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SAWMA VIEWPOINT

Since the last journal was published in May the Association has been continuing its normal technical programme with some success.

At least it seems that S.A.W.M.A. have found an ideal home at the Royal Show in the Arable Centre marquee. In 1979 it put on a small exhibit on the suitability of soil for direct drilling and drainage scheme design for different soil types. It fitted in well with the surrounding exhibits and we hope to have another exhibit there in 1980. (Royal Show 30th June – 3rd July 1980.)

After the Royal Show – towards the end of August – John Muirhead, Eastlands Farm, Broadwell-on-Sea, invited members to an afternoon farm walk. I was delighted to see such a str[illegible]ming representation at the visit. I am sure that everyone who went came away with plenty of food for thought. My own feeling is that S.A.W.M.A. if it wishes to strengthen its farming membership, should no longer concentrate on soil/water relationships but relate these to the farmers growing crop.

Congratulation to John Muirhead for being the 1979 recipient of the Joe Nickerson Cereal Award. It would be difficult to think of a more worthy winner. Stephen Bond, an ex-Chairman of the S.A.W.M.A. Technical Committee also shared in the awards congratulations.

October 7 saw the Conference Hall at the N.A.C. well filled with people attending the joint S.A.W.M.A./IAgriE Conference 'Tillage Equipment Design and Power Requirement in the '80s'. The Conference achieved its larger objective of getting all sides of the industry – farmer, engineer and advisor – together to discuss problems in machinery use, research work and future development trends in cultivation techniques. I believe all those attending found the day well worthwhile.

During December, the National College of Agricultural Engineering held two annual courses on Irrigation and Drainage Both courses were well attended and the College is to be congratulated in organising them. A special mention should go to the two course organisers, Dr. R. Godwin, N.C.A.E. and Mr. D. Castle of the A.D.A.S. Land Drainage School. Enquiries on future courses should be sent to the Editor.

The Annual General Meeting of the Association was held at the National Vegetable Research Station, Wellesbourne, Warwickshire on Thursday 7th February. There were two main changes in Committee officers.

Mr. A. E. T. Forsyth succeeds Mr. R. B. Dottridge as Vice-Chairman of C[illegible] Anthony, [illegible]n in South Warwickshire, has [illegible] experience in managing difficult soils. He also operates a large contracting business.

Dr. H. P. Allen retired as Chairman of the Association's Technical Committee after two years in the post. He is succeeded by Mr. Mike Darbishire, who is a farmer, journalist and public relations consultant from Norfolk.

The afternoon technical meeting was very worthwhile, with four papers on aspects of the Station's work. Two parts of this work are immediately of interest. Work on deep cultivations – up to 90cms. – has increased the yields of potatoes and broad beans by up to 75 or 95% respectively. Researchers believe this effect is made possible by increased rooting depth and more water being made available to the plant per unit depth.

Another interesting development is a nitrogen forecasting method whereby farmers are able to calculate how much nitrogen has been leached from the soil over winter and thereby readjust nitrogen applications to suit residual levels. The N.V.R.S. will be putting this on the market in the near future.

As there was considerable interest shown in the work of the station an afternoon visit to the N.V.R.S. has been organised for 18th July. More details later.

The Spring Drainage Conference will take place at the John O'Gaunt Hotel, Daventry on the afternoon of Wednesday 14th May. Various topics for discussion are being considered at the moment. The programme will be circulated later when this is finalised, together with the details of the Annual Dinner.

While we are on the subject of visits, the Norfolk Agricultural Station, Morley, Wymondham, has invited us to visit on Tuesday 3rd June – once again, details later. We will be looking at long-term experiments on soil improvement, short and long term experimental work on cereals and strip tillage of sugar beet, some combined work on fertiliser applications to sugar beet seedbeds and the results of sugar beet seedbed preparation experiments.

Course in Land Restoration

At Wolfson College, Cambridge, between the 23rd and 27th June 1980, there will be a course specifically concerned with the restoration of sand and gravel workings to agriculture. The course has a balance of visits and lecture room work so that those attending have a better understanding of crop requirements from soils after excavation has taken place. The course which is being organised by Land Capability Consultants Ltd., Nelson House, 52 Station Road, Fulbourn, Cambridgeshire. Telephone: (0223) 880726, is designed to attract estate managers, restoration supervisors and planners.

In this issue

Plastics Association

The Plastics Drainage Manufacturers Association (PLDMA) has been formed under the chairmanship of Richard Poole of Critchley Bros. The Association brings together five of the main U.K. manufacturers in the form of a trade association. Their role is to promote the use of plastics in U.K. land drainage and overcome the estimated 75% market which is held by the traditional clay tiles. Plastic pipes are manufactured to a high British standard and therefore form a reliable drainage product.

CULTIVATION AND SOIL/PLANT RELATIONSHIPS

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Introduction

Cultivation has traditionally been carried out for two main reasons, to remove weeds and to provide a suitable environment in which seeds can germinate and seedlings can develop.

However the nub of the problem is that it is not possible to indicate how much cultivation of soil is needed, nor can specifications for seed-beds be produced in any way approaching that in which engineers normally wish to work. Thus there would appear to be a considerable gulf between the users of cultivation machinery on the one hand, including agronomists and soil scientists, and those concerned with development and manufacture of that equipment on the other.

Faced with this long-standing dilemma, but with the growing range of herbicides available to cope with one of the traditional reasons for cultivation it is doubtful if we can do better than reflect on the opening address by Sir Charles Pereira at the ARC/ADAS Technical Meeting on Reduced Cultivation and Direct Drilling in 1975. He suggested that 'our most logical approach to the whole subject of tillage should start from the observation that, when free of man's interference, most of our soils are clothed with a vigorous system of vegetation which requires no uniform seed-beds'. He also reminded us that tillage can cause deterioration of the soil structure, by oxidation of organic matter, mechanical damage to the structure, including compaction and smearing, thus interfering with movement of air and water, and possibly adversely affecting root growth. Having produced these circumstances. he noted that further mechanical work on the soil is often the only way to trv to remedy the situation.

In favourable conditions cereal roots can reach depths of 100–150 cm, and sometimes greater depths, especially in winter cereals (Fig. 1). However most of the root system is found in the upper 20–30 cm of the soil (Russell, 1977). When a soil is compacted it is mainly the larger pores that are made smaller. This can have two main effects: i. since roots are unable to decrease their diameter to enter pores smaller than themselves, the rate of root elongation may be restricted, and a shallow root system can result (Fig. 2); ii. water may drain less freely and the soil becomes poorly aerated, because oxygen can not diffuse into the soil so easily. Oxygen is needed in soil for respiration in roots and soil organisms, and in low oxygen conditions root growth and nutrient and water uptake are all slower. In addition, in anaerobic conditions nitrate present in the soil can be denitrified to gases, and the nutrient is lost from the soil.

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Cultivation

Many soils that are prone to poor aeration are also those most subject to compaction, and so these problems are therefore often interrelated.

With these thoughts in mind, and conscious of the energy required in cultivation, it would seem most appropriate to consider how soil/plant relationships are affected when cultivation is simplified, including its most extreme form by direct drilling. Although the practical possibility of avoiding cultivation is fairly recent, due to the availability of herbicides, the idea is not. As long ago as 1849 Daniel Lee in the USA described tillage as an 'unnatural operation', and concluded that 'tillage and cropping exhaust land faster than can be done in any way short of carting off the surface soil in a mass' (Bagley, 1973). In a paper summarising a long series of cultivation experiments at Rothamsted in the 1920s and 30s, Keen and Russell (1937) found 'no justification for operations beyond the minimum needed to get a seedbed and to check weeds until the crop is well established. Work in excess of this minimum, far from increasing the crop, appreciably diminishes it.'

Effects of simplified cultivation on soil conditions and root growth

Soil properties and root growth have been measured in only a few cultivation experiments on a limited range of soil types. Furthermore the effects of continuing different methods of cultivation for several years have been followed in even fewer cases, and much remains unknown. Nevertheless, some trends from work so far are evident. Often investigators have confined their attention to the extremes of ploughing and direct drilling. When measured, shallow cultivation has tended to give intermediate effects.

Surface soil conditions. Many clay soils are self-mulching (Fig. 3) and this can provide very good conditions for germination in the surface 2–3 cm; self-mulching is most evident in calcareous clays, but is not confined to them. Disposal of straw residues by burning also can aid the formation of stable aggregates in the surface layer (Douglas, 1977). Crop establishment after direct drilling or sowing after shallow cultivation can be much more rapid in dry autumn conditions than when this layer is inverted by ploughing before drilling.

These effects have not been evident in silty soils (Fig. 4).

Soil conditions down the profile. The main effects that have been found, after direct drilling in comparison with ploughing are:

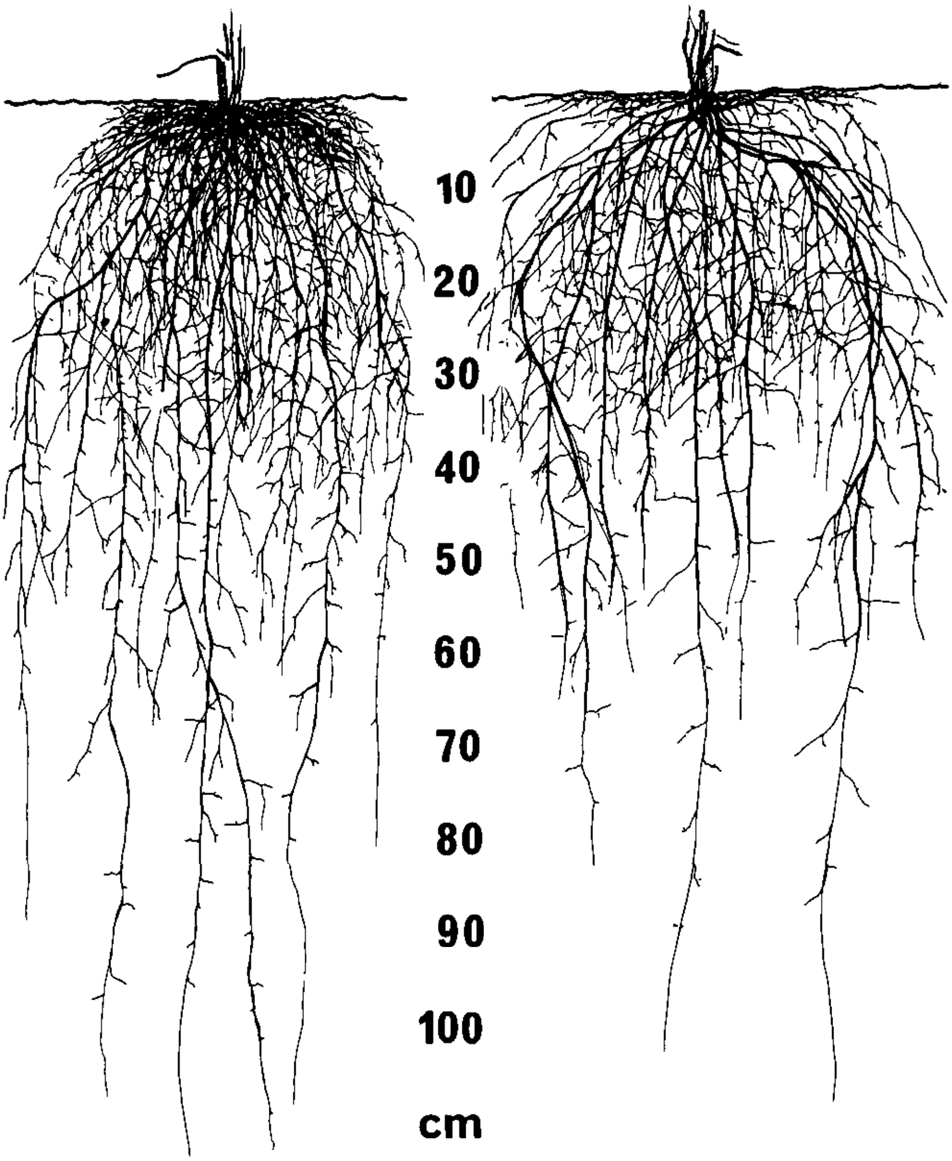

Fig. 1. Diagram of root system of winter wheat at the end of tillering (h April), based on root counts in soil cores. Left: after direct drilling; right: after ploughing. (Ellis and Barnes, 1980).

1. More compact top soil, reflected in greater penetrometer resistance, and smaller total pore space, with a larger proportion of the pores filled with water (Ellis *et al*, 1976; Pidgeon and Soane, 1977).
2. More earthworms and their channels; increases in the numbers of earthworms by a factor of two or three after three successive years have been found in many soils (Fig. 5) (Barnes and Ellis, 1979).
3. Increased penetration to depth of continuous cracks in clay soils (Fig. 6) (Ellis *et al*, 1979).
4. More rapid infiltration of water on some soils (Ehlers, 1975. Goss *et al*, 1978).
5. Improved aeration in some soils (Dowdell *et al*, 1979), but poorer aeration on the heaviest soils in wet winters (Dowdell, R. J., personal communicationj.
6. Slower mineralisation of nitrogen from organic matter (Dowdell and Cannell, 1975), and in wet seasons more losses of nitrous oxide gases by denitrification (Dowdell, R. J. personal communication).
7. Greater concentrations of phosphorus and potassium in the surface layers of soil (Riley *et al*, 1976; Drew and Saker, 1978).

Root growth. Direct drilling generally encourages proliferation of roots in the surface few cms of soil (Drew and Saker, 1978). but below that depth distribution may also be affected. Root growth of spring barley has sometimes been restricted (Ellis *et al*, 1977, Holmes, 1977; Hodgson *et al*, 1977), especially on coarse sandy soils containing little organic matter (Davies, D. B., personal communicationj. In winier wheat by the beginn-

Fig. 2. Effect of mechanical impedance on root growth of barley. Left: unimpeded; right: pore size too small for main root axes, but laterals develop. Goss, M. J. (1977) J. exp. Bot 28, 96–111.

ing of stem elongation (in April) the number of roots at 80–100 cm depth can be greater after direct drilling, especially in dry conditions (Fig. 1) (Ellis and Barnes, 1980); on the other hand in wet seasons on the heaviest soils direct drilling discourages deep rooting of winter cereals.

Root function. In spite of the accummulation of phosphorus and potassium in the surface layers of land that is not ploughed, generally the concentration of these nutrients in the crop has been unaffected, even in dry conditions (Cannell and Graham, 1979). The main exceptions have been less uptake of potassium by winter wheat on a heavy soil, after a wet winter when root growth was restricted (Cannell *et al,* 1980), and in spring crops when rooting has been restricted.

The uptake of nitrogen by winter and spring cereals that have been direct-drilled has tended to be slower, especially in the early stages of growth (Holmes, 1977; Cannell and Graham, 1979). The effect has been most evident on heavy soils after wet winters when rooting was restricted (Cannell *et al,* 1980). This has led to some modification of nitrogen fertilizer requirement. On average i 45 comparisons in the UK an liti 10 kg N ha^{-1} was required to give the same yield of winter wheat after direct drilling as after ploughing (Davies and Cannell, 1975).

The deeper rooting of direct-drilled winter cereals in the early spring has facilitated greater extraction of water from depth. In dry seasons this may lead to heavier yields; for example on 3 clay soils in 1976, crops of winter wheat on average extracted 17 mm more water from the top 100 cm of soil (Goss *et al,* 1978), that was associated with a mean yield increase of 16 per cent (Ellis *et al,* 1979; Cannell *et al,* 1980).

Effects of method of cultivation on crop yield

It is not possible to carry out experiments on all soil types, yet farmers are anxious to know the relevance of different methods of cultivation on their land. Crop yields have been measured in many experimental comparisons of different methods of cultivation, especially for cereal crops, and using this information an attempt has been made to classify soil types in relation to their suitability for direct drilling (Cannell *et al,* 1978) (Fig. 7).

The soils are classified into three categories according to the expected crop performance on them after direct drilling as follows:

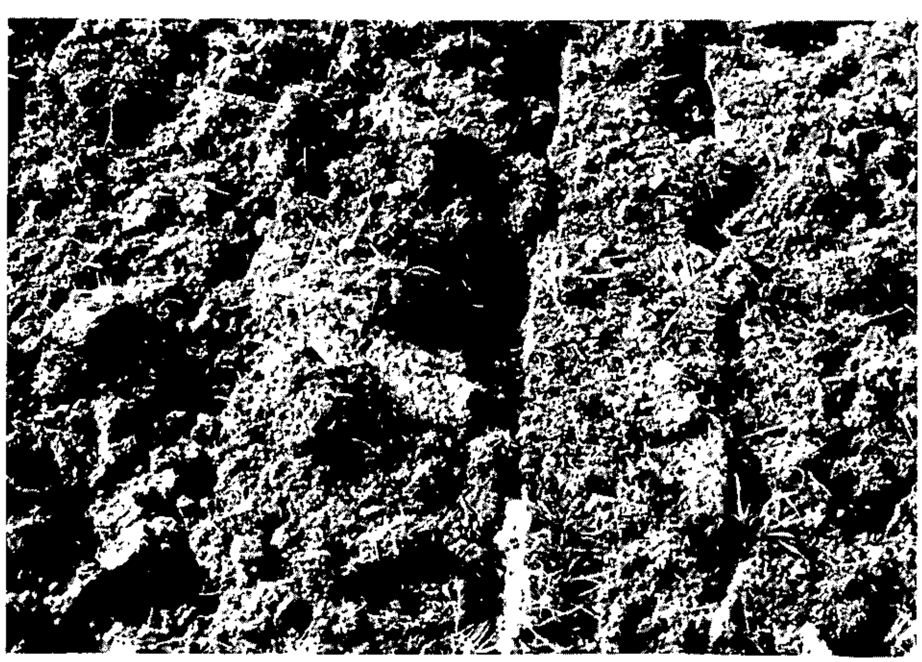

Fig. 3. Friable surface tilth on a clay soil that had been direct-drilled.

Cultivation

Category 1.

Soils with favourable properties, where yields from both autumn and spring sown cereals are t[illegible] equal those f[illegible] conventionally cultivated [illegible] *This category includes* chalk and limestone soils and well-drained loams, and occupies about 30 per cent of the cereal growing area of the country. For example see Fig. 8.

Category 2.

Soils where with good management, yields of winter cereals are likely to equal those after conventional cultivation, but yields of spring cereals are likely to be inferior. This category includes calcareous clays (8 per cent of the cereal growing area) and other clayey soils that have been improved by drainage measures. For examples see Figs. 3 and 9.

Category 3.

Soils where there is a substantial risk that yields will be smaller than from conventional cultivation, especially with spring sown crops. This category includes sandy soils with low organic matter content (Fig. 10), silty soils (Fig. 4) and many wet alluvial and clayey soils.

The classification can also be used as a guide for less extreme forms of simplified cultivation, since in experiments shallow soil disturbance has invariably given at least as satisfactory yields as direct drilling.

Although the large area of non-calcareous clays (about 35 per cent of the cereal area) have been put in Category 2, there is an element of uncertainty about the suitabiiity of the heaviest of these soils for simplified cultivation (Table 1), especially when the surface layers are unstable so that ponding of water occurs. However, the difficulties of *traditional culti[illegible] on these s[illegible]* in wet autumns are such that a smaller area of crops may be established; simplified cultivation may in practice be advantageous because of the greater likelihood of establishing the required area of winter crops, even if yields are sometimes less.

Until recently there had been no evidence that crops grown after simplified cultivation could achieve yields equal to those grown after deeper soil disturbance when conditions favour heavy yields. In 1977 – 78 such conditions existed, and yields of more than 10 t ha^{-1} were achieved in three experiments on clay soils, irrespective of the method of cultivation (Table 2). These yields are close to the potential for winter wheat in the UK of about 12 t ha^{-1} (Austin, 1978).

Fig. 4. A silt loom soil (hot had been direct-drilled. Note the absence of surface tilth. On soils of this type yields of cereals after direct drilling have usually been less than after ploughing.

Machinery problems that affect soil/plant relationships. Drills. With direct drilling, and to a lesser extent with shallow cultivation, success depends on thorough removal of straw (Ellis and Lynch, 1977). Unless this is achieved, the residues may impede the drill and also seeds are likely to be buried in contact with straw residues that may produce toxic substances in anaerobic soils. Germination and plant establishment can be restricted (Fig. 11), especially in wet autumns, when the advantages in timeliness of simplified methods of cultivation for establishing winier cereals are potentially greatest, and yield depressed. New direct drilling equipment, such as that being developed at the Scottish Institute of [illegible]ic[illegible]al Engineering, that avo[illegible]ds placing the seed in contact with s[illegible]w residues may h[illegible] to overcome [illegible]is problem (Fig. 12). [illegible]hemical tr[illegible]ment of 'seeds may also help to alleviate the problem. Direct drilling is still a relatively new procedure and further developments in drill design can be expected. Nevertheless, some of the recently introduced drills in this country and overseas are able to give satisfactory results in many conditions.

Most experiments on simplified cultivation have been concerned with cereals or other surface-harvested crops. However, important work is in progress at the Norfolk Agricultural Station where strip tillage for sugar beet in rotation with cereal crops is being studied; early results are encouraging (McClean, S.P., personal communication).

Compaction. Direct-drilled land is often [illegible]re resistant to [illegible]i[illegible] and thus more traffi[illegible] than [illegible]a[illegible] that has been ploughed, but many of the clay soils are easily deformed when wet (Fig. 13) and there is the possibility of cumulative effects of wheel damage; without cultivation there is no opportunity to counteract these effects. Compaction by com-

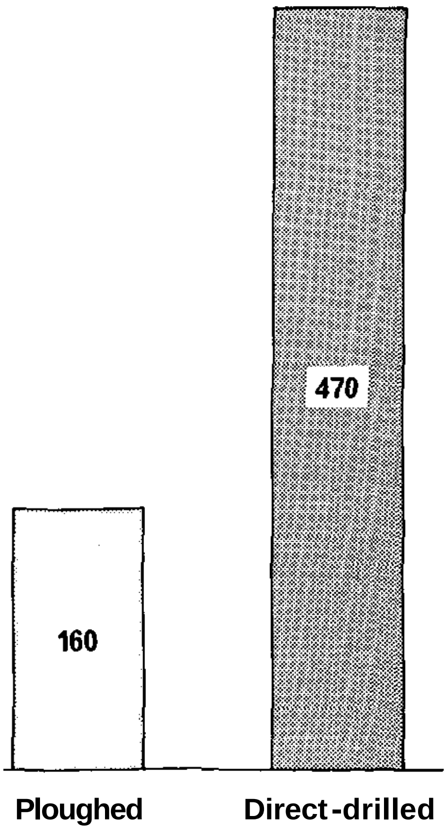

Fig. 5. Numbers of earthworms in o clay soil after direct drilling and ploughing after 2 years.

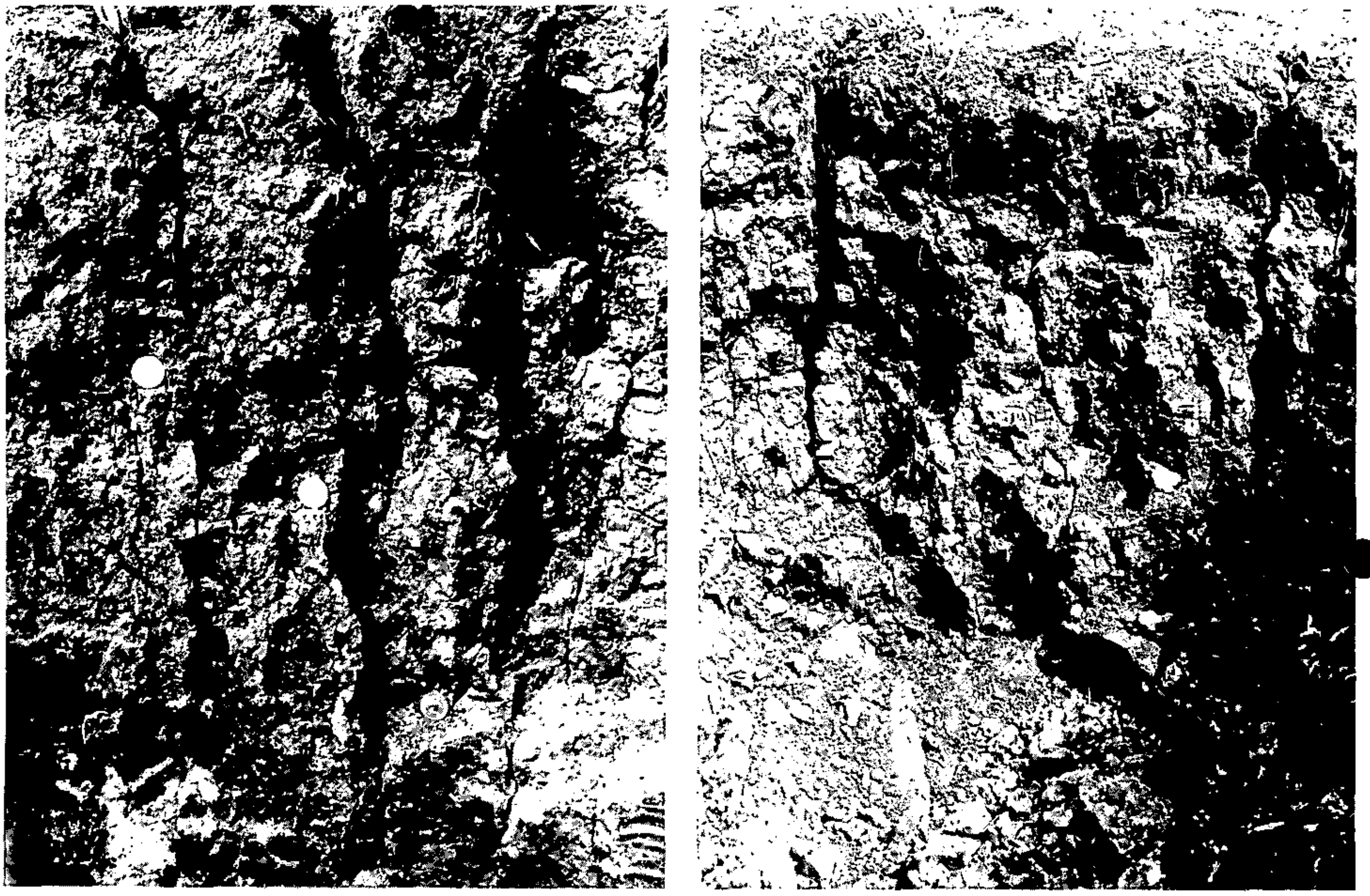

Fig. 6. Effect Of cultivation on depths ofcracking in summer in a cloy soil. Lefl: continuous crocks extend over I m offer direct drilling; right: shallower crocks after ploughing. Ellis et al (1979).

bine harvesters may be one of the worst causes of this problem. The need for low ground-pressure vehicles to minimise compaction in simplified cultivation systems has recently been discussed by Elliott (1979).

Drainage. Assessments of simplified cultivation on clay soils have been made on land drained according to recommendations for ploughed land. However in view of the effects on soil physical properties the drainage requirements may depend on the type of cultivation. The top soil of direct-drilled land has a smaller total pore space and possibly smaller hydraulic conductivity than ploughed land. If so, the lateral movement of water to drains is likely to be somewhat impeded. On the other hand, the presence of earthworm channels and cracks between peds that are not destroyed annually by ploughing can substantially aid infiltration of water. As yet the relative extent of these effects on the drainage of heavy land is not fully understood.

Subsoiling. There seem to be many soils where, for cereals, especially sown in the autumn, little soil disturbance is necessary (apart from drainage operations, including mole drainage). Plough pans such as in Fig. 14 need to be broken before direct drilling. On some soils in some years compaction may be unavoidable especially where root crops are grown in mixed rotation with cereals, e.g. after harvesting in wet seasons (Fig. 13). Furthermore, as already noted, some soils are unsuited to direct drilling and may benefit not only from cultivation, but possibly from a simultaneous deep placement of nutrients, particularly the immobile nutrients such as phosphorus. Until recently suitable machinery has not been available. In an experiment where subsoiling in a sandy loam was carried out by hand. with and without deep placement of P and K. the benefits have recently been described by McEwen and Johnson (1979). The treatments were applied once in 1973, and over the following 4 years subsoiling alone increased the mean yield of winter wheat by 21 per cent, barley by 24 per cent, and sugar (from beet) by 11 per cent; potato yields were not affected. Incorporating P and K into the subsoil did not affect wheat yield, but increased the mean yield of potatoes by 16 per cent, and further increased barley and sugar by 20 and 4 per cent respectively. The reasons for these effects are unknown. Machinery such as the winged subsoiler (Spoor, 1975) and the Wye double digger (Warboys et al, 1976) that can disturb subsoils to a greater extent than conventional subsoilers, and be adapted to place nutrients at depth will enable these procedures to be more readily and widely evaluated.

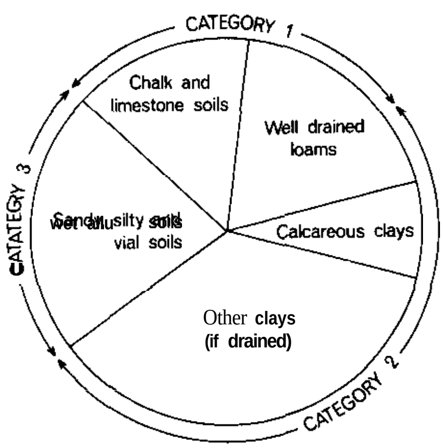

Fig. 7. The proportions of the main soil/types in cereal growing areas of England and Wales, classified according to their suitability for direct drilling of cereals (see lexl for expected crop performance in each category).

Cultivation

Fig. 8. Effecr of method of straw disposal on establishment of direct-drilled winter wheat. Left: slraw and stubble burnt; centre: straw present; right: straw baled, stubble present. Phorograph courtesy of Drayton Experimental Husbandry Form.

Conclusions

1. Without cultivation soil is more compact, and although this may be detrimental, in the absence of cultivation greater earthworm activity, more continuous fissures and channels in some soils can aid infiltration of water, aeration and root growth. As yet, however, the likely success or otherwise of simplified methods of cultivation in different soils can only be predicted in a general way. This is partly due to the inability to measure soil properties that affect root growth. Furthermore restricted rooting may not affect yield in all years.
2. Direct drilling of spring cereals is likely to be successful on chalk and limestone soils and well drained loams, and of winter cereals on these soils and also on clays where drainage is satisfactory. Direct drilling is least likely to be suc-

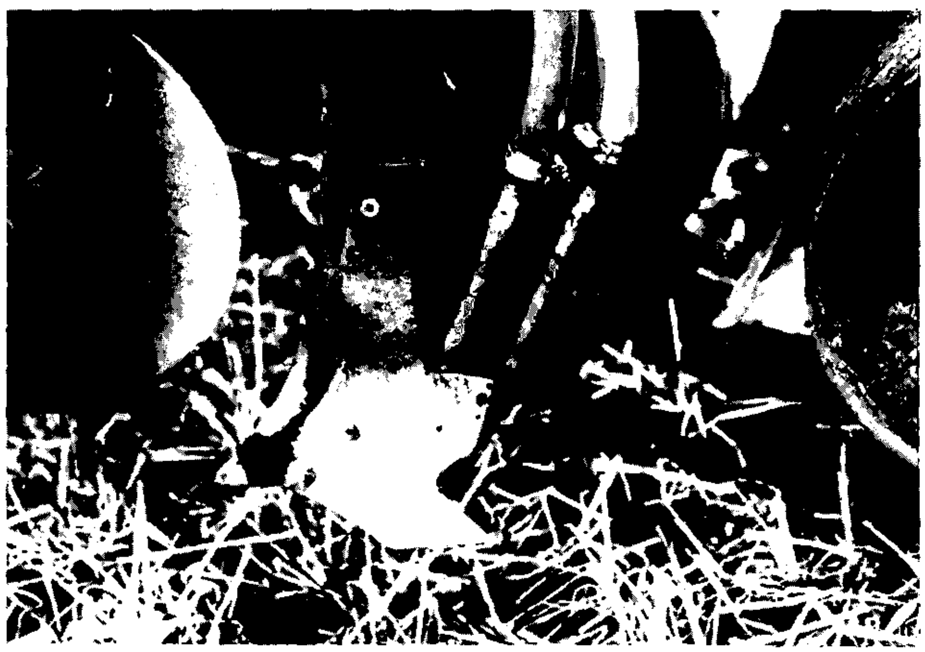

Fig. 9. Prototype direct-drill developed by Scottish Institute of Agricultural Engineering.

Fig. 10. A plough pan in a clay soil that can restrict drainage and impede root growth. Such pans should be broken before direct drilling.

cessful on coarse sands low in organic matter, in wet soils, and in weakly structured silts; on the latter shallow cultivation may be sufficient to give yields at least equal to those after ploughing.

3. In the UK the main attraction of simplified cultivation is its speed, enabling a larger area of heavier yielding autumn sown cereals especially winter wheat to be grown, and sown early enough for maximum yield.
4. Experiments in many countries point to the possibilities of simplifying cultivation without loss of yield. Although Keen and Russell stated more than forty years ago that 'We have been driven to revise our views' (on the possibility of simplifying cultivation), there is still scepticism about the applicability of new methods now possible. Systems involving shallow cultivation may be more readily adopted than the most extreme of direct drilling. Experiments now in progress should assist in clarifying where the techniques are most appropriate.
5. Improved direct drills and means of minimising compaction during all field operations will be important in further adoption of simplified cultivation techniques.
6. The role of subsoiling and the deep placement of nutrients in any cultivation system has not been adequately assessed. New machinery should now make this possible.

Table 1. Comparison of direct drilling and ploughing on yield of winter cereals on two non-calcareous clay soils.

	Direct-drilled yield as a per cent of ploughed treatment	
	Lawford series (35 per cent clay)	Denchworth series (50 per cent clay)
1974 – 75 (wet winter)	99	82
1975 – 76 (dry)	111	107
1976 – 77 (wet)	107	116*
1977 – 78 (wet)	102	94

* yield of ploughed crap depressed by more severe lodging (from Cannell *et al*, 1980)

Table 2. Yields (t ha^{-1}) of winter wheat on three clay soils after different methods of cultivation in 1977 – 78 season.

	Direct-drilled	Shallow tined	Ploughed
Evesham series	10.7	10.4	10.1
Lawford series	10.5	10.2	10.2
Denchworth series	9.4	—	10.0

Results are for the nitrogen fertilizer treatment giving the heaviest yield for each cultivation treatment.

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Loaded Wheels

THE PRICE OF LOADED WHEELS

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Back to the Strutt Report

Founder members of SAWMA will recall that the origins of the Association stem from the concern aroused in the late 1960's by farmers' reports of poor crop growth due to soil conditions following a number of wet autumns. The Ministry of Agriculture, Fisheries and Food conducted an enquiry led by Sir Nigel Strutt which pointed to the adverse consequences of use of powerful and heavy machinery on vulnerable soils. At the time many people felt that modern farming had moved too far away from a concern for the soil and that it was time for a return. SAWMA was one of the means by which farmers were encouraged to a re-awakening of interest in the soil.

It is interesting now to re-read 'Modern Farming and the Soil' in the light of today's experiences and particularly those relating to the new technique of direct drilling. The report examined a mass of evidence and came up with conclusions and a list of recommendations, one of which was:

> "206. We conclude that although the effects of compaction, deformation and smearing of soils by machines can be very damaging and the worst of them may appear to be permanent, we have found no instance where recovery has not taken place given time, suitable weather and appropriate treatment. Weather is one of the key factors. There will always be too few 'workable days' especially in wet seasons and the best way of coping with the situation is to improve soil condition by drainage and suitable cultivations to give more flexibility in the use of machines, to find ways of reducing compaction and to develop the best remedial methods when damage does occur."

What is sobering about the report is the way in which its authors seem to have accepted the inevitability of powerful heavy machines, of wheel compaction and could point only to 'timeliness' as a means of lessening the damaging effects of heavy machines. The spirit of the time was centred on an acceptance of the use of heavy cultural machinery in arable husbandry and did not apparently seek novel alternatives.

Why the new interest in the damaging effect of wheels?

A fact that we have to face is that a 30-year trend of more mechanisation, cultivation and powerful tractors is running out of steam. The recent jump in energy costs has for the first time put deep cultivation at both a financial and energy disadvantage compared with shallow cultivation and direct drilling. The cost of tractive power is rising more rapidly than the value of the produce (cereals particularly) which it is being used to produce. Since energy costs affect all parts of the manufacturing process this trend may be predicted to get worse. In their continued search for more efficient production British farmers will have to turn away from deep soil cultivation in all but the most valuable of crops which have to grow in deep loose soil because that is where their production forms (potatoes, carrots etc.). The certainty of reduced cultivation is with us now and we have to adjust our methods and equipment to the new technique.

Some 10 years' critical study of direct drilling by WRO, Letcombe Laboratory and other institutes has indicated that healthy crops cannot be grown regularly if the soil is compacted. The key to success in direct drilling is to have a freely percolating subsoil and a level firm (but uncompacted) topsoil with a good surface tilth to provide the seedbed each year. The maintenance of such a condition is not consistent with tractors designed for tillage which have to be built heavy in order to exert the ground pressure for grip which will transfer the tractive power to pull the implement through the soil: Tractor tyres have chevrons which penetrate the loose soil, compacting it and providing a soil resistance upon which the wheels can grip; they do not perform efficiently without some degree of slip. Slip implies the compaction and movement of loose soil. Thus the design of tyre linked to the design of tractor is highly suitable for old type cultivation but totally unacceptable on a surface which is not to be cultivated or compacted. New designs and new approaches are essential if the best is to be obtained from direct drilling, but first let us be clear about how wheels cause damage as they are used in our agriculture today.

The ways in which wheels damage soil

There are broadly three direct and three indirect ways in which compaction by wheels reduces the effective use of soil for crop production. The direct ways are:

1. Compaction reduces the ability of the soil to allow infiltration of rainfall or irrigation. Water held up by an impervious layer causes the collapse of soil structure locally and a progressive worsening leading to ponding.
2. There is a minimum size of pore space below which plant roots cannot penetrate. Root systems have a dynamic versatility which allows them to spread around looking for points of entry so limited compaction might have only a localised effect. But extensive compaction means shallow rooting.
3. A partial compaction of soil by wheels reduces the total volume of exploitable soil. This may have a generally prejudicial effect on the ability of the crop to survive periods of drought. For example a topsoil of depth 9 in. which has been subject to 30% compaction is effectively reduced to a depth of 6 in.

The indirect causes of damage are:

1. Where wheel compaction causes an uneven surface the efficient working of drills, harvesters etc. may be prevented. In these days of increasing precision in field operations this may be a significant factor in many vegetable or processed crops.
2. Soil which is compacted or rutted requires re-cultivation before the next crop. If the only reason that re-cultivation has to take place is to eliminate wheel markings then the whole cost of the deep cultivation has to be charged to the wheel markings.
3. Direct drilling offers savings in costs of labour and fuel. It also offers great opportunities of increased crop area sown during the autumn. If a wheel marked surface prevents direct drilling then the farm has been reduced in efficiency.

Much wheel marking is avoidable

In other walks of life there are needs for the carriage of loads over vulnerable surfaces which have had to be met by engineering design. And let us be clear on this point, once soil cultivation is removed the requirements for the growing of cereal crops, for example, are largely materials handling, transport, processing and placement, be it seed, fertilizer or chemicals and including the harvesting and transport of grain (Table 1). Cross country transport of materials has given rise to vehicles capable of carrying loads on all sorts of surfaces from desert sands to Alaskan snow. These specialist vehicles have one thing in common, they are equipped with special tyres or tracks. Usually the meeting-point between loaded vehicle and soil surface is the tyre. If loads are to be carried with the minimum of damaging effect on the soil then the role and choice of the tyre is crucial.

In America Goodyear for example make and sell a range of tyres (Terra-tires) for particular purposes having low inflation pressure. As an example of what can be achieved there are tyres capable of transporting a 12 ton loaded vehicle at a speed of 30 mph at an inflation pressure of 6 psi. However these tyres are expensive: for a given ground pressure upper limit, the greater the total load the more expensive the tyre. Hence the importance of keeping the vehicle as light as possible. A properly designed transport vehicle should carry at least its own weight in pay-load and some carry double that. This is in contrast to a tractor which cannot normally carry much more than two-thirds of its weight on its linkage. A purpose designed transport vehicle offers the facility of most of the total weight being pay-load (Table 2).

The approach to ascertaining what vehicle is needed in particular farming situations starts with a calculation of the necessary loads. How much seed, fertilizer or spray liquid to be carried at one filling to cover an adequate area at one go and therefore in a day's work. Until now weedkiller sprays have been some of the heaviest loads needing to be applied to the crop when the soil may be vulnerable to compaction (450 gallons ≡ 2 tons). However recent developments in low volume and controlled drop application suggest that we may reduce water volume by at least 75% and therefore the weight of the sprayer and its load. Far and away the heaviest load to be carried is that of grain at harvest time. Fortunately this task usually occurs when the soil is relatively dry and has some resistance to compaction and much of the load-carrying is off-field rather than on.

Carriage of typical loads over field surface for cereal production

Material	Weight per acre (lb)	Weight per 10 acres (lb)
Seed	140	1400
Fertilizer	350	3500
Sprays	200 (conventional)	2000
	40 (low volume)	400
No of passes: seeds — 1, fertilizer — 2–4, sprays 2–6		

Table I

It is appropriate to mention that it is not necessary for combine harvesters to make the wheel ruts that they do during wet harvests. At least three manufacturers of combines sold in UK market rice combines elsewhere in the world which are equipped with half tracks and low pressure steering tyres to ensure that the combine does not sink into the vulnerable soils on which rice is grown. One wonders why such facilities are not marketed in UK. Presumably it is because there is no demand, an indication of the way in which SAWMA and interested farmers could help towards an awareness of ways of avoiding wheel compaction. On the basis of present tyre designs it should be possible to carry all the loads associated with cereals at much lower tyre pressures, say at 5–10 psi, than at present with beneficial reduction in wheel compaction.

Low ground pressure means more than just a reduction in wheel-marking. Some of our best cereal soils are clays, and on them tractors cannot go when they have a high moisture content, an average figure is 43% of days workable on heavy soils in October and 33% in November (Table 3). The lower the ground pressure the greater the access on wet soil and increase in working time, a crucial requirement now that spraying has to occur in winter cereals in the autumn. Indeed one can go further: a cereal farmer wanting freedom to use a range of post-emergence herbicides in the autumn and top dress early in the spring must have a low ground pressure vehicle capable of going on the land.

Crop production with high speed, low ground pressure vehicles

In the farming of the future (which could be with us today given more pressure from farmers) the growing of surface harvested crops (cereals, maize, rape, grasses etc.) will be by direct drilling. We shall regard the topsoil and particularly its surface as a vulnerable biological medium which is valued and preserved for the crops it can grow and not to be destructured and rutted by wheels. If a recent official survey is to be believed some 80% of the land which grows cereals in England will come within this category. The transport of seed, fertilizer, chemicals and grain will be across the surface with specially designed light vehicles going at high speed so as to achieve a very much greater area cover than can be achieved with tractors. The field operations will be at speeds around 20 mph because the vehicles will be designed for this purpose. If cynics think that

Table 2 Vehicle details

	Tractor	Load transporters			Low ground pressure vehicles	
	MF 565	Ontop	Bedford CF340	Muli Reform 45	Argocat	Atlas
Engine power, HP	63	71 or 108	60	45	16 & 30	64
Vehicle weight, lb	6225	9918	3113	3440	690	1100
Maximum load, lb	3400	16530	4323	5379	970	2000
Weight of loaded vehicle, lb	9625	26448	7436	8819	1660	3100
Ratio load: unladen weight	0.55	1.7	1.4	1.6	1.4	1.8
Tyre pressure: front, psi	26–30	5–30'	20–40	20–40	2	3
rear, psi	12–16					
Ground clearance, in	13	15	6	12	+12	+12
Maximum speed, mph	15	36	+50	18	25	50

* may be fitted with Michelin 18–22.5 XF or Terra-tires

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this is too futuristic let's dwell on two vehicles which are available now.

Messrs. Willmot have recently made their Lightfoot **sprayer** which is purpose-designed for the operations that I have been describing. The vehicle weighs 10 cwt unladen and 20 cwt gross. With all-terrain tyres it is capable of spraying a 40 ft swath at 20 – 25 mph. The driver has excellent control and clear vision. I leave readers to work out how many acres in a day's spraying such a vehicle could achieve properly serviced at the field **edge.**

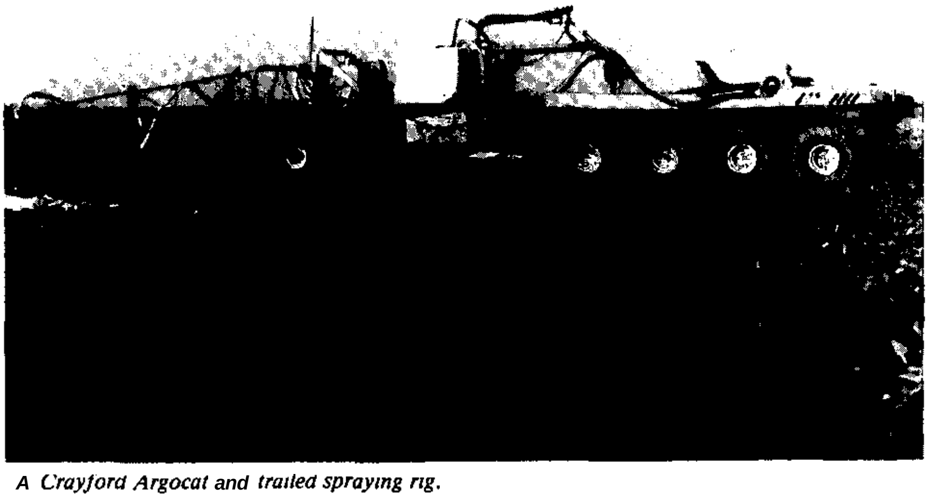
Scotlon Flotation Equipment Ltd. have produced their **Ontop** vehicle which weighs 4.5 tons and is capable of carrying 7-ton loads at speeds up to to 36 mph. It can be equipped with Terra-tires (48 × 31.00 × 20) which allow reductions in inflation pressure down to 5 psi. The Argocat and the Atlas are much smaller vehicles that carry pay-loads of less than a ton but they can progress at high speed and with ground pressures of only 2-3 psi. These vehicles are not dreams for the distant future, they exist now. They are but a few of the enormous range and variability of vehicles that could become available to farmers were the demand to grow.

Amongst all these possibilities is one enormous prize which could do more to revolutionise land management **for crop production than almost any other. We are conditioned to being** on the land only when the soil is dry or drying. This has for 50 years been the over-riding limitation of the tractor. One cannot move wet soil, nor may one dare to put heavy pressure on it because to do so is to court disaster. Thus field operations in autumn and spring have had to occur on a relatively small number of working days when the soil is dry.

Percentage of hours available for field work

Month	Lieht	Soil **Medium**	Heavy
March			
September			
October			
November	60		

(From Nix, J., Farm Management Pocket Book)



A Crayford Argocat and trailed spraying rig.

Yet we should want to work on wet soil. Grain germinates best in wet conditions providing there is good aeration. Fertilizers need water to break down so they may become active. Many soil-acting herbicides work best on wet soil, even with foliar herbicides the need is for actively growing plants commonly found in wet rather than dry soil. If the field operations necessary to grow our crops could occur on wet soil, think of the constraints and imponderables that would be removed from farm management.

Direct drilling with its lack of soil disturbance opens the door to a new vehicle technology for agriculture. Let's hope that the engineering industry will respond to this challenge with light, fast, low ground pressure vehicles that will reduce wheel **compaction,** increase the number of working days, increase the work done in a day and make farming less dependent on the weather.

SOIL SURVEY INTERPRETATIONS AND CONTRACTS

A. J. Thomasson, Soil Survey of England and Wales, Rothamsted Experimental Station, writes in this article **about** the developing role of the Soil Survey to meet the growing need of all land users.

The Soil Survey has published detailed soil maps at scales of 1 or 2½ inches to the mile **(1:63360,** or **1:25,000)** for some **30%** of Britain (Fig. **1).** The current programme aims to achieve full national cover of soil and land capability maps at ¼ inch to the mile **(1:250,000)** during the next 4 years. The customer and paymaster for this project is the Ministry of Agriculture.

The programme will satisfy many administrative and farm planning needs, but will not provide detailed information at 'field' level, except where soil cover is very uniform. There will thus be a continuing demand for detailed soil surveys on specific areas of land where an urgent need is identified and a customer is **prepared** to bear **the cost of** a contract.

Currently, the survey's contracting **.e is often :** with proposals for major land use changes. **Open**-cast coal sites are surveyed prior to working to identify the quality of soil-forming materials, with the aim of improving restoration standards and techniques. Numerous surveys for River Authorities involved in **hydrologic, water conservation or** forestry studies have been *under-*

taken. Some Local Authorities have also paid for surveys, or interpretat[illegible] work, relating to land use or waste [illegible]isposal problems. A further group of contractors in [illegible] ing are concerned with soil [illegible] in-relation to roads, pipeline corrosion and building foundations. There are, of course, many specialist consultants in these fields, and the Soil Survey's expertise is most effective where appreciable areas of land are involved. Where there is a published detailed soil map, potential users may require assistance to interpret the information for their particular needs. A random selection of these includes suitability for:— nutrient injection, sewage sludge disposal, potting loam, cricket pitch marl and willow-studs. Provided that the interpretation does not involve more than half a day's work by a skilled member of staff, no charge is made. Interpretations requiring more than half a day, or new field work, are necessarily charged to the customer.

'The development of a contracting role for soil surveys is a trend in most western countries. In the U.S. and Canada soil assessments for septic tan[illegible]wage dispos[illegible], [illegible]ural roads and leisure and camping areas involve soil survey contracts and interpretations. In the Netherlands some 25% of survey activity is contracted to aid rationalisation of farm holdings and the control of ground-water levels. This need is generated at parish (waard) level and many waards are requesting repeat surveys as farming needs change in response to the economic climate. There is also other contract work outside the agricultural section.

After the completion of field work for the 1:250,000 national map in 1981, it is probable that the survey will return to detailed mapping, the bulk of which will be contracted by MAFF in areas where agricultural advisory and development needs are recognised. However, an enlarged contractual role with other customers is also to be expected.

Detailed field surveys are time-consuming, though the cost will rarely exceed a ⅛ of 1% of the agricultural land value. The justification of detailed soil mapping is that the soil information is used (and reused) for different purposes over a number of years. For example one farmer consults the soil map when changing his cropping system, another when considering drainage investment, a third when acquiring new land. Food processors looking for land to produce particular crops under contract, water engineers concerned with flood risk and agricultural engineers concerned with trafficability problems are periodical users of soil maps. The 'planning industry' is involved in matters of soil and land quality where land use changes from agriculture to housing or to forestry are proposed.

The term 'general purpose' is applied to soil maps produced with a wide range of possible users in mind. The risk with any general purpose product is that it may be less than ideal for an individual purpose and require considerable skill from the user to extract relevant information. The alternative of a single purpose product raises other problems. An interpretative map of drainage need, workability or suitability for individual crops or techniques may be ideal for one type of user, but of no value to others.

This dilemma can be resolved, at extra cost, by publishing in addition to the basic soil map a number of simple interpretive maps. In the Netherlands up to nine interpretative maps are offered, including:— groundwater depth, depth of peat or loess, suitability for intensive arable and intensive grassland use, forestry and sports fields, all at 1:25,000 scale (2½ inches to the mile).

A number of interpretations of soil maps have been published in the United Kingdom at a variety of scales:—

- — Winter Rain Acceptance Potential, to predict flood risk.
- — Land Use Capability.
- — Suitability for Direct Drilling.
- — Under-drainage Design.
- — Ease of Cultivation.
- — Suitability for Intensive Grassland.

Technical Monograph 13 — Soil Survey Applications (Jarvis and Mackney, 1979) — describes recent work in the interpretative field.

Contract work will proceed alongside the main involvement of the Survey in accumulating general purpose soil information for all areas of the country. For the most part there is no discord between the two types of operation. Data collected in contract projects can be stored and is re-usable for other purposes, provided it is systematically recorded. General purpose mapping can be reassessed if a particular interpretation for contract purposes is needed. Ideally, a databank of all soil information, irrespective of the source organisation, should be feasible. Hitherto computer storage capacities have been unable to cope with horizontal and vertical variation in both objective and interpretative data, but this situation is now changing.

The interpretative role requires close consultation with many specialists and users outside the Research Service. This is a two-way educational process which can stimulate both sides of the discussion. Similarly the contract role serves to concentrate the customers' minds to assess their real needs. For the so surveyor a contract implies carefully organising his work to-complete the project to an agreed standard within an agreed time period. At a time when greater efficiency in the use of all our national resources, both human and physical, is needed, this new approach seems timely and desirable.

GRAVEL TUNNEL DRAINAGE IN IRELAND

John V. Courtney is a native Irishman working with one of Ireland's largest contractors — Prunty Contractors Ltd., as Technical Adviser.

A mole drainage system which forms a gravel filled channel has been in use for over five years in Ireland and is proving an effective and economic means of draining the heavy clay soils of the country.

This technique was first developed in Southern Ireland by Agricultural Research worker John Mulqueen and then advanced bv N. Ireland contractor Joe Prunty from Newtownbutler Co. Fermanagh.

Mechanism

The system incorporates the principle of mole drainage and soil fissuring with the addition of a tunnel of washed gravel to support the mole channel. The gravel filled mole drains are drawn across plastic pipe collector drains with a special mole plough. The plough is normally mounted on a crawler tractor but can be used with a high powered tractor on rubbers, and the moling depth is controlled by hydraulically operated wheels. The 20 mm gravel used is carried in a 127 kg capacity hopper mounted above' the mole and stones flow down a chute immediately behind the share. The share outlet is designed to prevent blockages and a 50 cm diameter disc coulter cuts a slit ahead of the share. The depth of gravel can be adjusted by a slide and an hydraulically controlled gate cuts off the flow of gravel when the plough is taken out of work.

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Tunnel Drainage

Similar to mole drainage a slit is left extending to the surface but no additional backfill is required and drained fields can be brought back into use almost immediately.

The Irish problem

The natural limitations on Agricultural developments in many parts of Ireland are those imposed by a combination of heavy poorly drained soils and a relatively wet climate. Most of the country was overrun by ice in the Quarternary Period and glacial and fluvio glacial deposits assume many forms but most conspicuous are the drumlin landforms. Most drumlin soils are heavy, poorly drained and may be classified as gleys. This land type dictates a predominantly grassland farming system.

Annual rainfall is over 1000 mm in many parts of the country and rainfall exceeds evaporation at all times of the year except for short periods in the summer. On average there are two rain days in every three throughout the year, with most rainy days having between 2 and 10 mm rainfall. Rainfalls of this magnitude cause wetting on the shallow topsoils which rest on the slow draining subsoils.

Among the problems encountered by farmers are poaching by grazing animals, short growing season, the necessity for large amounts of winter fodder and poor trafficability.

It is evident therefore that good soil drainage is an essential if the full potential of the grassland is to be realised.

Conventional drainage

The conventional method of draining these soils involves the laying of plastic pipes 50 to 60 cm deep in the ground and filling with 20 mm stones to the surface. These drains are in-

The Gravel Tunnel Mole Plough.

stalled at spacings of 6 to 7 metres but this method has two big disadvantages: it is an expensive system and even at this close spacing the ground between the drains is not effectively drained.

These drawbacks were supported by research work which suggests that equally spaced parallel tile or plastic drains installed in the conventional manner do not provide efficient drainage, do not intercept surface run-off and unless they are very close together, of the order of 1 to 2 metres, do not control the water table. Such a spacing would be highly 1e

To overcome the problem the soil's permeability must be artificially improved by shattering and fissuring so that water can pass from the surface down to a system of underdrainage.

Mole drainage was tried to achieve this effect and was fairly successful in good binding soil, but where the soil was unstable or where sand veins were present the system literally collapsed, sometimes within a couple of months.

It was because of this drawback with moling that John Mulqueen developed the idea of stabilising the mole channel using gravel and so the gravel filled mole or gravel tunnel was born. This new system has the following advantages when compared with conventional mole drainage;

1. It forestalls structural collapse of the mole in unstable soils.

2. As tunnels can be drawn on steep gradients the gravel infill forestalls deterioration of mole channels by erosion and siltation.

3. There is more flexibility in regard to the moisture content of the soil for installation.

4. Boulders and stones do not present as serious a oroblem with this system compared io moling.

Trials show **potential**

Trials were installed in the South of Ireland by Mulqueen in 1970 and up to date the gravel filled moles are working perfectly, compared to traditional moles which deteriorated rapidly in the early stages.

The first gravel tunnel trials to be carried out in N. Ireland were at the Agricultural Research Centre at Castle Archdale Co. Fermanagh in 1974. The objective was to evaluate the gravel tunnel system and to compare its effectiveness with mole and conventional pipe drain systems. The site had a silty clay soil (29 percent sand, 37 percent silt, 33 percent clay) a land slope of 10 percent, and a low hydraulic conductivity value of 0.008 to 0.0001 metres/day.

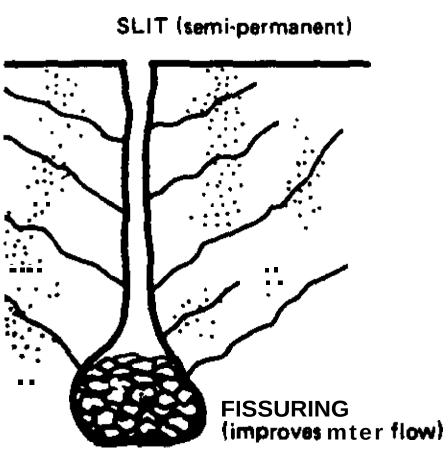

Fig. 1. Cross Section of a Gravel Tunnel Drain.

Tunnel Drainage

Methods of assessment used were;

a. Water table measurements
b. Scoring of surface conditions
c. Drain flow records

Results have shown that both mole drains and gravel tunnel drains were superior to the simple pipe drained system in lowering the water table levels and giving increased grass yields. A notable point was the occurence of several breakdowns in the moled plots; some even as early as six months after the beginning of the trials. A further replicated trial was laid down in 1975 and the table below shows how the different treatments control the water table. (Fig. 1.)

(Fig. 1) Mean Water Table Levels (mm below surface).

Month	No Drainage	Gravel Tunnel Drainage	Plastic Pipe Drainage	Mole Drainage
Jan	190	380	240	350
Feb	130	330	160	290
Mar	210	400	270	360
Apr	170	380	220	330
May	460	530	490	530
Jun	740	760	740	780
Oct	250	430	320	400
Nov	170	400	260	400
Dec	170	400	260	380

The effect of efficient drainage on grass growth was also clearly demonstrated when spring growth under the different treatments was measured. The fresh grass yield on each plot was measured from cuttings taken in May 1976 and 1977 as shown. (Fig. 2.)

(Fig. 2) Fresh Grass Yields (Tonnes per hectare), from trial plots.

	Date; 18.5.76	Date; 10.5.77
Gravel Tunnel	19.6	14.0
Mole	14.6	12.1
Pipe	13.3	9.8
No drainage	5.3	3.5

As both these trials are in their early stages it would be unwise to draw too many conclusions until more information is accumulated. However the results to date show that close spacing and soil loosening are crucial to satisfactory control of the water table.

Donagh O'Neill, Farm Director at Castle Archdale backs this up by stating that both mole drainage and gravel tunnel drainage effectively extended the grazing season by about six weeks compared to conventional drainage or the control. These plots would normally be trafficable to machinery and stock from the middle of March onwards whereas the conventional area could not be used until late April and the control until mid-May.

On the strength of the results obtained the system has been grant aided under the Farm Capital Grants Scheme. During this period when trials were ongoing the N. Ireland Agricultural Trust provided financial support for the system at farm level. Many farmers took advantage of this revolutionary system immediately and large areas were drained before any results were obtained.

Cost of the new technique

The cost of gravel tunneling an acre of ground is about £500/acre or £1200/ha). This includes a design consisting of permanent plastic pipe collector drains at 30 to 40 metre spacings, 0.9 m deep and stone up to 0.3 m from the surface. The gravel tunnels are drawn across them at 1.5 m intervals at a depth of 0.5 metres. About 25 to 30 tonnes of 20 mm gravel or stone is needed to construct an acre of gravel tunnels without considering collector drains. In comparison the cost of carrying out conventional drainage at 7 metre spacing is about £700 to 800/acre or about £1700 to 1800/ha. The cost of this new system can be further reduced by using wider spaced collectors. This wider spacing will depend on the land slope (preferably over five percent). However, in practice, when one considers surface irregularities, spring lines, changes of slope, etc. closer spaced collectors are advisable.

Gravel tunnels are best constructed in the summer months when evaporation is at its peak. This ensures maximum shattering and fissuring of the soil.

Farmers are quickly realising the potential of this drainage technique and the acreage drained in this way is rising rapidly. With 70 percent drainage grants available to farmers and about two million acres of i[illegible] drainage soils in Ireland there will be a busy time ahead for contractors in the business. To date there are about five contractors equipped to provide a gravel tunnel service in N. Ireland and three in S. Ireland but with the short working season and the increasing demand it is doubtful if they will be able to cope with the work load.

CREDIT

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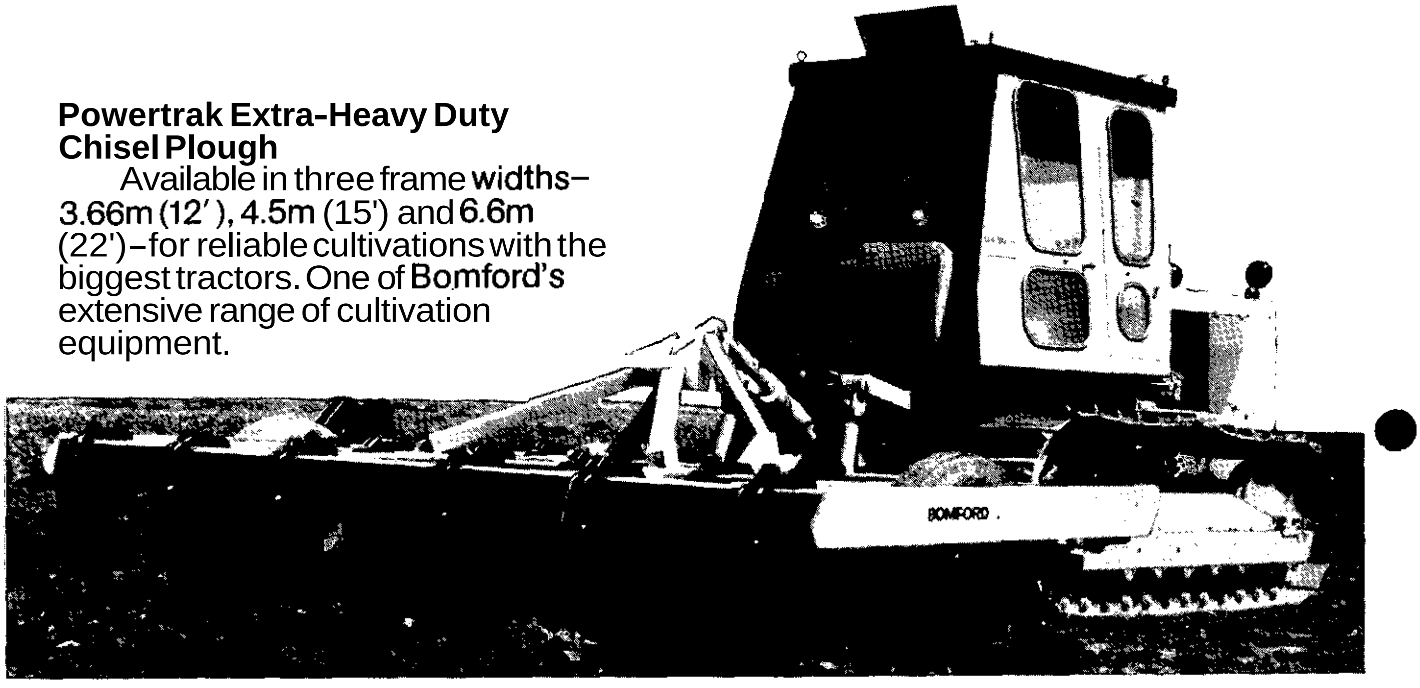

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