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How Much Cultivation?

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How much cultivation?

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Cultivation is the application of ideas derived from soil science, agronomy, plant pathology, entomology, engineering and economics to the practical problem of tilling the soil.

Few dogmatic statements can be made in view of the many variables of soil, climate and crop but for most arable farming situations the trend has been a progressive elimination of excessive cultivation saving particularly manpower. For many perennial crops, mainly horticultural, it is possible virtually to eliminate tillage. There is a need to establish how little soil disturbance is necessary for germination and growth.

Nevertheless, crops seldom achieve even half their theoretical potential yield. Sometimes the discrepancy can easily be accounted for because of weather, disease or pest attack. However, badly timed, ill-chosen or unnecessary cultivations are often culpable though seldom readily accepted by the farmer as valid reasons.

Clearly tillage techniques can be a limiting factor to crop performance, and, in the future, as the need for higher yields becomes economically more imperative, the farmer will have to pay increased attention to avoid the use of those implements and techniques restricting crop potential.

Introduction

Before trying to explore the implications of the rhetorical question which is my title, it may be appropriate to point out that although cultivation has a long history, the influence of scientific reasoning has been so recent that several of the distinguished pioneers are in this room. It may help to clarify the nature of the topic to quote the words of one of them:

'Cultivation of the soil has some of the basic characteristics of card games such as bridge and poker; the farmer attempts to apply both systems and skills to a set of random variables dealt to him by the weather and by the populations of weeds, pests and pathogens. He aims therefore to achieve the maximum control of the crop environment ... As scientists of the many disciplines concerned with soils we know full well that nothing of the sort has been achieved. The farmer has secured only a precarious and temporary balance of advantage in a seething micro-scale jungle, of whose pathways and inhabitants we know only a little and we understand even less.' (Pereira 1975).

In addition to weather and weeds, pests and pathogens, however, there are other important variables: soils, crops and economics, all of which affect the way farmers think and act. Cultivation is not just a branch of science but the means whereby arable farmers grow the crops which provide their income. My objective will be to attempt to show how, for various crops, farmers' ideas are being modified by science and economics, leading to changes in the whole approach to cultivation. There are obviously ecological implications of changing techniques of tillage, for example on soil fauna, pathogens and the weed flora. Time and my own background will not permit these being discussed as fully as inputs and yield which are more relevant to the title of this discussion meeting.

The stimulus to change is largely economic. Labour has been disappearing from farms – a 47 % reduction between 1960 and 1975 – and in the same period the minimum wage for an adult man rose by 380 %. In the past 2 years the cost of running a tractor has trebled. Farming has become more specialized, with most commodities being produced by fewer farmers on a larger scale, and this has created peak work loads which have become increasingly difficult to meet. It is now no longer likely that anyone could state that 'One of the firmly rooted traditions of British agriculture is the virtue of thorough cultivation; indeed the majority of farmers believe that crops will suffer and yields drop by just the extent that the soil tilth falls short of perfection.' (Keen & Russell 1937)

Table 1. Direct drilling by crops (hectares)

crop	1971	1972	1973	1974	1975
winter cereals	5957	15969	30680	36364	41737
spring cereals	959	2149	3693	6231	10158
kale and rape swedes and turnips	16378	20504	27136	37849	35083
catch crop fodder	3168	6107	13550	19934	28726
peas and beans	85	69	291	550	553
maize	—	100	93	524	1201
oilseed rape	—	1527	8090	15081	25440
fodder rye	—	591	1415	2395	2744
miscellaneous	—	184	205	306	870
grass into grass	7608	3919	5287	7436	13686
grass into stubbles		3587	8762	13883	18425
sugar beet	—	—	—	—	154
total	**34155**	**56160**	**101757**	**143804**	**183921**

A generation or so ago it was not uncommon to plough an arable field more than once, and follow with many operations by tine or disk implements. Occasionally the land would be worked ten times or more before planting potatoes or roots. This repeated cultivation was not merely costly and liable to delay sowing, but could be detrimental, by drying out the seedbed. It was usually unnecessary, science having shown with increasing clarity that weed competition generally affects crop yield more than does tilth. Not merely are farmers devoting less effort to conventional methods of cultivation but increasing proportions of some crops are now being sown by 'direct drilling' techniques into the undisturbed soil following a previous crop (Allen 1975 and private communication).

Before considering cultivation techniques for various crops, perhaps I should touch on the question of drainage. While it would be inappropriate to widen the definition of cultivation to include all aspects of land drainage, some might be prepared to argue that mole draining (probably the most effective and cheapest method of drainage where conditions are suitable) could be regarded as a cultivation. In my view subsoiling is certainly a cultivation, and its importance in permitting water to percolate into a drainage system or encouraging unrestricted root growth is unquestionable. One of the gaps in our knowledge seems to be whether subsoil must be disturbed more frequently as we move towards systems of reduced surface cultivation and how it should be done to ensure good results. If subsoiling could be dispensed with, or become an occasional job for a contractor, this would have a very significant effect on the farmer's tractor strength and its costs.

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Perennial crops

Most of our perennial crops, dominated as the acreage is by permanent grass, are never cultivated apart from superficial operations such as harrowing. For several perennial species, however, cultivation was traditional because the crop did not effectively cover the soil surface and so weeds had to be controlled by mechanical means. Farmers often claim other virtues for cultivation between the rows of perennials but it is interesting to see how the fruit grower over the past 20 years has come to rely almost entirely on herbicides for weed control. Progress was most rapid with blackcurrants and strawberries, enabling the industry to adopt new methods, such as bed systems of growing, hitherto out of the question where weeds had to be controlled by mechanical methods.

With top fruit progress has been slower, and there are greater problems, particularly with stone fruits, but the situation has been summarized as follows: 'In fruit growing the major revolution brought about by chemical herbicides is now over and their use is fully integrated with our systems of production. There seem to have been no bad side effects, indeed in what were thought to be problem areas such as soil structure, nothing but good has emerged. We are now left with a few remaining difficulties, including the resistant weed and possibly special application techniques to cope with our new ideas on bed systems of production.' (Walker 1973)

Substantial use of herbicides has also proved practicable in hop gardens – a site where most growers would have argued a few years ago that thorough cultivation was essential.

For perennials, then, it is reasonable to conclude that, in undisturbed soil, crop growth, including root growth, proceeds in a satisfactory way and the evolving root system provides the soil not merely with organic matter but with systems for aeration and drainage which enable the process to continue.

Annuals

Most of the rest of this paper is concerned with attempts being made to reconcile agronomic ideals with economic realities for the main annual crops. Here the situation is complicated by the need to provide conditions favourable to the sowing and germination of seed, and its early establishment free from excessive weed competition. This is much more demanding than is maintaining growth of perennial crops. Drills are seldom effective where there is trash, and the quality of tilth cannot be ignored where the seed is small or germination requirements are critical for other reasons. The tendency with some crops is for seedbed requirements to become more stringent to permit techniques like the precision sowing of reduced seed rates, or to produce tilths suitable for the effective use of soil applied herbicides.

Cereals

It is not surprising that most work has been done on cereals. These account for over 70% of the tillage acreage and they are, or were until recently, crops with relatively low returns thus encouraging cost saving, especially as they are not particularly sensitive to seedbed conditions. Indeed foliar disease, nitrogen supply and, for spring crops, time of drilling are probably more important in determining yield.

Winter cereals

The proportion of winter cereals has been tending to increase. These may follow crops such as peas or winter oil rape which are harvested sufficiently early to allow time for several tillage operations separated by periods when the land can weather. However, much of the area sown to winter cereals follows another cereal, sugar beet, field beans or potatoes where there is seldom time for much work to be done if the crop is to be sown timeously, especially since autumn weather tends to be so unpredictable and to get worse as the season advances.

After an early harvested crop there may be opportunities for post harvest soil disturbance ('stubble cultivating') to precede primary tillage. Traditionally this controlled weeds by encouraging shed seed to germinate. It is now probably irrelevant for broad leaved weeds, may be harmful for certain annual grass weeds, particularly wild oats, but can be helpful in controlling couch and volunteer cereals or oil seed rape. Crop plants are now often among our most troublesome 'weeds' in other crops.

TABLE 2. PRIMARY CULTIVATIONS FOR WHEAT ON CAMBRIDGESHIRE FARMS

harvest year	1974	1975	1976
previous autumn	dry	wet	dry
% winter wheat after:			
plough	19	28	8
cultivator over 12 cm deep	70	42	54
cultivator less than 12 cm deep	11	30	38

Source: J. Large, A.D.A.S., unpublished data.

Some land for winter cereals is still ploughed, and this is undoubtedly justified where bulky crop residues, such as sugar beet tops or unburned straw, have to be incorporated, or a ley is being broken up. The trend, however, is clearly towards systems which do not use the plough. Phillipson, Cox & Elliott (1972) recorded that in one district 10 years ago, 22 % of cereals following straw crops were established without ploughing. More recent data from Cambridgeshire arable farms (Large, unpublished) show how this proportion has increased and is influenced by season.

These farms on heavy clay soils had high proportions of cereals in the rotation and about two thirds of the cereal was winter wheat. Conventional ploughing is a major bottleneck in such farming systems. Not only is it slow, but on heavy land much subsequent work is needed to produce an acceptable seedbed. Cultivating has taken over because it is faster, it can be done by less-skilled labour and the land should not need as much subsequent seedbed preparation. Cultivating produces less soil smear under wet conditions, but weed problems may be more troublesome. Where these do not occur, or have been overcome, differences in yield between ploughed and cultivated treatments have been small. If the soil is no longer inverted, this can change the disease pattern. Those cereal diseases which must overwinter on living hosts (e.g. mildew, rust and virus diseases) seem to be least affected. Those which survive on infected debris on the soil surface (e.g. *Rhynchosporium* and *Septoria*) tend to be favoured, as there is more inoculum to infect the seeding crop, even if the straw is burned. Soil borne pathogens (e.g. the take-all fungus) do not seem to show any consistent response to the change to a non-ploughing system. (Yarham 1975)

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A cereal system based on cultivation has been evolved at the Drayton Experimental Husbandry Farm (e.h.f.) on Lias Clay in Warwickshire. Three passes with a 'Flexitine' cultivator on a cereal stubble, working progressively deeper, prepare a seedbed with just under half the man and tractor hours used previously when the land was ploughed, but give comparable crop yields. (A.D.A.S. 1974)

Elimination of the plough presents particular problems where all the straw, or even long stubble, has to be worked into the soil. The agronomic argument for burning straw, or at least stubble, becomes very strong as tillage is reduced. In 7 trials on winter wheat on 4 e.h.fs in the past 2 years, 3 tillage systems (based on plough, cultivator or direct drill) following 3 straw treatments (burn, bale and cart, or chop) were compared. The preliminary results suggest that method of cultivation had little effect on grain yield where straw had been burned, but yields were lower where it had been baled or chopped.

Table 3. Yields of wheat

(Mean of 7 trials in 1975 and 1976 at experimental husbandry farms.)

	plough (%)	cultivate (%)	direct drill (%)	mean (%)
burn	102	100	98	100 (4.96 t/ha)
bale	94	87	75	86
chop	94	76	77	83

It is, of course, possible to use the principle of ploughing in many ways and economies can be achieved by changing to types of plough which work much more widely but more shallowly than normal ploughing. Not merely do these save labour and fuel but there is less risk of soil smearing and on heavy land the clods produced tend to be smaller and easier to break down.

So far the tine has been regarded as the substitute for the plough. Clearly there are other alternatives. Disks have advantages where there is much trash or where the implement may have to ride over obstacles, but they can have high draught and are liable to block in wet conditions. Power-driven implements can reduce the draught required to break out soil and often reduce the need for secondary seedbed preparation. Normal rotary cultivators are liable to smear wet soil or produce a very loose 'puffy' tilth in dry soil, however, and they also need high power in relation to their output. Some of these problems can be reduced by the use of curved blades or spikes to replace the more common L-shaped blades. The N.I.A.E. rotary digger, in which a modified rotovator with fewer blades working at a low rotor speed is followed by tines working at a greater depth, is a promising new development now being tested. It has a work rate equivalent to a chisel plough, gives more inversion than a tined implement and seems particularly promising on heavy or wet land (Patterson 1975 and private communication).

Any cultivation is still a laborious system, however, compared with direct drilling seed into the undisturbed stubble of a previous crop, accompanied by killing any live plant remains with a suitable non-persistent herbicide. Direct drilling has been studied experimentally since the availability of the bipyridyls in the early 1960s. Winter cereals and oil rape make up a significant part of the area currently being direct drilled but in relation to the 3.6 M hectares of cereals in the U.K. area, although growing, is still small (Allen 1975 and private communication).

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In early experiments direct drilling cereals gave some very inconsistent results, because there were serious mechanical problems with the drill, the suitability of different soils could not be forecast, the problem of couch was underestimated, and not least because experimenters, farmers and workers had to develop skills in using a quite unfamiliar technique. More recently the machinery has been improved and some soils have been shown to be particularly suitable for direct drilling. These latter include some rendzina (shallow limestone or chalk) soils and certain calcareous clays if adequately drained (Davies & Cannell 1975).

Table 4. Labour and energy requirements for winter wheat with yields (5 years 1971–76)

cultivation system	clay loam man hrs/ha	clay loam energy MJ/ha	clay loam cost £/ha	clay loam yield tonne/ha	silty loam man hrs/ha	silty loam energy MJ/ha	silty loam cost £/ha	silty loam yield tonne/ha
plough (20 cm); disk harrow or cultivator; drill	3.5	330	20.7	5.92	2.2	179	13.9	4.91
chisel plough (13 cm), 2 passes; disk harrow or cultivator; drill	3.4	310	16.3	5.78	2.3	210	12.4	4.81
plough (20 cm); combined cultivator and drill	3.0	340	20.5	5.82	1.9	178	13.8	4.76
shallow plough (10 cm); combined cultivator and drill	1.6	193	11.3	5.71	1.2	104	9.2	4.65
N.I.A.E. rotary digger† (rotor 10 cm tines 20 cm); combined cultivator and drill	1.4	186	12.4	5.27	1.2	140	10.7	4.95
sprayer; direct drill†	0.5	27	16.4	5.62	0.6	36	16.0	4.53

† Data refer to 3 years only.
Source: D. A. Patterson.

Direct drilling has yielded crops equal to or better than conventional tillage in about two thirds of recent experiments. There is still a tendency for direct drilling – like other systems of reduced tillage – to increase problems with perennial weeds but some other weed problems, for example wild oats, are no worse and their build up may be reduced because stubbles are undisturbed. This method, although much less laborious than other techniques, may not be more economic in view of the higher costs of herbicide. Table 4, which is adapted from Patterson's data (1975 and private communication), indicates that in both his winter wheat trials conventional ploughing, chisel ploughing (i.e. a tine cultivation) and direct drilling all cost more than reduced cultivation based on either shallow plough or rotary digger. At the clay loam site (Boxworth e.h.f.) direct drilling was cheaper than ploughing but on the silty loam (Rothamsted) this was reversed because tillage costs on this soil were much less.

Opinions differ on the future importance of direct drilling. Some believe that the technique will become the standard method of tillage for cereals. There seem to be such extensive areas where soils readily become over-compact, are stony, are on steep slopes or have drainage, perennial grass weed, or slug problems, that the forecast seems optimistic even if direct drilling became more advantageous economically. Labour saving considerations, however, will ensure an increasing rôle for it in the future.

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Spring cereals

A great deal of the work on cultivations for spring cereals has assumed fairly conventional primary cultivation during the autumn or winter and has concentrated on pre-drilling operations. Much spring corn is grown on light land cheap to cultivate, and in farming systems involving other crops such as potatoes, sugar beet or leys which still necessitate fairly conventional tillage.

The importance of early spring sowing is becoming recognized on many soils and this is one factor tending to reduce work going into thorough seedbed preparation. There is often a conflict between the desire to sow early, when the tilth is often indifferent, and the wish to put crops in under better conditions, easier to achieve later in the season. Pre-drilling practice varies from drilling on the plough furrow, usually from necessity in wet conditions, to the thorough job our fathers believed in, using several implements. The latter tends to be justified for various reasons: remedying the shortcomings of bad ploughing, control of weeds, forcing a tilth or respect for one's ancestors. Limited experimental work on several e.h.fs underlines the conclusion of other workers, however, that the less work that is done the better: timely sowing and conservation of moisture in spring are more important, within limits, than the quality of the tilth for cereals, provided of course that the seed can be covered. Minimizing work in preparing the seedbed in spring may be assisted in some circumstances by suitable cultivations just after ploughing.

Sugar beet

Beet seedbeds present more difficult problems. To avoid the need for hand singling, precision drilling of very low seed rates is desirable, but it is still economically important to achieve a high plant population, so as many seeds as possible must grow. Maximum seedling emergence occurs in a defined range of moisture contents, characteristic of the soil, and decreases rapidly as the soil becomes drier or wetter. It is also reduced by excessive soil density, by capping or by a coarse tilth.

Current work particularly at the Norfolk Agricultural Station (R. W. Clare, private communication) is aimed at developing techniques for preparing a fine seedbed which can be used at relatively high moisture contents without causing damage to soil structure. The most promising approach at the moment seems to be to follow conventional ploughing with the minimum number of shallow cultivations with, for example, Dutch harrows 8 cm deep. For the future, the plough may well be replaced by some other implement. One of its limitations is that ploughing has to be done so often under conditions which are too wet, giving livery slices; or too dry, giving a mixture of large lumps, small clods and dusty tilth. Neither of these situations is conducive to good tilths or good brairds in the spring, and we seem to be in a period where frost mould has become a rare commodity!

Finally there is some hope for developing machinery which would permit a one-pass system working on stubble, and which could have great advantages in providing the higher soil bearing capacity necessary for beet lifting in a wet autumn. In 1975 about 150 hectares of sugar beet were direct drilled, and although the technique was less successful for the 1976 crops, it is used commercially in Holland and could well be of value especially on very light land where crops are liable to wind damage.

Potatoes

The potato crop is probably the least amenable to minimal tillage techniques. With current machinery it is essential for the crop to be grown in ridges sufficiently capacious to cover the tubers with enough depth of soil to exclude light and the spores of blight, and sufficiently friable to avoid problems of separating the produce from clods when a mechanical harvester is used.

This does not mean that there have not been changes through the impact of herbicides, harvesters and power driven machinery for seedbed preparation or inter-row tillage. The plough is still the dominant primary tillage implement, and to reduce the subsequent spring cultivations, increasing emphasis is being given to ploughing early under fairly dry conditions. So far only a few pioneers have attempted basing their potato enterprises on the chisel plough or other tined implements.

Spring operations should be as few and as shallow as possible consistent with producing enough tilth to give a satisfactory ridge. The move to wider rows (0.9 m) has been a substantial help in avoiding the need for deep cultivations into unweathered soil. In many years on many soils it is possible to complete the ridges at, or soon after, planting. In such cases inter-row cultivations are often unnecessary, and the crop can be left undisturbed after applying a suitable herbicide.

On heavier land, or following a mild winter, the tilth may be only just sufficient for the planter to cover the seed, and inter-row operations by a sequence of tined cultivations and inter-row power driven rotary cultivators becomes necessary to produce adequate tilth as early in the season as possible. The object must always be to minimize the number of passes, however, to avoid soil compaction and clod formation.

Fodder crops

Although the acreage of fodder crops is tending to decline, direct drilling has made considerable progress but, although accounting for a higher proportion of the acreage than any other crop, excluding oil rape, over 85 % of the kale and fodder root acreage is still sown on traditionally cultivated land. The new technique has clear advantages, particularly on the smaller stock farm which does not warrant a range of cultivating equipment, and, where the land has not been disturbed, the subsequent ultilization of the crop causes less poaching. A farther advantage is that many fodder crops are grown as catch crops and conventional tillage is not conducive to good establishment after, for example, taking a silage crop, because of moisture loss even if time were available. Direct drilling also lends itself to the practice of growing fodder crops as pioneer crops in the improvement of upland pastures, often on land which is unploughable.

Conclusion

'How much cultivation?' is a question clearly one cannot answer succinctly, even for the limited situation of one crop on a specific soil. The trend of experimental results and the experience of farmers clearly show that significant reductions in the labour and machinery devoted to tillage are possible. However, it is not yet proven that all cultivation can be eliminated economically for annual crops as it has been for perennials like fruit. In practice, there is much to be said for a pragmatic approach to cultivation – taking advantage of reduced

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cultivations or direct drilling where appropriate but being prepared to use other techniques where they are justified.

Perhaps finally I could speculate on future developments. There are substantial differences between present national average yields and the achievements of the better farmers. Further, even the best farmers' yields fall far short of the theoretical potential of our present varieties. Sometimes there is an explanation outside the farmer's control – for example extremes of rainfall, or low solar radiation at critical periods of crop development. Sometimes pests or pathogens cannot be fully controlled with our present knowledge, or the economics of control are dubious. However, some of the discrepancy may well be due to soil conditions induced by techniques of tillage. It seems conceivable that methods which seemed satisfactory for, say, cereal yields of 3 t/ha, and perhaps adequate for current yields of 4–6 t/ha, might become limiting if yields can be encouraged towards the theoretical potential of 12 t/ha or thereabouts.

The farmer and research worker have so far reacted to rising machinery and labour costs by seeking to reduce cultivation while maintaining output. They have not so far been inclined to consider whether there are techniques which might facilitate the achievement of yields approaching the potential of crops. Increased tillage costs could well be justified if the substantially greater potential returns could be reliably achieved. Because of an increasing population and further losses of agricultural land, such a principle could become necessary to maintain agricultural output.

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