February 2005

The Unilever Colworth R&D controlled traffic farming (CTF) trial and demonstration

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The Colworth R&D CTF trial and demonstration

Single page resumé

Lee Farm, Unilever R&D Colworth
Initiated by a CTF Focus Group on 12 August 2004

Abstract

A controlled traffic trial was set up in the Autumn of 2004 on a Hanslope clay soil at Unilever Colworth R&D, Shrnonbrook in Bedfordshire. The primary module width was 6.67 m and this was used with a machinery system having a primary track width of 3 m and non-sown tramlines at 20 m centres (see figure below). The permanent wheelways at 6.67 m centres were established during harvesting with a John Deere 9880 STS combine equipped with auto steer coupled to an on-board StarFire GPS guidance system.

Subsequent levelling of the site and infilling of the wheelways was conducted using a fast and shallow pass of a power harrow. Two weeks later the site was sprayed with glyphosate and drilled after a further two days with a John Dale Zero Till drill. Winter wheat was sown as part of a five-year cereal, oilseeds and pulse rotation.

Following the first set of wheelings, site conditions were recorded in terms of cone penetration resistance and moisture content to a depth of 0.5 m. Measurements were taken in the new “bed” areas, in single and repeated wheel pass positions and in the old crop tramlines. Results showed that the old tramlines were 108 mm below the surrounding bed areas and the new wheelways some 98 mm lower. Cone resistance showed that the first harvester pass had an effect to 300 mm depth, but where a second pass occurred, this increased the resistance more than proportionally and to a greater depth. The latter was also the case when the harvester passed over the old tramlines; little additional compaction occurred in the upper layers, but there was an increase in resistance deeper in the profile.

As far as the crop growing on the beds is concerned, the results suggest that its roots will experience less resistance and a greater depth of soil profile than it would in the adjacent wheeled areas. Differential effects on water infiltration will be observed compared with surrounding areas.

The trial will be used as a demonstration of the principles of controlled traffic with the aim of showing that significant soil, crop, environmental and management benefits can be gained while lowering production costs and increasing crop returns.

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The controlled traffic farming trial and demonstration
Lee Farm, Unilever R&D Colworth
Initiated by a CTF Focus Group on 12 August 2004

Objectives
The trial aims to:
• Demonstrate, to as wide an audience as possible, the benefits of controlled traffic farming.
• Show that CTF can, to a large extent, be achieved with existing equipment and on a practical scale.
• Identify unique selling points associated with the technologies that will deliver benefits to the commercial partners.
• Ascertain, and where possible quantify, the economic and environmental benefits of a CTF regime.
• Establish present constraints to a CTF system based on existing machinery and propose means to remove or overcome such constraints in a cost-effective and practical manner.

The Focus Group partners will also endeavour to identify novel and low cost methods of integrating CTF into existing production systems. It may similarly propose longer-term changes to current practice that will enhance the potential of CTF to deliver more efficient production methods.

Background to CTF layout and machinery selection
A wide range of factors was involved in deciding the CTF track width and the chemical application tramline spacing. These included on-farm equipment for chemical application, the availability and dimensions of a John Dale drill, the track and table width of a proffered John Deere combine harvester, the track width of an associated tractor and practical considerations. The latter were considerably simplified by having site access without the need for public road use and farm tracks generally wide enough to accommodate the equipment.

To maximise the non-wheeled area, a track width of 3 m was selected. This would exactly match that of the combine harvester (albeit that the tyre widths of the latter would be wider than those of the tractor) and John Deere offered a new 8520 tractor for this purpose. Although this has far more power than is likely to be required and would be inflexible for road use, it was designed for a 3 m track setting and would come with full warranty. Implement widths were selected to match the 20 m on-farm tramline system. John Dale Zero Till Ltd were willing to provide a modified drill of their design on a 3 m wheel track and 6.67 m working width. The illustration below provides an overview of the system.

Figure 1. Overview of the CTF operating system approximately to scale. The intermediate wheelways will be sown and not wheeled again until harvest

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Trial site and proposed management
The 1st Site Meeting report dealt with site selection, but soil details and conditions and their proposed management are repeated here. The 8 ha site is on a Hanslope clay (Field 28) and is basically level but with a slight slope from northwest to southeast. Historically, the site has been in arable production for many years with traditional plough-based cultivation. In the last eight years, ploughing has been with a tracked tractor operating on the soil surface. Upon inspection the soil revealed a good and open structure in the plough layer. Within and beneath this, it was interspersed with massive-structured aggregates with a maximum size of around 100 x 75 mm (Fig. 2). These had resisted the recent rainfall and remained fairly dry and hard, not breaking easily under hand force. In general the soil profile was close to the plastic limit water content. It was therefore agreed that deep loosening of the site would be inappropriate at this stage, both because of the high moisture content and the fact of randomly distributed clods that were unlikely to be ruptured during any deep loosening operation.

Loosening of this year’s tramlines, which showed marked evidence of compaction nearer the surface, was favoured, but only if soil conditions following harvest permit. If this isn’t possible, they will be left until next year. A farm tractor on 1.8 m track and the farm’s Flatlift subsoiler would be used for this operation.

In 2004 winter beans were grown in the following crop rotation:
- Winter wheat (for seed)
- Spring break (linseed or barley)
- Winter beans
- Winter wheat (for milling)
- Winter oilseed rape

Record of operations and measurements
Soil management and crop operations 2003/2004

Harvesting of winter beans. 2nd September 2004.
This was with a John Deere 9880 STS combine with a 25 foot wide cutterbar, both provided by John Deere Ltd. Details of this and other machines are provided in the Appendix.
Three cuts were made around the headland, the first centred on the existing 20 m tramline, the others spaced at 6.66 m either side of it using the StarFire GPS “CurveTrac” guidance system on the combine. This meant that the outer cut with the 25’ (7.62 m) cutterbar spanned the 2 m conservation headland against the north Eastern headland. The main impact of this was a significant distribution of weed seeds across the full cut width as a result of the chopper and spreader.
The main body of the field was then harvested commencing on a line from the westernmost tip of the field to the southernmost (Fig. 3). The centre of this pass has been marked with a steel pin immediately adjacent to the concrete track at the NW headland. Although a grassed headland across the centre of the field was considered the most efficient means of setting up a CTF system in this field, practicalities associated with operation of the guidance system and potential for operational errors led us to conclude that the chosen layout was the best compromise.

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The operation ran smoothly with each successive pass spaced at 6.66 m from the previous (Figure 4). Unloading of the beans was into a trailer standing on a concrete track alongside the northwestern headland.

Figure 3. Controlled traffic layout in Field 28 at Colworth R&D. The key first pass across the body of the field is indicated by the red arrows. (The white space in the middle was an inadvertent power shutdown)

Figure 4. The harvesting operation with passes at 6.66 m centres and wheel track of 3 m. The old tramline can just be discerned intersecting the new wheelways at an acute angle from the left.
Field measurements

Soil moisture content and cone resistance were measured across the site immediately after harvest. Cone resistance in the new bed areas of the field were considered to represent the “residual” field condition, while measures in the combine wheelings and old crop tramlines were taken to determine the more recent impact of wheels. A ‘W’ configuration was used to ensure representative sampling. An assessment of wheel sinkage was also made using a straight edge set at right angles across the wheelways. The old tramlines intersected the new wheelways at about 20 degrees.

A single 400 mm deep profile pit was also excavated to confirm the soil conditions that were identified at the first site meeting on 12 August 2004 (see Colworth CTF Trial Meet 1.doc).

Following analysis of the soil data, a second set of measurements was taken on 17th September in an attempt to correlate unexpected features of cone resistance with soil moisture.

Plant population was established from 25 randomly sited locations across the site where the total number of plants in one metre length of adjacent rows was counted. Sowing depth was established from single plants in each of these rows by measuring the distance between the seed coat and the white/green transition on their stems.

Results of field measurements

Soil moisture content

Figure 5 shows how soil moisture generally decreased with depth on both occasions of measurement and for both positions. It also suggests that by the 17th September, the old tramline was slightly drier throughout most of the depth profile than the bed area, but at 35 cm the trend of decreased moisture with depth became much less pronounced. Some care is needed in the interpretation of these data, particularly in relation to the penetration readings. Because the soil was visibly denser in the tramlines, inevitably there will less pore space and thus less space for water, but the soil was very plastic.

![Bed and old tramline water content, g/g](image)

Figure 5. Soil moisture content plotted against depth on two dates for the beds and on one date for the old tramlines

Cone resistance

The cone resistance measurements are presented in Fig. 6. These show the data related to the surface from which the measurements were taken, but as the combine wheelings and old tramlines had lowered the surfaces by 95 mm and 108 mm respectively compared with the bed area (see Fig. 7), these data have been presented with an appropriate depth allowance. This provides a more accurate comparison at each depth level, but as far as the crop is concerned, its roots will experience the resistance associated by each individual trace. In practice with minimum tillage, there is usually a loose layer of soil.
overlying random wheel tracks. With direct drilling, the number of wheel tracks may be fewer but sowing depth will be governed considerably by the design of the opener and the relative strength of different areas of the topsoil.

<table>
<thead>
<tr>
<th>Bed3Sep</th>
<th>Combine w heelings3Sep</th>
<th>Combine3Sep2pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combine17Sep2pass</td>
<td>Bed17Sep</td>
<td></td>
</tr>
</tbody>
</table>

![Penetrometer resistance, kPa](image)

**Figure 6.** Cone penetrometer resistance with depth measured on 3 & 17 September 2004 following combine harvesting with a John Deere 9880 STS combine on 2 September. The ‘bed’ readings are those taken between any visible wheelings. Wheel sinkage has been allowed for by offsetting the surface datum.

![Diagram](image)

**Figure 7.** Representation (not to scale) of the effect of wheel sinkage on the measurement of penetration resistance. At some point in the profile indicated by the lowest line above, and probably at between 30 & 50 cm depth for the data in Fig. 6, the force measurements will relate to a common but unidentifiable depth for all areas.

From Fig. 6 it can be seen that the principal impact of a single harvester pass was in the 10–30 cm profile where there was an increase in resistance compared with the bed. Limited data from positions where the harvester had passed twice are also presented from 3 September and these, because of their nature, were augmented by further measurements on the 17th. These confirmed that the second pass had a proportionally greater effect on resistance than the single pass. Although no differentiation has been made in the level of sinkage, which was observed to be modest, these data suggest a significant increase in resistance across most of the depth range compared with any of the other data sets. Within a conventionally trafficked and minimum tillage regime, the crop will be sown over a number of these and other wheel tracks, within a covering seedbed layer. From the plant’s perspective, its roots would experience a resistance profile equivalent to raising the wheeled traces vertically by around 5 cm.

The effect of multiple passes during the cropping season is represented by data from the old tramlines in Figure 8. The fact that resistance in the old tramlines below 25 cm was somewhat lower than in the beds, despite lower soil moisture content (see Fig. 5), is contrary to accepted relationships. However, soil structure, as already mentioned, was visibly different in these areas and was also reflected by quite...
different characteristics when driving in and extracting the soil sampling gouge auger. The soil exhibited plastic rather than structured attributes. This highlights the problem with cone resistance measurements that are a measure of a number of soil parameters, some of which might lead to a rise in resistance with compaction and others that might result in a fall depending on soil water content and structure. It is interesting to note that the pass over the tramlines by the harvester had little differential effect in the upper layers, but seems to have increased resistance lower in the profile. From these data it can be seen from a plant’s perspective that the new beds offer a greater depth and less dense profile above the subsoil. The manner in which roots penetrate and explore this profile remains to be seen.

Figure 8. Cone penetration resistance with depth for the new bed areas and the old crop tramlines, including those areas crossed by the harvester. Wheel sinkage has been allowed for by offsetting the surface datum.

Soil profile and structure
The profile to around 0.4 m depth as revealed in a single profile pit is illustrated in Fig 9 and individual soil “clods” extracted from this profile in Fig. 10. The latter show the nature of compaction in the ploughed profile and the futility of deep loosening that would only move the compacted aggregates from one spot to another. There was also evidence of a compact layer at around 25 cm depth, but whether this was associated with the transition from topsoil to subsoil is difficult to assess at this stage. Crop rooting and over-winter drainage should show whether this is limiting in any way.
GPS (StarFire) guidance

Setting up of the StarFire system required a heading to be selected and a start position on one headland. The latter was permanently marked with a steel pin inserted directly against the north-western concrete track. This pin will guarantee that we can always set up the guidance system in the correct lateral position. It is used by keying in the heading, driving the tractor or harvester with its StarFire receiver over the pin and setting the lateral offset to zero using ShiftTrac. This ensures that any drift with time is eliminated from the system. It is also important to note that the AutoTrac implement lateral offset feature cannot be used with CTF to compensate for a ground-working implement offset error, as would be the case with random traffic. With the latter, implement offset moves the tractor over to compensate for the implement out of alignment, but with CTF, this would move the tractor off the permanent wheelways. Any such offset has to be dealt with physically on the tractor. Observations during the harvesting operation and subsequently suggested that the prescribed layout had been followed very precisely, despite the harvester being the most difficult vehicle to control. Because of its rear steer and relatively long wheelbase, the harvester is sluggish in responding to steering corrections. The steered wheels will also tend to migrate further than their forward control counterparts found on tractors. Performance of the system during sowing of the crop remains to be assessed because at the time of writing the crop is not sufficiently advanced to check on skip rows or straightness.
Soil management and crop operations 2004/2005

Background
Following harvest on 2nd September there was further significant rainfall and therefore all thoughts of loosening the old crop tramlines were abandoned. Data from the soil measurements showed that the combine harvester made wheel impressions of around 95 mm and those in the old crop tramlines were nearly 110 mm deep. Such sinkage and the need for immediate filling was anticipated, particularly at the outset of a CTF system and particularly when deep ploughing had been employed in the previous crop season.

Soil levelling/infilling
The most effective implement obtainable to fill the new permanent wheelway and old crop tramline depressions was a 6 m wide power harrow kindly made available by Bedfordia Farming of Milton Ernest. This operation was carried out on 29th September using the power harrow at its minimum depth (set by the following packer roll) giving around 50 mm cultivation depth on the bed areas. The optimum forward speed was found to be 6 km/h. At this depth and speed most of the ground was moved and grasses, thistles and other well established weeds were effectively uprooted or severed. See Figures 11–13 for further information.

Fig. 11. John Deere 8520 tractor and Kuhn power harrow being used to fill the wheelways and level the beds

Figure 12. Stubble and soil conditions before power harrowing

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Fig. 13. Stubble and soil conditions after power harrowing. Most weeds had been uprooted or the roots severed.

Desiccating spray application
Glyphosate was applied at a rate of 3 l/ha in 100 l/ha of water to the whole site on 11 October 2004 with a mounted Hardi 20 m wide boom sprayer. Forward speed of the JD8520 was 8 km/h.

Drilling
Winter wheat (var. Claire) was sown on 13 October 2004 with a 6.67 m wide John Dale direct drill. Nominal rate of seeding was 165 kg/ha with seed having a 1000-grain weight of 43 g and 91% germination. Twenty six coulters on the drill placed seed in paired rows at nominal 256 mm centres (Fig. 14). Two out of every three pairs of wheelways were sown, leaving only those at 20 m centres unsown to form the chemical application tramlines. Soil moisture content at the time of sowing (Fig. 15) was 30.5%, which was estimated to be close to the plastic limit (assessment yet to be performed).

Fig. 14. Drill coulters showing paired openers offset from each other (inset)
Fig. 15. Sowing with the 6.67 m wide John Dale Zero Till drill. The wheels had been set out to 3 m and the permanent wheelways, other than those at 20 m centres used for chemical application, were drilled.

There was considerable rainfall following sowing and the crop had emerged when photographs were taken on 26 October as indicated in Fig. 16. There was also considerable further germination and growth of volunteer beans and some of the more established weeds were also still in evidence, despite the desiccating spray application two weeks earlier.

Fig. 16. The site on 26 October 2004. Inset shows development stage of some of the crop.
Plant population measured on 31 Jan. 2005 was 143/m$^2$ and ranged from 49 to 258/m$^2$. This represents a field establishment of 37%, which is considered low. The mean depth of sowing was 31 mm with a range of 5 to 70 mm. As these depths were determined from a sub sample of the population counts, it was possible to assess whether the effect of sowing depth had a significant effect on establishment. These data are shown in the Figure 17.

![Sowing depth vs plant numbers, A samples](image)

![Sowing depth vs plant numbers, B samples](image)

**Fig. 17.** Plant populations and sowing depth from two sub samples from the plant count areas

Although there is an indication of a normal distribution at around 30 mm depth, the evidence is not strong, suggesting that depth of sowing over this depth range had relatively little influence on the level of establishment. Slugs were very prevalent on the site, but because of very wet conditions immediately after sowing, treatment was delayed. It is therefore presumed that most of the losses occurred as a result of their activities in this early period.

![Winter wheat crop on 31 Jan. 2005](image)

**Fig. 18.** The winter wheat crop on 31 Jan. 2005. The two rows in the centre of the photo are the join between passes and indicate a good degree of accuracy achieved by the guidance and autosteer systems.

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Appendix

Summary of operations

<table>
<thead>
<tr>
<th>Date</th>
<th>Operation</th>
<th>Details</th>
<th>Crop year</th>
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<tbody>
<tr>
<td>29 Sept 2004</td>
<td>Soil levelling/wheelway infilling</td>
<td>JD 8520 + 6 m power harrow</td>
<td>2004/2005</td>
</tr>
<tr>
<td>11 Oct 2004</td>
<td>Desiccating spray</td>
<td>JD 8520 + Hardi sprayer</td>
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<tr>
<td>13 Oct 2004</td>
<td>Drilling of w. wheat Claire</td>
<td>JD 8520</td>
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<tr>
<td>3 Nov 2004</td>
<td>Slug control using ATV</td>
<td>JD 8520</td>
<td></td>
</tr>
<tr>
<td>10 Nov 2004</td>
<td>Herbicide and pesticide</td>
<td>JD 8520 + Hardi sprayer</td>
<td></td>
</tr>
</tbody>
</table>

Machine details

**John Deere 9880 STS combine harvester**

Tyres:
- Front: 800/65 R 32 at 2.96 m centres
- Rear: 480/80 R 26 at 3.30 m centres

Tyre pressures:
- Front: Not measured
- Rear: Not measured

Wheel loads:
- Front: Not measured
- Rear: Not measured

**John Deere 8520 tractor**

Tyres:
- Front: 16.9 R 34 at 3 m centres
- Rear: 520/85 R 46 at 3 m centres

Wheel loads:
- Front: 2400 kg
- Rear: 3450 kg

Tyre pressures:
- Front: 1.0 bar
- Rear: 1.0 bar

Wheel loads:
- Front: c. 2500 kg
- Rear: c. 4000 kg

**John Dale Drill**

Tyres: 14.9 R 28 6 ply at 3 m centres

Wheel loads: 2500 kg

Tyre pressures: 1.7 bar
February 2005

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- Unilever
- John Deere
- John Dale Zero Till
- Michelin
- Knight
- Farmade Management Systems

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