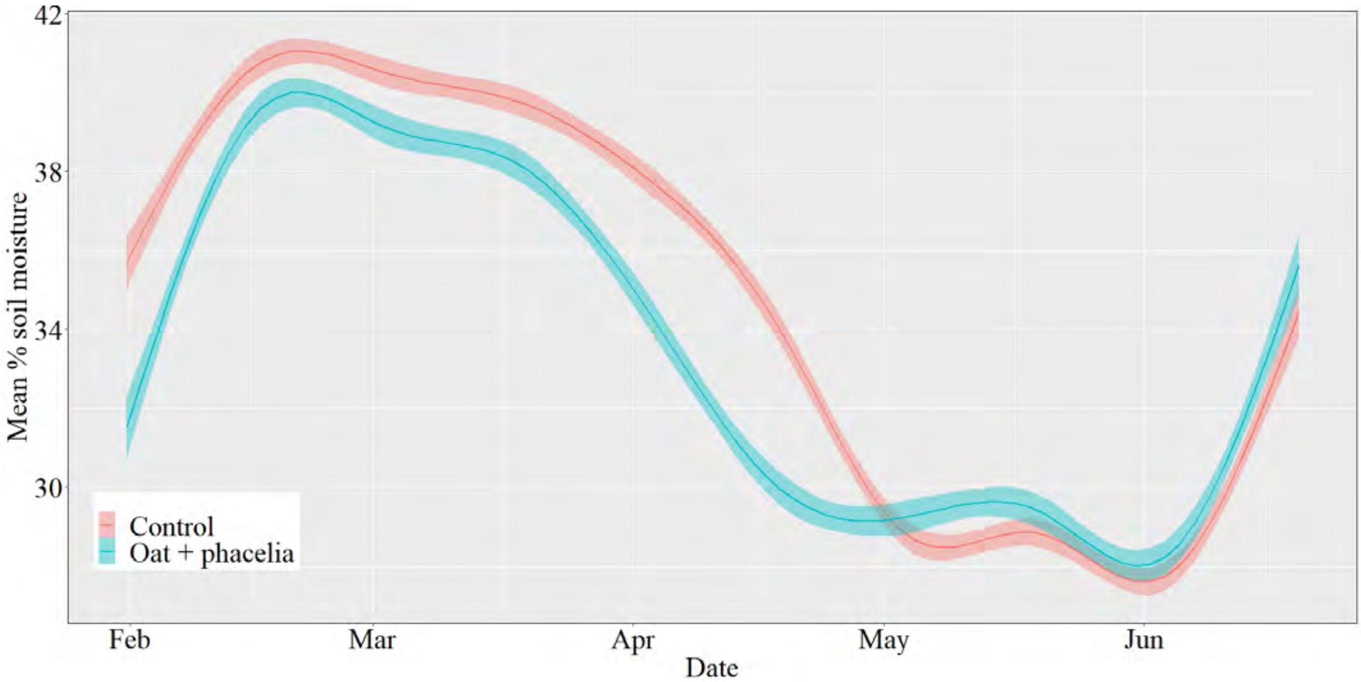

Figure 6: Mean % soil moisture from cover crop destruction to vining pea harvest, Eastfield Flint.

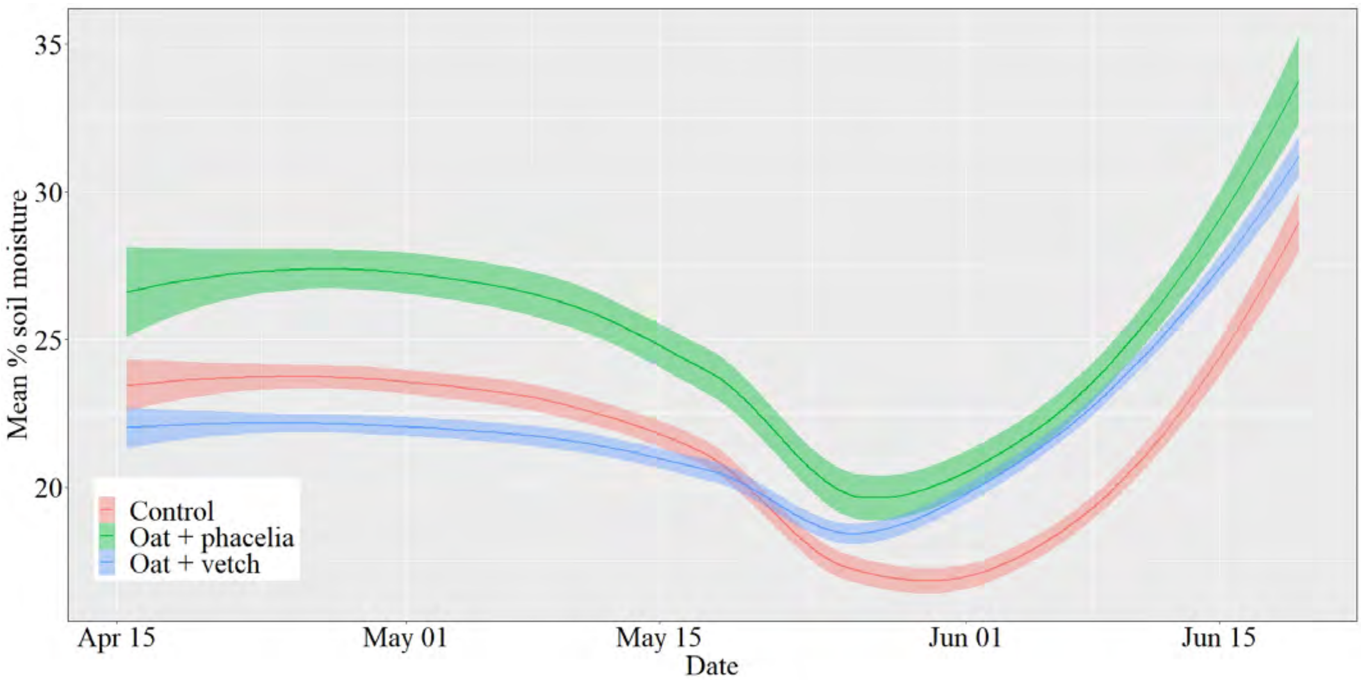

Figure 7: Mean % soil moisture from vining pea drilling to harvest, Vicarage Railway.

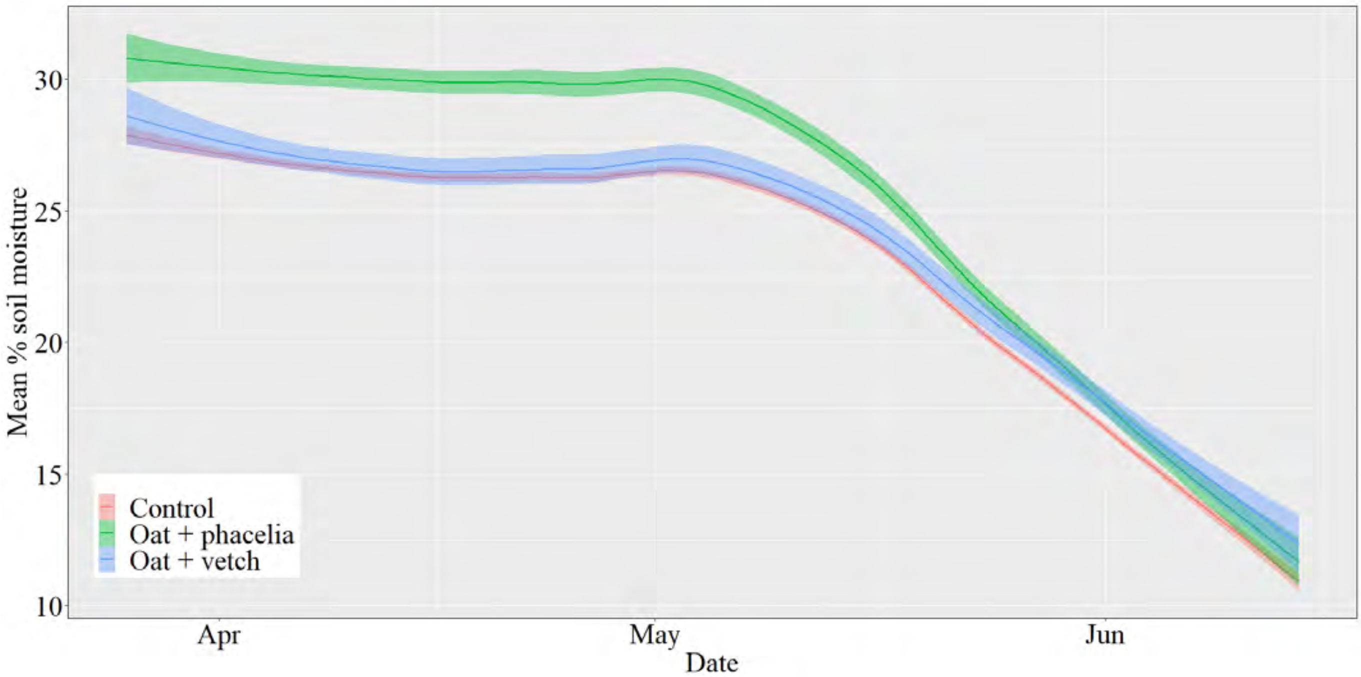

Figure 8: Mean % soil moisture from vining pea drilling to harvest, Russells.

3.5 Soil compaction

Soil penetrometer resistance was affected differently at each site. Measurements were taken shortly after vining pea drilling. At Molescroft 6, resistance was significantly lower throughout the soil profile following an oat + mustard cover crop but not an oat + phacelia mix. If genuine compaction relief was observed, this may have been due to the significantly greater amount of biomass accrued by the oat + mustard treatment. At Vicarage Railway, penetrometer resistance was not affected by either cover crop treatment. At Russells resistance was greater after both cover crop treatments compared to the control below the level of cultivation, possibly an effect of deep drying. The recordings were made shortly after drilling, when deep soil moisture was still quite high after the exceptionally wet winter. It is possible that the cover crops offered greater transpirational drying through the winter, thus drier at depth leading to greater penetrometer resistance. The data have not been corrected for variable soil moisture.

Figure 9: Least square mean penetrometer resistance (kPa) and accumulated least square mean penetrometer resistance (kPa) through 750mm soil profile. Recorded at drilling. *Marginally significant result.

Treatment	LS mean resistance			LS mean accumulated resistance		
	Molescroft	Vicarage	Russels	Molescroft	Vicarage	Russels
Control	3867_a	3968	1251_b	51.5_a	56.2_a	9.4_b
Oat + phacelia	3884_a	4034	1434_a	52.0_a	57.8_a	10.7_a
Oat + vetch	n/a	3878	1351_{ab}	n/a	54.0_b	9.7_b
Oat + mustard	3467_b	n/a	n/a	47.2_b	n/a	n/a
F statistic	9.61	0.48	2.15	11.8	4.79	3.57
p-value	0.00	0.62	0.07*	0.00	0.01	0.01

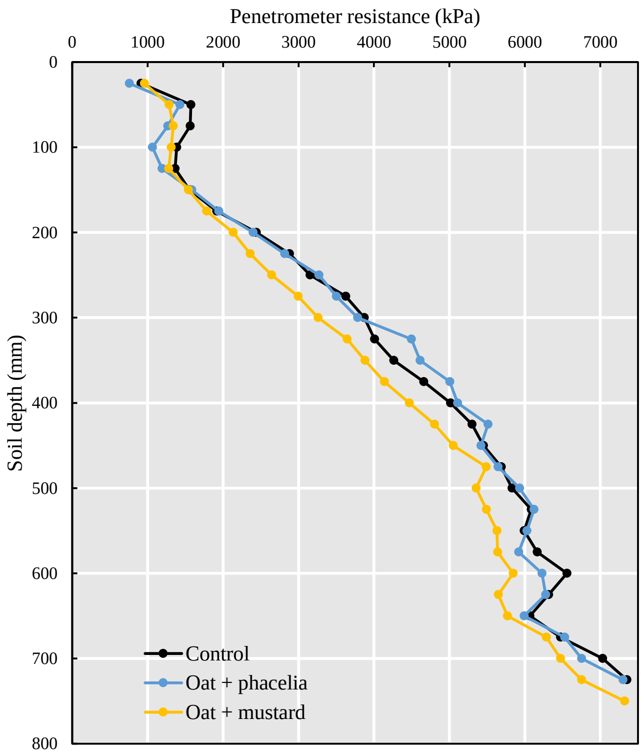

Figure 10: Mean penetrometer resistance profile, Molescroft 6. Recorded at drilling.

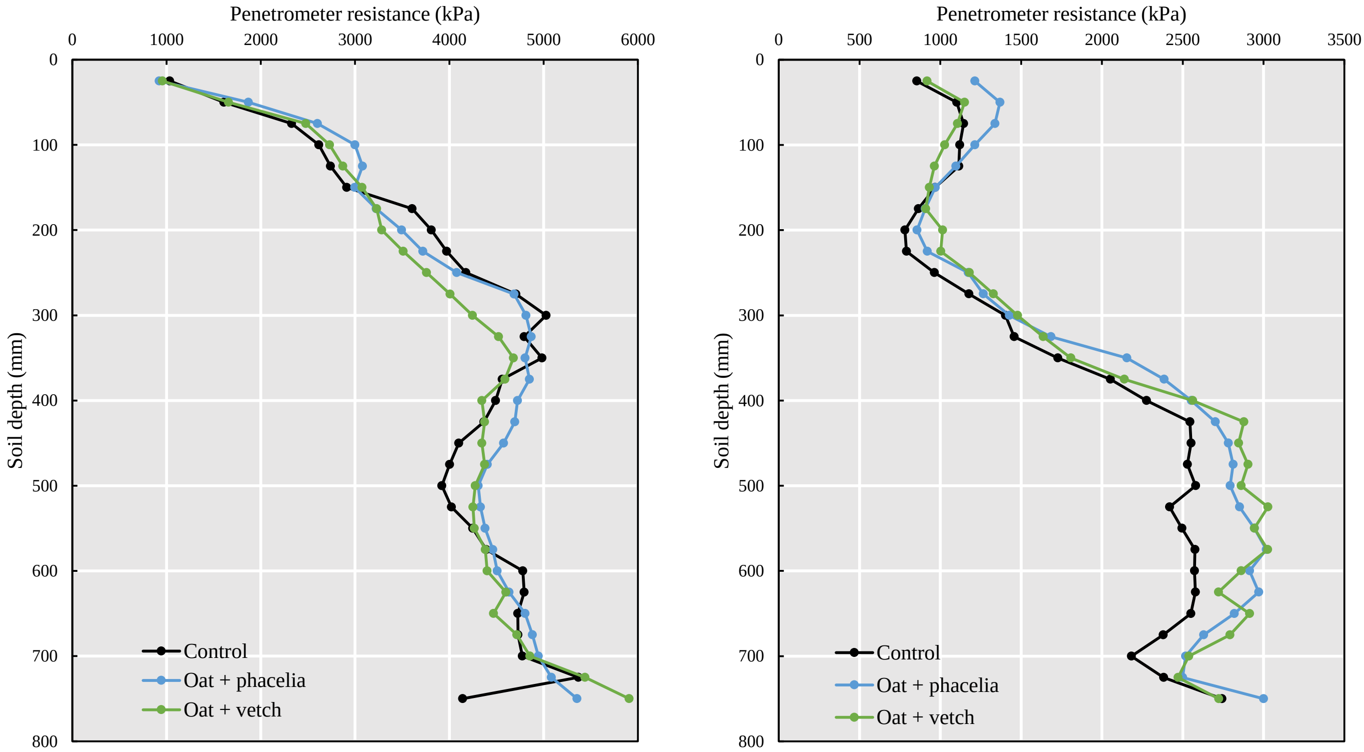

Figure 11: Mean penetrometer resistance profile, Vicarage Railway (left), Russells (right). Recorded at drilling.

3.6 Soil structure

Soil structure was assessed at two sites (Molescroft 6 and Russells) using VESS methods. Soil structure was slightly improved by cover cropping at both sites, however, the differences between treatments were marginal and not statistically significant. VESS assessments were not possible at Vicarage Railway and Eastfield Flint due to rapid drying of the land.

Table 11: Mean VESS scores at flower.

Treatment	Molescroft 6	Russells
Control	1.50	2.25
Oat + phacelia	1.42	2.17
Oat + vetch		1.83
Oat + mustard	1.17	
Kruskal-Wallis Chi-square	1.9	5.6
p-value	0.38	0.23

4 Conclusions

Cover crops were drilled in good time this year and got off to a good start. Sufficient growth was achieved at two sites where a small amount of starter nitrogen was applied. Vining pea drilling was slightly delayed in spring followed by a very dry spring that resulted in variable vining pea performance. Main findings are summarised below.

- Soil nutrition was not significantly affected by cover cropping.
- No affect of cover cropping on soil pH or soil organic matter was observed during the brief trial duration.
- Foot rot incidence was low this year. Even so, cover cropping did not increase foot rot severity in crop. On two occasions, cover cropping significantly reduced foot rot development compared to control measures. A winter vetch cover crop did not increase foot rot severity in crop, increasing confidence in its suitability preceding peas.
- No cover crop option significantly increased or depressed vining pea yield. Yield was extremely variable this year due to challenging conditions during emergence.
- Soil moisture retention was generally increased in the spring and summer following an oat + phacelia cover crop compared to control measures. No yield correlation was observed however.
- The effects of cover cropping on soil compaction were mixed. Pentrometer resistance was significantly reduced on one occasion following an oat + mustard cover crop. An oat + phacelia mix appeared to have increased penetrometer resistance below cultivation depth, perhaps due to deep drying.
- Soil structure was better following cover crops but only by a small and non-statistically significant margin.

5 Appendices

Methods

Soil macronutrients were determined from soil samples taken from a soil depth of 5-20 cm at six sampling zones per treatment. P, K, Mg, Ca, pH and soil organic matter (loss on ignition) were determined by laboratory analysis. Foot rot risk was determined from soil samples taken from a depth of 5-20 cm at six sampling zones per treatment. Risk was determined by in-house methods at PGRO. Mean change in colony numbers (which reflect risk) between autumn and spring are reported in this document. Risk is based on the presence of *Fusarium solani*, *Didymella pinodella* and *Aphanomyces euteiches*. Foot rot development in crop was measured by noting the severity of foot rot infection on 150 individual plants per treatment. Each plant was assessed on an ordinal scale ranging from 0 to 5 (no infection to severe root infection). Vining pea yield was determined by threshing $8m^2$ plots replicated six times per treatment. Assessments of soil structure were carried out in six 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 a digital 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. Soil moisture was recorded using SM150T probes (Delta-T Technologies). Due to a limited number of probes the data were only recorded in two treatments per trial but replicated three times. Field cultivations, drilling and crop maintenance were conducted by GPC/HMC project partners. Details can be found in the diary.

Table 12: Trials diary.

	Molescroft 6	Eastfield Flint	Vicarage Railway	Russells
Initial sampling	19/09/19	22/08/19	22/08/19	12/08/19
Cover crop drilled	10/09/19	12/08/19	15/08/19	07/09/19
Destruction	Plough Early winter	Sprayed Mid-winter	Sprayed Mid-winter	Plough Late winter
Cultivation	Power harrow	Light power harrowing	Shallow disc	Power harrow
Crop sampling	14/04/20	29/04/20	14/04/20	25/03/20
Peas drilled	14/04/20	24/04/20	07/04/20	17/03/20
Variety	Ida	Boston	Aloha	Tomahawk
Crop assessments	19/06/20	19/06/20	04/06/20	29/05/20
Harvest	06/07/20	14/07/20	22/06/20	14/06/20

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 and foot rot assessments are analysed using chi-squared independence of fit or Kruskal-Wallis rank sum analysis.

***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 taking soil depth into account in the analysis.

Table 13: Molescroft 6. Colony abundance of foot rot pathogens *Fusarium solani* and *Didymella pinodella*, plus mean *Aphanomyces euteiches* score at vining pea drilling.

Treatment	Pre cover crop			Pre vining pea drilling		
	Fusarium	*Didymella*	*Aphanomyces*	*Fusarium*	*Didymella*	*Aphanomyces*
Control	0	1.7	n/a	15.7	1.3	0.24
Oat + phacelia	0	0.5	n/a	3.3	2.3	0.52
Oat + mustard	0	2	n/a	3.3	0.8	0.57

Table 14: Eastfield Flint. Colony abundance of foot rot pathogens *Fusarium solani* and *Didymella pinodella*, plus mean *Aphanomyces euteiches* score at vining pea drilling.

Treatment	Pre cover crop			Pre vining pea drilling		
	Fusarium	*Didymella*	*Aphanomyces*	*Fusarium*	*Didymella*	*Aphanomyces*
Control	0.3	0.7	n/a	4.3	0	0.04
Oat + phacelia	0.5	1.7	n/a	1.3	0.3	0
Oat + mustard	0.7	0.8	n/a	3.8	0.7	0.17

Table 15: Vicarage Railway. Colony abundance of foot rot pathogens *Fusarium solani* and *Didymella pinodella*, plus mean *Aphanomyces euteiches* score at vining pea drilling.

Treatment	Pre cover crop			Pre vining pea drilling		
	Fusarium	*Didymella*	*Aphanomyces*	*Fusarium*	*Didymella*	*Aphanomyces*
Control	11.5	15	n/a	0.17	6.2	0.38
Oat + phacelia	15	10	n/a	0.7	4.7	1.6
Oat + vetch	17.5	10.3	n/a	0.3	4	0.85

Table 16: Russells. Colony abundance of foot rot pathogens *Fusarium solani* and *Didymella pinodella*, plus mean *Aphanomyces euteiches* score at vining pea drilling.

Treatment	Pre cover crop			Pre vining pea drilling		
	Fusarium	*Didymella*	*Aphanomyces*	*Fusarium*	*Didymella*	*Aphanomyces*
Control	0.5	65.3	n/a	1.2	10.8	0
Oat + phacelia	1.5	31.2	n/a	1	9.2	0.1
Oat + vetch	0.2	60.5	n/a	0.7	14	0

Table 17: Molescroft 6. Mean nutrient availability (mg/kg), pH and soil organic matter %.

Treatment	Pre cover crop						Pre vining pea drilling					
	P	K	Mg	Ca	pH	OM%	P	K	Mg	Ca	pH	OM%
Control	41	239	75	1726	5.9	3.5	22	131	73	1735	6.5	3.2
Oat + phacelia	51	240	68	1704	5.9	3.7	21	117	60	1586	6.3	3.3
Oat + mustard	44	298	67	1733	6.0	3.5	22	124	59	1609	6.4	3.1

Table 18: Eastfield Flint. Mean nutrient availability (mg/kg), pH and soil organic matter %.

Treatment	Pre cover crop						Pre vining pea drilling					
	P	K	Mg	Ca	pH	OM%	P	K	Mg	Ca	pH	OM%
Control	40	273	176	1825	5.7	4.2	25	126	130	1824	6.2	3.3
Oat + phacelia	42	257	151	1845	5.7	4.2	29	105	118	1511	5.9	3.1
Oat + mustard	45	282	156	1696	5.3	4.2	32	163	134	1585	6.1	3.5

Table 19: Vicarage Railway. Mean nutrient availability (mg/kg), pH and soil organic matter %.

Treatment	Pre cover crop						Pre vining pea drilling					
	P	K	Mg	Ca	pH	OM%	P	K	Mg	Ca	pH	OM%
Control	31	63	187	1346	6.5	2.1	29	65	149	1248	6.8	1.9
Oat + phacelia	28	68	182	1315	6.5	2.1	30	61	144	1266	6.8	1.8
Oat + vetch	27	55	208	1470	6.8	2.2	23	78	155	1218	6.8	1.9

Table 20: Russells. Mean nutrient availability (mg/kg), pH and soil organic matter %.

Treatment	Pre cover crop						Pre vining pea drilling					
	P	K	Mg	Ca	pH	OM%	P	K	Mg	Ca	pH	OM%
Control	36	303	153	2304	7.8	2.5	41.5	187	118	1935	7.8	2.4
Oat + phacelia	36	324	180	2130	7.7	2.4	36	183	140	1805	7.7	2.4
Oat + vetch	32	270	132	2419	7.9	2.4	34	158	101	1878	7.8	2.2