Tillage Practices and Mechanization

J. C. HAWKINS and N. J. BROWN

National Institute of Agricultural Engineering, Silsoe, Bedford, England

Summary

During this century the introduction of herbicides has created an opportunity for the greatest changes in tillage operations. It now becomes increasingly important to establish the minimum tillage requirements for maximum crop production.
Problems related to the plant root environment can best be solved by the measurement of basic physical properties such as the state of the soil water, soil air, soil temperature and the mechanical resistance to roots and shoots rather than by continuing the type of experiment which relies only on crop yield as a measure of tillage efficiency.
The introduction of herbicides challenges the mouldboard plough as the most effective method of weed control, but its value as a method of burying damaged soil surfaces still remains. The harmful effects of the smearing and compaction of furrow bottoms in tractor ploughing is discussed. Certain tillage operations such as levelling, carried out to help other mechanical treatments, can create poor plant conditions. The mechanical separation of potato tubers from clods in harvesters can be improved by preparing clod free seed beds and controlling weeds by means of herbicides. In specialised vegetable production growers are achieving success by using a bed system of cultivation where a carefully prepared cropping area remains untouched until harvest.

Introduction

The major advance in tillage in this country has not been made by the engineer but by the chemist with the introduction of selective herbicides. Now that we are in sight of complete weed control in agricultural crops by chemical means rather than by cultivations, it becomes increasingly important to consider what cultivations will be needed if and when this comes about. It is possible to think of these under two headings — cultivations done to meet the requirements of the plant and cultivations done to make the production and harvesting of a crop simpler and cheaper. While the main purpose of this paper is to discuss the second type of cultivation we must devote some time to thinking about the needs of the plant because the two types of cultivation are so inter-related that they cannot be separated in practice. It seems quite likely that it will in most cases be possible to choose cultivation techniques that are both right for providing what the plant wants and for making subsequent mechanization as simple and as cheap as possible.

Tillage-plant requirements

In deciding on tillage to provide plant root systems with all that they want from the soil in physical terms, there seems little prospect of significant advance by continuing the form of cultivation experiment that has been carried out for hundreds of years where the tillage treatments used have been evaluated only in terms of crop yield, COLLIS-GEORGE and DAVEY (1960). In practice none of the so-called treat-

FIG. 1. Marrowstem kale growing in 2000 litre respirometers. Uncropped control tank in foreground

FIG. 3. Rain water lying on puddled surface after land levelling operations. Sandy loam soil

ments used in these experiments can be taken as a true treatment. For example, many cultivation experiments use ploughing as a treatment and yet a mouldboard plough set in exactly the same way and used at the same depth and the same speed on different days can produce quite different effects. The result is that such tillage experiments yield information that is only of importance in a very small area and under the conditions prevailing at the time of the experiment, BYERS and WEBBER (1957). If there is a valid conclusion of general importance to be drawn from them it is that plants are remarkably tolerant of a wide range of soil conditions, RUSSELL (1950).

Many workers, realising the limitations of conventional cultivation experiments, have turned their attention to the problem of measuring soil properties, which are only indirectly related to the root environment, in an attempt to put a value on soil structure. They have measured such things as aggregate size and stability but have failed to show a consistent relationship between these and plant growth. This is hardly surprising because, from the point of view of the plant, the size of soil aggregates are of only indirect importance: it is the properties that they confer on root environment that are important. A much better approach, assuming nutrition, genetic potential and aerial environment are adequate, is to determine which measurable physical properties of the soil are of importance in plant growth and to establish a range of values for these over which maximum economic growth is possible. In other words, to approach the problem from the plant rather than from the soil. Considering the four principal physical factors which effect the plant, namely, soil water, soil air, soil temperature and the resistance that soil offers to the movement of roots and shoots there must be a range of values over which a farmer can normally expect maximum economic yields, FOUNTAINE (1958). It is important that these be determined as soon as possible and techniques for measuring these properties in the field established so that numerical values that have a real meaning can be applied for example to a seedbed. Consequently an attempt has been made recently at the N.I.A.E. to measure the oxygen use by plants and soil using large field respirometers, FOUNTAINE and BROWN (1959). Various crops, soil types and conditions have been examined and some of the results are given in TABLE 1. The crops, which were grown at normal agricultural spacings, FIG. 1, used similar quantities of oxygen, while the requirement of the soils varied widely with type and condition.

TABLE 1. The oxygen consumption of agricultural crop roots and soils

Soils			Crops	
Soil type	Soil condition	Maximum O_2 used $1/m^2/day$	Species	Maximum O_2 used $1/m^2/day$
Sandy clay loam	Undisturbed profile	5,3	Potatoes	4,5
	Loose profile	6,6	Marrowstem kale	6,6
Sandy loam	Loose topsoil	11,0	Barley	5,1
Organic silt loam	Loose topsoil	10,9		

Tillage-production requirements

Turning from tillage for the need of the plant to tillage for the sake of mechanization, it is natural to start with the most common basic cultivation that we do —

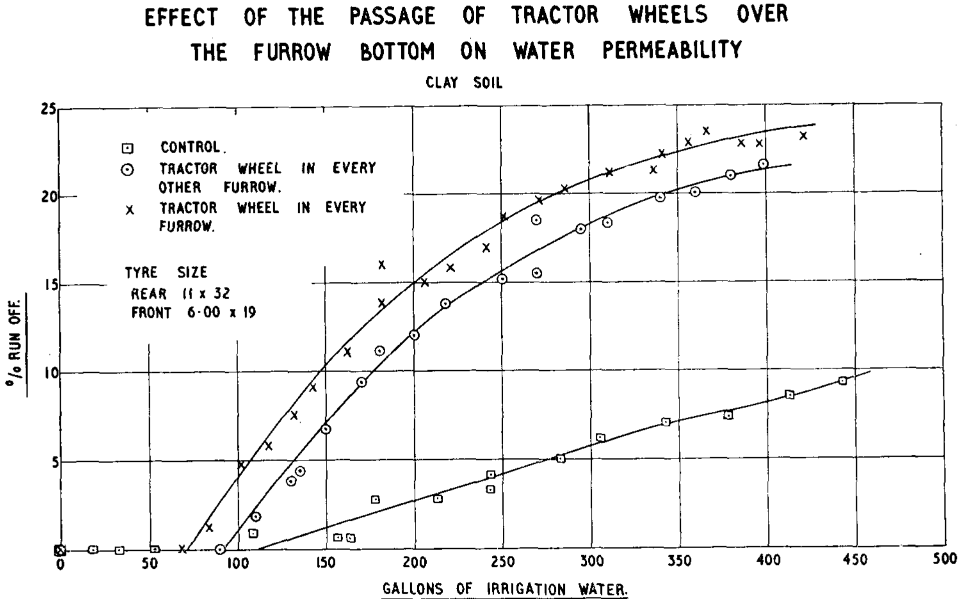
ploughing. The mouldboard plough has long been used in Europe because it offers one of the most effective ways of *controlling weeds* in temperate climates. BYERS and WEBBER (1957), and we must bear in mind the effect of weed competition on crop growth in deciding whether to change from ploughing to some other form of basic cultivation. The decision may well rest upon the cost of spraying. However, ploughing is not always used today, instead of other forms of cultivation with tines for example, because of weed control; but because of the need to *bury the soil surface*. With modern methods of harvesting root crops like sugar beet and potatoes, up to twelve heavily-loaded wheels may pass across the field in lifting every row. The weather is often quite unsuitable in late autumn for this sort of traffic and so the structure of the surface soil on the field is damaged severely. If, as is often the case, it is important to plant another crop as quickly as possible so that there is no time for the weather to put matters right; the only solution is to plough under this destroyed surface and present a fresh one for seed bed production. Damage is less severe in harvesting crops like cereals or in grazing leys; but after them it is still necessary to re-create each time the right soil conditions for plants, at least in their early stages, and surface burial by ploughing is often the cheapest and easiest way of doing this.

There has long been concern about the *consolidation* effects brought about by tractor wheels and attempts to measure this in terms of an increase in volume weight have rarely proved successful, FOUNTAINE and PAYNE (1952). The changes brought about are too small to show up with such an insensitive form of measurement, yet it has been demonstrated that the passage of loaded pneumatic tyres does bring about changes in the soil that appear to be undesirable. In one set of experiments it has been clearly shown that one pass with a tractor ballasted to 2016 lbs (915 kg) per rear wheel and 896 lbs (406 kg) per front wheel did not bring about significant consolidation on a clay soil and yet water ran off such a surface when it penetrated freely into one that had not been so treated, FIG. II. It is suggested, therefore, that the important ill-effects of tractor traffic are probably confined mainly to the surface where puddling and smearing destroys the structure and creates a less permeable layer restricting the movement of air and water. Ordinary ploughing may well undo such damage at the surface, but there still remains, under many conditions, the effect of the tractor wheels with pneumatic tyres running in the furrow bottom. This is covered by the furrow slice and may well remain unmodified by the effects of the weather until the land is ploughed again. Thus a pan can be formed by ploughing always at the same depth from the effects of the wheels, increased by any smearing and compression from the shares, and reinforced by fine particles of soil brought down by water and deposited when it meets the restriction of this incipient pan. Such a situation can however be easily avoided by a relatively shallow cultivation below ploughing depth either at the time of ploughing or as a separate operation.

With the increased use of spacing drills, down-the-row thinning and other machines which are much more efficient on a level surface, there is an increasing tendency to regard levelling as a standard operation on some farms. This is one of the practices which can do nothing to help the growth of the crop and may well do the reverse. Many levellers carry out the type of smearing and puddling of the surface which occurs under pneumatic tyres as shown in FIG. III. It is therefore an operation done purely to help with mechanization and may involve extra cultivations to counteract its ill effects.

One of the major problems in *potato harvesting* is that of separating the tubers

FIG. 2.



from clods. This is becoming increasingly important as it is realised that potatoes must be handled very carefully if they are not to be damaged so much that they are unsuitable for washing and packing in polythene bags. The gentle handling of the tubers means gentle handling of the soil, so less of it is broken down and more clods appear at the final stages of separation in a potato harvester. Research over many years has failed to establish a reliable and simple method of separating these clods automatically and so farmers are turning their attention towards finding cultivation techniques which produce the minimum number of clods in potato ridges at harvesting time. Experiments have suggested that on many soils if potatoes are planted in a clod-free seed bed and all inter-row cultivations are avoided by an effective weed control spray just before emergence, there will be far fewer clods at harvest time and often an increase in yield due possibly to avoiding damage to the roots with inter-row cultivation, ROBERTSON (1960). It seems likely that every time a tractor wheel goes down a potato row some clods are formed.

In horticulture, there is a growing demand from canners and freezing plants for a product graded to very close limits. If this is to be produced without a great deal of wastage, the grower must do all he can to produce a crop that is very even at the stage at which it is required for processing. Experience is beginning to suggest that this depends to a large extent on the cultivations that are done before the crop is planted. In order to grow such an even crop the surface must be level and the seed bed as consistent as possible, free of the sort of variation that can be brought about, for example, by the passage of tractor wheels. Accordingly growers catering for this specialised market are turning to a *bed system* of cultivation in which the tractor wheels always run in the same place for every operation and on land which grows no crop. The area between these wheel marks is treated as a bed over which a wheel never passes. This system is also being tried for other crops, GREEN (1962).

Finally, if cultivations in *tropical agriculture* are considered there are a number of tillage operations that may be done without any direct benefit to the crop. Most of these are aimed at soil conservation which is of indirect benefit; CASHMORE and HAWKINS (1957), but often crops are put on ridges to help in mechanization. Where drivers are not very skilled, ridges can provide rails to guide the tractor and its implements in planting, spraying, inter-row cultivation and harvesting.

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