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Introduction: Historical notes on the zero-tillage concept

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Summary

In the very active and productive German school of tillage research in the first half of our century soil structure was the central theme, weed control was regarded as a secondary effect.
In English research the fact was stresses that weed control was the only sure effect of tillage on crop production. Zero-tillage makes it possible to test this weed hypothesis. In future farmers should be able to use the greater freedom in tillage that is brought about by the introduction of chemical weed control. Tillage research should apply the basic information to avoid unacceptable risks when tillage practices are changed.

Introduction

Power requirements for soil tillage are considerable. In modern agriculture this may be a technical challenge or an economic problem, but formerly this meant hard, long-lasting labour for a large percentage of all the people that ever lived on earth. Forces required are so great that animals were used already very early to make the physical stress endurable.
The simple question whether all this is really necessary must have risen in many minds, but this did not result in a material change of the system. When tillage research started, the question of the objectives of soil tillage was rapidly recognized as a central theme, and it got so much attention that one may doubt about the clearness of the answers given (Kuipers, 1963).

Development of the German School

In 1802 Thaer mentions 7 aims for tillage, that mainly have to do with the physical and nutritive condition of the soil. It is remarkable that weed control is mentioned only in the fifth place. The general idea is that tillage makes the soil fertile and therefore cannot be overdone. The same idea is found back in old French and German literature (Dehérain, 1893, 1896, 1897, 1898; von Liebig, 1863), but it is soon felt that more accurate terms are needed to describe the fertile state of the soil. In France Dehérain's early work on nitrogen, or in the USA King's work for instance on soil temperature (King, 1890a, b, 1891, 1892, 1894a, b), are clear examples of this specifying approach. Especially in Germany much tillage research work was done in the first half of our century. The very long way of more or less exact descriptions of the pro-

cesses involved in tillage permanently occupied research workers, but in the same time more practical people tried to make shortcuts by introducing complex ideas. Most famous is the concept of 'Bodengare', like soil tilth, the highly productive state of the soil that can be reached by cultural practices and that is in the German conception opposite to the unfertile natural state of the soil (Roemer, 1929). Soil tillage should initiate the processes that will lead to this desirable state. It is clear that in this approach the physical condition of the soil is regarded as the principal point in tillage. A favourable physical condition has much to do with nutrient supply, but this is a secondary effect. Weed control is normally mentioned as another secondary effect on the same level as mixing in of substances. Even for tillage operations like cultivation of stubble fields in fall and like hoeing in spring, where weed control is an important aspect, the physical implications are discussed: Roemer (1929) states that the shallow ploughing of stubble fields after harvest and before the winter furrow was introduced by von Rosenberg Lipinski (about 1870). The main argument was that the loosened topsoil prevented water loss by evaporation, and this was mainly important because the soil would be easy to crumble at ploughing lateron. In the famous work of Wollny (1895, 1897a, b) we find an article where hoeing is compared with pulling out the weeds by hand; it is concluded that hoeing gives higher yields, and therefore the hoe is regarded to have a beneficial effect on soil structure.
The whole literature indicates that soil structure is the central theme in tillage research in what we might call the German School, a school with a long tradition, of many excellent research workers, that produced a really impressive amount of literature (von Nitzsch, 1937; Tornau, 1931).

English School

In England reports in tillage research are found in the famous series of 11 papers 'Studies in soil cultivation' in the *Journal of Agricultural Science* between 1925 and 1942 (Keen and Haines, 1925; Haines and Keen, 1925a, b, 1928; Keen, 1930; Keen and Cashen, 1932; Pereira, 1941; Russell and Keen, 1938, 1941; Russell and Melta, 1938; Russell et al., 1942). It is worth while to mention that a kind of minimum tillage concept has already been formulated in 1938 by E. W. Russell in the seventh article of the series.
An important role plays the experimental field at Rothamsted where the plough, the cultivator and the rotavator are compared for three crops. By introducing variations like differences in depth of cultivation and in permanent and changing treatments, the lay-out was complicated very much. Each year 144 plots had to be harvested. No soil-physical research is reported, and it must be admitted that even now it would be quite a problem to deal with a so complicated field, especially on a stony soil. From this experimental field the final conclusion of two 3-year rotations, formulated by Russell in 1941, was that weed control may account for all the yield differences found.
This, however, is no more than a hypothesis (Russell and Keen, 1941, p. 345) that sounds only simpler than the statement that soil structure differences and consequently differences in nutrient supply can account for the differences in crop yield observed, because this first hypothesis restricts itself to the only relation that was really sure, be it in a qualitative sense.
However it is likely that differences in nutrient supply influenced crop yield on this experimental field. The authors contribute indeed clearly lower yields in the second three years of the rotation to a poorer nutrient supply in this period (Russell and Keen,

1941, p. 332). They mention nitrogen competition between weeds and the crop as a factor that influences differences in wheat yield, and report that in the last three years mangolds stayed dark-green on the deep-ploughed plots, turned lighter green on the shallow-ploughed plots and even yellow on the rotavated and grubbed plots (Russell and Keen, 1941, p. 343). This should be caused by a set-back in the first stages of the growth on the weedy plots (Russell and Keen, 1941, p. 345).
However it is very unlikely that this can be explained in the field of nutrient competition, and this might be regarded as an indication that a soil-structure hypothesis could perhaps do better than a strict weed-control hypothesis.
However the idea that the only benefit of soil tillage could be weed control was repeated in later research (Russell, 1953), and because in the first place mechanical weed control by tillage was undispensable anyhow, and in the second place, the relation between soil structure and plant growth appeared to be too complicated to be really understood, the suggestion could not be proven to be wrong.

Anti-plough movements

On the fringe of agricultural research the idea of getting rid of the laborious ploughing operation was sensationally ventilated at least on two occasions. It is certainly not by chance that these occasions coincided with the two world wars. In the first world war manpower, horsepower and food got very short in Germany. On 4 May 1918 Prof. Holldack published an article on a cultivation method of Mr Jean near Carcassone in the South of France, a farmer who used a cultivator instead of a plough. Holldack mentioned carefully that he got the article from a neutral foreign country. It has a tremendous effect. In the journal we find no less than 28 reactions in 1918 an 1919. In the next years more critical remarks were given and finally the few negative results of experiments seem to come too late to be relevant. Although Glanz (1926) practiced this method in Tsjechoslovakia for some time, it was out of affairs till in the next world war Faulkner (1943) reached the headlines in American magazines with his booklet Plowmans' Folly.
Although Faulkner had an agricultural education, his experiments had little to do with real agriculture. This may be the reason that we find little about it in scientific publications. His idea of a kind of mulch-farming was nothing new, and insiders knew this system was certainly not suited for all conditions. In the dryer regions of the USA it was already applied successfully for a longer time (Duley et al., 1947), but this did not mean that it was suited for wetter and cooler regions.
That Faulkner's ideas were within the scope of research workers can also be deduced from an article of L. D. Baver (1947), where he answers Faulkner's questions referring to existing experimental fields. One of these experiments started already in 1937 in Ohio, and on an average of 8 years, maize yields dropped from 46.7 to 34.5 bushels/acre (from 2940 to 2175 kg/ha) by very shallow cultivation instead of ploughing. There were more weeds and the corn plants suffered from potash deficiency in two years.

Minimum tillage

The above-mentioned experiment is obviously the same as mentioned in the article of Page et al. (1946). There it is explained that the experiment was started to find

optimal soil conditions for maize in order to get a base for an advise on new tillage equipment offered by industry. In this article the term 'minimum soil preparation' is used for one of the objects, therefore we may regard this as the experimental start of minimum tillage. It is stated clearly that well-aggregated soils of open but stable structure most nearly fullfill the ideal condition for most field crops. It ends with the brilliant saying: 'Good soil structure — tilth is not made and may easily be destroyed by gasoline.'
The same idea that the purpose of minimum tillage is to avoid compaction is found in other early reports (Bower et al., 1944; Musgrave et al., 1955). Other effects as better weed control, less erosion hazard and less labour are added, but it is clear that minimum tillage developed from the idea that soil structure should be kept in an optimal condition.

Tillage and chemical weed control

From this point of view chemical weed control will not necessarily influence tillage practices. If, however, the English hypothesis that the only important factor in tillage is weed control, is correct,tillage may be replaced in future by chemical weed control. Therefore chemical weed control will make it possible to test the Englilsh hypothesis. For tillage specialists of what we called the German school the idea to abandon soil tillage may be ridiculous, but we should not forget that the relations between tillage and soil structure, between wheels and soil structure and between soil structure and plant growth are still certainly not sufficiently known to predict with any certainty that tillage cannot be left out for a longer or shorter time. A more practical man will argue that tillage has more benefits than just soil structure: it buries the thresh, it mixes fertilizers through the soil, etc. But here too we must admit that the value of these aspects was not really tested.
From these arguments it is clear that chemical weed control is at least a very important tool in tillage research. After about five years of research it is clear that tillage is really too complex to expect a uniform solution for all circumstances. But successes of chemical weed control are large enough to be sure that it will give the farmer more freedom with regard to tillage operations. Tillage research should give the necessary information to enable farmers to use this freedom without unacceptable risks.
Chemical weed control should never be seen as an enemy or rival of tillage. Both, tillage and chemical weed control, are management operations with their own advantages and disadvantages, and both should be examined in research on their intrinsic value. Perhaps in tillage research the magnitude of the influence of soil tillage on soil structure was sometimes overestimated, but surely weed control was studied far too less in tillage research to make up to any extent with research in the chemical branche. Furthermore chemical weed control is still developing, but mechanization and tillage as a part of it is also on its way.

The objective of this issue

It is tried in this series of papers to evaluate the present state of knowledge after the impact that new chemicals for weed control gave to tillage research, enabling

research workers to grow crops without the main tillage operation. Several aspects of the problem like soil structure, crop management, weed control and mechanization aspects will be discussed. To avoid a too local vision two articles from abroad written by research workers who are in close contact with the Dutch group are added.
It is hoped that this issue may stimulate further research to keep ahead of the changing practices and that it will contribute to international co-operation in tillage research.

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