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Soil Water and Available Nitrogen during Cover Crop Growth

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Summary

A field trial in Ely, Cambridgeshire was set up to investigate the soil moisture and nitrogen dynamics of a frost sensitive cover crop compared to a control of an over winter stubble. Cover crops were established in late summer following wheat harvest and a summer tillage operation. Soil and aboveground biomass sampling commenced in September 2017 was continued at 2–3 week intervals until May 2018. The results highlight the fast growth of cover crops which rapidly reduced the total oxides of nitrogen present in the soil by late autumn. During winter a gradual increase in total oxides of nitrogen is measured as the cover crop residue is mineralized. The use of the frost sensitive cover crop permitted ease of management and termination, though it is not completely reliable and termination times can vary from year to year.

Key words: Cover crops, Soil moisture, Nitrogen

Introduction

The use of over winter cover crops is gaining interest in the UK and has been supported by the Basic Payment Scheme (BPS) as an ecological focus area (EFA). The most recent available data shows that the total area of catch crops and green cover increased by 45% under the Basic Payment Scheme between 2014/15–2015/16 (DEFRA, 2017). Cover crops can be utilised to improve soil structure (Stobart *et al*., 2015), soil erosion control (Panagos *et al*., 2015), aid weed suppression (Brust *et al*., 2014) and soil moisture management (Dabney *et al*., 2001). Cover crops also perform an important ecosystem service by reducing nitrate leaching by 20–90% when compared to a bare soil (Justes *et al*., 2012) .

Following cover crop growth and decomposition, the nitrogen contained with the cover crop biomass can be mineralized for the following cash crop thus having a green manure effect (Thorup-kristensen *et al*., 2003). The nitrogen dynamics of the cover crop – cash crop system are affected by numerous variables; C:N - linked to cover crop species (Couëdel *et al*., 2018) and maturity, termination date, use of tillage (Wyland *et al*., 1996), weather and soil type. Cover crop growth can also reduce soil moisture and may be used to dry out heavy land (Shah *et al*., 2015).

The research conducted compared the concentration of available of nitrogen and the soil moisture in a high organic matter soil between cover crops and an over wintered stubble control. This will allow a greater understanding of the nitrogen and water dynamics of a system using frost sensitive cover crops that will self-senesce over winter.

Materials and Methods

The trial field is located at Littleport, near Ely on an organo-mineral top soil of the Adventurers' series which is approximately 28% w/w soil organic matter. Following wheat harvest in late summer 2017 the trial area was cultivated using a progressive cultivator (Keeble). A triplicate of cover crop plots (24m × 100m) were established alternating with equally sized control plots. The cover crop mixture of 60% black oats (Cadence), 35% oil radish (Final) and 5% white mustard (Braco) were established on 24 August 2017 and rolled. The control plots were cultivated and were initially bare ground but subsequently grew with wheat volunteers. The field trial was terminated on 21 April 2018 with glyphosate at 4L/Ha. Forage maize (P8200) was then zero tilled into the desiccated cover crop on 20 May 2018.
Three soil samples at 0–15cm depth per plot were randomly collected and mixed before the determination of total oxides of nitrogen (TON) and gravimetric soil water content. TON was determined following a standard method and extraction with 2mol KCl. Above ground biomass was cut from a 0.25m^2 quadrat, dried and weighed. Soil and above ground biomass samples were taken at 2–3 week intervals between September 2017 and May 2018. For brevity rainfall data is not shown but was recorded by an on farm weather station to evaluate any potential influence on soil moisture and nitrogen. Results between the treatments were analysed using the students T-test.

Results

Figure 1 highlights the above ground biomass of the frost sensitive cover crop and the control (naturally regenerated wheat volunteers). Peak cover crop biomass is achieved in late autumn and then recedes as some of the frost sensitive plants begin to senesce.

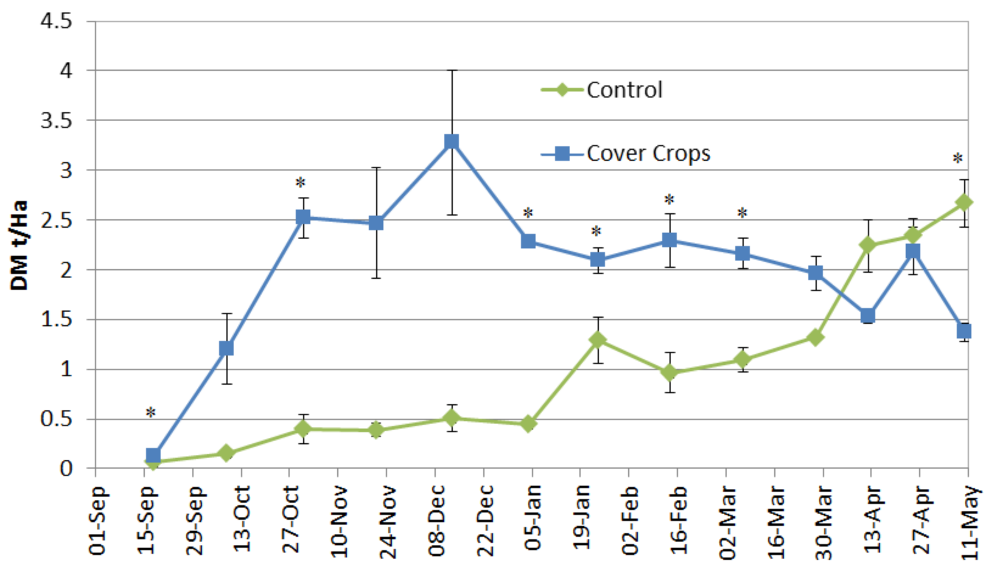

Figure 1: Above ground dry biomass sampled between September 2017 and May 2018. Significant difference (*t*-test; $P<0.05$) between treatments on the same date is denoted by an *. n = 3 per treatment at each sample point. Error bars = standard error.
Note: above ground biomass samples were not collected on the 4 September 2017 as the cover crop had only just emerged.

A rapid depletion of TON in the soil is observed in the cover crop treatment (Figure 2) in autumn before a gradual increase in TON availability from mid-winter onwards. A large increase in TON is measured in the soil following termination for both the control and cover crop treatment.

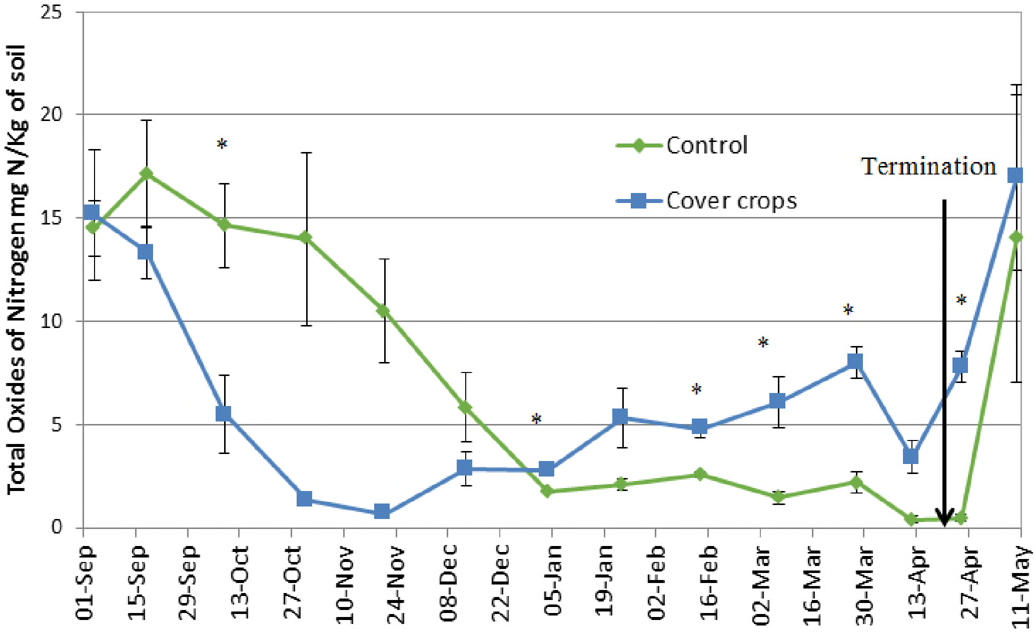

Figure 2 Total oxides of nitrogen as sampled at 0–15cm between September 2017 and May 2018. Significant difference (t-test; $P<0.05$) between treatments on the same date is denoted by an *. n = 3 per treatment at each sample point. Error bars = standard error.

During the growth of the cover crop and into late-winter Figure 3 shows that cover crops reduce, although not significantly the gravimetric soil moisture content. At the last sampling point the difference between the cover crop treatment and the control is greatest, but again not significantly different possibly due to the large variability in the control treatment.

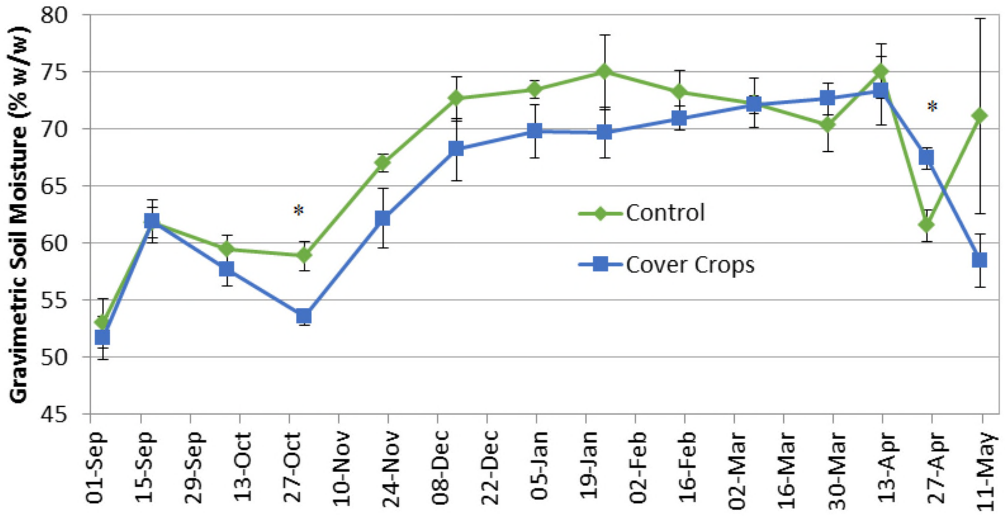

Figure 3: Gravimetric soil moisture sampled at 0-15cm between September 2017 and May 2018. Significant difference (*t*-test; $P<0.05$) between treatments on the same date is denoted by an *. n = 3 per treatment at each sample point. Error bars = standard error.

Discussion

Figure 1 highlights the rapid growth of the cover crops over the autumn months which is expected given that fast growing cover crop species (black oats, oilseed radish and white mustard) were selected for the trial. The slow but increasing biomass of the control indicates the regrowth of wheat volunteers into the control plots. As expected the biomass of the cover crop treatment decreases after mid-December as the species selected were all frost sensitive. This frost sensitive trait of the cover crops is desirable from a management point of view as a smaller cover crop canopy at termination would prevent the shading of weeds and volunteers from herbicide. During January, Figure 1 shows that the cover crop aboveground biomass begins to plateau around 2 t ha^{-1} which is explained by the mustard species becoming lignified but also it was observed that a small but noticeable number of oilseed radish plants were not terminated by the frost. This is unexpected as the oilseed radish variety selected had been used in the previous season where it was effectively controlled by the frost. As the cover crop biomass gradually decreases for the remainder of the sampling period, the wheat volunteers in both the cover crop treatment and control continue to grow.

TON present at the start of the field trial is similar in both treatments. Though as the autumn progresses, Figure 2 highlights the large differences in TON present in the soil between the cover crop treatment and the control. The cover crop treatment has rapidly reduced TON present in the soil compared to the control treatment, which is an over winter stubble with wheat volunteers. As the wheat volunteers emerge in the control a steady reduction in TON is measured and achieves a similar minimum TON as the cover crop treatments. Research by Baggs *et al.* (2000) also reports that naturally regenerated vegetation (volunteers) are as effective as cover crops at retaining N over winter . However the reduction of soil TON in the cover crop treatment is a achieved at a much greater rate than the control containing volunteers – the rate of nitrate reduction was not reported in the study undertaken by Baggs *et al.* (2000).The differences in rate of TON depletion of the soil are inversely related to the aboveground biomass (Figure 1). As the cover crops senesce and their aboveground biomass decomposes a gradual increase in TON is observed for the remainder of winter and early spring, with the exception been measured on the 12 April 2018. The reduction in TON measured on this date in both the cover crop treatment and the control, may be explained by high soil moisture recorded on the same date (Figure 3). Weier (1993) reports that denitrification can result from high soil moisture contents as oxygen is reduced to the soil microorganisms. Secondly, the rainfall prior to sampling on the 12 April may have led to the leaching of mobile available nitrogen through the soil profile. Additionally in the control plots there is an increase in above ground biomass to the 12 April 2018. After 19 days following termination with herbicide there is rapid increase in TON from both the cover crop treatment and the control plot when measured on the final sampling date 10 May 2018. Presumably this is due to the nitrogen mineralised from the plant biomass in both the cover crop treatment and control.

Following both the control and cover crop treatment, similar levels of TON are returned to the soil in May when compared to the start of the field trial in September 2017. The return of this nitrogen may be manipulated depending on cover crop species selection. Cover crop species may be differentiated by their ability to tolerate cold temperatures and may begin to senesce in late winter/ early spring essentially terminating the cover crop and starting the process of decomposition. The timing and effectiveness of using cold temperatures to terminate a cover crop is variable and not always reliable. Vincent-Caboud *et al*. (2017) highlights that cover crop regrowth and/ or incomplete termination can be limitation of relying solely on frost killed cover crops in an organic farming system, especially under no-till circumstances. The benefit of using a frost sensitive cover crop may i) allow reduced application of herbicide (Kabir & Koide, 2002) ii) prevent trafficking fields earlier in the year when they are likely to be at field capacity for cover crop termination purposes iii) allow some nitrogen to become available earlier in the season for initial cash crop growth. With the cover crop dying back earlier in the growing season, there is a risk that nitrate leaching would still be a problem. This risk may be reduced by allowing wheat volunteers to continue growing in the cover crop (as permitted in this trial) or use of a winter hardy cover crop species.

From late autumn until the end of winter soil moisture in the cover crop treatment was reduced, although not significantly at most sampling time points, when compared to the control plot. During autumn average temperatures remained between 10–15°C and given the exposed and windy location of the trial it can be expect these factors helped drive transpiration from the cover crops, thus increasing water uptake from the soil. Furthermore, the use of cover crop following cultivations can improve infiltration rate when compared to no cover crops (Nunes *et al*., 2018) thus moving water through the soil profile and below the 15 cm depth sampled. Soil moisture in the cover crop treatment declines rapidly at the end of April and early May, this may be attributed to the greater evaporation from the exposed soil surface as only lignified mustard stems and some wheat volunteers remain, compared to the larger wheat volunteer population in the control.

In conclusion, the use of frost sensitive cover crops facilitated the earlier return of TON to the soils, following the majority of the cover crop biomass senescing in the cold temperatures. The fast growth rate of the cover crops quickly and significantly reduced the TON present in the soil in autumn and this was maintained until early January. By reducing TON present in the soil over late autumn and early winter the risk of leaching is reduced for part of the winter period. However, from January onwards there is a trade-off; the nitrogen captured by the cover crops begins to return to soils thus benefitting early crop growth and there may be reduced reliance on chemical control of the cover crop. But it must also be acknowledged that nitrogen is returning to the soils at a time when there is still a risk of leaching in late winter and early spring before the next crop is planted.

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