The Art and Science of Cultivation

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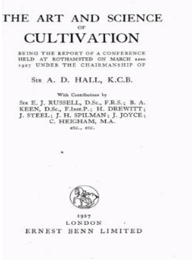
THE ART AND SCIENCE OF CULTIVATION

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CULTIVATION: THE ART AND THE SCIENCE

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CULTIVATION in this country has reached a high level of development. The farmer has the accumulated experience of many hundreds of years on which to draw, and this great bulk of information has long since been crystallized into a mass of traditional knowledge in which are hidden, no doubt, many scientific principles. Speculations on cultivation problems are found in the earliest agricultural literature, and, on the whole, progress in some form was always going on. Nevertheless, just as in any other art, there were certain periods when a great acceleration occurred. Jethro Tull's seed-drill and horse-hoes eventually revolutionized our cultural methods; the Industrial Revolution of the last century and the growth of large manufacturing centres not only caused a large demand for foodstuffs, but it provided the specialized technical knowledge and constructional skill required for the manufacture of the new implements, without which the change of farming methods could scarcely have been effected. A great variety of implements sprang into existence between 1840 and 1875 to meet the more frequent and detailed cultivation operations necessitated by the new farming. Although the designs were empirical and the improvements based on the slow process of trial and error, exceedingly valuable work was done by the implement-makers, in modifying the old implements and increasing their efficiency. Yet, in spite of this great advance, the essential nature of the implements was not changed. Unlike the thresher and the binder, which are in no sense adaptations of the flail and the sickle, the tillage implements of to-day would be recognized without difficulty by the farmer of two centuries ago. He would also immediately recognize the actual operations. We still have to undertake a long series of operations—ploughing, cultivating, harrowing and rolling—to produce a tilth; we are still largely dependent on the weather, on winter frosts, and an alternation of dry and moist conditions in the spring, and we are still compelled, in adverse circumstances, to force a tilth and be content with a condition that does not really deserve to be called a tilth at all.

Another significant aspect of soil cultivation is the variation in practices in different parts of the country. A good farmer moving to another district has little real difficulty in adapting his

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crop and stock management to the new conditions, but some time passes before he feels thoroughly at home with his cultivations. He finds not only that the operations are modified from those he formerly used, but the implements differ in design. It is instructive to count up the variety of ploughs listed by any large implement firm. Even when every allowance is made for unimportant variations in design, the number of types remaining is surprising. To my mind it shows either that ploughing—the basic operation of all cultivation—is a very complex business, or else that there is still scope for further standardization of a few types of plough and the elimination of the remainder. It is possible, indeed probable, that both conclusions are true, but at present hardly any data exist on which a reliable opinion could be based. In spite of our wide practical experience, we know little or nothing of what really happens to the soil when it is ploughed or cultivated. We can recognize the final effects, certainly, and, from experience, we have found out how to arrange our operations so that there is a good chance of securing these effects or any reasonable degree of modification. But, except in a very general and incomplete way, the explanation of how the effects are produced and, indeed, the causes of tilth still escape us.

Although we have made little real change in the fundamental design of cultivation implements in the last century, improvements have been effected in important details that have resulted in better work and a definite reduction in draught. Had the cost of labour remained the same we should be tilling to-day more cheaply. But labour costs have increased to an extent that more than offsets this advantage. Tillage is still the most costly single item in arable farming.

It is evident that there is a sound case for systematic inquiry into cultivation matters. There is no reason to assume that we have reached finality either in implements or methods, and, even if there were, the important question of reducing tillage costs is still awaiting exploration. The necessity for inquiry is not of recent origin, so it is significant to find that there are very few tillage experiments recorded in the literature. Those found are almost entirely of American origin. Agricultural teachers and investigators are compelled to refer to them, and to assume that the conclusions apply unaltered to conditions in this country. Those who have had the opportunity of comparing British and American implements and methods must have the gravest doubts whether this assumption is correct. Unfortunately, owing to the absence of adequate cultivation experiments in this country, the assumption remains, neither controverted nor confirmed.

There is a most instructive comparison in this connexion between tillage and artificial fertilizers. Whereas tillage experiments are few and far between, there have been innumerable manurial experiments during the past seventy or eighty years, and there is no sign of their numbers decreasing. The advances in soil chemistry associated with Lawes and Gilbert formed the basis of the field trials of manures; theory and experiment mutually aided each other, and in a comparatively short period a science of manuring was evolved. Herein is the essential distinction between it and cultivation. Artificial manuring has grown up under the guidance and control of the laboratory; cultivation has not. It is far older than the physics and physical chemistry of soil, the branches of knowledge mainly concerned.

Only in recent years has any systematic study of the soil been made from these aspects. The laboratory results have been so satisfactory that for some time past it has also been possible to undertake with confidence investigations under practical field conditions. I shall give, with special reference to cultivations and the problem of soil tilth, an account of the main results obtained to date by Dr Haines and myself, and a statement of the promising extensions of this work.

The laboratory work revolves round the central fact that we cannot understand the causes of tilth until we have a further knowledge of the physical properties of soil.

The first stage was to sort out these factors and to devise methods and apparatus so that they could be studied singly. Such work is of necessity rather technical in character, and for the purpose of to-day's conference our field investigations are of more direct interest. It is sufficient to mention that the laboratory work includes a study of such factors as cohesion—the tendency of the soil to form hard clods when dry; plasticity—the ability to be moulded in the moist state, like modellers' clay; surface friction between soil and a metal surface; movement of moisture in the soil; flocculation, or the aggregation of individual soil particles into little crumbs or granules, that characterize a soil in good tilth. Studies of this kind, when combined with appropriate measurements in the field, are enabling us to understand what happens to the soil when it is cultivated. It will eventually be possible to give for any cultivation operation a specification of the soil properties concerned, analogous to those that, under the name of "properties of materials," the engineer already has for the metals used in the actual implements. In the field much use is made of the dynamometer, an instrument measuring the resistance offered by the soil to the passage of a cultivation implement. Our first experiments were done with a dynamometer suitable only for tractor work. We have now filled an important gap in our equipment by the construction of a very light dynamometer, suitable for all types of work, from the lightest horse-drawn implements to the

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heaviest steam tackle. Further, the records, being impressed on a celluloid ribbon, are permanent, and unaffected by oil, water or dirt.

Dealing now with the field investigations, they can be grouped into two main divisions:

(1) Comparison of various alternative forms of cultivations.

(2) The possibility of increasing the efficiency of cultivations.

The first of these two divisions may be illustrated by an experiment recently carried out at Rothamsted in comparing three different methods of preparing a seed-bed for roots. It is one of a series that we intend to carry on for several years. The three methods were (*a*) ridging, (*b*) an unridged seed-bed, (*c*) rotary cultivation. To eliminate soil variations, on which I shall have more to say later, each treatment was triplicated, so that there were, in all, nine plots. The whole area was autumn-ploughed, after wheat, and in February cross-ploughed, with the exception of the plots intended for rotary cultivation. The seed-beds were prepared in May, and immediately before and during the cultivations samples of the soil were passed through a series of sieves to obtain a measure of the amount of disintegration produced by each operation. As the soil was in excellent physical condition it readily broke down, hence the differences in the three treatments were not as great as might have been expected. However, it was evident that the rotary cultivator left very few large lumps behind it, and further, the seed-bed produced was much more spongy or "puffed up" in texture than with either of the other treatments. Germination of the swede seed was earlier on the rotary cultivation plots, and in the early stages of growth the plants were definitely better and more forward. Later on, however, a striking change took place. The tendency of the Rothamsted soil to "cap" or to harden down in the surface layers became greatly accentuated on these plots and, to judge by both the feel and appearance of the soil, the hard layer extended much deeper than with the other treatments. It is probable that the tendency to hardening was accentuated by the deep and uniformly fine tilth produced by the rotary tines, but, whatever the explanation, the results were very apparent. Growth was severely checked, the plants fell behind those on the other plots and remained so right up to harvest. The average yields of roots obtained in the experiments were:

Normal or ridge cultivation	11·81 tons per acre
Cultivation on the flat	11·05 ,, ,,
Rotary cultivation	9·40 ,, ,,

These yields are well below what would have been secured by full manuring, which was withheld so as not to mask the cultivation differences. Attention is directed, not to the actual yields, but to the differences. The difference in the first two figures is not significant, but the difference between either of them and the rotary cultivation figures is statistically significant. We thus have the striking result that a form of cultivation definitely superior in the early and presumably critical stages of growth produces serious adverse effects at a later period.

As far as this single experiment goes, it could be taken as disproving the usefulness of rotary cultivation, but in my view such a conclusion is too drastic. It is true that in the soil and weather conditions of this particular experiment it failed in comparison with more orthodox treatments, but it cannot be condemned completely on this account. It is possible, for instance, that if the tines had been set to produce a coarser tilth—*i.e.* more of a digging spade-like action than the fine comminution actually produced—better results would have been secured. It is hoped to continue this work in a variety of different conditions, because there is something inherently attractive about the idea of rotary cultivation. The principle is, as far as I can judge, a sound one, and directly utilizes in a natural way the fundamental characteristic of the internal combustion engine, which is the production of circular motion. It may be legitimately argued that, if our next advance in cultivation is to be the production of a tillage *machine* as distinct from a series of tillage *implements*, rotary cultivation in some form will be the solution.

Turning now to the second division of the field investigations, the efficiency of cultivation processes may possibly be increased in one or all of several ways. We can modify the soil or improve the implement, or, again, reduce the actual costs of cultivation.

One method of modifying the soil is to reduce its resistance. The use of farmyard manure or green manure in this connexion has been known for a long while. Our dynamometer results show this effect very clearly. The reduction in draft may be as much as 20 per cent. in cases where very considerable qualities of farmyard manure are added, but in ordinary farming the reduction would be less, although the accompanying effects of improved tilth and better water relationships would of course be secured as well.

A second method of reducing draft that has definitely passed the experimental stage and is awaiting commercial exploitation has been devised by my colleagues, Dr Crowther and Dr Haines, as the direct outcome of laboratory investigations. It has been known for some time that soil possesses colloidal properties. Dr Crowther and Dr Haines have utilized the fact that when an electric current is passed through moist colloidal material there is a movement of water to one of the electrodes. By insulating the coulter from the framework of a plough and passing a current down it, and making the mould-board the negative electrode, a film of soil moisture becomes deposited on the mould-board and acts as an efficient lubricator. Field experiments showed that a reduction of draft was secured whenever the current was switched on, and there is little doubt that the device could be successfully developed. It is of especial interest in its possible adaptation to soils that are very difficult to work in normal circumstances and also to such operations as mole drainage.

A third method which has been followed up at Rothamsted for some years is the effect of chalking heavy land. The operation was extensively practised a century ago, but the increase in cost of labour has caused it to be largely abandoned. We have found from our dynamometer records that a chalking of 10 to 15 tons per acre applied sixteen years ago is still causing an appreciable reduction in the resistance to tillage implements. The effect is a variable one: in very dry or very wet conditions it is not marked, but when the soil is moist, reductions of 14 or 15 per cent. in draft have been obtained. Further, the chalked area is ready for cultivation earlier than the corresponding unchalked strips. This reduction in draft has not hitherto been generally recognized, and it constitutes an appreciable credit item to set against the initial heavy cost of chalking. The question also arises whether lime in smaller quantities would also produce a similar effect, and, thanks to the financial co-operation of lime-producing associations, we have been enabled this year to lay out some experiments to test this point.

In dealing with the effect of chalk I mentioned that the state of the soil affects the dynamometer records. In the course of our experimental work we have frequently observed such effects. Loose soil, for instance, may have a surprisingly high resistance. Instead of sliding smoothly and in a comparatively unbroken furrow slice over the surface of a mould-board, considerable friction is developed, not so much on the mould-board itself as between the large number of independent lumps of soil. It is necessary to allow for this effect in the interpretation of records obtained in a field of variable texture. In the early stages of our work we selected, as far as possible, fields which, to visual inspection, appeared quite uniform. We were surprised to find that such fields were by no means uniform in the resistance offered to the cultivation implements. Variations of as much as 50 per cent. were obtained in different parts of the field, and could not be attributed to differences in moisture-content nor by any means entirely to variations in the amount of clay present in the soil. They seem, however, to be closely associated with changes in such properties as cohesion and plasticity, which were mentioned earlier as forming

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part of the laboratory investigations into soil tilth. Their immediate practical interest is in the bearing they have on competitive implement trials or on tests of new patterns. If the particular field in question had been divided up into strips a chain wide and one of them allotted to each implement (the invariable procedure in such trials), differences in the average dynamometer records of over 10 per cent. would have resulted, due to the soil variations alone. It is apparent that in such a test no reliable information would have been obtained as to the relative efficiency of the different implements. In fact the relative order of the implements would have been decided more by the chance of which particular strips were allotted to them than by their innate merits. The soil variations, fortunately, can be ascertained by a previous experiment and allowed for in interpreting the final results. Several years' work at Rothamsted has also shown that they do not vary from season to season. Those interested are referred to my paper in the *Journal of the Royal Agricultural Society of England*, 1925, for practical details as to how implement trials and comparative tests should be arranged.

In addition to the possibilities of draft reduction by improved design we must also consider another possibility of even more direct economic importance. This is the question of increased speed of operation. Our results have shown that, even with our existing implements designed for work at speeds around 3 miles per hour, very little increase in draft takes place for a most appreciable increase in speed. In the case of ploughing, for instance, an increase from $2\frac{1}{2}$ to $4\frac{1}{2}$ miles per hour requires only an extra 7 per cent. pull on the plough. In tractor-ploughing it is highly unlikely that the cost of the extra fuel needed to sustain the 7 per cent. increase in the drawbar pull would be anything like sufficient to outweigh the large saving of time by ploughing at a 60 per cent. greater speed. The limit is set, of course, by the extra fuel needed to propel the weight of the tractor and by the increased wear and tear. Nevertheless, the direct and indirect advantages of increased speed in all our cultivation operations are of such supreme importance that an advance in this direction is highly desirable. The only feasible way is a greater use of mechanical power. There has already been one successful example in the form of steam tackle, and the tractor will, in my opinion, provide another. It is well to remember that the tractor in agriculture is still in its infancy. The first considerable use on British farms dates only from the later stages of the war. With the passing of the abnormal war conditions tractor cultivation declined, but recently there have been encouraging signs of a return to favour. The machines

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have greatly improved in simplicity and reliability, and, even in their present early stage of development, their value for autumn cultivations in both dry and wet weather and for spring work has been conclusively shown. Nevertheless, we still have much to learn in this new development. It is not simply a case of substituting one form of haulage for another; there is a host of concomitant problems in adapting implements and cultural methods to the new conditions. Such straightforward questions as the relative merits of deep cultivation and subsoiling still await solution. Some experiments appear to show no advantage, while others show a considerable benefit. Such divergent results are to be expected until our knowledge of the physical effects produced in the soil is extended.

The fundamental point to be borne in mind in all work of this nature is that the form of power and the implements are only a means to an end—the production of a suitable seed-bed for the given crop, and the maintenance of appropriate soil conditions for the plant over the whole of the growth period.

Our best hope of systematic advance is to pursue steadily our investigations into the soil properties on which tilth depends and, as opportunities offer, to test our conclusions by selecting outstanding problems for practical field trials under a variety of different conditions. It is essential for the progress of our work that it should be critically reviewed from time to time by the practical farmers, the implement- and tractor-makers, so that the field trials may be designed to give the maximum practical information to all concerned.

CULTIVATING THE CHALK & BRICK-EARTH SOILS OF WEST SUSSEX

By H. DREWITT

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To a farmer the subject of this conference is his daily concern, although perhaps he seldom tries to analyse the reasons for what he does.

Modern cultivation of the soil may be said to have begun when the common fields were enclosed and distributed among individual cultivators, each of whom was then, for the first time, able to carry out his own ideas on the subject without reference to what his neighbours were doing. Up to about forty years ago the preparation of the soil was carried out with the same implements, improved

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