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Highlights

- Litter quality affected decomposition rates: grass decomposed faster than straw residues.
- Mixture of litter did not facilitate the decomposition process.
- Compacted soil slowed down decomposition.
- Presence of the soil macrobiota was a required factor to litter decomposition.
- Headland and litter management could minimise effects of wheeling.

Soil compaction upon litter decomposition in an arable field and implications for management of crop residues and headlands

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Abstract

Soil compaction is a major threat to agricultural soils. Heavy machinery is responsible for damaging soil chemical, physical and biological properties. Among these, organic matter decomposition, predominantly mediated by the soil biota, is a necessary process since it underpins nutrient cycling and provision of plant nutrients. Hence understanding factors which impact the functionality of the biota is necessary to improve agricultural practices. In the present study, to understand the effects of compaction on the soil system, we determined the effects of soil bulk density and soil penetration resistance, on the decomposition rates of litter in three distinct field zones: the margin, the tramlines in the crop:margin interface, and the crop. Three litters of different quality (ryegrass, straw residues and mixed litter) were buried for 1, 2, 4 and 6 months in litter bags comprising two different mesh sizes (<0.2 and >2 mm). Bulk density and soil resistance were greater in the compacted tramline than in the margin or the crop. The greatest mass loss of buried organic matter occurred in the grass margin and the lowest in the tramline. Differences between treatments increased with burial time. No significant difference of mass loss between the two mesh sizes was detected before the fourth month, implying that microbial activities were the main processes involved in the early stages of decomposition. Decomposition in the tramline was clearly affected by the degradation of soil structure and limitation of water and nutrient supplies due to heavy compaction. This study shows that poor soil conditions at the edge of arable fields affect major soil processes such as decomposition. It also reveals that there is potential to mitigate these effects by managing the headland, the crop residues and the machinery traffic in the field.

Key words: Decomposition; Compaction; Field margins; Environmental Stewardship Scheme; Soil quality

1 Introduction

Land-use is a primary determinant in driving soil processes (Holland et al., 2014; Postma-Blaauw et al., 2010; Sousa et al., 2004). It has been shown that vegetation cover modifies soil biodiversity (Crotty et al., 2015) and that established grasslands have improved soil function compared to arable fields (Crotty et al., 2014). In 1994, the United Kingdom government published a first Biodiversity Action Plan, establishing arable field margins as priority habitat (Department for Environment, Food & Rural Affairs, 2008) and was supported by a new environmental stewardship scheme for farmers to increase and support biodiversity in the agricultural landscape in 2014 (Department for Environment, Food & Rural Affairs, 2014). This included compensation for the setting up of grass margins around arable fields with the primary aim of encouraging aboveground biodiversity (Department for Environment, Food & Rural Affairs, 2014; Meek et al., 2002). Evidence suggest such margins can provide imortance ecosystem services including pollination and pest management (Lu et al., 2014). However, the implications for the belowground biodiversity have been less considered even though it has been established that the soil biota can be adversely affected by field management (Sechi et al., 2017). This may also have impacts on the functions which are supported by a diverse soil community which are less well understood.

The soil fauna play a pivotal role in many of the soil processes that, in turn, deliver ecosystem services (Bardgett and van der Putten, 2014; Wall et al., 2015). Among these services, decomposition, a biologically driven process, enables nutrient cycling and primary production (Coleman et al., 2004; Hättenschwiler et al., 2005). During the process, the interaction of the different classes of organisms (microbiome and macrobiome) is necessary to undertake the decomposition of primary organic matter (Bradford et al., 2002). Although the role of the microbiome (bacteria and fungi) is reasonably well understood, Setälä et al. (1996) demonstrated the benefits of a more complex community for improved nutrient cycling. It has also been showed that the macrofauna modify the process of decomposition by its action on the microbiota (Hättenschwiler et al., 2005; Joly et al., 2015). In relation to the importance of the macrobiome to modify dynamics of organic matter degradation (Wolters, 2000), activity of this compartment (meso- and macrofauna) is a required step to achieve the decomposition of litter and should be regarded as a potential tool for crop management and nutrient cycling in agricultural contexts.

In agricultural soils, factors affecting litter decomposition are essentially determined by the human activity. The amount and quality of organic matter returned to the system (Fierer et al., 2005; Gergócs and Hufnagel, 2016; Milcu and Manning, 2011) together with the presence of the biotic communities (Murray et al. 2009) are primary factors regulating decomposition rates. Thiele-Bruhn et al. (2012) noted the capability of agricultural practice to control the quality of primary organic matter entering soil systems and therefore its capability to modify the soil community and its activity. To understand the effects of litter quality, Johnson et al. (2007) tested the decomposition of five crops of varying chemical composition and three different organs of each plant, and showed that crop and plant parts affected decomposition rates and C-pools at the soil surface. This implies some potential for agricultural soil management via crop residues.

The architecture of the habitat and the associated propensity for belowground oxygen supply (modulated by the soil pore networks) are two more factors affecting decomposition rates. The deterioration of the soil structure (principally reduction in porosity and connectivity of pores) via external factors has been shown to affect microbial mineralisation (Beylich et al., 2010; De Neve and Hofman, 2000), as well as the habitat and food resources that support the soil fauna (Beylich et al., 2010; Althoff et al., 2009; Larsen et al., 2004). In agricultural contexts, soil structure is exposed to deterioration by heavy machinery traffic and many arable soils in the UK are sensitive to increased compaction, causing a decline in crop yield (Hamza and Anderson, 2005). Within the scope of environmental schemes and to prevent damages to improved biodiversity habitats, such as field margins, the policy requires that farmers do not manoeuvre on the field margins, obligating them to turn at the edges of the crop and thus creating a compacted area between the main crop and the margin. A better understanding of the effects of compaction on organic matter decomposition and biological activity in soils is another step to improve soil management in agricultural systems and mitigate the impacts of compaction.

In this study, we determined organic matter decomposition rates of plant material (wheat straw and ryegrass residues) in contrasting zones of an arable field that had been subjected to different pressures. We aimed to identify effects of machinery wheeling and agricultural management on decomposition and understand how the response changes with respect to litter type and soil faunal exclusion. We hypothesised: (i) decomposition rate would be lowest in more compacted soils; (ii) ryegrass litter, because of its lower C:N ratio, would decompose faster than straw residues; (iii) exclusion of the soil mesofauna would reduce the decomposition rate.

2 Materials and methods

2.1 Site and soil characteristics

The experiment was carried between October 2016 and April 2017 at The Grange Farm, Northamptonshire, United Kingdom (52° 18' 2.73" N; 0° 45' 52.83" W) in an arable field planted with oilseed rape (*Brassica napus* L.) and which had previously been in winter wheat (*Triticum aestivum* L.). The field was managed using minimum tillage techniques (i.e. no deep ploughing) for 15 years or more. Mineral fertilisation and chemical inputs were applied to the crop following the UK standard scheme management for farmers (Agriculture and Horticulture Development Board, 2017). The crop was planted in a field bordered by a 10-year-old grass margin that had been set up to promote biodiversity in the agricultural landscape (Department for Environment, Food & Rural Affairs, 2008; 2014). The soil was classified as Hanslope series, a typical calcareous pelosol from a clayey chalky drift series with poor drainage capacity and high sensitivity to compaction (Cranfield University, 2017).

The experimental area consisted of split plot design of 18 plots (6 x 6m) distributed within six blocks along the south side of the field. Each block comprised three plots; one in the grass margin, one in the tramlines between the margin and the crop, which were visibly compacted, and one in the actual crop.

2.2 Soil compaction assessment

Soil bulk density (Laryea et al. (1997) was determined from cores (8 cm diameter x 10 cm depth) taken at random from each of the 18 plots at the beginning of the experiment. This sampling method was considered appropriate to our requirements as it has been shown to not significantly affect bulk density measurement (Özgöz et al., 2006; Page-Dumroese et al., 1999). Samples were dried at 105°C for 24h, then plant residues and stones were removed by 2 mm sieving. Soil penetration resistance was recorded on April 1st 2017 with a penetrometer (Solution for Research Ltd, Silsoe, Bedfordshire, UK) fitted with a 9.45 mm diameter (base area 7 x 10-5 m2), 30-degree cone. At every sampling point, 14 different measurements, between 3.7 cm and 51.8 cm depth, were made. Penetrometer resistance was calculated by dividing force at each depth by the cone base area. Ten replicate measurements were randomly taken on each plot. Data were converted from mV to KPa as follows:

$$\text{Force(KPa)} = (\text{Force(mV)} - 57.48) \times 139.9 \times 0.0781 \quad (1)$$

2.3 Organic matter decomposition experiment

Litter bags (6 cm length by 5 cm height) were made using two mesh sizes; one set with a mesh size of >2 mm allowed full access by the soil biota, and one set <0.2 mm which excluded most of the fauna and allowed microbial access only.

Three types of litter of different quality (C:N ratio) were prepared: a low C:N ratio perennial ryegrass (*Lolium perenne* L.), a high C:N ratio wheat straw (*T. aestivum*) and a mixture of both types of litter. Ryegrass and wheat straw were oven dried to constant weight at 105°C. Then, 1.0 g of the litter was added to each of the litter bags (0.5 g of both litter types was added for the mixed litter treatment). Average values of total carbon and total nitrogen of wheat straw and ryegrass were measured from 5 subsamples of each of the initial material using an elemental analyser (N1500, Carlo Erba, Milan, Italy) linked to an isotope ratio mass spectrometer (20/22, Sercon, Crewe, UK). The C:N ratio was calculated from the average values of the two separate litters and estimated for the mixture as follows:

$$CN_{(mix)} = \frac{(m_{(straw)} * CN_{(straw)}) + (m_{(ryegrass)} * CN_{(ryegrass)})}{m_{(total)}} \quad (1)$$

Where, CN is the carbon:nitrogen ratio and m is the amount of dry plant material (grams).

A total of 432 litter bags were buried within each plot on the 1 October 2016 and a sub-set of 108 bags were removed on 1 November 2016, 1 December 2016, 1

February 2017 and 1 April 2017. Hence 18 litter bags of each treatment (2 mesh sizes x 3 litter types x 3 zones), replicated 6 times (block), were exposed in the soil over 1, 2, 4 or 6 months. Litter bags were buried in the top soil at 5 cm depth in each plot and bags of each treatment was completely randomised within the plot. A string and a knot code system were used to identify each treatment. One bag was missing on the first and third collection dates, and 5 bags were missing on the last date.

After removing the litter bags from the ground, the litter was removed from the bags, soil particles were gently washed away from the litter using a 15 μm sieve to retain plant materials. The litter was then dried and weighed as described above. The proportion of litter remaining following each given time period spent in the ground was then calculated.

2.4 Statistical analyses

Impacts of field zone, time and the combined effect of these on bulk density were estimated by a 2-way analysis of variance (ANOVA). An analysis of covariance (ANCOVA) was used to test the effect of field zone (grass margin, tramline and crop) on the soil resistance, controlling for the effects of depth, which co-vary with the field zone effect. Because soil resistances of the “grass margin” and “crop” levels had similar values, the two levels were combined; the ANCOVA therefore tested for the differences between the effects of a compacted area (tramline) and the effects of a non-compacted areas (grass margin and crop) on soil resistance.

A one-way ANOVA was used to test the effect of the litter type (straw residues VS ryegrass) on the initial value of the C:N ratio.

A four-way analysis of variance (ANOVA) of the split-plot design was used to determine effect of the treatments (mesh size, litter type, field zone and time period in the ground), and their interactions, on the quantity of litter remaining at the end of the experiment. We assessed the normal distribution of the residuals by using model checking plots (normal probability and quantile-quantile plots). Because of the destructive sampling of the litter bags, time was not considered as a repeated measurement. To preserve a balanced design and because the number of missing bags was negligible given the total number, the missing values were projected from the average value of the treatment they belonged to. Similarly, the effect of mesh size, litter type and field zone were analysed using a 3-way ANOVA for month 1, 2, 4 and 6 separately. All statistical analyses were done using R software 3.1.2 (http://www.r-project.org/).

3 Results

3.1 Soil compaction

3.1.1 Bulk density

Bulk density was significantly greater in the compacted area of the tramline compared to the grass margin or the crop ($F_{(2,10)}$=13.66, P=0.001; Table 1).

Table 1

3.1.2 Soil resistance

The soil resistance increased linearly with depth in all the three field zones. However, a peak was observed at 7.4 cm in the tramline, whereas, the slope of the resistance in the crop increased below the ploughed layer at 23 cm depth (Figure 1). Soil resistance was significantly highest at all depths in the tramline ($_{F(2,10)}$=30.46, P<0.001), whereas there was no difference in resistance between the crop and the field margin zones ($F_{(1,5)}$=0.16, P=0.706). Overall, the soil resistance was significantly greater in the compacted zone (tramline in the crop-margin interface) than in the uncompacted zone (crop and field margin zones combined) ($F_{(1,11)}$=66.24 P<0.001).

Figure 1

3.2 Litter decomposition

3.2.1 Comparison of the two mesh sizes

In the first two months of the experiment, regardless of the field zone or the litter type, there was no significant difference in decomposition between large and small mesh size bags (for Month 1 and Month 2, $F_{(1,74)}$=0.63, P=0.431 and $F_{(1,75)}$=0.67, P=0.415, respectively). However, from Month 4, there was more litter remaining undecomposed in the small mesh than in the large mesh size bags ($F_{1,74}$=69.27, P<0.001) (Table 2). This effect was persistent from Month 6 ($F_{(1,70)}$=92.73, P<0.001). Overall the combined effect of mesh size on decomposition over time was significant ($F_{(3,350)}$=34.84, P<0.001). The effect of the field zone combined with the mesh size was also significant ($F_{(2,350)}$=3.65, P=0.027), with relatively less litter decomposed in the large compared to the small mesh bags when these were buried in the tramline or the crop rather than in the grass margin (Table 2).

Table 2

3.2.2 Effects of crop litter quality

The initial C:N ratio of the three litter types was significantly different ($F_{(1,8)}$=18961, P<0.001). The ryegrass had the smallest value with a mean of 17.5 (s.e. 0.19) and the wheat straw the greatest at 84.2 (s.e. 0.45). The C:N ratio of the mixed litter was calculated from the initial values of both straw and ryegrass litter and was on average 50.9.

Litter type significantly affected the proportion of plant material remaining in the bags at the end of the experiment ($F_{(2,350)}$=385.94, P<0.001): 72.6 ± 7.3 % of the straw remained after 6 months, while 47.1 ± 8.1 % of the ryegrass was left. Mixed litter had an intermediate decomposition rate, with 60.4 ± 8.0 % of material remaining. There was a significant interaction of the combined effects of litter type and mesh size ($F_{(2,350)}$=22.43, P<0.001), with more ryegrass decomposed in the large litter bags than straw residues or mixed litter in small and large mesh size bags (Figure 3). Even though the difference in litter remaining between the two mesh sizes at Months 1 and 2 was not significant, mass loss of ryegrass in the large mesh size litter bags was greater than the loss in other treatments ($F_{(2,74)}$=3.08, P=0.052 and $F_{(1,75)}$=2.94, P=0.059 for Month 1 and Month 2, respectively; Figure 3).

3.2.3 Effect of the field zone on decomposition

The location of the litter bags in the field (zone) significantly affected the decomposition rate of all litter types within bags of the two different mesh sizes ($F_{(2,10)}$=33.99,P<0.001). With a mean of 64.8 ± 7.8 % of litter remaining, mass loss was lowest in bags placed in the tramline and similar decomposition rates were observed in bags buried in the grass margin and the crop (on average 55.0% and 60.2% of litter remaining, respectively).

4 Discussion

We hypothesised that in the field, litter decomposition at the interface between the crop and the margin would be reduced in comparison to the grass margin. This particular area was distinguished by a degraded soil conditions: trafficking and limited quantity of inputs would deteriorate pore networks occupied by the soil fauna and reduce food resources for them. In the current study, we used bulk density as a simple surrogate to evaluate the pore space and therefore soil compaction (Buckman and Brady, 1960). Bulk density was greater in the compacted area of the tramlines at the margin:crop interface than in the crop or the grass margin, and was an indicator of poor habitat and conditions for soil life (Beylich et al., 2010; Horn et al., 1995). We assessed compaction of the whole soil profile by taking soil resistance measurements, which is useful to identify variability of the soil structure at depth. Here, soil resistance was greater at all depths in the compacted tramline zone with a peak observed at 7.4 cm which is another indicator of poor soil condition (Duiker, 2002). It might have created a hermetic layer of soil, which would prevent water drainage, increasing the likelihood that water capacity over the winter season would be exceed and where the absence of oxygen would limit the decomposition process (Beylich et al., 2010; Horn et al., 1995; Whalley et al., 1995), and would consequently impact the soil biota (Beylich et al., 2010). The shallow angle of the slope observed in the crop resistance measurements correspond to the ploughed layer at 23 cm. Above this layer, soil resistance in the grass margin and the crop zone behaved differently but reached similar intensities below this interface. Even though the field had been farmed under minimum tillage for the past 15 years, this shows the long-term effect of previous ploughing practices on soil structure and its potential impact on soil biota. Our results showed that decomposition occurs more slowly in the compacted soil of the tramlines at the crop-margin interface regardless of the litter type or the mesh size of the bags used in the experiment.

The two different mesh sizes of litter bags used in the decomposition experiment enabled assessment of the effects of microbial communities (small mesh size) and larger soil fauna (large size) on decomposition since the large mesh size allowed access of the soil fauna and the small mesh size excluded the soil fauna. Before

Month 4, there was no difference in mass loss between litter bags of the two mesh sizes, implying that the initial decomposition (Month 1 and Month 2) was primarily carried out by microbes. This corresponds with the established dynamics of litter decomposition processes, where microbes are first to colonise and mineralise the fresh organic matter, leaving humified organic matter (Wardle and Lavelle, 1997). Over time, the activity of larger invertebrates become important as they break down this recalcitrant pool of organic matter, making it available to mineralisation (Bradford et al., 2002; Schädler and Brandl, 2005). However, in the large mesh size litter bags, decomposition varied between the three different field zones. In the compacted tramline zone, the presence of soil fauna played an important part in the decaying process of all litter types while the role of the fauna in the grass margin tended to be lower. Unlike the mixed litter contained in the large mesh size bags in the tramline or the crop, this particular treatment did not decompose faster than in the small mesh size bags in the grass margin. This might suggest that soil organisms in the grass margin, that would benefit from a ‘priming effect’ from the grass litter (Fontaine et al., 2003), are not adapted to utilise a highly lignified material such as wheat straw, and unlike organisms in the field, hence they do not benefit from a "home field advantage" to decompose poor-quality plant residues (Milcu and Manning, 2011). Alternatively, as straw residues alone decomposed faster in the large mesh size bags, it might be that soil invertebrates in the grass margin do not need to utilise the straw residues as grass may provide enough high quality and easily decomposable food resources that they are already adapted to process.

Litter quality (expressed here as C:N ratio) is well established as a driver of decomposition (Hamza and Anderson, 2005; Wardle and Lavelle, 1997) and accordingly in this study, the decomposition rate was influenced by litter type and its quality; the greater the C:N ratio of the litter, the slower the decomposition. After 6 months in the soil, significantly more litter remained in the bags containing wheat straw than those containing ryegrass. Decomposition of mixed litter varied under the different treatments. The decomposition of mixed litter in the small mesh size bags did not significantly differ from ryegrass. Likewise, decomposition of mixed litter in the small mesh bags in the crop did not differ from decomposition of the straw. Hättenschwiler et al. (2005) showed a similar variable response of decomposition to different litter types and mixtures. In a sophisticated crossed experiment, Redin et al. (2014) demonstrated that the diversity of functional and chemical traits of crop residues mixture (regarding the plants alone) is influencing decomposition rates of the mixture. The study showed that functions of decomposition (C and N mineralisation) were affecting differently by synergistic, antagonistic or additive effects of the residues mixtures and thus depended on the mixture heterogeneity. Because the effect of the mixed litter on decomposition rates was null only in the small mesh size treatment - where only microbial decomposition occurred - it might be evidence for the ‘resource concentration hypothesis’ presented by Pan et al. (2015). This posits that the diversity of plants in a litter mixture decelerates decomposition of litter because decomposers of each species suffer from a reduced availability of their preferred food resource. Because this was not observed in the large mesh size litter bags, it implies the role of larger soil invertebrates regulating and promoting the microbial decomposition (García-Palacios et al., 2013; Schädler and Brandl, 2005).

Our experiment shows that poor soil conditions at the edge of arable fields affect major soil processes such as decomposition. Soil porosity is particularly affected in this area due to heavy machinery traffic, and inputs (fertilizers, crops residues) are less homogenously distributed here than in the middle of the field. The uneven management and the increased disturbance at the edge of the field are probably causal factors of the observed lower crop yields in this area. For instance, Sparkes et al. (1998) recorded 3-19% less yield at the edge than in the middle of cereal fields and Wilcox et al. (2000) reported high variability in yield in the same zone of winter wheat fields. This results in a “sensitive zone” between the margin and the crop where soil biological and chemical dynamics are reduced if not appropriately managed. However, this study also revealed that there is potential to mitigate the effects of compaction in this sensitive zone. We have shown that the quality of organic amendments can partially mitigate the lower decomposition rates in the compacted zone, but to be effective, this process needs to be supported by the adapted soil fauna community, which consist not only of the microbiome (directly involved in organic matter transformation), but also of the macrobiome (which needs structured soil architecture to live in and sufficient food resource to live of). As stated by Baveye et al. (2016), both the characteristics of the habitat and the structure of the soil fauna community living there are of importance to sustain soil ecosystems.

We underlined the important role of soil dwelling invertebrates in the decomposition process. In the current United Kingdom subsidy schemes, farmers are paid to manage crop margins to enhance botanical diversity, thereby supporting farmland birds and pollinators (Dept. for Environment, Food & Rural Affairs, 2014; Hatt et al., 2017; Kovács-Hostyánszki et al., 2017; Mansion-Vaquié et al., 2017). These schemes also tend to benefit belowground diversity, but the resulting compacted zone, created by machine turning in the tramlines of the margin-crop interface (as operations are not allowed on the margins), impairs the ability of soil invertebrates to migrate into the crop. The ban on driving on the margin exacerbates this. One option would be to increase the width of the margin to allow turning on this additional area. Grasslands are more resistant to compaction (Matthews et al., 2010) and we believe that such a system would minimise the “sensitive zone” and allow migration of important soil species into the crop.

This study highlights that the current regulations for the use of grass margins could be modified to optimise the ecosystem services they provide as well as maintaining the financial sustainability of arable farming systems. Future work should investigate, in more detail, the effects of organic inputs to the crop (e.g. quality of the plant residues; manure; sewage). We propose that adapting the rules regarding grass margins could result in a combined benefit for growers and ecosystem services. For instance, extending the field margin over the compacted tramline and allowing farmers to drive and turn in this extra-margin could result in improvement of soil structure, increase of above and belowground biodiversity, enhancement of ecosystem services, and reduction of the costs resulting from farming this non-profitable part of the field, thereby contributing to achieve more sustainable food production systems.

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394

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Figure captions

Figure 1. Profiles of soil resistance (KPa) within three field zones (grass margin, tramline wheeling in the crop-margin interface and, crop) at 14 depth points (3.7 cm to 51.8 cm depth) within a field containing oilseed rape, 2017 cropping season. Points show means (n=60); bars denote standard error.

Figure 2. Percentage of different litter types (perennial ryegrass (*Lolium perenne*), wheat straw *Triticum aestivum*) and a 50:50% mixture of both litters) remaining in litter bags with small (<0.2 mm) and large (>2 mm) mesh sizes after 1, 2 ,4 and 6 months buried in three different zones of a field containing oilseed rape. Month 0 corresponds to the start of the experiment (1st October 2016) and Month 6 to the end of the experiment (1st of April 2017). Zones = a) grass margin; b) tramline in crop-margin interface; c) crop. Points show means (n=18); bars denote standard error.

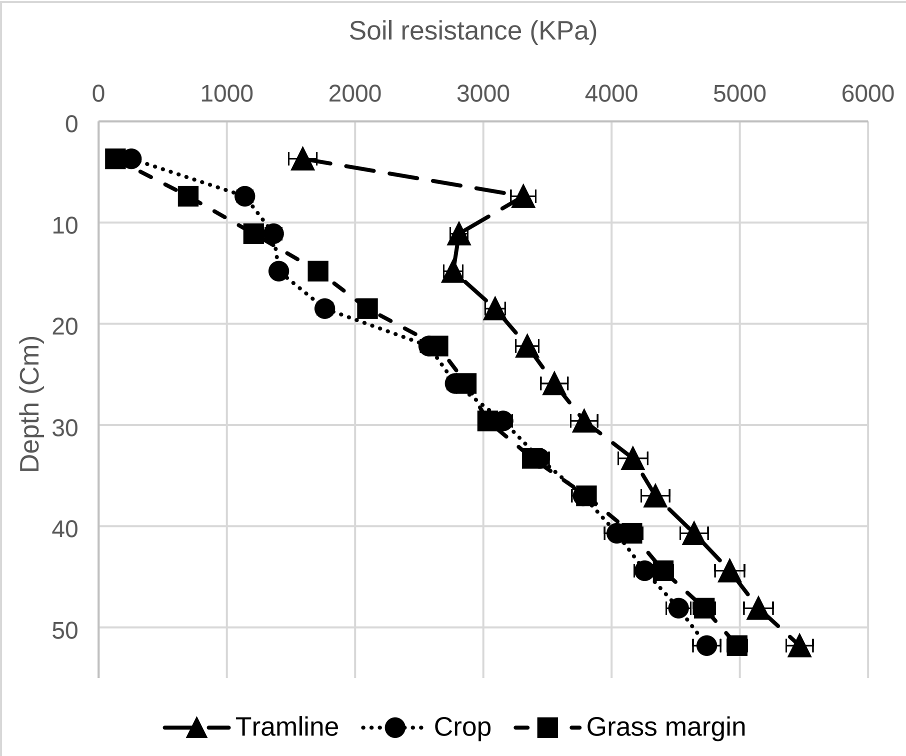
Soil resistance (KPa)
0
1000
2000
3000
4000
5000
6000
0
10
20
30
40
50
Depth (Cm)
Tramline
Crop
Grass margin

Figure 1

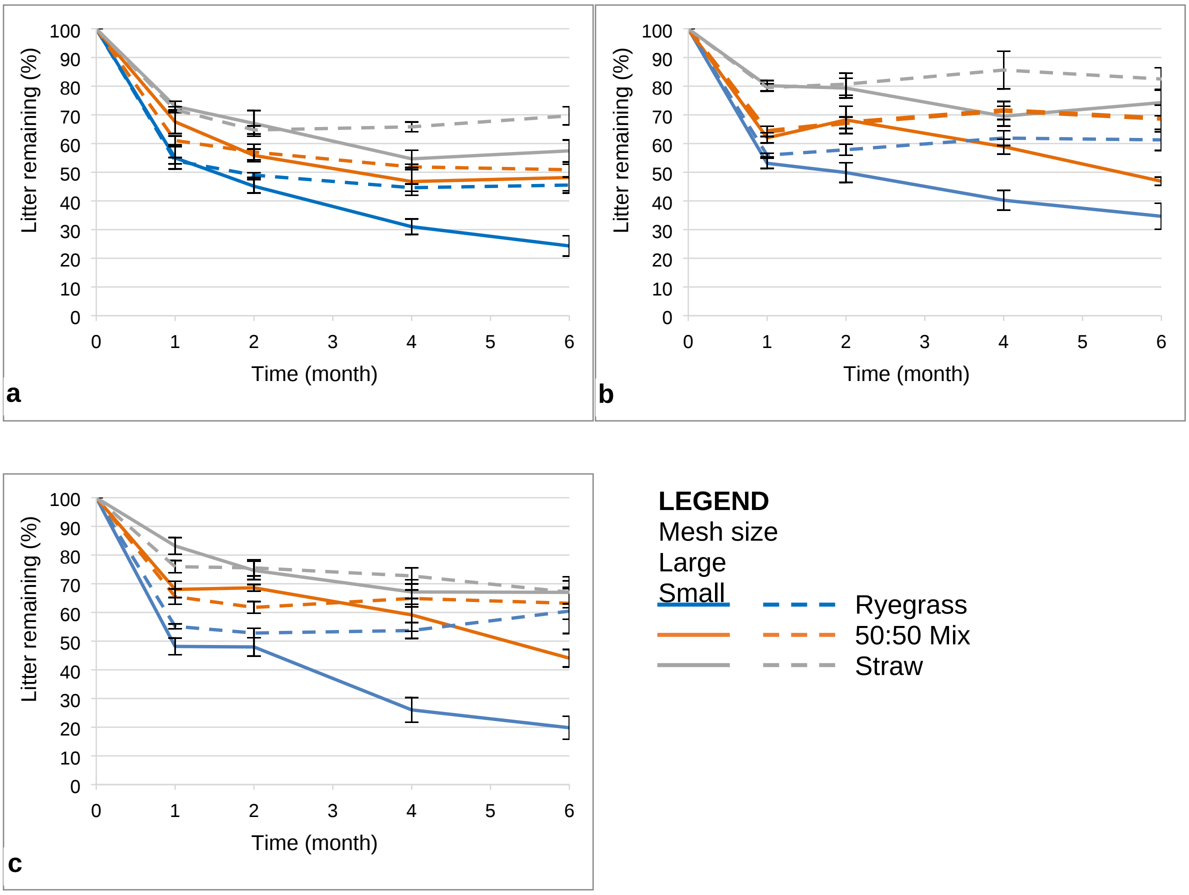
a
b
c
Litter remaining (%)
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
Time (month)
LEGEND
Mesh size
Large
Small
Ryegrass
50:50 Mix
Straw

Figure 2

Table 1 Soil properties measured in three zones of an oilseed rape field (October 2016)

Field zones		Water content (% Volume of Soil-1)	Bulk density (g.cm-3)	Total C (% Volume of Soil-1)	Total N (% Volume of Soil-1)	C:N ratio
Grass margin						
	Mean	17.4	0.89	4.08	0.40	10.2
	± SE	1.02	0.03	0.39	0.02	0.39
Tramline						
	Mean	11.7	1.25	2.32	0.27	8.61
	± SE	0.62	0.03	0.14	0.01	0.46
Crop						
	Mean	14.6	1.02	2.36	0.25	9.58
	± SE	0.25	0.06	0.19	0.02	0.42

Table 2 Effect of litter type (ryegrass, wheat straw or a 50:50 mix) and field zone position (margin, tramline and crop on the mean (± SE) proportion of litter remaining in large (>2 mm) and small (<0.2 mm) mesh-size litter bags removed after 1, 2, 4 or 6 months burial time

		Field margin			**Tramline**			**Crop**		
Mesh size	Time buried	**Ryegrass**	**Mix**	**Straw**	**Ryegrass**	**Mix**	**Straw**	**Ryegrass**	**Mix**	**Straw**
Large										
	Month 1	55.0 (±0.8)	67.6 (±1.0)	73.0 (±1.0)	53.1 (±1.9)	62.0 (±1.6)	80.2 (±1.7)	48.1 (±2.2)	68.0 (±2.4)	83.2 (±1.0)
	Month 2	45.1 (±1.4)	55.9 (±2.8)	67.0 (±2.0)	49.9 (±2.1)	68.2 (±0.7)	79.3 (±1.8)	48.0 (±1.4)	68.6 (±1.3)	74.6 (±2.6)
	Month 4	31.0 (±1.4)	46.8 (±1.5)	54.7 (±2.0)	40.2 (±1.0)	58.9 (±3.3)	69.5 (±2.5)	26.0 (±1.6)	59.2 (±2.8)	67.1 (±1.7)
	Month 6	24.3 (±1.2)	48.2 (±0.8)	57.5 (±2.6)	34.7 (±1.9)	46.9 (±1.8)	74.3 (±2.3)	19.8 (±2.0)	44.1 (±2.7)	67.0 (±2.2)
Small										
	Month 1	54.0 (±0.4)	61.1 (±1.0)	71.8 (±0.8)	56.0 (±0.5)	64.2 (±1.5)	79.5 (±1.2)	55.1 (±0.6)	65.5 (±0.9)	76.0 (±0.6)
	Month 2	49.0 (±1.1)	57.0 (±1.2)	64.7 (±2.2)	57.8 (±1.0)	67.2 (±1.2)	80.7 (±1.6)	52.8 (±0.5)	61.8 (±1.6)	75.5 (±0.8)
	Month 4	44.6 (±1.5)	51.9 (±1.8)	65.8 (±3.8)	61.9 (±1.6)	71.5 (±1.7)	85.6 (±1.6)	53.7 (±0.7)	64.9 (±0.5)	72.7 (±1.0)
	Month 6	45.5 (±2.1)	50.9 (±2.7)	69.7 (±2.3)	61.3 (±4.5)	68.7 (±3.2)	82.5 (±3.1)	60.5 (±1.6)	63.2 (±1.5)	67.1 (±1.8)