CANADIAN AGRICULTURAL TRAVEL SCHOLARSHIP ASSOC.
(NUFFIELD TRAVEL SCHOLARSHIP)

REDUCED CULTIVATION SYSTEMS IN THE UNITED KINGDOM

BY
ARTHUR L. WESTLUND

JANUARY 1981

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My wife Frances.

OBJECTIVES OF STUDY TOUR

To study reduced cultivation systems of cereal growing in the U.K.

To visit individuals and research organization to gather information on reduced cultivation systems in the hopes that some of this information may be applicable to the Canadian situation.

BACKGROUND TO THE REPORT

Nuffield Farming Scholarships.

In 1946 the suggestion was put forward that the Nuffield Foundation might sponsor travelling scholarships for established farmers and growers. The first scholarships were awarded in 1947.

Running parallel with the United Kingdom scheme since 1950 the Nuffield Foundation organized a similiar scheme for farmers from the commonwealth to visit the United Kingdom for a period of six months to study modern techniques of husbandry and research.

In 1974 the Nuffield Foundation requested the participating countries - Australia, New Zealand and Canada - to fund their awards from their own resources, but agreed to continue to adminster the scheme.

Each country has now established a Nuffield Scholars Association which has close links with the Association in the United Kingdom.

In line with the devolution of responsibility from the Nuffield Foundation, which has now been completed for United Kingdom Farming Scholarships, the administration of the Commonwealth Scheme passed to Nuffield Farming Scholarships in 1977. Negotiations will be taking place with U.S.A. and E.E.C. countries to encourage their participation.

AUTHOR'S BACKGROUND

I'm a third generation farmer, and have lived at Brownlee Saskatchewan for most of my life. I recieved a B.S.A. in 1966 from the University of Saskatchewan, Saskatoon.

Since 1963 I have been actively engaged in farming and now have expanded into a mobile seed cleaning plant.

During the winter months from 1966 to 1975 I was employed as a Laboratory Assistant Supervisor by the Crop Science Dept. College of Agriculture, University of Saskatchewan.

I am also active in local community organizations and service groups.

INTRODUCTION

Since man first scratched the ground with a stick before planting seed his methods of cultivation have developed continuously. Today he has powerful tractors backed by a formidable choice of Agro chemicals, so that, when things go well, a very satisfying visual impression results with "everything under control".

With the great tecnological resources behind him why does the farmer still find his soil structure deteriorating.

Tillage is clearly responsible for a major part of this deterioration. The adverse effects of tillage on soil structure are well established - oxidation of organic matter by exposure to the surface, mechanical dispersion by puddling through the compaction and shearing action of implements, and by rainfall impact on bare soil. The readily noticable penalties are water and wind erosion. Less obvious are the interruptions to the circulation of air and water, both at the soil surface by capping and at the bottom of the plow furrow by wheel damage.

Therefore; our tillage operations should be designed to do minimum damage to the old root channels, to do minimum mechanical damage to soil structure and to provide minimum exposure of the soil surface to the destruction of organic matter and the battering of rain. There is also the very important consideration, in North America of reduced evaporation rates from undisturbed soil surfaces.

Ploughing has had several functions as the traditional method for preparing ground before sowing cereal crops. These include controlling weeds, bury crop residues and creating a seed bed to encourage germination and seedling establishment. Experiments in the 1930's on favourable soils shown that the main benefit from ploughing and other forms of cultivation was weed control. More recent research has examined the possibility of diminishing the number of cultivations in the seed bed preparation by exploiting the discovery of chemical herbicides, initially paraquat, (and atrazine for corn in the U.S.A.), amino-triazole and more recently glyphosate.

The estimated annual cost of cultivating the 3.7 million hectares of land on which cereals are grown in England and Wales is about $315 million Canadian dollars. Clay soils that can be difficult to manage by traditional methods occupies nearly half of this area. These soils are best suited to autumn sown crops and have the potential to produce heavy yields when adequately drained, but untimely cultivation, especially in wet autumns, can cause delay in sowing and often prevent achievement of this potential. Furthermore after ploughing such soils, the production of satisfactory seedbed usually involves much expenditure of energy and labour. The possiblity of minimizing or eliminating soil disturbance before sowing therefore has considerable practical and economic importance.

SITE OR FIELD SELECTION

Suitability of the soil for direct drilling is considered in terms of the likelihood of loss of yield from growing crops without cultivation in comparison with conventional methods based on mouldboard ploughs or heavy tined implements.

Evidence from field experiments and advisory work indicates that direct drilled crops can be affected by compaction in the top soil, often associated with lack of tilth, and water logging caused by low hydraulic conductivity in the subsoil both of which may lead to yield reductions.

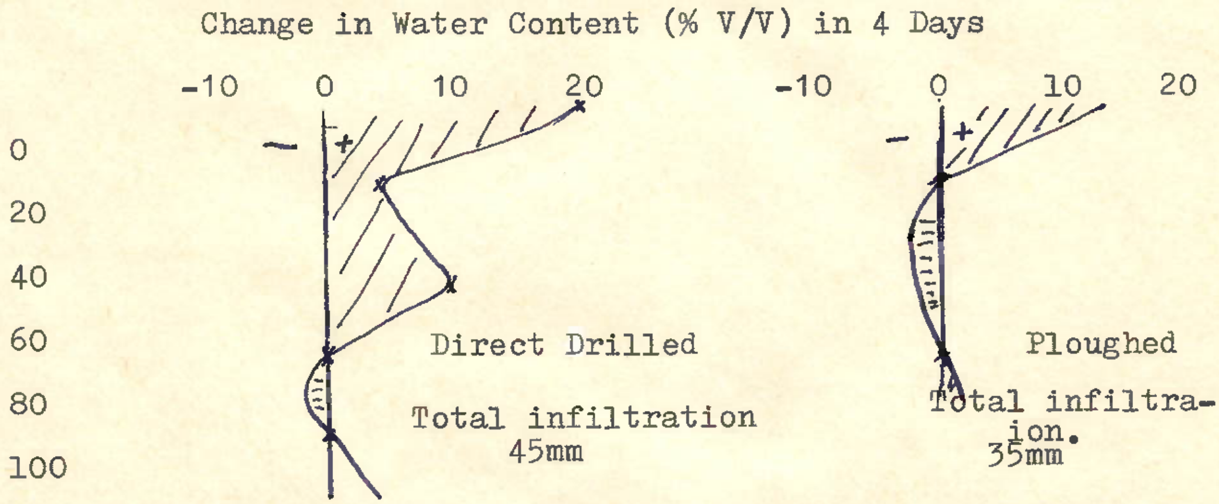
However, for most soils, there is insufficient informations on the effects of repeated direct drilling on soil conditions. Some of the effects may adversely affect crop growth, and others may be beneficial; the effects may not be as expected on all soils and they may not be important in all seasons.

With direct drilling the surface layers of the soil are more compacted than they are after ploughing also the total and air-filled pore space is considerably reduced.

Total Pore Space and Air-Filled Pore Space in Drenchworth Series Soil After One Year of Ploughing or Direct Drilling.

	Total Voloume of Pores as % of Soil Volume		Volume of Air-Filled pores as % of soil Volumne.	
Depth (cm)	Plough	Direct Drill	Plough	Direct Drill
0-5	72	68	41	22
5-10	70	63	26	16
10-15	69	68	24	20

However, on well structured soils, and especially on some clay soils, these changes are poor indices fo the suitability of the soil for root growth. In particular on such soils which have been direct drilled for two to three years there is some evidence of changes in soil conditions, some of which may lead to improvement in root growth. The main effects may be summarized as: the formation of friable surface tilths, associated with increased organic matter in the soil, and greater stability of soil aggregates in the surface zone: deeper and more continuous cracking, increased earthworm populations: sometimes aeration below seed depth can be greater than on ploughed land; ploughing in wet conditions can cause smearing of the plough sole which may restrict infiltrations of water. (Even after ploughing in relatively dry condition infiltrations of water can be much retarded in comparison with direct drilled land, providing further evidence of more continous channels in unploughed soil); better trafficabilty root elongation of seedlings may be slower but when the changes related to cracking and earthworm populations have occurred roots can be more numerous below about 50cm, making possible greater withdrawalof water in dry conditions, sometimes with increased yield.



Effect of cultivation on infiltration and movement of water in a silt loam soil in the four days after 49mm rainfall.

LIMITING SOIL FACTORS

Lack of Tilth- Soils exhibiting a tendancy for the surface layers to pack tightly either through slaking or the inability of the soil to form a natural surface tilth by weathering are less suitable for direct drilling unless it includes surface cultivation. When crops are drilled into a compacted surface there is likelihood of inadequately covered seeds, of smearing soil by drill coulters, and of both excessive soil strength and local ponding in the vicinity of seeds. In such conditions there is a greater risk of seedling losses from slugs and from the toxic effects of decomposing straw residues. Any form of cultivation in such conditions, including the use of tine drills may be expected to reduce the risk of unsatisfactory establishment and growth.

TOPSOIL COMPACTIONS

Given sufficient pressure all mineral soil types will compact to restrict drill preformance and crop growth, but soils vary widely in their resistance to, and recovery from compaction. Pressure under the wheels of farm machinery is the major source of compaction in U.K. agriculture, and the overriding cause of compaction on non-slaking soils eg. many clays. On the weaker structured soils the formations of dense layers can occur by slaking without traffic, but is intensified by traffic.

Timely cultivations provide an opportunity to relieve compaction in the topsoil and , to the extent that excesssive compaction may occur in direct drilled land, the system is more at risk. In the absence of cultivation a soil reaches an equilibrium level of consolidation dependant on the inherent soil properties and amount of traffic over the soil, interacting with the soil moisture regime. Where excessive compaction develops, the risk of surface ponding and water erosion is increased during wet periods, and during prolonged dry periods, effects of drought will be accentuated. In these conditions crop establishment is liable to be patchy and retarded, tillering reduced, weed populations greater and final yield lower. Although direct drilled land is more trafficable than cultivated land, large reductions in ground pressures under machinery and / or use of flotation tire, would extend the soil types on which direct drilling could be routinely adopted.

Resistance to compaction in soils is usually associated with the following soils and soil property.

a) drainage-- soils that drain rapidly are less at risk from both wheel traffic and slaking damage than soils which drain slowly.

b) texture-- loamy and peaty soils and some calcareous clayey soils are relatively resistant to compaction. Conversly low organic matter sandy soils with either a wide distribution of grain sizes or a predominace of fine sand particles, usually compact readily. Others which tend to compact are non-calareous soils with large amounts of silt, sandy clay loams and sandy loams and loamy sands with small amounts of clay- sized particles.

FREE LIME

Large quantities of natural occurring calcium carbonate is generally associated with easier working properties, a greater tendancy to weather down to fine stable tilth and more resistant to over compaction.

SURFACE MULCHING

Many clayey and loamy soils in England break down to give a fine stable surface tilth under the influence of weathering cycles. Surface tilth although not essential for successful direct drilling, ensures both adequate drill penetration and sufficient fine soil for covering the seed.

SLOW SUBSOIL DRAINAGE

Periodic waterlogging over several years causes a gradual deterioration of soil structure, increased weed population and a decline in crop yields.It has been shown that direct drilled and shallow cultivated crops can be more susceptible to these changes than conventionally cultivated crops. Possible explanations for this difference are that in direct drilled topsoils there is less air-filled pore space and therefore saturation is reached more quickly excess water is unable to drain laterally at "plough" depth; and there is a lack of surface roughness and the opportunity that this provides for local drainage of water. Surface ponding is more likely on inadequately drained undulating fields.

Experience has shown that direct drilled crops can be more at risk in wet years. The problems encountered in wetter areas are:

- more structured damage and rutting at harvest and during subsequent field operations.
- more risk of surface ponding and waterlogging on clayey and weakly structure soils.
- later harvest, reducing opportunity for disposal of crop residues and for weed control.
- less development of surface tilth produced by weathering
- more risk of grass weed competition.
- more delay in drilling of surface crops because of surface wetness.

CROP RESIDUE MANAGEMENT

The importance of maintaining an adequate organic matter content in the soil has been long recognized in arable cultivation. Extensive comparisons of the effects of different methods of straw disposal (7.5 tonnes per acre from a good winter wheat crop) on arable land which has been ploughed and cultivated by traditional methos has been carried out. There was large responesto nitrogen when straw was present, and the benefits of organic manuring could be explained in terms of their content of other nutrients; there was no indication that the incorporation of straw benefited yields in other ways. Nor was their evidence that the organic matter content of the soil was appreciably increased. Thus the plowing of straw into the soil appears to be not so much a methods of improving soil fertility as the most convenient way of disposing of unwanted material, except perhaps on soils with poor structural qualities and a low organic matter content.

Lately, simplified methos of cultivation, made possible by the use of herbicides, have directed increased attention to the problems straw can create. Not only is there a much shorter interval in which it can decompose but there is no opportunity to bury it deeply in the soil and the surface litter which is left can lead to very poor establishment of the subsequent crop. Disposal of the straw can be essential for success.

The most obvious advantages of straw burning in the short term are;

a) direct cost of removal is low.

b) volunteer cereal and weed seeds, expecially black grass and wild oat, may be destroyed, or at least discouraged.

c) slugs are less numerous.

d) the incidence of leaf blotch is reduced.

e) crop production may be increased.

f) there are fewer mechanical problems at drilling.

However despite these immediate advantages of straw burning, it is also necessary to consider whether the soil will suffer in the long run. With reduced cultivation or direct drilling the possible augmentation of soil organic matter by straw appears to less important because, irrespective of whether standing stubble is left or the straw is burnt; the organic matter of the surface soil normally increases compared with that found when the soil is ploughed. One reason for the conservation of organic matter is these conditions was identified many years before herbicides made simplified cultivation practicable. The oxidation of organic matter, and therefore its loss, is increased by the disturbance of the soil and with conventional cultivation disturbance is particulary great in the surface layers in which plant roots are most numerous. This is a reason why soil conditions improve when land is under grass for a period of year; though ploughing for a single season can sometimes largely eliminate the greater soil stability which has been developed.

Not only is the organic matter content of the surface layers of the soil increased, in a reduced cultivation system, but the soil aggregates are more stable. Results from a sandy loam soil which had been ploughed or direct drilled for two years after grass (Table below), show the resistance of soil aggregates to disintegration on the impact of droplets of water and the organic matter content for both were considerably decreased by ploughing; after direct drilling the decreases were considerably smaller. In the United Kingdom the organic matter content of the surface soil increased significantly on a clay soil; (8% organic matter prior to harvest and 11% after fall burning) which had been direct drilled rather than ploughed for ten years.

STABILTIY OF SOIL AGGREATES AND ORGANIC MATTER CONTENT IN A SANDY LOAM AFTER 2 YEARS PLOUGHING OR DIRECT DRILLING.

Depth ('cm)	%aggregates in each stability category: Low Stability	High Stability	organic matter content %
Ploughed Plots			
0-2.5	46	7	7.8
2.5-5	58	2	7.4
Direct Drilled Plots			
0-2.5	20	36	9.5
2.5-5	26	6	7.8
Grass Reference Area			
0-2.5	6	56	10.0
2.5-5	5	26	7.4

Low stabilty aggregates required <25 droplets of water for disintegration and high stability aggregates >200 droplets.

There are also some indications that the burning of straw may increase soil stability and cause the moisture content of the surface soil at the time of plowing to be lower. Also, water may infiltrate more rapidly into direct-drilled land than into land which has been cultivated by conventional means.

The disposal of straw by burning or by other means seems no disadvantage for the maintenance of good soil conditions which reduced cultivation or direct drilling. Moreover, the agronomic problems which can arise when straw is present in appreciable quantities can be serious. The presence of straw residues resulted in smaller crop yields, especially after direct drilling, but small decreases also occurred when straw was ploughed into the soil.

EFFECTS OF DIFFERENT METHODS OF STRAW DISPOSAL ON THE YIELD OF WINTER WHEAT AFTER CONTRASTING METHODS OF CULTIVATION.

Drayton Experimental Husbandry Farm 1974-1976

Yield t/ha and as percentage of yield following burning.

	Burned	Baled	Chopped
Ploughed	4.37	4.87	3.66
Cultivated	4.34	3.73	3.49
Direct Drilled	4.59	2.18	2.06
Mean	100% 4.43	74% 3.26	71% 3.15

When wet wheat staw which had started to decompose was taken from the field, it was shown to contain water soluable phytotoxic materials which retarded the extension of young seedling roots, leading to necrosis of the apical meristems and death of the plants. Acetic acid and smaller amounts of propionic and butyric acids were produced under anerobic conditions.

Decomposing plant residues can be of considerable greater significance with mininmal tillage than in conventional systems of cultivation for two reasons. First, the short interval between successive crops gives little opportunity for the toxic substances to be lost by leaching or by further microbical degradation. Secondly, with shallow cultivation, and still more with direct drilling using present machinery the decomposing straw is likely to be in much closer contact with the germinating seed, which is therefore exposed to higher concentrations of toxic substances. Some experiments have shown that the concentration of acetic acid 1.5 cm. from a continuous layer of straw is only about half that immediately adjacent to it. The movement of the acid must be expected to differ between soils but it is clear that the toxic effects are greatest when the seed and straw are in close contact.

It has also been shown that there is a relationship between nitrogen and phosphorous and toxin formation. Nitrates prevents formation of acetic acid so prevents formation of toxin; on the other hand phosphorous seems to hasten breakdown of straw and thus toxin formation is increased.

The satisfactory disposal of straw in the case of a previous cereal can have a bearing on the potential of the following crop and this is particularly so with certain methods of establishment.

EFFECT OF STRAW TREATMENT ON YIELD

ALL CROPS

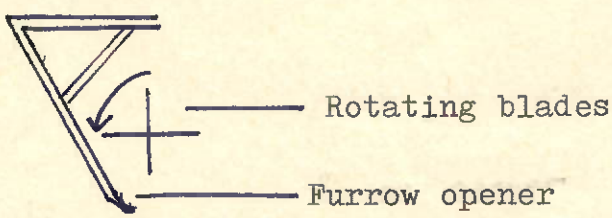
Treatment	Sowing Date	Yield T/ha
Baled	13 Oct	6.7
Poor Burn	14 Oct	6.4
Good Burn	11 Oct	7.0

DIRECT DRILLED CROPS

Treatment	Sowing Date	Yield T/ha
Baled	14 Oct	6.0
Poor Burn	12 Oct	6.2
Good Burn	9 Oct	7.1

TYPE OF DRILL

In general, the soil condition most influencing cereal drill performance are mechanical resistance and shear strength, which are both greatly increased under zero tillage. This makes it more difficult for the soil opening device to penetrate to its proper working depth and increases the force required to pull the coulter through the ground. However, the amount of straw or trash on the surface may also be much greater under zero tillage and the soil opener must cut through this if it is to penetrate the soil and preform well without frequent stoppages. The major advantages of tine coulters is that their shape generates a downward force component, which facilitates penetration to the required working depth. A heavy drill frame is thus not needed, and unecessary soil compaction is avoided. However loose straw makes the use of tine drills difficult and frequent blockages may occur. A rotating knife placed in front of the tine may help to alleviate the problem of straw bridging.



The sharp leading edge of a disc coulter usually deals effectively with surface trash and requires a lower draught force than a tine, but the shape of the disc does not aid downward penetration because any resultant force is upward, tending to lift the disc out of the soil.

The increased strength and resistance of soils under zero-tillage tend to aggrevate this problem. A heavy frame is required to achieve adequate and uniform working depth in all but the lighest soils, and this can give rise to undesirable compaction effects. Direct drills with discs coulters are very heavy and do not always achieve and adequate working depth. They are also more likely to cause smearing of the slit wall than are tine drills, and are more likely to leave the slot open, leading to possible slug infestation and poor germination unless an tilth is present naturally or is created by harrowing. Neither tine nor disc coulter, when mounted in commonly available direct drills, show adequate contour following ability for soils which lack a natural titlh and which show wheel rutting.

Refinement of current soil - opener systems, using disc, tines or some combination of these, may increase their efficiency in zero-tillage condition. However it seems likely that a different approach will be needed if a substantial improvement in preformance is to be made. This may involve its trash clearing properties, to reduce silt smearing and to assist penetration. Although a drill of this type would apply some cultivating power to the soil, it would differ from conventional reduced-cultivation systems in that no cultivation is required prior to drilling and only narrow strips to recieve the seed are cultivated.

The following are brief descriptions of direct drills used in the United Kingdom. All of these drills are capable of either traditional cultivations, minimum cultivations or direct drilling.

The Betteson 3D

A number of coulter systems are avaible for the Bettison Drill. All are readily interchangeable and allow the user to chose the most appropiate system for his condition.

1) 3 disc - for general purpose direct drilling.
 - good penetration on all but the hardest soils, excellent trash clearance.

2) single disc - for conventional and minimal cultivation systems.
 - direct drilling into tilthy conditions.

3) single disc and spring tine coulter--spring cereal direct drilling and conventional sowing.
 - creates extra tilth
 - better contour following and trash clearance.

The Moore Uni Drill

A single disc and roller drill specially designed for direct drilling grass and forage crops, which incorporates a Cambridge roller to conserve moisture around the seed.

IHC 511 Cultivator Drill

A drill having spring tines making it ideal on most heavy land if not too much trash is present.

Howard Rotaseeder

A drill in which special rotors cut a slot in the soil into which the seed is placed. This slot cutting facility makes it particularly useful on hard soils or grassland.

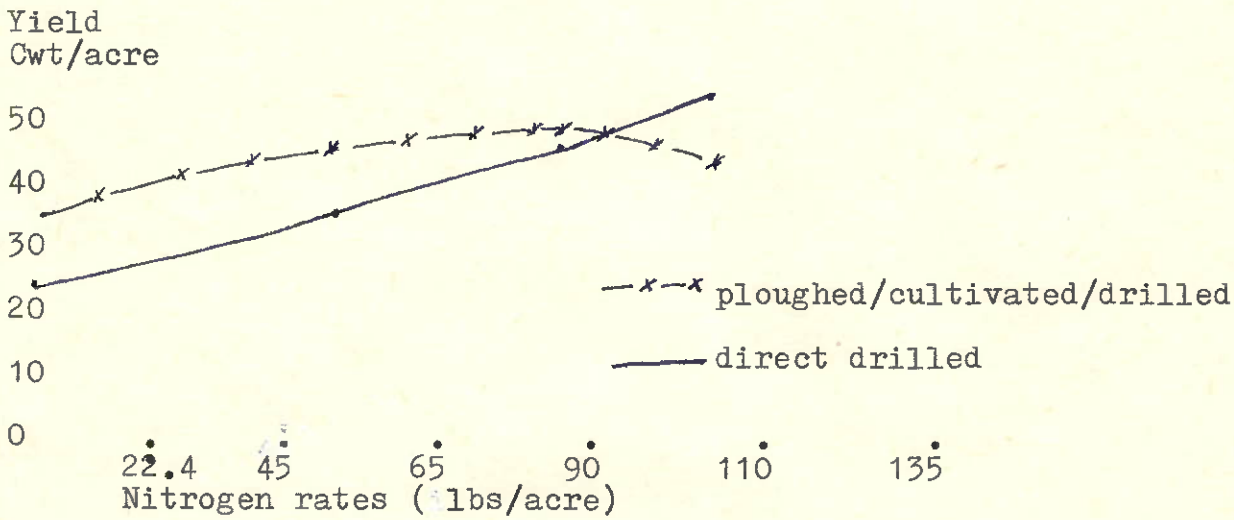
TIMING OF DRILLING

Direct drilled winter cereals should be sown earlier than crops drilled into cultivated land. Whenever possible drilling should be finished by mid October particularly important on the less suitable soils for direct drilling. However, earlier drilling in the autumn, (eg. during Sept.,) bring with it the additional risks from grass weed competition and possibly from certain cereal diseases. Direct drilled plants grow more slowly partially due to the fact that the soil temperature is lower.

FERTILIZERS

There is some evidence that direct drilled crops may require more nitrogen fertilizer to reach their maxium yield.

Spring Barley Yield
Jealotts Hill Berkshire



But on the otherhand the response to nitrogen at Boxworth Experimental Husbandry Farm has been the same for winter wheat crops after direct drilling or after cultivations. During the period 1976-1979 experimental results indicated that between 145 and 180 kg/haN. produced the optimum economic yield response in long runs of wheat. Further work, done at the Letcombe Laboratory, using nitrogen -15 labelled fertilizer in microplots on a clay soil indicate that the uptake of nitorgen by winter wheat was not influenced by the cultivation methods used in the previous five years. Concurrent studies at the same site on the response of winter wheat to a range of nitrogen application rates showed no interaction between nitrogen and cultivation.

Reduced uptake of phosphorous and potassium by direct drilled crops in dry seasons might be expected because of dehydration of the roots and soil in the surface layers where nutrients are concentrated. Nevertheless, even in an abnormally dry season (1976) the uptake of phosphorous and potassium were similiar after all types of cultivation.

Since the uptake of phosphorous and potassium was similar after direct drilling and other methods of cultivation, it seems unlikely that on these soils direct drilling will lead to any restriction of nutrient uptake by cereals, unless continuation of the direct drilling leads to more pronounced differences in nutrient gradients. Nutrient uptake after direct drilling under dry conditions on soils of low nutrient status, low moisture holding capacity or with very pronounced nutrient gradients may be restricted. Reduced phosphorous and potassium uptake may also occur under drought conditions with late spring sown direct drilled crops.

The smaller uptake of nitrogen by the winter wheat crops at the beginning of stem elongation on the direct drilled land may be partly attributable to lower rates of mineralization of organic matter in uncultivated soil.

An investigation into the timing of nitrogen for direct drilled winter wheat during the period 1975-1979 at Boxworth EHF showed a clear requirement for a small amount of autumn nitrogen to counteract the lower mineralized nitrogen available in an undisturbed soil. Early sowing in September and early October benefited most from 25 kg/ha autumn nitrogen. which was shown to be more efficiently utilized in terms of kg grain yield per kg nitrogen than the same amount of extra nitrogen applied with the spring top dressing. The benefit from autumn nitrogen was additional to that from even the higest rate of spring nitrogen tested. This result was in complete contrast to the effect of autumn nitrogen in conventionally cutivated soils where most evidence has shown no response except when spring nitrogen rates have been well below optimum.

The requirement of direct drilling for a small increment of autumn nitrogen has been confiremed. It was shown that the autumn nitrogen requirement was inversely related to the degree of soil disturbance.

Effects of autumn nitrogen in minimum cultivation systems.

Yield of grain (Tonnes/ hectare)

	Single nitrogen first node of stem visual	30kg autumn N balance at first node of stem visual
Direct Drill -single disc	5.83	+ 0.19
Direct Drill - tined drill	5.67	+ 0.17
5 cm cultivation	6.14	+ 0.02
10 cm shallow plough	5.93	+ 0.05
15 cm cultivation	5.87	- 0.05
Rotadigger	5.55	- 0.06

Three years of trials with direct drilled winter wheat at Boxworth EHF have shown an average yield increase from splitting the spring nitrogen top dressing particularly when autumn nitrogen was applied. This response was confirmed to early drilled crops (early - mid October). The split treatment was 30 Kg/ha N in early March with the remainder in late April, compared with the full amount at the later date. These results confirm the need to apply a small amount of nitrogen early to direct drilled winter cereals to compensate for the reduced contribution of nitrogen from mineralization of soil organic matter.

Effects of Timing of Nitrogen on Yield of Direct Drilled Winter Wheat at Boxworth (October Sown) tonnes/hectare

	Autumn N		Autumn N	
	Nil	.25 Kg/ha	Nil	25 Kg/ha
	Spring top dressing at GS 5-6[1] (Early May)		Spring top dressing at GS 2-3[2] (March) and GS 5-6[1] (early May)	
1974-75	6.45	6.78	6.81	6.97
1975-76	5.01	5.27	5.11	5.77
1976-77	5.89	6.25	6.15	6.34
Average	5.78	6.10	6.02	6.36
%Yield	91%	96%	95%	100%

[1]GS 5-6 --leaf sheaths strongly erected to first node of stem visible

[2]GS 2-3 --tillering begins to tillers formed.

Very late top dressings applied at flag leaf or ear emergence have shown no advantages in terms of yield over applying all the nitrogen at G.S. 5. They will however increase the protein content of the grain.

The results of an experiment done at Boxworth EHF are shown in the following tables. The basal top dressing was 105 kg/ha applied as a split dressing with one third applied in April and two thirds applied in early May. The effect of 37 kg/ha nitrogen applied at ear emergence as a foliar spray or top dressing.

Tonnes/hectare for different varieties

	1	2	3	4	5	6	7	Mean
Nil	8.32	6.25	6.67	5.65	5.06	6.10	6.51	6.36
Top Dressing	7.39	6.20	6.89	5.80	4.79	5.80	6.30	6.16
Foliar Spray	7.83	6.67	7.19	6.00	4.91	6.69	6.83	6.59

Percentage Crude Protein

Nil	12.2	12.6	12.3	13.3	13.8	13.1	12.8	12.9
Top Dressing	12.6	13.3	13.7	14.0	13.9	13.1	12.8	13.3
Foliar Spray	12.6	13.3	13.1	14.5	14.1	13.4	13.4	13.5

The split application of the basal top dressing resulted in good yields with moderately good grain protein content. The late application of nitrogen especially when applied as a foliar spray further increased the percentage grain protein.

ECONOMIC ASPECTS OF REDUCED TILLAGE SYSTEMS

To achieve any economic advantage over traditional methods, non-plough techniques must

a) show a reduction in costs

b) and / or show an increase in the productivity of resources.

Approximate total costs per hectare of cultivation methods compared in a cereal rotation

Direct Drilling		Reduced Cutlivation		Traditional Ploughing	
Spray Materials	$31.40	3X Tine Cultivation	$63.00	Plough	$50.40
Spraying	7.70	Spray Material	15.70	2X Discing	35.00
Harrowing	10.00	Spraying	7.70	Spray Material	7.85
Drill Hire	56.00	Harrowing	10.00	Spraying	7.70
		Drill	14.85	Harrowing	10.00
				Drill	14.85
Total Cost	$105.10		$111.25		$125.80

The above table shows that the cost of traditional ploughing in 1978 was approximately $20 per hectare greater than for direct drilling.

In a mixed farming situation the fixed costs of labour, machinery depreciation etc. cannot be readily reduced. The equipment and labour have to be maintained to carry on essential operations and also as an insurance against the possibility of conditions preventing the use of direct drilling in a certain seasons. In order to arrive at a decision of whether to introduce direct drilling in a mixed arable system, it is therefore desirable to examine and compare the variable costs incurred by the cultivation methods to be adopted or introduced.

Approximate Variable Costs of Cultivation Methods Compared (per hectare)

Direct Drilled	Reduced Cultivations	Traditional Ploughing
Spray Material $31.35	Spray Material $15.70	Spray Material $ 7.85
Fuel, Oil, Repairs 7.35	Fuel,Oil, Repairs (including drilling) 31.95	Fuel, Oil, Repairs (including drilling) 45.35
*Drill Hire 56.00		
Total Variable Costs $94.70	$47.65	$53.20

* The cost of a special drill or a contractor must be included with direct drilling.

The purchase of a direct drill can only be justified on farms with large cereal acreages. Thus for a small cereal grower wishing to introduce direct drilling the employment of a contractor would be the better proposition. The alternative would be the purchase of a dual purpose drill which would be used for direct drilling where soil conditions are suitable. Generally speaking the introduction of direct drilling in a mixed arable farming system remains a doubtful proposition if the direct costs of the methods above are considered.

The system can be substantially different on a large, predominantly cereal farm. There could be significant savings in fixed costs if the whole system is based on non ploughing techniques. The investment in motive power would be substantially reduced and the only additional investment that would have to be incurred for direct drilling is the purchase of an appropriate drill.

The greatest economic advantage from adopting non ploughing techniques, however, will be obtained from increased production through

1) better timeliness of sowing at or near optimum time
2) establishment of crops giving higher gross margins
3) establishment of winter cereal crops in years of adverse weather conditions.

On arable farms the critical peak demand for labour occurs after the cereal harvest. Ploughing for winter cereals often coincides with root harvesting, straw disposal and stubble clearing. At this time root and vegetable harvesting is usually given priority due to the competition for available labour, and there is a danger that autumn crops will not be sown on time.

The choice is often between a crop of winter wheat and spring barley.

On average, winter wheat has outyielded spring barley

Average yields 1974-1978

Wheat -	4.65 tonnes/ hectare
Barley[1]-	3.97 tonnes/ hectare

1- spring and winter barely

The price differential is also in favour of wheat. On 1978 prices and taking average yields winter wheat will generate an additional gross margin of approximately $170.00 per hectare.

Winter wheat		Spring Barley	
4.5 tonnes @ $252/tonne=	$1171.80	3.97 tonnes @ $238/tonne=	944.85
Less variable costs		Less variable costs	
Seed	$100.00	Seed	$ 84.00
Fertilizers	95.20	Fertilizers	92.40
Sprays	84.00	Sprays	44.80
	280.00		221.20
Gross Margin	$891.80	Gross Margin	723.65

The objective should, therefore, be to establish the maximum area of winter wheat within any given rotational constraints, but a major determining factor is usually the weather conditions during the autumn peak labour period.

Area established by different cultivation methods
(including drilling)

	Plough	Reduced Cultivation	Direct Drill
Man hrs/ hectare	5.2	3.7	1
Hectare established per 40 hour week	7.7	10.8	40

It can be seen from the above chart that direct drilling lends itself to more acres of cereals being established at the optimum time in the fall.

EFFECTS ON YIELD

First results from the experiments on non-calcareous clay support the view that simplified cultivation systems are at least as satisfactory as ploughing, although on heavier clays in wet easons ploughing still had an advantage, expecially when insufficient nitrogen fertilzer was applied.

Effect of method of cultivation on yield (tonnes/ha) of winter wheat on clay soils.

	Lawford Series (35% clay)			Drenchworth Series (50% clay)	
	Direct Drill	Shallow-tined	Ploughed	Direct Drilled	Ploughed
1976	5.5	5.2	4.8	6.4	5.8
1978 Low N	8.6	8.3	9.3	7.5	9.0
High N	10.5	10.2	10.2	9.4	10.0

Note: 1976 was a very low rainfall year.

The results for 1978 are of special interest because where the nitrogen fertilizer applications was adequate heavy yields, between 9.4 and 10.5 tonnes per hectare, where achieved whatever the cultivation treatment.

The ARC Letcombe Laboratory and Weed Research Organization have conducted long term experiments comparing traditional and reduced cultivation systems. Since 1968 the effects of direct drilling, tine cultivation (to 8cm or 15cm depth) and ploughing on spring barely and winter wheat have been compared for at least four consecutive seasons on three contrasting arable cultivations in Britian: a sandy loam; a calcareous silt loam over chalk and a calcareous clay.

Summary of Cereal Grain Yields Obtained after Different Cultivation Treatments.

Crop and Soil	Number of Harvests	Average Yield after plough t/ha	Yield as a percentage of that after ploughing		
			Tine Cultivation		Direct Drill
			Shallow	Deep	
Spring Barley					
Sandy Loam	5	5.02	99	97	97
Silt Loam over Chalk	4	3.70	107	105	104
Clay	4	4.76	101	100	100
Winter Wheat					
Sandy Loam	5	4.02	104	103	99
Silt Loam over Chalk	4	5.77	98	96	99
Clay	4	4.91	104	95	104

These findings, together with observations on the effects of cultivation on soil structure, suggests that direct drilling and shallow cultivation might be of greatest practical value on soils with structural problems but which are otherwise fertile and capable, with good management, of consistently producing heavy crop yields.

ASPECTS OF DIRECT DRILLING REQUIRING FURTHER RESEARCH

The effects of simplified cultivations on soil conditions need to be observed over a longer period, so that the cumulative effects on soil physical properties and on the availability of nitrogen can be more accurately described. Although direct drilled land is often more resistant to compaction and thus more trafficable than land that has been ploughed, many of the clay soils are easily deformed when wet and there is the possibility of cumulative effects of wheel damage; without cultivation there is no opportunity to counteract these effects. The possible benefits from sub-soiling also needs to be more clearly established.

Assessments of simplified cultivation on clay soils have been made on land drained according to recommendations for ploughed land. However, in view of the effects of soil physical properties, the drainage requirements may depend upon the cultivation treatments. The top soil of direct drilled land has a relatively small total pore space and could be expected also to have a smaller hydraulic conductivity than ploughed soil. Thus, the lateral movement of water to drains is likely to be relatively impeded. On the other hand, these effects of persisting earthworm channels and cracks between peds that are not destroyed each year by ploughing can substantially aid infiltration of water.

As, yet the relative extent of these effects on the drainage requirements of heavy land are not full understood.

On many soils it would seem advantageous to leave the soil below seeding depth undisturbed apart from drainage operations or sub-soiling to disrupt compact layers. However soil conditions may not be the main constraint limiting the adaption of simplified methods of cultivation. The problems of coping with straw residues, designing direct drills for fast and accurate working and controlling some weeds remain to be fully solved and continue to be the subjcet of investigation at several Institutes of the Agricultural Research Service, and by the Ministry of Agriculture, Fisheries and Food and the Universities.

INDIVIDUALS AND INSTITUTIONS VISITED DURING THE STUDY

Agricultural Advisory and Development Services

-numerous field officers and staff

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Bridgets Experimental Husbandry Farm, Hampshire.
-Mr. Colin Slade-Director

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Drayton Experimental Husbandry Farm, Warwickshire
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European Economic Community, Brussels. Belgium
-various department heads, officials and staff.

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-various departmental heads.

National Agriculture Centre, Stoneleigh

National Farmers Union
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-various officers and directors
-county secretaries and local officials.

National Insitute of Agriculture Engineering, Silsoe
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Wye College, Kent.

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Fact or Fantasy

b) Progress with Reduced Cultivation

c) The Yield of Cereals

ICI Plant Protection

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ADAS Eastern Region 1973-76.

k) Wheat production at Boxworth EHF

Outlook on Agriculture Volume 8
ICI Plant Protection Division

Outlook on Agriculture Volume (9)
ICI Plant Protection Division

Pointer to Profitable Wheat

PLACES VISITED ON THE NUFFIELD SCHOLARS TOUR OF THE SOUTH WEST REGION AND THE STUDY AREA.

Mr. H. Black- Hill farming, suckler cows.

Ms S. Chick- Beef and meat marketing.

Dartington Glass- Hand made glass.

Darlington Hall Farms- Large scale dairying, AI centre, crafts

Express Dairy Foods Ltd.- Cheese making.

Mr. M.D. Horrell- Dairying.

Mr. C.G. Hyde- Sheep; Landlord/Tennant Co-operation

Mr. G. Maddever- Pigs.

Mr. H.B. Maund- Fish Farming

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Mr. M. Perry- Mooreland grazing.

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Mr. J. Rossiter- South Devon Cattle.

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