SOIL CULTIVATION:

INTRODUCTION AND ORIENTATION

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The title first suggested for this symposium was 'Soil Management', and the final choice has been 'Soil Cultivation'. To avoid any confusion in my own mind, I have considered the subject of 'soil disturbance'. My conscience does not bother me too much on this score because, in fact, Dr Luitingh invited me to give myself free rein.

In preparing this introduction, I attempted to consider the subject from as many points of view as possible. I enjoyed doing this very much because, in contrast with preparing a technical paper which is concerned only with the presentation and interpretation of data, I was now able to play with some of the ideas and opinions which I have suppressed for quite a long time.

The soil and the plant

My first consideration was the soil as part of the soil-plant-atmosphere continuum. I have been concenred for many years about the restraints imposed on our scientific progress by the inclination of research workers to consider a problem exclusively, or almost so, from the point of view of their own discipline alone. I am not entirely convinced that this habit of wearing blinkers isn't learned at some of our universities. If we are going to talk about the soil today, I trust that all of us here appreciate that the crop and the climate are important considerations before we start spending money and dissipating energy on some soil operation.

To try to express this concept in the simplest practical terms, if we have a crop that can successfully germinate and develop on a given soil as it stands, there is scarcely any argument for soil disturbance. And if the evaporative demand and nutrient requirements of the crop can be adequately met by a root system confined to a friable surface stratum of soil, is there any need to worry about modifications to the subsoil? Of course, the textbooks will tell you which crops are suited to which soils, and which crops are adapted to which climates, but our concern here is what we need to *do* to the soil for the crop to grow most advantageously in the existing climate.

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Soil characteristics

A second approach to the subject might be made by considering all of the soil characteristics. Once again, I think we might chide ourselves sometimes for being too channelled in our thinking – soil disturbance is concerned with the physical characteristics of the soil, fertilization is concerned with the chemical characteristics of the soil, and the biology of the soil is very complicated so leave it be! In fact, we are all aware that all three aspects of the soil are inextricably tied together, but it is not always easy to keep the mind wide open to such a basic truth.

As an illustration of a relationship between soil physical and soil biological characteristics, I am reminded of an experiment that we conducted on a deep recent wind-blown sand. We were really concerned with nematodes, which we knew to be a problem, but because we were doing some work on deep tillage at the time, this was included as an additional treatment. Some of us thought this was a waste of time on a sand, and so we deserved to be surprised by the results. Deep ploughing was as effective as a nematicide, and the effects of the treatments were not additive. In fact, when all was done, the nematologist blandly informed us that nematodes hate to be disturbed.

And while I am on the subject of being surprised, I might tell you about an episode that does concern tillage and the physical characteristics of the soil. Way back in about 1957 when I was at Illovo, a gentleman from Italy came along with his heavy duty plough and offered to create soil for us on one of our shaley hillsides. He said he would plough the area in May and would return in August the same year to rotavate it. We were all in favour of miracles, but were rather jocularly sceptical when the ploughing was done and tons of shale were exposed. By August our scepticism had gradually metamorphosed, and we were all converts to the effects of wide diurnal temperature fluctuations on exposed shale. The rotavator simply finished off the job.

The one soil characteristic which is of particular interest to me is soil moisture. Most of my research work has been concerned with crop water relations, and perhaps this explains, at least in part, my emphasis on the soil-plant-atmosphere continuum. If soil disturbance can in any way increase the amount of water available to the crop, then I am an early proponent. In the sugarcane belt of Natal, most of our crop is rainfed and water is undoubtedly the most limiting resource. We therefore favoured work on deep tillage from the start, and I think it will be generally accepted that my colleague, Peter Moberly, did some

outstanding work on this subject. But when we prepared our motivation for the project, we did temper our enthusiasm, because sugarcane is a vigorously deep-rooting crop. It seemed to us that deep soil disturbance was not likely to affect the depth of crop rooting appreciably, but that it could increase the speed of root penetration and the amount of root proliferation. These two factors could, conceivably increase the efficiency with which rainfall was used by the crop. In the event, however, it was shown that deep tillage was not a worthwhile operation on sugarcane lands in Natal.

You will forgive me if I belabour the moisture aspect of soils a little more. In the light of what I have to say later, it might be important for us to know what crops can do when left to their own devices, rather than how they perform when we attempt to make the environment as suitable as possible. We did a growth analysis experiment with sugarcane on a Waldene series soil, and we placed gypsum moisture blocks in the profile to a depth of 120 cm. At this depth the soil was a very heavy clay. In winter the blocks soon read zero, indicating no available moisture. Because of the relative impermeability of the subsoil to roots, we might have doubted these results, but attempts to take soil samples at depth for gravimetric moisture determinations were foiled by the continuous breaking of the augers in the bone dry clay. My point is simply that there is a time element involved here, and that a crop like sugarcane will exploit even an unlikely medium of all of its available water eventually.

Energy usage

A third approach to soil disturbance might one day be the most important of all our concerns. Disturbance requires energy, and we are depleting limited fossil fuel reserves to achieve what we believe to be necessary for crop production. Although total energy usage for the production of almost all crops comprises mainly that used for manufacturing fertilizer, estimates of tractor fuel requirements for four crops are:

Spring barley	: 14% of total energy input
Winter wheat	: 12% of total energy input
Lucerne	: 29% of total energy input
Perennial ryegrass	: 3% of total energy input

In fact, estimates of the E ratio, $\left[\frac{\text{gross energy in product}}{\text{energy input}}\right]$ for various crops must give us pause:

Banana	: 130
Maize	: 40
Rice	: 20
Sugarcane	: 11

Certainly, the less soil disturbance we need to effect, the less it should cost to produce the crop and the more fossil fuel we can save. My earlier reference to what a crop can do when left to its own devices comes in here, because the day may come when the value of fuel resources are such that the return from soil disturbance will no longer warrant its being done.

Conservation

As a fourth aspect of soil disturbance, I cannot ignore a subject which is dear to the hearts of many earnest agriculturalists in Natal, and that is conservation. If cultivation means an extra loss of soil, it might be an operation that *we* can afford, but it is not one that our successors on the land will thank us for having perpetrated. There are many things that can be done and are being done to prevent or reduce erosion, but we cannot escape the fact that bare tilled land is the most vulnerable land to erosion.

Minimum tillage

And this seems to be the logical point at which to introduce the subject of minium tillage. If we are serious in our concerns to reduce tractor fuel usage and to avoid unnecessary erosion, then minimum tillage must be an immediately attractive proposition. Minimum tillage is already practised extensively in some Western countries. There were 830 000 hectares in the United Kingdom which were managed in this way in 1973. More impressive still, there were 430 000 hectares in the United States in 1971 and 105 000 hectares in the United Kingdom in 1973 that were established under the 'no tillage' system, ie no soil disturbance at all.

The problem of introducing minimum tillage for sugarcane on our steep coastal hillsides has always been beyond us because we lacked an effective cane killer. The advent of a chemical called glyphosate appears to have eliminated this restraint, and there is now the prospect that many of our hillsides will only be tilled in a narrow band in the old interrow to permit the drawing of a furrow for the establishment of the new crop. In one experiment harvested so far, minimum tillage gave yields superior to those from conventional land preparation. In two other experiments on different soil types, minimum tillage is expected at least to hold its own. On the coastal sands, it has not even been necessary to till the old interrow. The only replant operation has been the drawing of a new furrow.

With sugarcane we effect a great deal of soil disturbance, not only when we plough out the old crop, but also during the ensuing months when we need to kill volunteer sugarcane plants which could carry ratoon stunting disease through to the next crop cycle. We therefore have an additional reason to welcome the concept of minimum tillage, which would obviate four or five field tillage operations that are now carried out in most areas.

It would be difficult to deny that some kind of land preparation is necessary in order to get good germination of many crops. Seedbed preparation therefore seems to be one undeniable advantage of soil tillage. For a crop like sugarcane, seedbed tilth need be of relatively minor importance if the weather after planting favours rapid germination Our recent experience with sugar beet in the midlands, on the other hand, has illustrated only too graphically how important seedbed preparation can be.

Soil aeration

Looking for further distinctive approaches to the subject of soil cultivation, one might ask the question: what is the single most important effect of soil disturbance? Many would answer unhesitatingly that it is soil aeration. I am sure there are circumstances where this is undoubtedly true, and I used to think that it was generally true for sugarcane. However, we have sustained yields for ten successive crops ploughing out both at Shakaskraal on a Waldene and at Pongola on a Makatini series soil, both under irrigation. The average throughout the cane industry is a plant crop and two or three ratoons before ploughing out. How much this is due to physiological deterioration of the crop and how much to soil conditions we do not know, but poor aeration in the heavier soils seems a very likely contributor to yield decline. I would refer here again to the performance of a crop when left to its own devices, and suggest that the day may come when we will not always be able to afford the luxury of modifying the environment to suit the crop. Crops that require frequent or intensive soil cultivation may become relics of the past.

Weed control

If 'soil aeration' is not the reason given automatically for soil cultivation, then perhaps weed control is the most likely alternative to spring to mind. However, the modern trend towards chemical weed control might already make this response seem a little old-fashioned to a newly-graduated agronomist. But the rising price of oil and the resulting increases in the costs of agricultural chemicals begins to make mechanical cultivation an attractive proposition again. Even from the point of view of energy conservation, we may yet smile again on the mule-drawn cultivator, providing that 'cane-tops' remain an acceptable diet to the uncomplaining animal.

Mulching

The pros and cons of surface soil mulching have been debated back and forth for many years in many quarters. If my memory serves me correctly, the consensus seems to be that surface soil disturbance to create a dry mulch which inhibits further evaporative losses, is only advantageous when soil wetting is really infrequent, and that it can be a disadvantage when the soil receives regular precipitation. This would seem to be confirmed by unreplicated results which we have from our lysimeters at Pongola.

On the other hand, one argument in favour of soil surface disturbance that I find very acceptable is that surface capping needs to be broken down in order to enhance water acceptance by the soil. It is suggested that, under irrigated conditions, this can be done chemically, but under rainfed conditions there seems to be no substitute for a light cultivation.

Taking the subject of water acceptance by the soil a step further, I am reminded of an experience I had quite a few years ago in Uganda. Whilst visiting a cotton research station there we experienced one of the most severe tropical downpours that I can remember. Ten minutes after the rain stopped I was taken out into the fields, where basin listing had entirely prevented runoff from a reasonably heavy soil on a medium slope. We have since investigated the potential of basin listing as a partial substitute for the trash layer in sugarcane fields, and our Agricultural Engineering department designed and built a very effective basin-listing machine.

Fertilization and liming

Finally, one may consider soil disturbance from the point of view of incorporating fertilizers and ameliorants. These subjects will be considered during the afternoon session of the symposium. I would simply like to comment here that, if the only reason for disturbing the soil was to incorporate chemicals, we would very seldom do anything in our sugarcane fields.

Summary

Attempting to collate all of the pros and cons regarding soil cultivation, then, I would say that:

i) tradition seems to favour a remarkable amount of soil disturbance

ii) preparation of a well tilled seedbed is often necessary

iii) for some crops in some soils, soil disturbance may be advantageous to improve aeration, and also to effect necessary crop hygiene

iv) some soil disturbance is unavoidable if mechanical weed control methods are to be employed

v) it is worthwhile to break a soil up in order to improve water acceptance, but surface soil disturbance to form a 'mulch' will seldom be warranted.

On the other hand, I would also say that:

i) some of the soil disturbance that we effect is not very logical and much of it does not have experimental evidence to support its being done

ii) we must begin to train ourselves to consider the energy usage involved in various agricultural operations, including soil cultivation, and to ensure that the dissipation of our fossil fuel reserves is warranted

iii) we must welcome the concept of minimum tillage, particularly in South Africa, where soil erosion is such a real hazard.