Optimising drilling methods in conservation tillage systems for wheat and oilseed rape production

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Abstract

Sustainable agriculture requires methods which are environmentally friendly, socially acceptable and economically competitive. In the UK, conservation tillage practices are receiving increased interest as farmers seek to increase the timeliness of crop establishment whilst reducing machinery and labour costs. This paper presents some initial results from a new project to investigate the effects of five conservation tillage systems on the development and yields of autumn-sown wheat and oilseed rape. The treatments include the current farm practice of a Sumo Trio followed by a Kuhn HR 4002 seed drill, a Claydon Hybrid drill, a Sumo Deep Tillage Seeder (DTS), a Mzuri Pro-Til 3, and a Väderstad Seed Hawk or Väderstad Rapid. The paper describes the study site, the tillage treatments, and some initial treatment effects on selected crop and soil properties. Eight months after tillage, the leaf area index of the wheat and the oilseed rape sown with two of the reduced tillage systems (Sumo DTS and the Claydon Hybrid) was higher than that for the crops grown using the current farm practice. The Mzuri Pro-Til 3 treatment resulted in a greater leaf area index for the wheat than the Sumo DTS and Claydon Hybrid, and a similar leaf area index in the oilseed rape crop. In the initial year of treatments, eight months after tillage, we did not determine significant effects of the tillage treatments on soil bulk density, penetration resistance, or soil moisture content.

Keywords: Soil, crop performance, conservation tillage

1 Introduction

Increased food demand due to a growing global population will have to be met by increased land productivity, whilst maintaining or even improving the quality of air, soil and water resources. Thus, sustainable agriculture requires systems which are environmentally friendly and economically competitive.

Sustainable agriculture relies on farmers maintaining a delicate balance between the economic implications of farming methods and the environmental consequences of using inappropriate practices (Baker & Saxton, 2007). In arable systems, a key decision is the choice of the type, intensity and frequency of the tillage system.

An initial analysis of the literature shows that there are multiple and often conflicting names given to tillage systems. Some categories refer to “no-tillage” or “zero-tillage”, some refer to “reduced tillage” and some use the term “conservation tillage” (Table 1). In the UK, we identified three prin-
Principal forms of soil preparation for arable crops: inversion tillage; reduced- or minimum-tillage; and no- or zero-tillage.

Table 1. Characteristics of inversion tillage, reduced tillage, and no tillage according to selected authors

<table>
<thead>
<tr>
<th>Tillage system</th>
<th>Residue cover (%)</th>
<th>Other characteristics</th>
<th>Conservation tillage</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inversion tillage</strong></td>
<td>&lt;15</td>
<td>Residue incorporation; prevents growth of all plants except the particular crop being raised</td>
<td>No</td>
<td>(Gajri et al., 2002; Köller, 2003)</td>
</tr>
<tr>
<td><strong>Reduced tillage</strong></td>
<td>15-30</td>
<td>Minimum disturbance; modern practice emphasizes the amount of residue retention</td>
<td>Yes</td>
<td>(Köller, 2003; Baker &amp; Saxton, 2007)</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>One or more tillage trips, disturbs all of the soil surface</td>
<td>No</td>
<td>(CTIC, 2002; Lobb et al. 2007)</td>
</tr>
<tr>
<td><strong>No tillage</strong></td>
<td>&gt;30</td>
<td>Eliminate operations compared to conventional tillage; residue cover varies around 30%</td>
<td>Yes</td>
<td>(D’Haene, 2008)</td>
</tr>
<tr>
<td></td>
<td>&lt;5% soil disturbance</td>
<td>No primary or secondary tillage other than the “no till” planter</td>
<td>Yes</td>
<td>(Mahboubi &amp; Lal, 1998)</td>
</tr>
</tbody>
</table>

Inversion or traditional tillage involves inversion of the soil normally with a mouldboard plough as the primary tillage operation followed by secondary tillage.

Reduced or minimum tillage systems include one or more passes of tillage equipment without inverting the soil before planting, and the level of residue cover is typically 15-30% (Table 1). It is possible to distinguish between systems that comprise i) a single pass and ii) those using two passes where the cultivation occurs separately from seed placement.

No-tillage or zero-tillage involves planting seeds without any prior loosening of the soil by cultivation other than very shallow disturbance (< 5 cm) by the drill coulters. Here, typically plant residues remain on 30-100% of the surface (Soane et al., 2012).

The selection of crop establishment method has a direct effect on production and economic efficiency. Lower-cost establishment combined with minimum pass husbandry can provide cost advantages compared to inversion systems (Knight, 2003). The increased area that can be covered by a single piece of equipment can also allow for better “timeliness” of operations. However, the benefits of reduced cultivation methods over inversion systems are inconsistent (Gooding & Davies, 1997).

Köller (2003) argues that reduced tillage systems are being considered because of concerns about the soil’s physical, biological and chemical quality, including the soil organic matter content. Effects of reduced tillage regimes on soil condition and its impact on yield potential and environmental issues have been researched (Baig & Gamache, 2009). However there are few field-based experiments in the UK generating robust evidence which farmers and advisors can use to make appropriate decisions on soil management practice. Tillage techniques can affect soil physical properties such as soil structure, shear strength and bulk density. In turn, these have been shown to affect rates of crop germination, establishment and growth (Fuentes et al. 2009; Aikins & Afuakwa 2012).

In this study, specific emphasis will be given to determining the agronomic, environmental and economic performance of five conservation tillage systems within a crop rotation of autumn sown wheat (*Triticum aestivum*) and oilseed rape (*Brassica napus*). Our hypothesis is that the cultivation and seed placement method will have significant effects on the soil and wheat and oilseed...
rape production. The objectives of the study are: i) to evaluate the agronomic, environmental, and economic performance of different reduced tillage systems, and ii) to identify how the configuration and use of reduced tillage systems can be optimised.

2 Materials and methods

2.1 Study site
The experimental work is located on the Lamport Hall estate (52°35'85"N 0.87°25'63"W) which is situated about 14 km north of Northampton in United Kingdom. The mean annual precipitation is 610 mm and the mean daily minimum and maximum air temperatures are 6°C and 13.4°C respectively (Pitsford School Weather Station 2013). The predominant soil belongs to the Banbury series with a small proportion belonging to the Denchworth series (Cranfield University, 2014). The Banbury series is described as well drained, fine and coarse loam, ferruginous soils over ironstone. Some are deep, fine loams over clayey soils with slowly permeable subsoils and slight seasonal waterlogging. The Denchworth series are seasonally-waterlogged slowly-permeable soils (Cranfield University, 2014).

2.2 Experimental design
The study consists of two fields each of which contains five conservation tillage treatments which have been randomly applied within four replicated blocks. The study started in September 2013 and is planned to continue until at least 2015-16. Autumn-sown wheat and oilseed rape are grown alternately in rotation on the two experimental fields (Fig 1). An “L-shaped” field called “Snagsborough” (6.04 ha) was planted to oilseed rape on 5 September 2013. A square field called “Top Furze” (5.27 ha) was planted to winter wheat between 23 September and 5 October 2013. As each field comprises four blocks of five treatments, there are 20 experimental plots in each field.

2.3 Treatments
The five tillage treatments comprise four single-pass treatments (which combine tillage and seed placement in one operation) and one current practice treatment which involves separate tillage and seed placement operations in two separate passes (Table 2). The spatial allocation of the treatments is illustrated in Figure 1.

i) Current practice: the current practice involves a first pass with a Sumo Trio cultivator (Sumo UK Ltd, York, UK) and a second pass with a Kuhn HR 4002 seed drill. The Sumo Trio is tractor-mounted and comprises three main parts. These are i) subsoiler legs, ii) a double row of 500 mm concave discs mounted in pairs on independently-suspended arms, and iii) a tube fitted with notched-cutting drive rings of 800 mm diameter. The convex shaped rings help to break down and consolidate the soil. The Kuhn HR 4002 seed drill comprises: i) front tines that loosen and prepare the soil, ii) 13 horizontally mounted “stirrers” (driven from the power-take-off of the tractor) that rotate and distribute the residue across the soil surface, iii) bar harrows which chop the residue and mix it with the surface soil, and iv) 32 coulters that plant seeds. This is then followed by spring tines to cover the planted seeds with soil.

ii) Claydon Hybrid drill (Claydon Drills, Newmarket, UK) is a mounted drill where a leading tine is followed directly in-line by the sowing tine. There are three main parts: i) a leading leg loosening the soil, ii) seeding tines which release the seeds into the strip, and iii) leveling boards which are designed to level the ridges created by the leading tine.

iii) Sumo Deep Tillage Seeder (DTS) (Sumo UK Ltd, York, UK) is trailed by a tractor and comprises five main parts: i) leading opener discs which cut the surface trash, ii) tungsten-edged deep loosening legs which loosen the soil, iii) wide or narrow seed opener shoots which place seed in the loosened strip, iv) covering discs which channel loosened soil over the seed and iv) pneumatic press wheels that firm the soil around the seed and govern the sowing depth of the coulters.
iv) Mzuri Pro-Til 3 (Mzuri Ltd, Peopleton, Worcestershire, UK) is also trailed by a tractor and comprises: i) a leading tine which loosens the soil; ii) wheels which follow each leg and consolidate the soil (and carry the weight of the equipment); iii) an independent, double shoot seeding tine which is followed by iv) semi-pneumatic reconsolidation wheels to improve seed-soil contact.

v) The Väderstad Seed Hawk (Väderstad Ltd, Hogstadvågen, Sweden), which was used only for the oilseed rape, is also trailed by a tractor and has three main components. These are: i) a fertilizer knife which cuts a slot where the fertilizer is placed, ii) a seed knife for seed placement and iii) a press wheel which controls the depth of the fertilizer and seed knives and improves the seed-soil contact. Hence the Seed Hawk is effectively a “No-till” treatment. Due to unforeseen circumstances the Väderstad equipment used for the wheat field was different. In the wheat field, we used a Väderstad Rapid 400C. This includes five main processes: i) initial soil consolidation by wheels before drilling, ii) two rows of working and slicing discs that are slightly conical in shape which chop the residue and prepare the seedbed, iii) an optional set of discs used for fertilizer placement and some soil loosening, and following disc which is responsible for seed placement. This is following by iv) soil consolidation wheels and v) harrows to create a loose soil environment. The Rapid 400C is effectively a “Reduced-tillage” treatment.

Table 2: Characteristics of the tillage treatments used

<table>
<thead>
<tr>
<th>Conservation tillage treatment</th>
<th>Number of passes</th>
<th>Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current practice: Sumo Trio + Kuhn seed drill</td>
<td>2</td>
<td>Wheat and oilseed rape</td>
</tr>
<tr>
<td>Claydon Hybrid drill</td>
<td>1</td>
<td>Wheat and oilseed rape</td>
</tr>
<tr>
<td>Sumo Deep Tillage Seeder</td>
<td>1</td>
<td>Wheat and oilseed rape</td>
</tr>
<tr>
<td>Mzuri Pro-Til 3</td>
<td>1</td>
<td>Wheat and oilseed rape</td>
</tr>
<tr>
<td>Väderstad Seed Hawk</td>
<td>1</td>
<td>Oilseed rape</td>
</tr>
<tr>
<td>Väderstad Rapid 400 C</td>
<td>1</td>
<td>Wheat</td>
</tr>
</tbody>
</table>
2.4 Measurements and analyses
Soil properties and crop characteristics were measured during April 2014. Samples for soil particle size distribution from each field were analysed using the sieving and sedimentation method. Dry bulk density of the soil was measured by taking four undisturbed cores (50 mm in diameter and 51 mm deep) from the soil surface of each plot avoiding visible areas of traffic. Hence there were 80 bulk density samples per field. Penetration resistance of the soil was measured using an Eijkelkamp penetrometer with a push speed of 20 mm s\(^{-1}\) into the soil surface, a 30° cone angle, and a basal area of 120 mm\(^2\). Penetration resistance was measured three times for each bulk density sampling point, giving 240 penetration resistance readings.

Plant counts, stages of development, and leaf area index were also assessed in each treatment in each field. The leaf area index is the ratio of the leaf area of the crop to the leaf area of the ground. Plant counts were taken in March 2014 using a square meter quadrat while leaf area index was measured in early April using the Delta-T (Delta-T Devices Ltd, Burwell, UK) SunScan device. Both plant counts and leaf area index were measured, as proposed by Brêda (2003), at regular spacing within each of the 20 plots in each field.

3 Results and discussion

3.1 Soil properties
The particle size analyses showed that the dominant soil type in the L-shaped field, currently planted to oilseed rape was clay loam. The dominant soil in the square “Top Furze” field, currently planted to winter wheat, was clay.

In April 2014, eight months after the imposition of treatments, the mean bulk density (0-100 mm depth) of an individual sample ranged from 1.13 to 1.49 Mg m\(^{-3}\) in the wheat field and from 1.00 to 1.55 Mg m\(^{-3}\) in oilseed rape field. There was no significant difference (\(p = 0.8\)) in the mean soil bulk density of the five tillage treatments in the wheat field (1.21-1.37 Mg m\(^{-3}\)) and no significant difference (\(p = 0.12\)) in the bulk density of the soil of the five treatments in the oilseed rape (1.15-1.45 Mg m\(^{-3}\)). In April 2014, the mean penetration resistance of three readings at a specific point ranged from 0.5 to 1.6 MPa. However, as with the bulk density, there was no significant difference (p<0.05) in the mean penetration resistance of the tillage treatments in either field. Similarly the measurements in April 2014 showed no significant effect of tillage treatment on the mean soil moisture content (24-30%).

An analysis of variance of the results suggests that there was a significant block effect on penetration resistance in the wheat field. The block with the lowest penetration resistance also had the highest moisture content. A similar relationship between high soil moisture and low penetration resistance has been observed by Singh & Malhi (2006). During the rest of the season, soil bulk density and penetration resistance measurements are planned at deeper depths.

3.2 Plant characteristics
In March 2014, there was no significant (p=0.68) effect of tillage treatment on the mean plant count (146-186 plants m\(^{-2}\)) in the wheat crop. However in the oilseed rape, there were significant (p<0.01) effects (Figure 2). The mean plant count in the treatments prepared with the Sumo DTS, the Mzuri Pro-Til and the Claydon Hybrid (34.2-37.8 plants m\(^{-2}\)) were greater (p=0.05) than the current practice (29.5 plants m\(^{-2}\)). In turn, the current cultivation practice resulted in a higher (p=0.05) plant count than that for the Väderstad Seed Hawk (20.2 plants m\(^{-2}\)). There was no significant effect of the tillage treatment on the crop development stage in either the oilseed rape or the wheat crop.
On 4 April 2014, there were significant effects of the tillage treatments on the leaf area index of both the oilseed rape (p<0.05) and the wheat (p<0.001) (Fig 3). In the oilseed rape crop, the leaf area index of the areas prepared with the Sumo DTS and the Claydon Hybrid (3.2) was greater (p=0.05) than for the current practice and the Väderstad Seed Hawk (2.3-2.4). The leaf area index in the Mzuri Pro-Til plots (3.1) was similar to that for the Sumo DTS and the Claydon Hybrid. The leaf area index of the wheat in the Mzuri Pro-Til 3 treatment (0.86) was greater than in the areas prepared with the Sumo DTS (0.77), which in turn was greater than that (0.65-0.67) for the Claydon Hybrid and Väderstad Rapid 400C treatments. The lowest leaf area index was observed for the current practice (0.56). The high leaf area index of the Mzuri Pro-Til 3, the Sumo DTS, and the Claydon Hybrid may partly be due to these treatments being planted on 23 September, compared to 1 October for the Väderstad Rapid, and 5 October for the current practice.
4 Conclusions

The aim of this three-year study, which started in September 2013, is to determine how different conservation tillage treatments affect the agronomic, environmental and economic performance of wheat and oilseed rape production. The initial results presented here indicate that there are significant effects of the tillage treatments on the plant count of the oilseed rape, and on the leaf area index of both the oilseed rape and the wheat crops. Three of the reduced tillage treatments were resulting in higher leaf area indices than the current practice, although this may be confounded with differences in planting date. We will determine the effects on yield during July-August 2014. During April 2014, we were unable to determine significant treatment effects on soil bulk density, penetration resistance, and soil moisture content. On the basis of the level of variance determined in the first season, we will revisit the level of replication needed for such measurements in future years.

5 Acknowledgements

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6 References


