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Do Cover Crops Give Short Term Benefits for Soil Health?

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Summary

Cover crop use in the UK is increasing with establishment often before spring cereal crops. Therefore trials were implemented to assess two different cover crop mixtures for i) their ability to remediate soil compaction, ii) aid water management and iii) increase earthworm numbers. Two cover crop mixtures; frost sensitive (black oats, oil radish and mustard) and winter hardy (forage rye, oil radish and berseem clover) were compared to control plots. This replicated trial was based at G's Growers on an organo-mineral soil with a cover crop sown between wheat harvested in August 2016 and maize sown in May 2017. The results suggest that in the short term there are small differences in soil physical characteristics. Notably at a depth of 10–20 cm there is a reduction in soil strength as measured by the penetrologger and shear vane following the frost sensitive cover crop mix. Juvenile earthworm population was significantly greater in the control treatment compared to the frost sensitive cover crop treatment. In May 2017 maize was established across all plots.

Key words: Soil health, compaction, cover crops, frost sensitive, winter hardy

Introduction

The use of cover crops in the UK is increasing and may be sown to provide a number of benefits: soil erosion control (Magdoff & Van Es, 2000), increase soil organic matter (Wilson *et al*., 1982) and soil structure amelioration (Chen & Weil, 2010), weed suppression (Dorn *et al*., 2013) and nutrient cycling (Wendling *et al*., 2015). Cover crops are also reported to reduce compaction (Chen & Weil, 2010) especially species with strong tap roots such as radish (*Raphanus sativus* var *longipinnatus*). This trial aimed to answer the following hypotheses: i) do cover crops reduce soil compaction, ii) do cover crops aid in water management and iii) do cover crops enhance earthworm populations? Additional considerations were the ease of management of the cover crops therefore two cover crop mixtures were chosen based on their growth characteristics (sensitivity to frost). Ideally the use of cover crops would remove the need for intensive tillage pre maize establishment and ultimately leave a seedbed and soil profile that is amenable to direct drill maize.

Materials and Methods

The trial field was located in Prickwillow, near Ely where there was no previous history of cover crops grown. Soil type is an organo-mineral top soil of the Adventurers' Chatteris series

(Seale, 1975) with approximately 25% w/w soil organic matter to 40 cm depth. The subsoil is heavy clay.

Following wheat harvest in 2016 and a uniform application of digestate liquor, two different cover crop mixtures were sown directly into wheat stubble on 26th August 2016 using a tine Horsch Sprinter drill. The two cover crop mixtures: 1) Frost sensitive (FS) and 2) Winter hardy (WH) mixture (Table 1) and a control (stubble field) were replicated three times in a 6 ha field. On the 11th May 2017 maize was drilled i) with companion crop simultaneously with maize using the Pöttinger Aerosem 3002 ADD drill and ii) without companion crop; both of which were replicated 3 times perpendicular to the direction of the cover crops. This created a split plot trial design, with 6 treatments replicated 9 times giving a total of 54 plots each measuring approximately 24 m × 10 m (Table 2).

Table 1. *Cover crops established following wheat harvest 2016*

Frost sensitive mixture (25 kg ha^{-1}) £42 ha^{-1}	Winter hardy mixture (30 kg ha^{-1}) £36 ha^{-1}
60% Cadence black oats	60% Protector forage rye
35% Final oil radish	30% Evergreen oil radish
5% Braco white mustard	10% Berseem clover

Table 2. *Treatments implemented and planned within the trial 2016* –2017 [1]

Treatment
Control & No Companion crop
Control & Companion crop
FS cover crop & No companion crop
FS cover crop & Companion crop
WH cover crop & No companion crop
WH cover crop & Companion crop

[1] There were 9 plots per treatment

Cover crop biomass was sampled on the 15th November 2016 and 23rd March 2017 using a 0.5 × 0.5 m quadrat. Soil moisture access tubes were installed on 9th December to a depth of 40 cm. Six soil moisture access tubes were installed randomly in the control and FS treatment plots. Allowing a period of time for the soil moisture access tubes to settle soil moisture measurements were taken weekly using an PR2 profile probe (Delta T) from the 5th January 2017 until the 4th May 2017. Herbicide was applied to the trial field on the 7th April 2017 to terminate the cover crops and volunteer wheat growth. For the following measurements 5 of the 9 plots were sampled. On the 12th April 2017 three shear vane (P ILCON) readings at 4.5-7.0 cm and 14.5-17.0 cm were taken and median averaged per plot. Soil penetrologger (Eijkelkamp) readings to 50 cm were taken on the 28th April 2017 with five readings from random locations taken per plot. These were median averaged at 1cm intervals to give a representative value for each plot per cm of the soil profile. The Visual Evaluation of Soil Structure (VESS) (Guimares et al., 2011) and earthworms counted in 6 minutes from VESS assessment material were conducted once per plot between the 2nd–5th of May.

Due to the exceptionally dry weather in spring with (only 9 mm of rain falling in the 7 weeks prior to sampling), the soil was wetted up so that VESS and earthworms counts could be conducted on moist soil. A 22 cm diameter single ring was filled twice (equivalent of 140 mm of rain) and allowed to drain into the soil before the immediate assessments of VESS and earthworms. Sampling could not be postponed due to the practicalities of fitting in with field operations required for maize establishment planned for the 6th May.

Results

Cover Crop establishment and Growth

Although not significant, $t(4) = -0.658$, $p > 0.05$, a greater aboveground biomass was produced by the FS cover crop in October 2016 (Table 3). This is likely due to the reliable establishment of the FS mixture with 121 plants per m^2 as compared to only 64 plants per m^2 for the WH mixture. In March 2017 there was a considerable biomass of wheat volunteers in the control treatment as compared to the FS and WH cover crop treatments.

Table 3. *Above ground fresh biomass (t ha^{-1}) of the treatments (including volunteer wheat in the spring). Standard error is shown in brackets. n= 3 per treatment.*

Date	Control	Winter Hardy		Frost Sensitive	
	Wheat Volunteers	Cover Crop	Wheat Volunteers	Cover Crop	Wheat Volunteers
Oct-16	Not sampled	12.8 (±2.9)	Not sampled	15.6 (±3.1)	Not sampled
Mar-17	9.1 (±3.5)	3.5 (±1.3)	2.9 (±1.1)	-	2.1 (±1.1)

Physical Soil Quality Indicators

The VESS score indicated that there was a slight improvement in soil structural condition following cover crops. Both cover crop mixtures scored *sq* 3 whilst the control scored *sq* 3.5. Shear vane values (Table 4) show that there is no significant difference between the treatments at shallow and deep topsoil depths though the FS cover crop reduced shear vane force at both depths when compared to the control. Penetrative resistance (*Figure 1*) is reduced at the 11–20 cm depth following a FS cover crop, which corresponds to deep topsoil depth of the shear vane results. Soil moisture data (*Figure 2*), taken on the same day (28th April 2017) as the penetrative resistance values show that at depths of 20 and 30 cm a significantly greater soil moisture content is found following the FS cover crops.

Table 4: *Shear vane readings (kPa) of the treatments taken on the 12 April 2017. Standard error is shown in brackets (n = 10 per treatment)*

Depth	Control	Winter Hardy	Frost Sensitive	*p* value
4.5–7.0 cm	103 (±7)	89 (±5)	90 (±8)	0.266
14.5–17.0 cm	95 (±6)	95 (±7)	85 (±8)	0.549

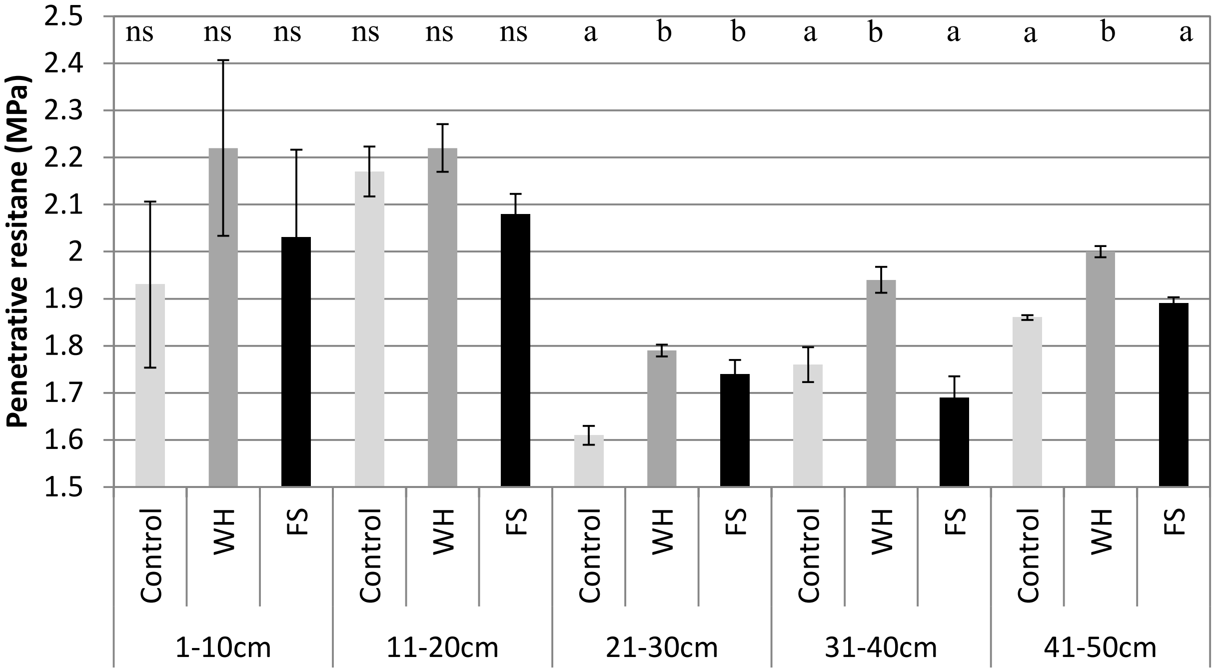

Figure 1: Penetrative resistance values of each treatment averaged over 10 cm depths. Standard error is denoted by the error bars (n = 10 per treatment).Within each 10 cm depth interval significant differences (ANOVA p= <0.05) are denoted by different lower case letters, ns = not significant.

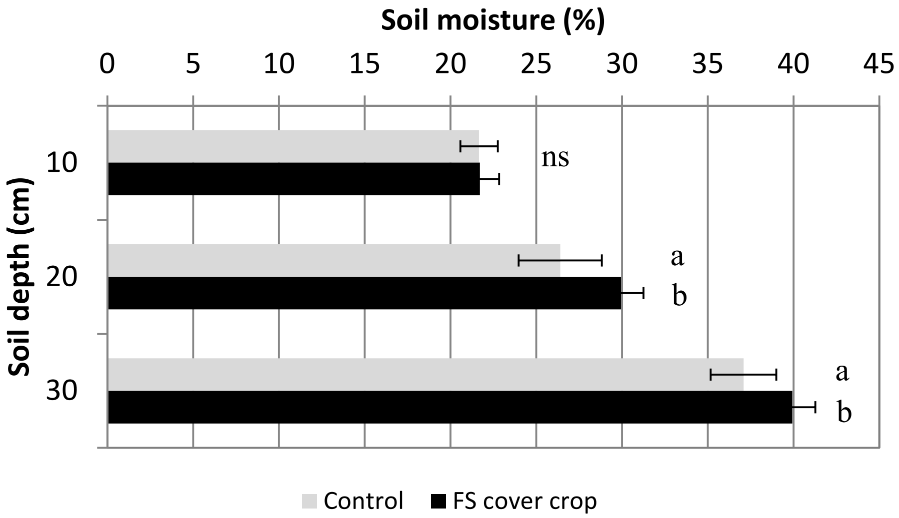

Figure 2: Average soil moisture taken on the 28th April 2017. Within each depth significant differences (t-test; p <0.05) are denoted by different lower case letters, ns = not significant.

Biological soil quality indicators

Table 5 shows that a significantly greater number of juvenile earthworms were found in the control treatment as compared to the FS treatment, however the number of mature earthworms across all treatments was similar with two earthworms for control and WH treatments and three for the FS treatment (Table 5).

Table 5. *Average number of mature and juvenile earthworms counted. Different lower case letters indicate treatments significantly different from each other (ANOVA,* p=<*0.05). Standard error is shown in brackets (n = 10 per treatment)*

Earthworms	Control	Winter Hardy	Frost sensitive	*P value*
Juvenile	10^{a} (±2)	7^{ab} (±1)	5^{b} (±2)	0.044
Mature	2 (±1)	2 (±1)	3 (±1)	0.625

Discussion

The high biomass of the FS cover crop (Table 3) can be attributed to fast and reliable establishment of all the species present in the mixture. The lower biomass for the WH cover crop mix was sensitive to dry establishment conditions. The rye in the WH mixture struggled to germinate due to a larger seed size requiring a greater soil moisture content to initiate seed imbibition. At the time of establishment the soil moisture was 28% vol. The berseem clover in the WH mix also failed to establish well possibly due to i) small seed was sown too deep and/or ii) observed predation by cabbage stem flea beetle. The WH mix did produce a strong stand of radish plants with sporadic rye establishment. Sampling in March 2017 assessed the wheat volunteer growth in addition to any over winter surviving cover crop biomass. There was no living biomass remaining of the FS cover crop, as would be expected from species selected specifically for over winter kill. There is a positive relationship between cover crop biomass and weed suppression (Finney *et al*., 2016) an effect that was measured in this trial if the volunteer wheat biomass is considered as a weed (Table 3). However, volunteer wheat can potentially be viewed as a low cost 'cover crop' itself as it could be expected to perform similar soil and ecosystem services as other cereal cover crops.

Small but notable benefits to the soil structure were measured in the short period of time the cover crop was established; 4 months for FS and 7 months for the WH cover crop. The qualitative VESS assessment following cover crops indicated a 0.5 improvement in soil structural condition over the control which is similar to the findings of Stobart *et al*. (2015) comparing cover crops to a stubble field.

Quantifying the changes to the soil structure using a shear vane and penetrologger showed slight improvements following cover crops at certain depths. Focusing on the 11–20 cm depth of the soil profile there is a measured but not significant (p=0.142) reduction in soil penetrative resistance (*Figure 1*) following FS cover crops which is supported by the deeper (14.5–17.0 cm) shear vane assessment (Table 4). The reduction in soil strength at this depth by the FS cover crops may be attributed to root characteristics of radish in combination with mustard; a species that was absent in the WH cover crop mixture. The compaction alleviating ability of radish is highlighted by Chen & Weil (2010) whilst mustard, when compared to rye is reported to have a greater root length density in the topsoil effecting soil porosity (Scholl *et al*., 2014). The effect of the mustard may be evidenced by the reduction in shear vane and penetrative resistance at 11–20 cm depth, a depth that corresponds to the greatest diameters of mustard roots (Liu *et al*., 2011), when compared to the control and WH mixture.

The lower penetrative resistance recorded in the control plots (*Figure 1*) especially at 0-10cm may be explained by the absence of a drilling machine with tire packer roller, which was used in the other plots to establish the cover crops. In addition, the fibrous roots of wheat volunteers can be expected to help create and maintain soil pores providing a soil tilth and general improvement to the soil structure. These living roots of the wheat volunteers which remained until the trial desiccation may also help to explain the lower soil moisture (*Figure 2*) and greater earthworm population (Table 5) of the control treatment. Additionally, due to soil shrinkage large cracks in the soil profile to depth were observed which may have influenced the penetrologger readings – though care was taken when sampling to avoid these cracks in all plots.

Significantly greater soil moisture was measured in the FS cover crop treatment at 20 and 30 cm depth (*Figure 2*) which may result from the cessation of transpiration from the plant species contained within the mixture which were frost killed by the end of the January 2017. Therefore incident rainfall was not used by the crop but retained in the highly organic soils. Low solar radiation and temperatures at this time of the year would also limit evaporation. On the contrary the control plots had live plants through-out the cover crop trial period (wheat volunteers were present until the termination of the cover crops on the 7th April 2017). The wheat volunteers would have drawn on water reserves deeper in the soil profile (Jackson *et al*., 2000) given the early Spring period was dry and only 11 mm of rain fell in the 4 weeks prior to cover crop termination. The live plants depleted the soil moisture content compared to the decayed cover crops where greater soil moisture content was present. Similar values of soil moisture at 10 cm depth for the FS and control treatment may be linked to the prevention of water evaporation from the soil surface. All treatments had surface stubble and chopped straw residue, the FS cover crop treatments had additional lignified mustard debris and the control treatments were covered by the remaining wheat volunteer residue.

Earthworm population (Table 5) may be explained by the cover crop species used and present in the treatments. The FS, WH and control treatments contained 2.1, 6.4 and 9.1 t ha^{-1} of above ground fresh biomass in March, 2017 respectively. Earthworms have a feeding preference for grasses over brassicas and oat species (Valckx *et al*., 2011) and therefore it can be expected that earthworm abundance is greater in the WH mixture which contained cereal rye and the control plots which contained substantial wheat volunteer growth. Furthermore Stroud *et al.* (2017) suggest that allelochemicals exuded by brassica species, of which the cover crop mixtures contained at least 30%, may result in avoidance behaviour of earthworms. This earthworm behaviour may explain the higher earthworm numbers in control plots with volunteer wheat growth as compared to the cover crop areas.

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