Minimum tillage for crop planting

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This article is condensed from a report of studies of minimum tillage systems and research in the United Kingdom and North America during 1976.

The author, Mr. Geoff Pearce, is a Senior Research Officer in the Department of Agriculture’s Weed Agronomy Section. He has been associated with reduced tillage research in Western Australia for several years and undertook the study tour to gain the benefit of intensive overseas research on the subject.

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Of the 4 000 000 hectares planted to cereals in Western Australia each year, about 25 per cent. are sprayed for the control of weeds. Although by spending about $6 million each year, farmers reduce yield losses by some $20 million, weeds still cost them another $30 million, because of weed competition before spraying, weeds not sprayed, and extra cultivations undertaken to kill weeds.

To overcome these problems, research has been carried out in different parts of the world under the general title of minimum tillage. This term is used to describe any planting system which reduces the normal number of cultivations.

The result of developing techniques using minimum tillage principles would produce a number of major benefits to the farmer. If the number of cultivations required for the planting programme could be reduced the crop could be sown more quickly, with consequent savings in energy input and capital cost of equipment.

The main purpose of the normal delay in sowing is to allow adequate weed control to be obtained. Practically all major weeds can now be controlled with herbicides and research workers hope to make further progress by developing the use of residual-type herbicides to control the weed problem, with a non-disturbance planting technique to discourage the weed seeds from germinating.

Another major advantage of minimum tillage is related to soil conditions. With reduced cultivation
an increase in the organic matter in the surface soil layers is claimed. Wind erosion is reduced because more trash can be left on the surface. In addition, soil structure is maintained or improved.

Perhaps the greatest attraction of minimum tillage in the United States is in the field of energy conservation. Because of the savings possible from use of a single-pass planting technique the Department of Agriculture is carrying out a major review of minimum tillage practices in American agriculture.

Time of planting trials by the Western Australian Department of Agriculture have shown that where weeds are not a problem crop yields decrease by about 65 kg/ha for every week planting is delayed, after mid May. Techniques to allow earlier planting will therefore often result in increased crop yields.

Such techniques are being used in both the United Kingdom and the U.S.A. on a number of crops, including wheat.

Research policies

When the number of people engaged in agricultural research in countries such as the United Kingdom, the United States and Canada is appreciated, it must be quickly realised that we in Australia can learn a great deal from these countries.

At ICI's Jealott's Hill Research Centre about 800 people are involved in research related to pesticides. About 100 of these are working on environmental studies; of these, 25 are ecologists specifically studying the effects of pesticides on the environment. There would not be 25 scientists in the whole of Australia studying this subject.

Other companies have similar research establishments, while government research organisations such as the English Agricultural Development and Advisory Service also have large research centres for agricultural investigation. The subject of direct drilling and minimum tillage has been under investigation at many of these centres for 10 years or longer, and far more work has been carried out than in Australia.

Today, various types of minimum tillage practices are established commercial procedures, and the area involved is steadily growing. Crops involved include rape, kale, maize, brassicas, grasses and cereals.

People engaged in weed control in Australia recognise that the lack of well designed spray equipment capable of covering large areas quickly is a major concern. Such types of equipment are far more readily available overseas than in Australia.

UNITED KINGDOM

The pattern of development of minimum tillage in Australia is similar to that which occurred in the U.K., except that we are some years behind.

The early investigations left scientists disenchanted and slightly suspicious that the company involved was mostly concerned with selling a chemical. A re-examination of the principles and a change in methods of testing systems, some five or six years later, has brought encouraging results and guarded optimism.

Government researchers in England have learned that there is a skill to be acquired in using minimum tillage techniques, and that persistent long term trials are required to give new systems a chance to prove themselves.

Trials carried out by the National Institute of Agricultural Engineering at Cambridge produced results in 1976 in which the direct-drilled treatment outyielded the conventionally planted treatment by 26.6 per cent. (4 770 vs 3 760 kg/ha). Similar yields had been recorded over the previous three years. Eleven different combinations of cultural treatments are being tested and the trial has been repeated on the same sites each year since 1971.

In terms of costs and system capabilities, their conclusion after five years is that direct drilling and the shallow primary cultivation systems have the highest potential of the systems under test.

In one of these trials measurements have been made on energy input involved in establishing the crop, expressed in kilowatt hours per hectare. The estimates are based on NIAE figures for similar operations checked against field records of tractor type, axle weight and wheel slip, and are:

<table>
<thead>
<tr>
<th>Kilowatt hours per hectare</th>
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<tr>
<td>Conventional 10.7</td>
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<tr>
<td>Reduced tillage 5.6</td>
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<tr>
<td>Direct drilling 2.4</td>
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The main object of the trial is to examine different physical states of the soil brought about by a range of tillage treatments and relate these to root growth and crop yield in both the short and long term.

There is a marked interaction between tillage and rate of nitrogen application caused by the relatively low yield from direct drilling at lower rates of nitrogen and the marginal differences at 150 kg per hectare compared with ploughing. Dr. J. Holmes, who is in charge of the projects, advances the following hypotheses for this interaction:

- Root growth is inhibited under direct drilling because of mechanical impedance in compact soil. This in turn results in slower uptake of nitrogen and other nutrients, which results in slower shoot growth.
- Once the root system has reached a critical size, uptake of nutrients and shoot growth rate become the same as under ploughing.

<table>
<thead>
<tr>
<th>Table 1—Interactions between rate of nitrogen application and tillage systems (U.K.)</th>
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<tr>
<td>Rate of nitrogen kg/ha</td>
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<tr>
<td>0</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>150</td>
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</tbody>
</table>
• However, by anthesis, which occurs in all systems at the same time, the crop dry weight and the number of grains set is less with direct drilling than ploughing and final yield is also less.

• Extra nitrogen (about 50 kg N/ha) increases the rate of nutrient uptake in the early weeks and thus increases root growth and shoot growth so that by anthesis time, the crop dry weight and number of grains set in the direct drilled crop is the same as in the crop on ploughed soil with 50 kg nitrogen less.

• The extra nitrogen, however, increases the amount of nitrogen taken up by the crop in the middle part of the season and results in grain of higher nitrogen content. This shows that the extra nitrogen is needed mainly because of slowness of uptake and not because there is less available in the soil.

• The need for extra nitrogen under direct drilling is related to the pore size structure in the soil when it is compacted through lack of cultivation. In this connection the loam soil in the trials had a lesser need for extra nitrogen than heavier soil.

Other conclusions from this long term project have been:

Take-all
There has been a gradual increase in root infection by the take-all fungus on the trial site over the years but it has not yet reached a level sufficient to affect yield noticeably. In the first four years, incidence was lower under deep ploughing and no tillage but by 1975 only the no-tillage treatment was significantly lower in take-all incidence than the other three treatments.

Earthworm population
Earthworm biomass in 1973 was related to the rates of nitrogen application, being 0.42 tonnes per hectare on the no-nitrogen plots and 0.59 tonnes per hectare on the 150 kg N/ha plots. Deep ploughing resulted in the smallest population of 0.32 tonnes per hectare on average of all nitrogen rates compared with 0.42 for normal ploughing and tyned cultivation, and a much higher population of 0.88 tonnes per hectare on the uncultivated soil.

The earthworm population was higher on the heavier soil than on the loam soil. The increased numbers of earthworms on the uncultivated plots on this soil have apparently not improved its physical state for barley growing under a direct drilling system.

Conclusions
Dr. Holmes concludes that direct drilling has great potential on loam soils. Yields equal to those of conventional ploughing can be maintained indefinitely without cultivation. On the other hand, the heavy soil type in the same trial is not well suited to direct drilling and has shown no sign of improvement in topsoil structure or water infiltration over the first eight years of direct drilling.

The five-fold reduction in labour and energy input required for crop establishment suggests that direct drilling will become a widely used system when pressures of labour and energy availability increase.

One lesson to learn from the U.K. research experience, is that success does not always come immediately and often much hard work is required to develop a suitable technique which will work for a particular set of conditions.

We should also remember that success in other countries does not guarantee that the same results can be obtained in Western Australia. On the other hand, neither should we completely accept the conservative view that things are so different in Australia that overseas experience can not be applied to our conditions.

Minimum tillage commercial practices
One of the most important statements heard was, "Direct drilling is not the lazy man's way of planting a crop". It is now appreciated that all the conditions which favour the production of a good crop using conventional planting procedures also operate and are important in growing a crop under minimum tillage.

Too often, minimum tillage has been used to plant crops in poor conditions, and the technique has been blamed for the disappointing results.

Crop yields in the U.K. are three to four times as high as those in Western Australia so that it is economical to spend more on crop production than is common here. In the U.K., Gramoxone is used in conjunction with minimum tillage and the rate of application is at least double that used in Australia. Reducing application rates to the bare minimum, as has been done here, often results in poor weed control and does not allow a safety margin for less favourable conditions.
Again, it is well accepted that the early growth of the plant and particularly the root system, is slower than with conventional planting. To overcome this slower growth rate, recommended practice in the U.K. is to plant direct-drilled crops two weeks earlier than is usual for conventional cropping. This is quite possible under their conditions as the time of planting can be chosen out of a six to eight week period. Our problem is to obtain adequate weed control.

Even though they plant in October and harvest in July (eight months growing season) it is still considered important to get the crop well established before the cold wet weather sets in. This principle also applies in Western Australia.

Another practice accepted as a necessary modification for minimum tillage in the U.K. is to split the nitrogen application. Usually, nitrogen is added only in the spring. With direct drilling it is recommended that half the amount of nitrogen should be applied in autumn. The purpose of this is to stimulate early growth.

It is also generally accepted that the previous crop's stubble should be burned fairly soon after harvest.

Soil compaction, either through grazing stock or cultivation to a constant level, is another problem recognised in the U.K.

Minimum tillage is mostly associated with continuous cropping and it is felt that any compaction problems should first be overcome. This is usually done by embarking on a minimum tillage programme immediately following a conventionally planted crop. Although continuous cropping is practiced, the type of crop grown may vary from one year to another.

The machinery used in the U.K. is mostly standard tyne drills with perhaps one or two rows of tynes removed. The tynes might only be 2.5 cm wide so that soil disturbance is limited to the drill row. Several non-disturbance disc drills are also available.

One strong impression that was left with me was the importance placed on earthworms in improving soil structure in the U.K.

Direct drilling does not reduce the earthworm population but ploughing is very severe on them because of the great multitudes of birds that flock onto newly ploughed paddocks. Farmers express great concern at this loss and it is an aspect which has been virtually ignored in Australia. Significant increases in earthworm populations have often been recorded in trials.

Commercial use

A farm visited in the Cotswold district gave an example of the commercial use of direct drilling. The farm of 890 hectares, has 600 hectares planted to cereals each year. The same area is planted every year in a continuous cropping programme. This farmer failed with his first attempt with direct drilling but tried again three or four years later and has been using direct drilling for the past seven years.

One paddock inspected has had six crops in the last seven years, and yields have been reasonably constant at about 5 000 kg/ha.

Mr. Jenkinson, the farmer concerned, uses both a Bettinson and an International 6/2 tyne drill. He emphasises the value of soil structure improvement, the build up in earthworm population, the reduced amount of overtime worked and the reduction in the amount of equipment required.

There is no doubt that direct drilling is well established in the United Kingdom and the area planted in this way for a wide variety of crops will continue to increase.

THE UNITED STATES OF AMERICA

Whereas in the U.K. and Australia the only interest in minimum tillage has been related to costs and yields of crops and the possible value to soil structure, in the U.S.A. the question is related to the energy crisis and reducing costs of production for competition on world markets.

According to annual estimates compiled by the Soil Conservation Service, the area under minimum tillage systems increased from about 1.5 million hectares in 1963, to nearly 13.3 million hectares in 1974.

Production costs

In the U.S.A., as in Australia, the largest proportion of labour involved in crop planting is family labour rather than hired labour. Thus any savings in labour with minimum tillage must be directed towards alternative uses to have

Maintaining a straw cover on newly planted crops is an important aspect of wind erosion control in Canada. This area has been planted with a Bettinson triple disc drill.
Table 2—The total energy costs (Joules per hectare) for four tillage systems (U.S.A.)

<table>
<thead>
<tr>
<th>System</th>
<th>Equipment, fuel and tyres J/ha</th>
<th>Herbicides J/ha</th>
<th>Total J/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>1 085 153 x 10^5</td>
<td>72 080 x 10^3</td>
<td>1 157 233 x 10^5</td>
</tr>
<tr>
<td>Modified till-plant</td>
<td>918 511 x 10^5</td>
<td>72 080 x 10^3</td>
<td>990 591 x 10^5</td>
</tr>
<tr>
<td>Till-plant</td>
<td>502 927 x 10^5</td>
<td>124 550 x 10^3</td>
<td>627 477 x 10^5</td>
</tr>
<tr>
<td>No-till</td>
<td>424 106 x 10^5</td>
<td>27 720 x 10^3</td>
<td>451 826 x 10^5</td>
</tr>
</tbody>
</table>

economic value. The other possibility is more leisure time for farm families.

Probably of greater concern in the U.S.A. is the continuing availability of petroleum products for agriculture and the effect of their prices on production costs. This question has attracted the attention of many agricultural engineers and Clark and Johnson3,4 have produced some extremely interesting figures on the energy costs of tillage systems. Their evaluation of the systems has continued since 1970 and their results are summarised in Table 2.

Soil erosion

Soil conservation is a major concern in the U.S.A. and according to Wadleigh6 the annual rate of soil loss through erosion from farmlands in 1968 was 3.6 billion tonnes, or the equivalent of about 26 tonnes per cropped hectare.

Woodruff7, in summarising results of a number of studies, indicated that in wheat-fallow rotation experiments in western Nebraska, soil loss for sub-till stubble mulching averaged 1.9 tonnes per hectare compared with 6.58 tonnes per hectare loss for ploughed plots. In one trial in northwestern Ohio, during a severe windstorm, 291 tonnes per hectare of soil was lost from a ploughed-planted cornfield as compared with 4.48 tonnes for a no-tillage cornfield.

According to the U.S.D.A. report1, estimates of soil losses for various soil resource areas, land capability classes, and crop rotations, indicate 50 per cent. or more of soil erosion losses can be stopped by a shift from conventional to conservation tillage. Because some conservation tillage systems are plough-based, further reductions would result from a complete shift to no-tillage.

The report concludes that “available estimates and data suggest occurrence of a potential decrease in the national soil erosion problem with continued reduction in tillage. More soil erosion reduction could be accomplished through change in tillage systems during the next 30 years than has been accomplished in about 40 years (since 1935) with substantial Federal investments in conservation education, technical assistance, and financial (cost-sharing) assistance”.

CONCLUSIONS

In a number of countries minimum tillage techniques for planting crops are commercial practices. This applies also to Western Australia and, to a very limited extent, the eastern States of Australia.

It appears that until more of our agriculturalists accept the broad concept that the goal of once-over the ground, to plant a crop, is attainable and worthwhile, local problems will be solved at a very slow rate.

The problems we face in crops sown with minimum tillage are fewer than several years ago. The problems of weed control are virtually solved. Those that remain include soil compaction, slow initial crop growth, increased risk of disease and a slower release of soil nitrogen.

Long term trials, particularly with continuous cropping, are required to provide the answers to these problems.

References

2 Anon (1976).—Handbook of direct drilling—Plant Protection Ltd.
7 Woodruff, N. P. (1972).—Wind erosion as affected by reduced tillage systems. Proc. No Tillage Systems Symposium, Ohio, State Univ.