Reduced Cultivations – Update from Oak Park Experiments

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SUMMARY

Pressure on cereal margins is forcing farmers to examine all their inputs in an effort to reduce costs. Shallow, non-inversion tillage (reduced cultivation) can offer the benefits of high work rates and lower costs, but does it have any disadvantages? This paper reviews some of the results of the work on reduced cultivation at Oak Park and Knockbeg over the past four years. The performance of winter wheat, winter barley, spring barley and sugar beet was studied under reduced cultivation and plough-based systems with straw chopped and incorporated or baled and removed.

Crop establishment was lower under reduced cultivation but the reduction did not affect grain yield. Winter wheat yields on the shallow cultivated areas were at least as good as those from ploughing. Winter barley yields were more variable; yield reductions after reduced cultivation were caused by grass weeds – annual meadow grass and sterile brome. Differences in spring barley yields were quite small.

Aphid numbers and BYDV incidence were lower after reduced cultivation particularly where the straw was chopped and incorporated. Slug numbers increased under reduced cultivation with a consequent increase in leaf damage to the young plants but there was no increase in seed damage or reduction in plant population. Earthworm biomass increased on the reduced cultivation areas over the period of the experiment.

Soil strength was greater on the shallow cultivated plots. This increased strength did not affect cereal yields but did have a negative effect on sugar beet root yield and shape.

Reduced cultivation, while having some negative aspects, offers the potential for establishing good cereal crops in a short time span.

INTRODUCTION

There has been serious pressure on cereal margins in recent years. There is little room for reduction in input costs – fertilizers, fungicides, pesticides - from present levels while maintaining yields. There is scope for significant savings in crop establishment costs through the adoption of more efficient cultivation techniques. Reduced cultivation systems have higher work rates, lower energy inputs and lower machinery costs than traditional plough based systems. Labour requirement can be reduced, although the peak labour demand may be increased (Forristal and Fortune, 2002). The high work rates possible with these systems provides the opportunity to take full advantage of any spells of good weather to establish substantial areas.

When our experiments started in August 2000 there were only a handful of growers who had committed themselves to reduced cultivation for cereals. Most of these are still operating the system. The main perceived disadvantages of the system at the time were:

Grass weeds
Slug problems
Soil compaction
Diseases
Cost of converting from the plough-based system

There was a fear among farmers of a yield reduction and loss of profitability from insufficient experience of new techniques. It was against a background of a few committed pioneers of the system, and a much larger group who might like to try the system but who were afraid of the financial consequences if it did not work out, that the experiments were commenced.

METHODOLOGY

Before going on to describe our results and experiments it may be opportune to describe the equipment and techniques used.

1. Experiments are being conducted on winter wheat and barley, spring barley and a rotation that includes sugar beet. The experiments are described in Fortune *et al.*, 2003.

2. In nearly all of the experiments conventional plough based cultivations were compared with shallow cultivation, i.e. one or two passes of a heavy-duty tine cultivator (5-10 cm deep). The exceptions are the rotation experiment and the weed control experiment which are both confined to reduced cultivation only.

3. Straw was baled and removed from all plots after the harvest of 2000, before sowing our first crops. Subsequently a comparison of the effects of straw chopping versus baling and removing was introduced into some of the experiments – winter wheat (Knockbeg), spring barley (Clonaherk and Pump field). The straw was chopped to a target length of < 10 cm and spread from the combine.

4. The shallow cultivations were carried out as soon as possible after harvesting the previous crop irrespective of whether the following crop was autumn or spring sown. In the first three years the shallow cultivations consisted of two passes with a trailed tine cultivator (Horsch FG 4.5 m) working about 7-10 cm deep. In 2003 this was reduced to one pass with a Kocherling tine cultivator at 7 cm deep. Last autumn the reduced cultivation areas were worked with a Horsch Terrano 3 FX 3m mounted cultivator, one pass at ~ 10 cm.

   In the conventional treatment ploughing for the autumn sown crops was done at various intervals from a few days to a couple of weeks before cultivation and sowing. Ploughing depth varied from 20–25 cm. For the spring sown crops the ploughing was done in autumn or in February for March sowing. After ploughing the ground was usually furrow-pressed or rolled. Seedbed cultivation was one pass of a rotary power harrow at about 10 cm deep.

5. All the shallow cultivated areas were left for a few weeks (as long as possible) before spraying with glyphosate a few days prior to sowing to kill off any crop volunteers or established weeds. The seed was sown into this stale seedbed without any further cultivation. The ploughed treatments were sown at the same time.

6. Almost all the sowing on plough and reduced cultivation has been done with a Vaderstad disc cultivator drill. In the first year this was a mounted 3 metre version but since 2001 we have been using a trailed 3m Vaderstad Rapid drill. This was fitted with a set of discs mounted in front of the coulters, which could be raised or lowered independently of the coulters, where extra cultivation was required. Target sowing depth was 4 cm. Winter barley was usually sown during the last week in September and winter wheat during the first week in October. Spring barley was sown as soon as soil conditions were suitable in March.

7. Except where the experiment or crop demanded, all of the post-sowing fertiliser, and herbicide, fungicide and pesticide applications were the same on the ploughed and reduced cultivation areas.

8. In the remainder of this paper the abbreviations PL and RC are used for the plough-based and reduced cultivation treatments respectively.

RESULTS

Crop establishment

One of the question marks over the reduced cultivation system at the beginning of our experiments in 2000 was whether plant establishment would be as good as from the plough-based system. There was also the problem of establishing a crop where straw was being incorporated. The winter wheat crop in Knockbeg has been sown during the first week in October for the past five seasons. The soil in Knockbeg is classed as a free draining loam over a sandy clay loam, which gets very sticky when wet. In the first autumn (2000) soil was in rather poor condition at and after sowing and establishment was poor on both the plough (PL) and reduced cultivation (RC) areas, but particularly on the RC plots. Soil conditions and crop establishment were similar in 2001 (Table 1), when the figures for the final establishment were ~ 170 and 124 plants/m on the PL and RC respectively. The initial figures were somewhat better at ~ 215 and 165 plants/m^2 but these were subsequently reduced.

Table 1: Plant establishment – winter wheat, Knockbeg, 2001-2004

Treatment	Plants/m^2			
	2001-02	2002-03	2003-04	2004-05
Plough – straw	166	239	256	254
Plough + straw	171	254	256	255
Reduced cultivation – straw	123	240	239	230
Reduced cultivation + straw	124	237	234	229

Over the past three sowing seasons seedling establishment has stabilized with the PL system achieving our target of 250 plants/m^2, while the RC was slightly lower at 230-240 plants/m^2. One of the slightly surprising results was that there was no difference in plant establishment between the treatments which had straw baled and removed or chopped and incorporated.

The winter barley experiments are split into two categories

(i) Replicated experiments designed to study the effects of cultivation technique on topics such as aphids and BYDV occurrence, slug populations and earthworm and beetle populations. The results of this work will be described later.

(ii) A split field experiment, examining the agronomic performance of winter barley under PL and RC systems, was located on a gravelly sandy loam at Oak Park. These soils are very free draining. Straw was baled and removed. Sowing has taken place in the last week of September up to 2004 when it was delayed in an attempt to deal with a sterile brome problem.

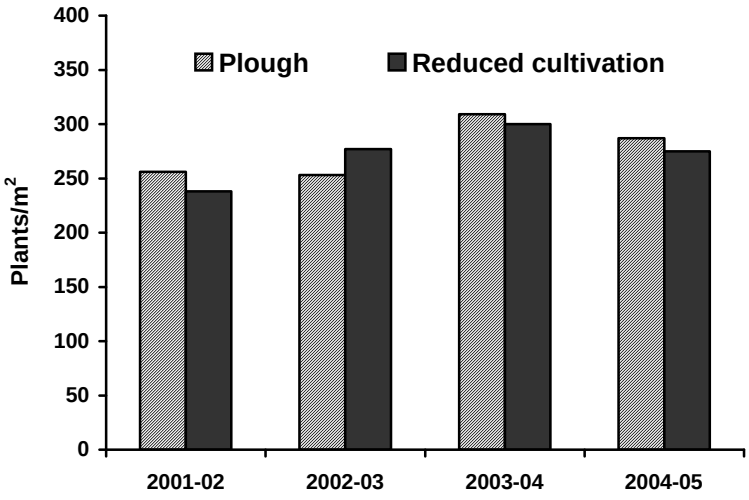

Fig. 1: Plant establishment – winter barley, House Field, 2002-2004

Ploughing usually gave better establishment than shallow cultivation in winter barley but the differences were quite small (Fig. 1).

The spring barley experiments are located on a sandy loam soil overlying a slower draining loam soil. This is a split field experiment comparing PL and RC; in 2004 each half of the field was further sub-divided into straw removed or incorporated. Establishment figures for the years 2001-2004 are shown in Table 2. Plant establishment was low in the first two years, being particularly so on the RC in 2002. It improved considerably in 2003 and 2004 but was still somewhat lower on the RC area.

Table 2: Plant establishment – spring barley, Clonaherk, 2001-2004

	Plants/m^2			
	2001	2002	2003	2004
Plough	217	208	325	320
Reduced cultivation	210	167	281	312

Yields

While good establishment figures are important in planning seed rates and minimizing seed costs, the real test is whether they are translated into grain yields at the end of the season. The winter wheat yield figures for 2001-2004 are given in Table 3.

Table 3: Grain yields @ 15% m.c. – winter wheat, Knockbeg, 2001-2004

Treatment	Grain yield (t/ha)			
	2001	2002	2003	2004
Plough – straw	10.28	9.72	10.22	11.23
Plough + straw	-	9.79	10.59	10.60
Reduced cultivation – straw	10.18	10.56	9.78	11.44
Reduced cultivation + straw	-	10.23	10.31	10.88

In spite of the low establishment figures in 2000-01 and 2001-02 the yields were quite good, and, even though establishment was significantly lower on the RC area, the yields were as good as the PL plots in 2001 and better in 2002. The lower yields on the PL plots in 2002 can be explained by the disease assessments for that year. Take-all levels were higher on the PL treatments (Table 4), and this obviously had an effect on the crop. In 2003, establishment was good and yields high except on the reduced cultivation/straw removed treatment. In that year annual meadow grass was a serious problem in all our experiments and was worse on this particular treatment, more by chance from location in this field, than as a treatment effect.

Straw disposal method did not have a consistent effect on yield. In 2003 yields were higher where straw was incorporated and in 2004 the pattern was reversed, but in neither case was the difference statistically significant.

Table 4: Disease assessments (Take –all) – winter wheat, Knockbeg, 2001-2003

	Disease index (%)		
Treatment	2001	2002	2003
Plough – straw	43.4	73.0	68.8
Plough + straw	NA	70.1	79.1
Reduced cultivation – straw	39.6	52.9	79.3
Reduced cultivation + straw	NA	52.3	77.8

NA = not applicable

Winter barley yields varied considerably over the four years (Fig. 2). Yields from PL and RC were identical in 2001. In 2002 the RC yielded 1 t/ha more than ploughing. The situation was reversed in 2003 when the yield on the RC area was 2 t/ha lower than the PL. This was caused by a bad infestation of annual meadow grass, which was not controlled. Yields on both treatments were identical in 2004 at 9.5 t/ha. Over the four years the PL area averaged 0.25 t/ha more than the reduced cultivation.

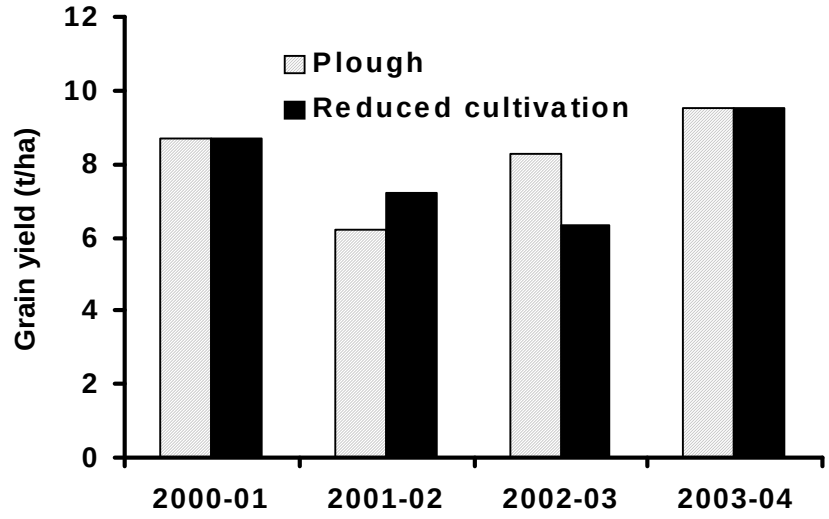

Fig. 2: Grain yield @ 15% m.c. – winter barley, House Field, 2001-2004

There were small differences in grain yield of spring barley between the ploughed and shallow cultivated areas. In 2004 the yield pattern was reversed with the RC treatment yielding 0.5 t/ha more than the PL (Fig. 3).

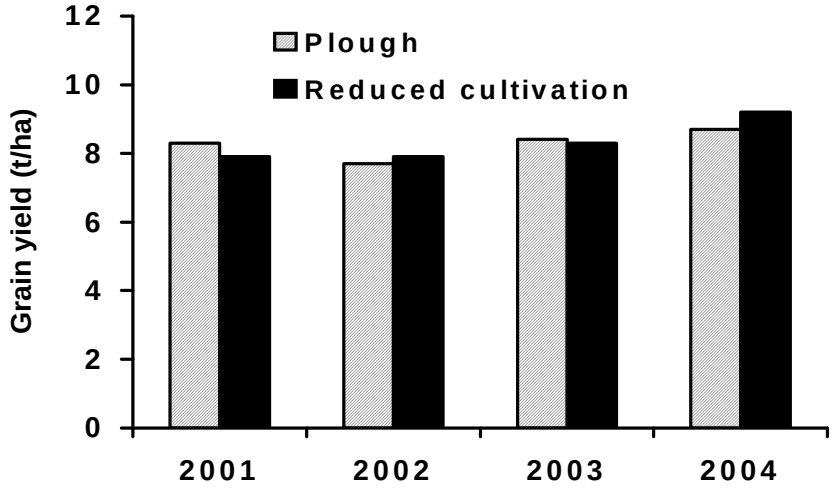

Fig. 3: Grain yield @ 15% m.c. – spring barley, Clonaherk, 2001-2004

The yield trend has been towards improving results from RC but the average difference over the four years has been 0.05 t/ha in favour of PL.

Weeds

Annual broadleaved weeds have not been a problem in the RC system, and have usually been present in lower numbers than after ploughing (Table 5). The current season is an exception to this where there is a higher population of cleavers on the RC area of the winter barley than on the PL. However, some grass weeds were more problematic on the RC area.

Table 5: Annual weeds and grasses per m^2 in reduced cultivation trials, 2001-2002 (straw removed)

Weed type	Winter barley, Oak Park		Winter wheat, Knockbeg	
	Plough	Reduced cultivation	Plough	Reduced cultivation
Annual weeds	106	17	10	2
Annual grasses	14	16	50	72

In the autumn of 2002 annual meadowgrass was very prevalent on the RC areas in winter barley (Table 6) and was not dealt with in time. It became a serious problem subsequently and caused a serious reduction in yield in the winter barley and also in some plots in the winter wheat. We have used pre-emergence or early post-emergence (weed) application of Trump (Pendimethalin + Isoproturon) in the past two seasons with good control of annual meadowgrass. In the past it has been regarded as a fairly innocuous weed, but in recent years, with early sowing and low seed rates, has become very competitive and must be sprayed early to achieve good control.

A weed control experiment in 2003-2004 on a reduced cultivation site with a high incidence of meadowgrass produced some interesting results. As may be seen from Table 7, all of the pre-emergence treatments gave excellent control of the meadowgrass and indeed many of the broad-leaved weeds even at half rates. The post-emergence treatments were much less effective on the meadowgrass and poorer on most of the broad-leaved weeds.

In 2003-2004 the annual meadowgrass problem was solved by early herbicide application but another grass weed problem emerged. Sterile brome became a serious problem on the reduced cultivation area of the winter barley trials. Several large patches appeared in which the barley was crowded out and the brome took over completely. This weed, if allowed to encroach into a winter barley situation, is almost impossible to control under a non-ploughing regime. For 2004-2005 we have tried a combination of pre-sowing cultivation and spraying to reduce, if not eliminate the problem.

Table 6: Reduced cultivation experiment 2002-2003 winter barley, Oak Park (House Field) – weed counts/m^2

	Counted 13/11/02- pre-herbicide		Counted 27/01/03 – Post-herbicide*	
Weed	Plough	Reduced cultivation	Plough	Reduced cultivation
Charlock	-	0.53	-	-
Chickweed	0.80	0.93	-	-
Cleavers	0.53	-	-	-
Forget-me-not	0.53	-	-	-
Fumitory	3.33	0.53	0.27	-
Groundsel	0.53	1.07	-	0.53
Knot grass	-	2.27	-	-
Annual meadow grass	3.20	194.27	1.07	113.07
Pansy	42.67	40.13	0.93	3.73
Parsley piert	-	0.67	0.67	0.40
Poppy	2.93	1.20	-	0.93
Red deadnettle	7.60	15.73	0.40	0.80
Speedwell	14.00	79.60	0.40	2.67

*****Herbicide applied: Cougar @ 1.5 l/ha – 22/11/02

Table 7: Control of annual meadow grass and broadleaf weeds in winter wheat 2003-2004 (% control)

Treatment dose/ha	Annual meadow grass	Knotgrass	Pansy	Groundsel	Speedwell
(Pre-emergence)					
Trump @ 5.5 l	99.6	100	98.5	98.7	98.5
Trump @ 2.75 l	99.5	100	95.5	98.7	100
Cougar @ 1.5 l	99.5	100	95.5	98.4	98.4
Cougar @ 0.75 l	99.4	100	91.8	85.5	93.0
Stomp @ 5.0 l	99.6	100	91.2	80.0	89.0
Stomp @ 2.5 l	99.3	100	91.7	64.5	83.4
(Post-emergence)					
Cougar/IPU @ 0.75 + 5.0 l	66.6	99.1	82.6	51.6	61.2
Cougar/IPU @ 0.75 + 2.5 l	59.2	99.4	75.6	71.0	66.6
Stomp/IPU @ 2.5 + 5.0 l	62.6	100	75.5	64.5	61.2
Stomp/IPU @ 2.5 + 2.5 l	63.4	100	76.5	64.5	61.2

Pest and non-pest invertebrates in cereals

A study was started in 2001 looking at pest and beneficial invertebrates in winter barley and wheat. The investigations include assessments of the:

- Incidence of aphids and aphid transmitted virus disease (BYDV) in minimum tilled crops relative to those grown on a conventionally prepared seedbed.
- Effects of ploughing or shallow cultivation on soil invertebrates including slugs, earthworms and beetles.
- Sources of aphids and virus affecting autumn sown crops.
- Role of aphid predators in reducing BYDV.

Aphids and BYDV

In 2001 on the winter barley site aphid numbers and virus incidence in the RC treatments were approximately 50% and 30%, respectively, of those recorded for ploughed plots (Table 8).

Table 8: Aphids and BYDV in winter barley, 2001-2004

Cultivation treatments	2001-2002		2002-2003		2003-2004	
	Aphids/ m^2 12^{th} Oct.	BYDV % 30^{th} April	Aphids/ m^2 18^{th} Nov.	BYDV % 6^{th} May	Aphids/ m^2 19^{th} Nov.	BYDV % 4^{th} May
Plough - straw	278.8	46.2	9.7	13.2	75.9	18.3
Plough + straw	222.8	42.3	3.0	14.2	82.6	9.8
Reduced cultivation – straw	144.8	13.4	5.9	7.4	74.0	14.2
Reduced cultivation + straw	46.3	6.0	3.8	8.0	95.5	10.7

Where straw was incorporated on the RC plots aphid numbers were reduced by 68% and virus by 56%. Grain yield was 1 t/ha higher on the RC plots than on the PL. Incorporating straw increased yield on RC and PL treatments. In 2002-2003 aphid numbers were very low and there was little variation in aphid numbers between the treatments but the BYDV levels were significantly lower on the RC plots. In 2003-2004 aphid numbers were higher than the previous year but there was no significant difference in aphid or disease levels. There were serious problems with sterile brome on this site in 2003-2004, resulting in very low yield on the RC plots.

In the winter wheat trial at Knockbeg there were very few aphids in 2001, 2002 and 2004 but there were fewer on the RC plots. Aphid numbers were not recorded in 2003. There was less BYDV on the RC plots relative to ploughing and less where straw was incorporated.

Slugs and slug damage

Slug numbers were monitored by means of refuge traps for a six-week period from mid October each year. Numbers increased in all treatments on the winter barley site from 2001-2004. They were more numerous on the RC plots in 2003 and 2004; straw disposal method did not seem to affect slug numbers. Damage to barley plants was proportional to slug numbers (Fig. 4).

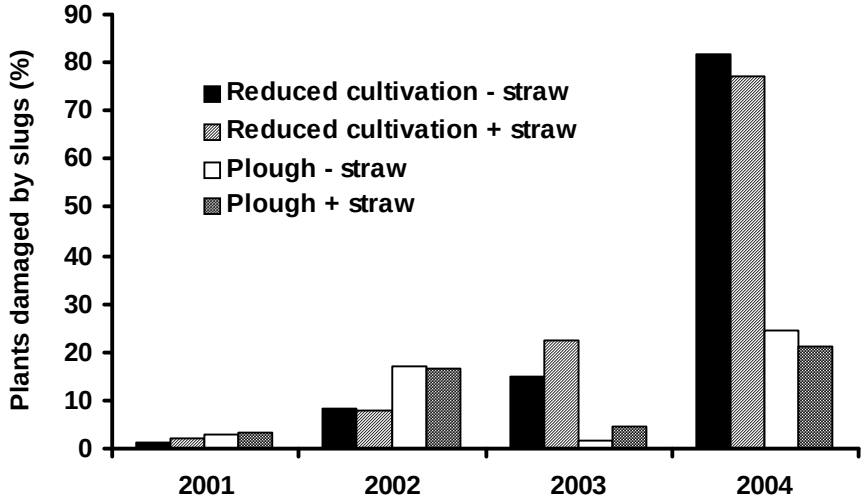

Fig. 4: Slug damage – winter barley, Oak Park 2001-04

On the winter wheat site in Knockbeg in 2001-2002 there was no significant difference in slug numbers between cultivation treatments but there were more slugs on the PL treatment in 2002-2003 (Table 9).

Table 9: Slug numbers in refuge traps – winter wheat, Knockbeg

Treatment	Slug numbers/refuge trap		
	2001-2002	2002-2003	2003-2004
Plough – straw	66.8	130.8	55.0
Plough + straw	52.3	103.0	47.5
Reduced cultivation – straw	58.0	95.8	64.5
Reduced cultivation + straw	63.5	93.8	67.8

While there was some slug damage on the wheat leaves (shredding and severing) there was no evidence of slugs feeding on seed or severing plants below the soil surface and no measurable effect on plant populations. There was more leaf damage last autumn on the RC areas, particularly where the straw was incorporated.

Earthworms

There was no difference in earthworm numbers between PL and RC treatments at the start of the winter barley experiments in autumn 2001; since then both numbers and weight of earthworms have increased on all treatments but more particularly on the RC plots. Straw incorporation increased earthworm numbers on both treatments but more especially on the RC (Table 10).

Table 10: Earthworm numbers – winter barley, Oak Park, 2001-2004

Treatment	Earthworm numbers/m^2			
	2001	2002	2003	2004
Plough – straw	2	24	40	58
Plough + straw	38	48	28	94
Reduced cultivation – straw	18	114	114	286
Reduced cultivation + straw	36	94	184	456

In Knockbeg (winter wheat) the number and weight of earthworms increased on both cultivation treatments from 2002 to 2004, especially on the straw incorporated plots (Table 11). The increase in worm biomass was relatively greater than the increase in numbers over the period, indicating an increase in worm size (Fig. 5).

Table 11: Earthworm numbers – winter wheat, Knockbeg, 2002-2004

Treatment	Earthworm numbers/m^2		
	2002	2003	2004
Plough – straw	72	130	130
Plough + straw	84	220	214
Reduced cultivation – straw	84	142	180
Reduced cultivation + straw	114	162	156

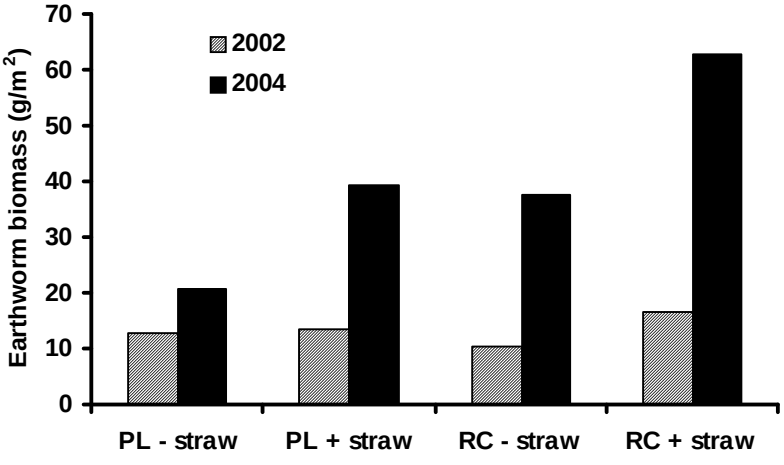

Fig. 5: Earthworm biomass – winter wheat, Knockbeg, 2002 and 2004

Cultivation method had a greater effect on groundbeetle numbers than straw disposal method. Large species were favoured by reduced cultivation while smaller species occurred in greater numbers on ploughed plots.

Soil

One of the concerns regarding reduced cultivation is the possibility of soil compaction by wheel traffic which is not removed by the shallow cultivation. Measurements with the cone penetrometer at Knockbeg in December 2003 showed little variation between cultivation treatments down to about 6-7 cm. The cone resistance on the RC plots increased very rapidly from 8 to 18 cm and then less rapidly down to 44 cm. On the PL plots the soil strength increased at a much lower rate down to about 23-24 cm (ploughing depth) below which it increased rapidly again reaching the same strength as the RC at about 36 cm (Fig. 6). The presence or absence of straw had no significant effect on the soil cone resistance.

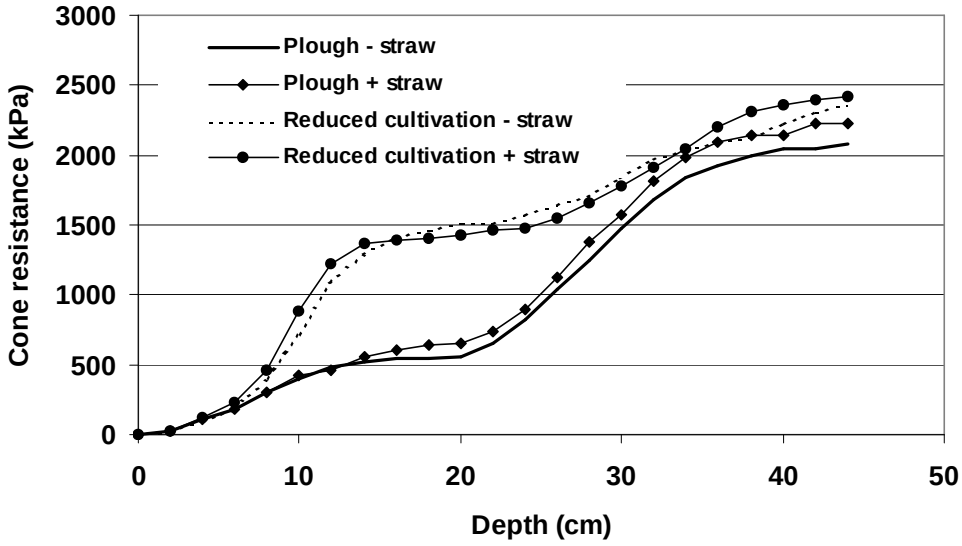

Fig. 6: Cone penetrometer resistance – winter wheat, Knockbeg – December 2003

Results from shear vane tests (another measure of soil strength) show a similar pattern (Fig. 7). Readings were taken at two depths 4 and 12 cm below the surface. At the shallower depth differences between the treatments were small but the RC figures were slightly higher. At 12 cm the readings from the PL plots were similar to those at 4 cm but those on the RC area were significantly higher.

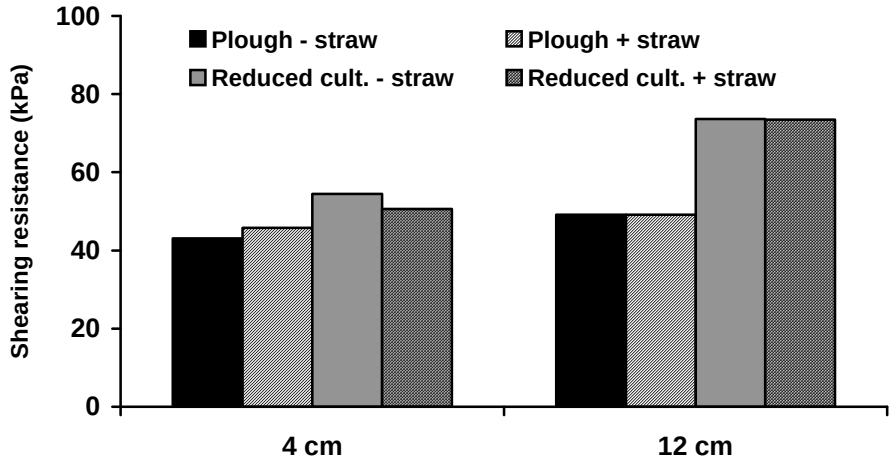

Fig. 7: Soil shear strength – winter wheat, Knockbeg

While the soil under RC is firmer and more compact and has a lower pore volume, the pore system is more stable and less easily damaged by traffic than pores in PL areas. Compaction damage does not extend as far into the soil on the reduced cultivation system (Tebrugge and During, 1999). The difference in depth of the tramlines between the RC and PL areas confirms this, with those on the RC barely visible while those on the PL can be quite deep. This does not mean that minimum tillage soil cannot be compacted sufficiently to cause crop yield loss, particularly on headlands.

Sugar Beet

Sugar beet is an important crop for many cereal growers and is perceived as a reason why they cannot commit themselves to a reduced cultivation system. For the past two years we have had a rotation experiment, on a reduced cultivation site at Oak Park (no ploughing), which includes sugar beet. The rotation is winter wheat, spring barley, sugar beet. Pre-sowing operations for the sugar beet consisted of a shallow (10 cm) tine cultivation after harvesting the previous barley crop followed by a total herbicide in September/October; in early March the plots were sprayed again with a total herbicide. The seedbed was prepared with a Kongskilde Triple K (2 runs) at about 10 cm deep the day before sowing with an Armer seeder. It was rolled after sowing. Some results for the sugar beet are given in Table 12.

Table 12: Plant population and yields – sugar beet – rotation experiment, Oak Park 2003-2004

Year	Root numbers (/ha)	Root yield (t/ha)	Sugar (%)	Extractability (%)	Extractable sugar (t/ha)
2003	84913	56.91	20.2	95.7	10.98
2004	80031	59.91	17.9	95.2	10.23
2004 (ploughed)	86383	71.39	17.7	95.6	12.10

Establishment has been uneven and early growth uneven and lacking in vigour. The root yields were similar in the two years. In 2003 there was considerable forking of the roots and while there was no direct comparison with roots from a ploughed crop, it was considered excessive at 18.3% badly forked. In 2004 a comparison was made with the commercial ploughed beet crop within a few metres of the experiment. In this case the commercial crop yielded 11 tonnes per hectare more than that on the reduced cultivation area. There was a big difference in the degree of forking between the two; in the commercial crop 11.9% of the roots were badly forked while in the reduced cultivation plots 28.2% were badly forked.

A study of the effects of reduced cultivation on weed beet has produced some interesting findings. On a site badly infested with weed beet, a comparison was made between PL and RC on a rotation with spring barley (2002 and 2003) and sugar beet in 2004. Obviously the weed beet would not be a problem in the cereal crop but the 2004 results were quite interesting. In the reduced cultivation plots the numbers of weed beet were greatly reduced (Table 13) and the yields were considerably higher compared with the ploughed areas. The yields of beet were much better and roots had less forking than on the reduced cultivation area at Oak Park.

Table 13: Weed beet counts and sugar beet yields – Ballybar 2004

Treatment	Weed beet nos. (/m^2)	Root yield (t/ha)	Sugar (%)	Extractable sugar (t/ha)
Reduced cultivation	2.2	68.5	18.1	11.8
Reduced cultivation + glyphosate	4.7	61.1	17.9	10.3
Glyphosate, cultivated, plough	18.6	46.8	17.1	7.8
Glyphosate + plough	28.4	51.5	17.8	8.7

It would seem that in the absence of weed beet, sugar beet yield and root shape are worse under a RC system. Where weed beet is a serious problem it may be worth considering changing from ploughing, as weed beet numbers can be reduced substantially with the stale seedbed and shallow cultivation technique.

CONCLUSIONS

- Plant establishment tends to be lower on RC than on PL especially in the first couple of years of the transition from a plough-based system. However, RC provides the opportunity to cultivate and sow large areas in a short time allowing crops to be sown in good conditions.

- Straw disposal method had no effect on plant establishment in these experiments, probably because the straw was well chopped and spread where it was being incorporated. Good chopping and spreading of straw is essential to maximise plant establishment under reduced cultivation systems.

- Reduced cultivation is capable of giving yields equal to or better than those after ploughing particularly with winter wheat, but problems arise which do not occur to the same extent with the conventional system. Diseases, such as take-all, may be less of a problem with shallow cultivation.

- Annual broadleaved weed populations tend to be lower under the reduced cultivation system but grass weeds may be more of a problem. Sterile brome in winter barley has proved to be a serious problem in these experiments.

- Crops grown in reduced cultivation systems, particularly where straw is incorporated, may have fewer aphids and less BYDV problems than those in plough-based systems.

- While slug numbers and leaf damage may increase after changing over to reduced cultivation, there does not appear to be any increase in damage to the seed or increase in plant loss. This may be due to slightly deeper sowing and the better consolidation which cultivator drills provide.

- Earthworms increase over time under shallow non-inversion tillage compared with ploughing. Straw incorporation also boosts earthworm populations.

- Soil strength increases in the topsoil under shallow cultivation making it less susceptible to compaction from wheel traffic. However, because the shallow cultivation will not remove any compaction that is caused, great care must be taken to avoid unnecessary traffic when the soil is moist and to use low ground pressure tyres on tractors, trailers and combines.

- Sugar beet yields have been lower and root shape poorer under reduced cultivation. Deeper cultivation may be needed for beet than we have used to date. Where weed beet is a serious problem reduced cultivation may provide a solution by reducing the seed bank in the top layer.

- Overall our experience with reduced cultivation has been quite positive to date and, provided certain basic precautions are taken, this system should prove successful on a large proportion of our tillage land. The only major problem that we have had is with grass weeds, in particular sterile brome.

REFERENCES

Forristal, D. and Fortune, T. 2002. New options for cereal cultivation. Teagasc National Tillage Conference Proceedings, Carlow, January 2002, 1-11.

Fortune, T., Kennedy, T., Mitchell, B. and Dunne, B. 2003. Reduced cultivations – agronomic and environmental aspects. Teagasc National Tillage Conference Proceedings, Carlow, January 2003, 70-82.

Tebrugge, F. and During, R.A. 1999. Reducing tillage intensity – a review of results from a long-term study in Germany. *Soil and Tillage Research* 53: 15-28.