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PROJECT REPORT No. OS10

# DIRECT DRILLING OF OILSEED RAPE THROUGH CEREAL STRAW RESIDUES: TESTING AND DEVELOPMENT OF TWO DRILLS

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# DIRECT DRILLING OF OILSEED RAPE THROUGH CEREAL STRAW RESIDUES: TESTING AND DEVELOPMENT OF TWO DRILLS

by

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This is the final report of a seventeen month project which commenced in May 1991. The work was funded by grants of £22,304 from the cereals R&D levy, and £10,484 and £22,304 from the oilseeds R&D levy through the Home-Grown Cereals Authority (Project Nos. 0004/1/92, 0S31/1/90 and 0S01/1/92 respectively).

## ABSTRACT

A two year investigation was carried out to develop direct drilling techniques in the presence of straw residues. In order to highlight potential short-comings of this technique, difficult soils in terms of their suitability for direct drilling were selected using a classification system developed by Cannell et al (4). Work was concerned with the testing and further development of two direct drills:-

1) a cross-slot coultered drill developed in New Zealand, and

2) a single disc coultered drill manufactured by Moore Uni-drill.

The performance of both drills was initially tested in short term crop establishment trials through a range of soil, straw and climatic conditions, and then in comparative trials, in conjunction with ADAS, which were taken through to harvest.

Following modifications to both drills, performance in dry conditions was found to be very satisfactory providing adequate penetration was achieved. Problems were, however, encountered when drilling in wet conditions. In particular, prolonged waterlogging and slug attack seriously affected crop establishment at a number of sites.

Better yield results were achieved where straw was removed prior to direct drilling, however, in general, the direct drilling suitability classifications for the sites were reflected in the results. Direct drilled plots produced yields approximately 15% lower than those from conventionally cultivated plots.

Investigations over the past two years have provided a valuable insight into factors affecting the performance of direct drilled crops in the presence of straw residues. The results suggest that, with further development, this technique has considerable potential, however, due regard must be given to a soil's suitability for direct drilling particularly if the season proves to be wet.

## ACKNOWLEDGEMENTS

The Authors are grateful to:-

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ADAS, Silsoe Research Institute, Mr M Whitlock and Mr A Tapper for providing field sites, and
Moore Uni-drill Ltd for their support and the loan of a seed drill.

# CONTENTS

# 1. BACKGROUND

The problems associated with the production of oilseed rape and cereals in the UK in the absence of straw burning can be severe. Establishment and subsequent crop performance are often erratic, particularly on heavy soils. Current drilling equipment is not designed to work through large quantities of straw. Tillage, sufficient to overcome the straw problems, is expensive and often produces undesirable side effects. Seedbeds produced in wet or dry years are often poor following tillage and there is a risk of delayed germination or moisture loss.

These problems have prompted the need to further develop direct drilling techniques and equipment capable of establishing oilseed rape and cereals in the presence of straw.

This report details findings from two years of research into direct drilling techniques following the ban on straw burning.

## 1.1 The 1991/92 project

The main thrust of the project was to investigate the establishment of oilseed rape following the ban on straw burning. This was approached by integrating the research efforts of three organisations:-

1) University of Nottingham
   Detailed germination, seedling development and plant compensation studies.

2) ADAS
   Trials of current establishment techniques of difficult soils.

3) Silsoe College, Cranfield University
   Development of new drilling techniques.

The Silsoe College work involved the testing and further development of a cross-slot direct drilling opener developed by Baker and others at Massey University, New Zealand ((1), (2) and (3)) - see Figure 1 and Plate 1.

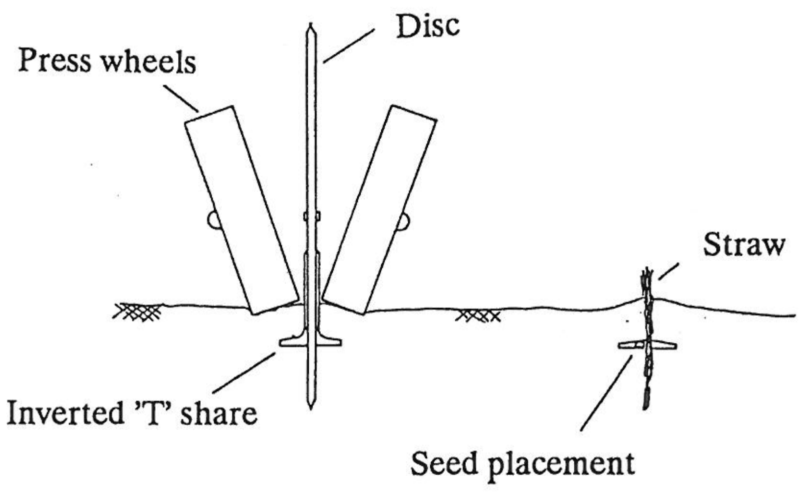


**Figure 1. Seed placement by the cross-slot openers**

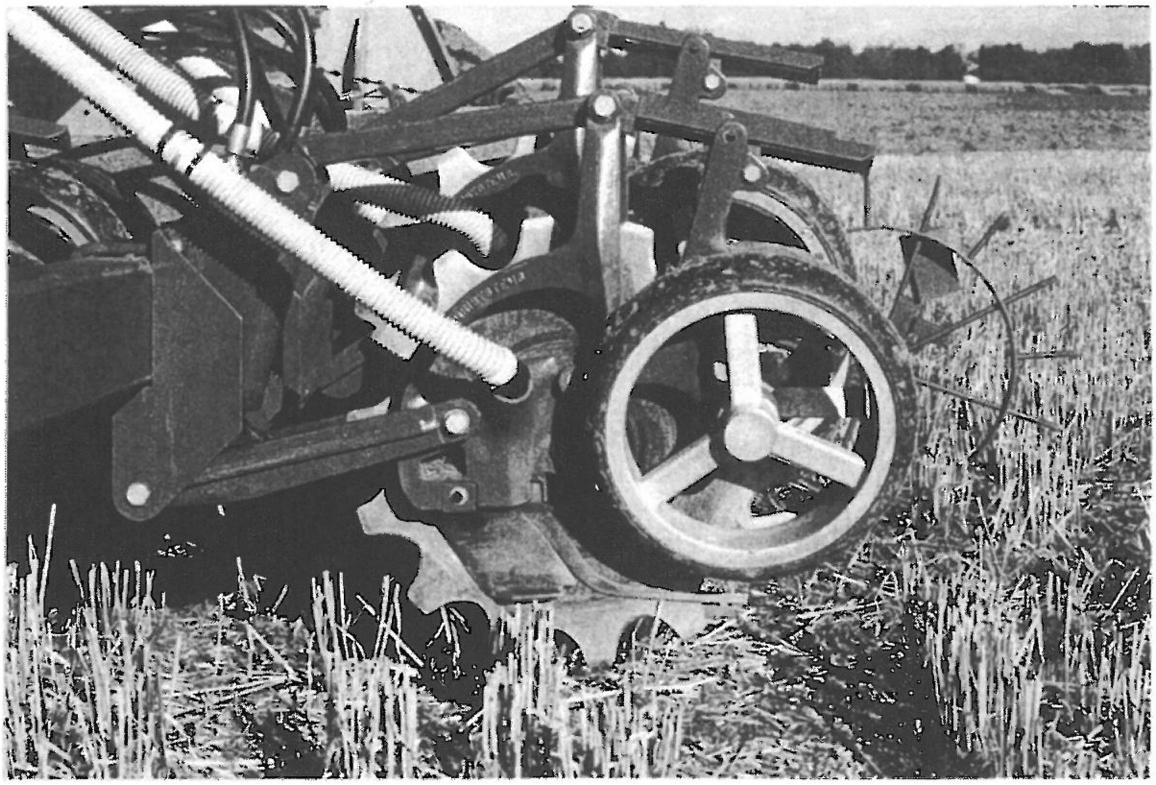

**Plate 1. The cross-slot direct drill opener**

1.1.1. Objectives (1991/92)

The main objectives of the study were as follows:-

1) To assess the perfomance of the cross-slot drill opener when operating through straw residues.

2) To evaluate the influence of straw and stubble condition on opener performance, identifying the most desirable straw/stubble conditions and opener design.

3) To develop establishment systems for oilseed rape, in the absence of burning, under a range of field conditions.

1.1.2. Material and methods (1991/92)

Six cross-slot openers were imported for the 1991/92 season. In addition, a Moore Uni-drill was operated alongside the New Zealand drill for comparative purposes - see Figure 2 and Plate 2.

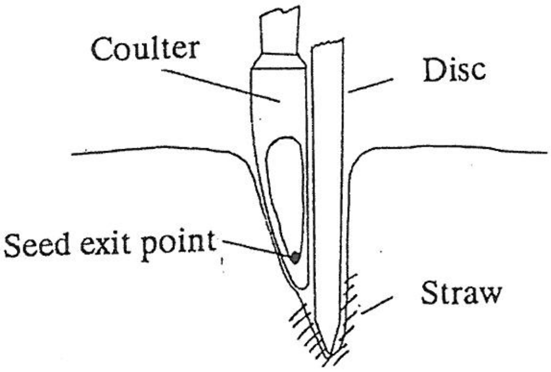


**Figure 2. Seed placement by the Moore drill coulter**


**Plate 2. The Moore Uni-drill**

Two types of experimental study were conducted:-

1) Short term establishment studies to identify the major soil, straw and operational factors influencing opener performance.

2) Comparative trials, in conjunction with ADAS, to monitor crop performance from seeding through to harvest.

The experiments were carried out at four heavy clay sites of the Evesham (x2), Worcester and Denchworth soil series. The straw and cultivation treatments on each site were selected to span the range of straw conditions likely to be found in field situations, ranging from stubble only through chopped and spread to standing and laid straw.

1.1.3. Results and discussion (1991/92)

**Performance of the cross-slot direct drill**

a) The disc coulter worked well through all types of straw and straw condition. Straw was often forced into the vertical disc slot.

b) Seed placement in the wing opening to the side of the vertical disc slot was achieved.

c) In dry conditions, performance was very satisfactory providing coulter penetration was adequate. Some penetration problems were encountered under very hard dry conditions (common with all disc type coulters). Seed depth control was adequate although it was necessary to set the depth adjustment to drill rather deeper than the optimum to avoid shallow seed placement in local surface depressions.

d) The following problems were encountered under wet conditions:-

(i) Straw and soil pick-up by the disc and press-wheels resulting in seed disturbance, loss of depth control and drill blockage.

(ii) Skidding of the press-wheel in loose surface conditions causing straw blockage.

(iii) Soil and straw pick-up by the 2nd row press-wheels causing blockage and reduced seeding depth.

**Modifications to the cross-slot drill**

The following modifications were made to the drill:-

(i) Addition of press-wheel scrapers. These performed satisfactorily under compact surface soil conditions, but caused skidding in loose conditions.

(ii) Removal of press-wheels. Seeding depth was controlled by hydraulics and satisfactory results were obtained when the soil was consolidated separately using a light furrow press.

(iii) New design for the disc scrapers to improve efficiency. This functioned well.

**Crop germination and emergence**

With the exception of the Moore drill working in thick chopped straw, the total number of plants to emerge, and the rate at which they emerged, following direct drilling was favourable when compared with treatments involving tillage - see Figure 3.

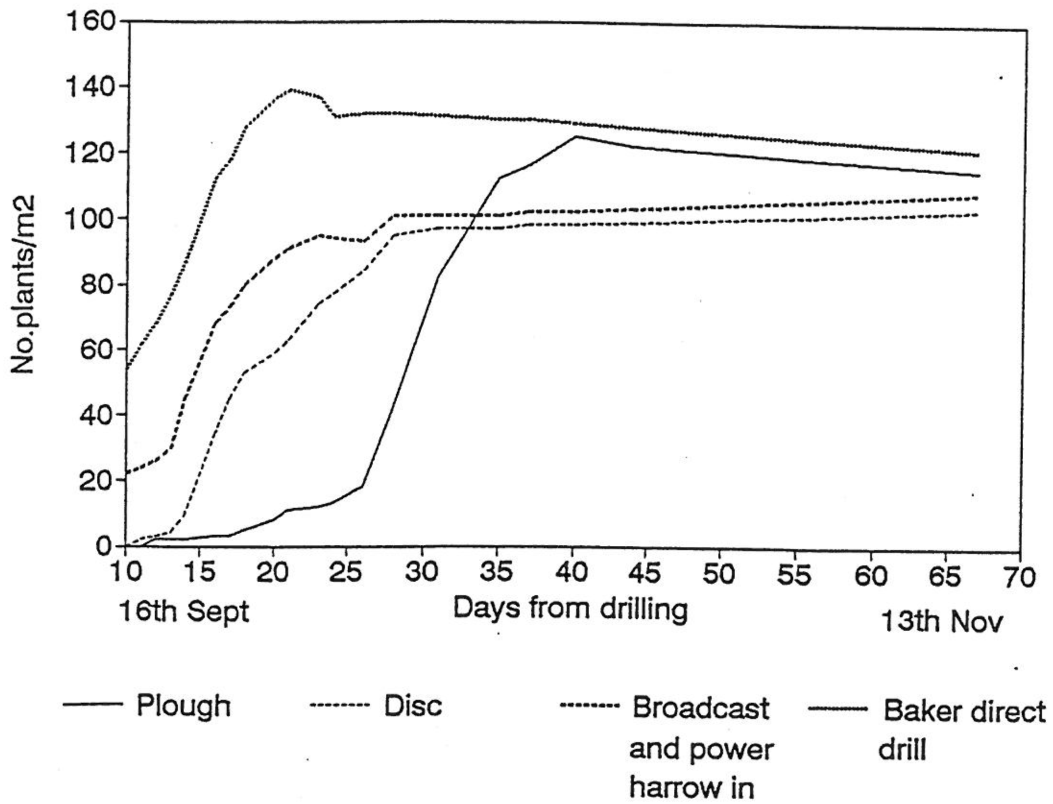


**Figure 3. Establishment of oilseed rape, Denchworth series**

The moisture conservation advantage of direct drilling over tillage in this dry season was very apparent.

**Subsequent crop development**

After a promising establishment in September, problems of reducing plant numbers and vigour started to develop in December. This damage, which in some cases resulted in total loss of crop, was much more prevalent in areas where straw lay on the surface. An assessment of crop condition relative to surface straw cover was carried out in April 1992 and the results are presented in Figure 4. The crop condition assessment was determined by averaging qualitative scores for plant density, vigour and height. The strong influence of straw cover on crop condition is very obvious.

Reasons for this straw effect are not fully understood. The major factor , however, was damage by pigeons which apparently have a strong preference for landing, walking and feeding on straw covered areas. Having chosen particular feeding areas, they appear to return to those same areas and keep the crop grazed down throughout the season. Pigeons do not seem to like long standing stubble and this could be one condition to be aimed at and explored further for direct drilling. Other factors contributing to the problem could be anoxic zones occurring during straw breakdown and the influence of straw cover on frost damage through insulation of soil heat from foliage.

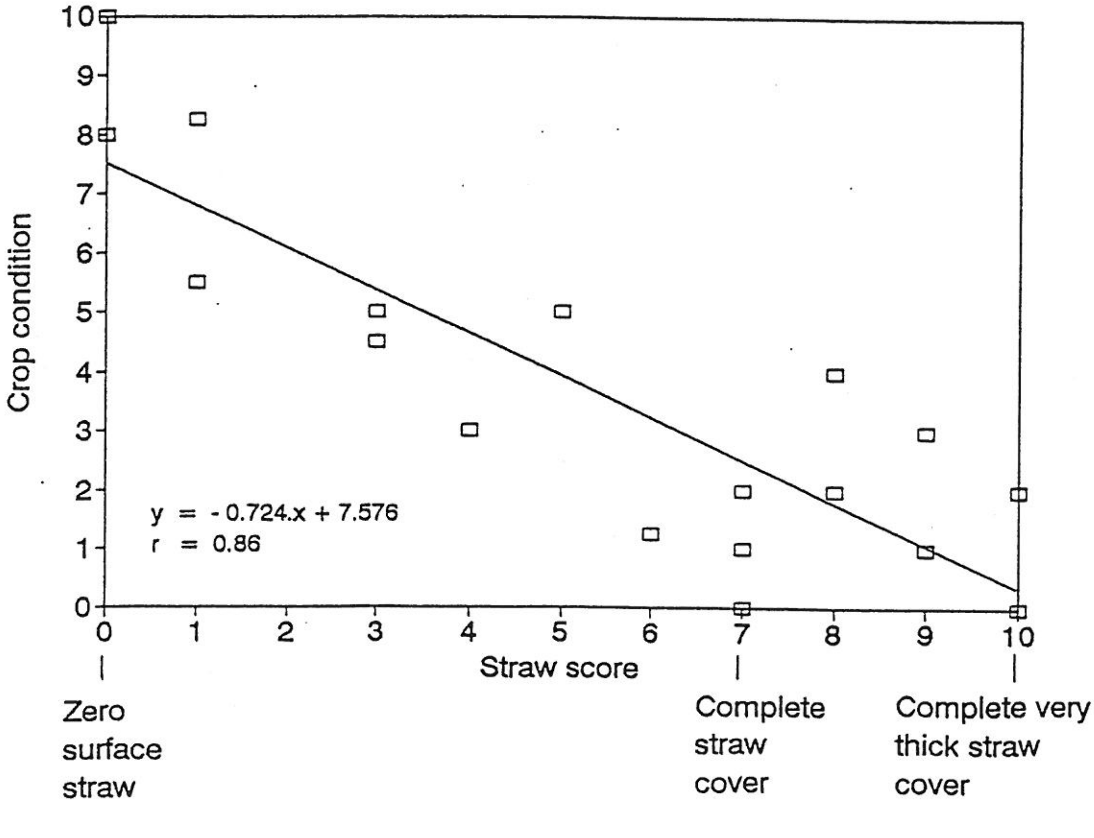


**Figure 4. Crop condition relative to straw score, Denchworth soil series.**

**Final yield (1991/92)**

Yield results for the Evesham and Worcester sites are presented in Table 1.

**Table 1. Oilseed rape yield results**

| Treatment | Evesham plants/m$^2$ | Evesham t/ha | Worcester plants/m$^2$ | Worcester t/ha |
|---|---|---|---|---|
| Chopped, plough, drill | 65 | 1.41 | 81 | 2.58 |
| Chopped, disc x2, drill | 50 | 1.20 | 74 | 2.85 |
| Chopped, tine x2, drill | 23 | 1.37 | 50 | 2.89 |
| Chopped, b/cast, power harrow | 16 | 1.09 | 44 | 2.70 |
| Chopped, direct drilled (Moore) | 6 | 0.79 | 24 | 2.66 |
| Baled, direct drilled (Moore) | 48 | 1.27 | 37 | 3.18 |
| Chopped, direct drilled (NZ) | 4 | 0.82 | 23 | 2.99 |

It is interesting to note that despite very low plant numbers on direct drilled plots, the relative yield is high particularly on the baled plots.

1.1.4. Conclusions (1991/92)

After modifications to suit UK conditions, the cross-slot drill openers proved capable of working under dry conditions through a range of straw and soil conditions, but experienced some penetration problems where soil strength was high.

Plant emergence following direct drilling was as good as, or better than, that following other establishment techniques involving cultivation with significant benefits in terms of rate of emergence in dry conditions which prevailed during the establishment period.

The severe reduction in plant numbers and condition, over the winter period, was most marked on areas with a thick straw covering. The reason for this straw related effect is not entirely clear, however, possible explanations include:-

1) a preference of pigeons for walking and feeding on straw

2) toxins released during straw breakdown

3) straw preventing beneficial heat loss from the soil affording frost protection, and

4) straw reducing the rate of freezing of the upper profile promoting frost heave and root damage.

The results of the 1991/92 work suggest that, where possible, cereal straw should be removed from the soil surface prior to direct drilling.

## 1.2. The 1992/93 project

Results from the 1991/92 trials, using six coulters, were very promising and so a further year's work was carried out. Trials included winter wheat in addition to oilseed rape. Moore Uni-drill supplied one drill, free of charge, for adaption to emulate the New Zealand's drill action.

### 1.2.1. Objectives (1992/93)

1) To test the performance of the cross-slot (Moore emulation) coulter to be developed prior to the drilling season.

2) To modify and test the standard Moore Uni-drill coulter to improve its direct drilling performance.

3) To evaluate the performance of the cross-slot and modified coulters, on clay soil, for establishing oilseed rape and winter wheat under a variety of straw and soil conditions.

4) To investigate factors affecting the establishment and subsequent development of oilseed rape in the presence of straw to identify where technique improvements need to be made.

5) To establish both oilseed rape and winter wheat in comparative establishment trials with both the cross-slot and modified coulters.

For the 1992/93 work, the Home-Grown Cereals Authority requested that "difficult" soils were studied to amplify any short comings of the establishment systems.

Cannel et al (4) developed a classification system for categorising soils in terms of their suitability for direct drilling. The system assumes that any residue from the previous crop is burnt prior to drilling and so following the ban on straw burning, direct drilled crops are likely to perform less well than the suitability prediction. The classification system is based on limiting soil, site and climatic factors which combine to influence the performance of direct drilled crops:-

**Category 1**
These are soils with favourable properties on which yields similar to those from well-managed conventional cultivations can be expected, from both autumn and spring-sown crops.

**Category 2**
These are soils where with good management the yield of winter cereals is likely to be similar after direct drilling and conventional cultivation, but where the yield of spring crops is likely to be appreciably reduced.

**Category 3**
These are soils on which there is a substantial risk of loss of yield after direct drilling, especially of spring-sown crops.

Eight sites conforming to categories 2 and 3 were selected for the establishment trials in order to satisfy the requirement for "difficult" soils. These are listed in Table 2.

**Table 2. The location, soil series and direct drilling suitability category of soils selected for the 1992/93 work**

**Oilseed rape**

| Location | Soil series | Direct drilling category |
|---|---|---|
| Kneesal | Worcester | 3 |
| Drayton | Evesham | 2/3 |
| Swineshead | Denchworth | 3 |
| Silsoe Campus | Evesham | 2/3 |
| Silsoe Research Institute | Evesham | 2/3 |

**Winter wheat**

| | | |
|---|---|---|
| Shuttleworth | Oxpastures | 2 |
| Boxworth | Hanslope | 2 |
| Silsoe Campus | Denchworth | 3 |

Site plans for each location are presented in Appendix 1.

## 2. MACHINERY DEVELOPMENT

The two main areas of machinery development were:-

1) to adapt the Moore Uni-drill coulter to emulate the action of the cross-slot coulter, and

2) to develop the standard Moore coulter to improve seed placement and penetration.

A Moore Uni-drill coulter, adapted to emulate the cross-slot coulter is shown in Plate 3.

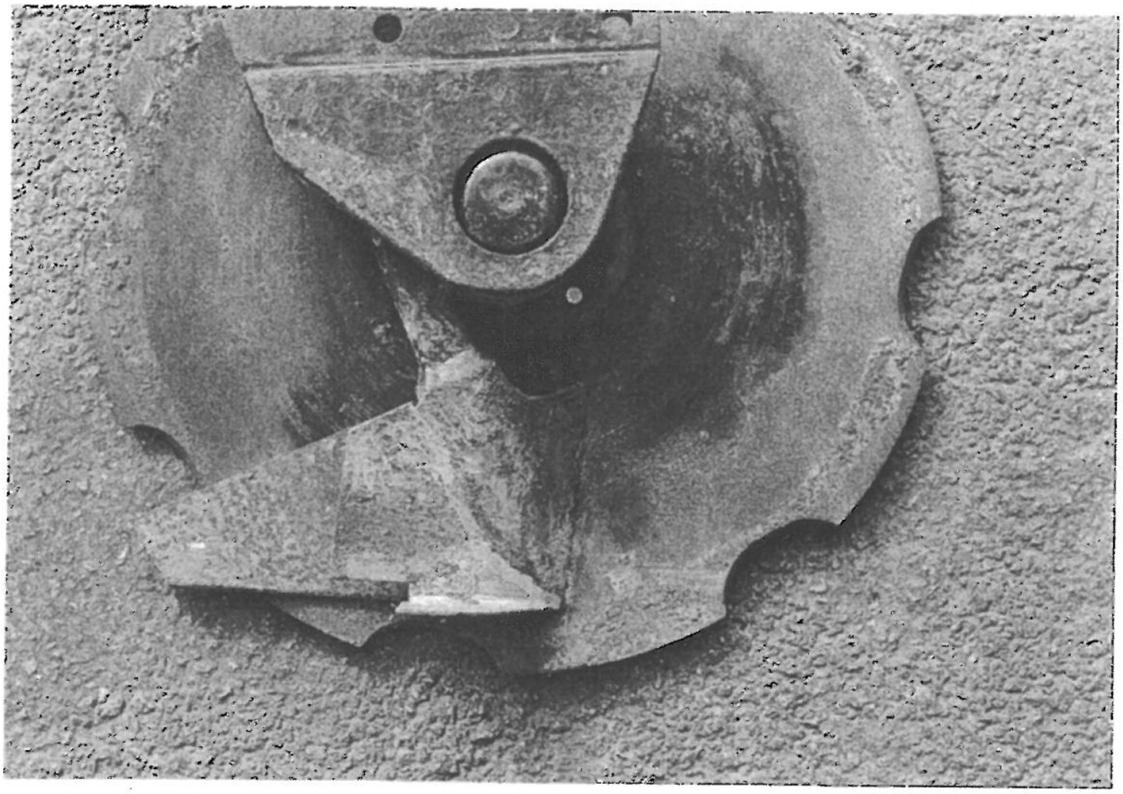

**Plate 3. The cross-slot type coulter used in the 1992/93 trials**

## 2.1 Development of the standard Moore coulter

The standard Moore coulter arrangement places seed adjacent to any straw that has been forced down the seed slot - see Figure 5.

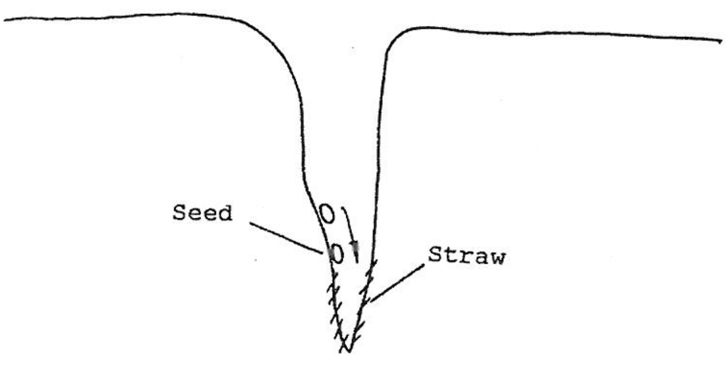


**Figure 5. Seed placement from the standard Moore coulter**

Extensive trials were conducted under controlled conditions in a tank of soil. A range of modified coulters were tested to improve seed placement, cover and penetration characteristics. Details of these trials are presented in Hope-Ryan (5). Plate 4 shows a range of modified coulter fitted to a Moore Uni-drill during field testing.

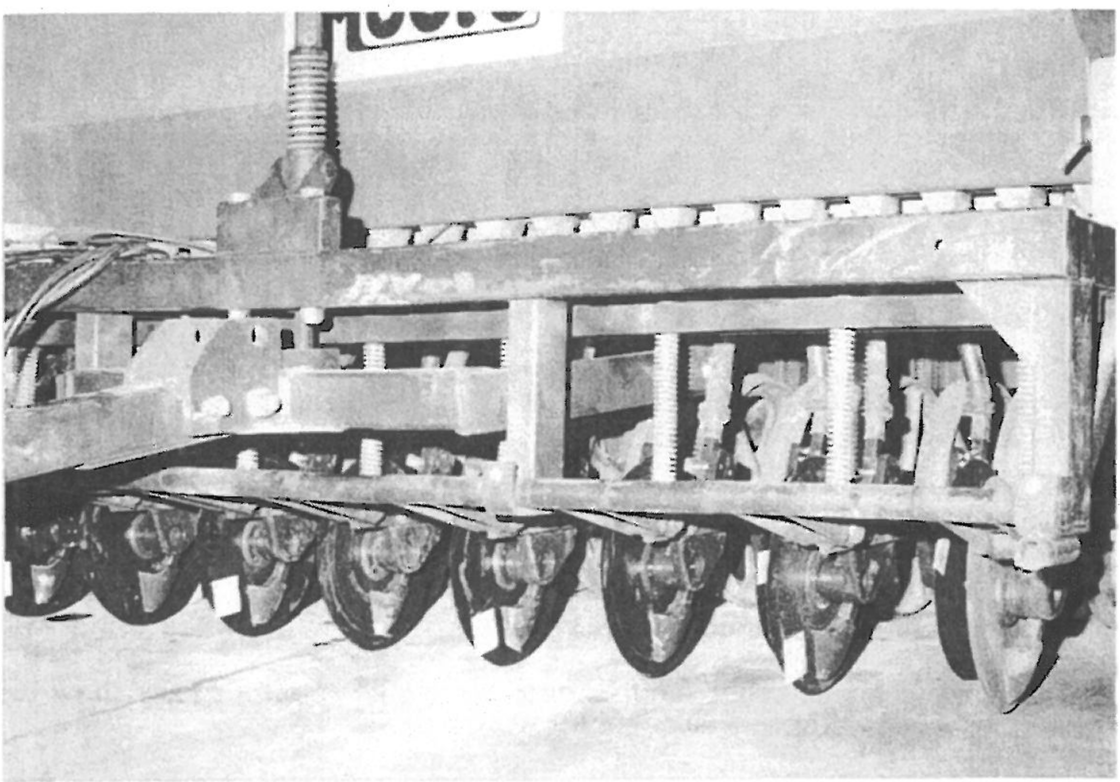

**Plate 4. A range of modified coulters under test**

The optimum coulter geometry, termed "modified Moore", places seed as illustrated in Figure 6. The force required to achieve adequate penetration was marginally greater than that required by the standard coulter.

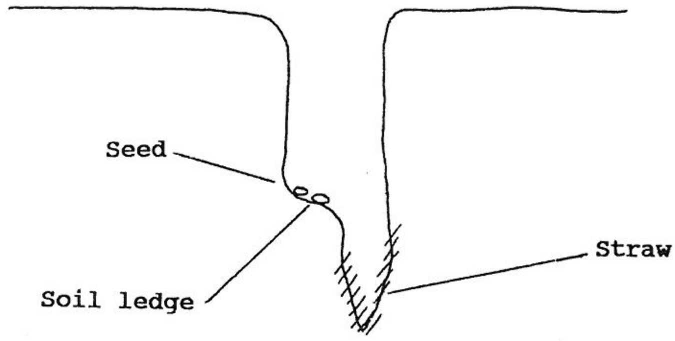


**Figure 6. Seed placement from the modified Moore coulter**

## 3. RESULTS FROM FIELD TRIALS

### 3.1. Drill performance

1) The standard Moore coulter
The coulter did not block under any soil condition. It created a "V" shaped slot, and, if straw was present it was pushed into the slot by the discs prior to seed placement. Dependent on conditions, slot closure varied from complete to an opening of 10mm after the passage of the presswheels. When tested in sandy soils, closure was complete.

2) The cross-slot coulter
This coulter created a soil shelf half way down the seed slot. Seed was placed on this shelf anywhere from 0 to 15mm away from the slot centre. The slot remained relatively straw free except under extreme straw and chaff conditions. The coulter was susceptible to blockage through either straw entrapment between the disc and coulter or clods sealing the seed outlet. These problems occurred regularly under wet conditions.

3) The modified Moore coulter
Similar seed slot characteristics to those created by the cross-slot coulter were achieved but this coulter was found to be much less susceptible to blockage. There was a tendency for seed to be stirred in with the soil when it was operated in previously cultivated soil. Slot closure was intermittent, but improved when drilling through green vegetation because of the binding action of the roots.

4) The presswheels
These generally operated well except in extremely wet conditions when they were prone to soil in-fill between the wheels followed by bulldozing. They did not, however, always close the slot completely particularly with the cross-slot and modified Moore coulters. The soilscrapers functioned efficiently.

3.2. **Crop establishment and performance**

3.2.1. Conditions at the time of drilling

Soil moisture content, and Atterberg limits, were determined at the time of drilling to compare conditions at the various sites. Atterberg limits represent the moisture content of a given soil when it becomes plastic (lower plastic limit) and liquid (upper plastic limit) on wetting. The results are presented in Figure 7

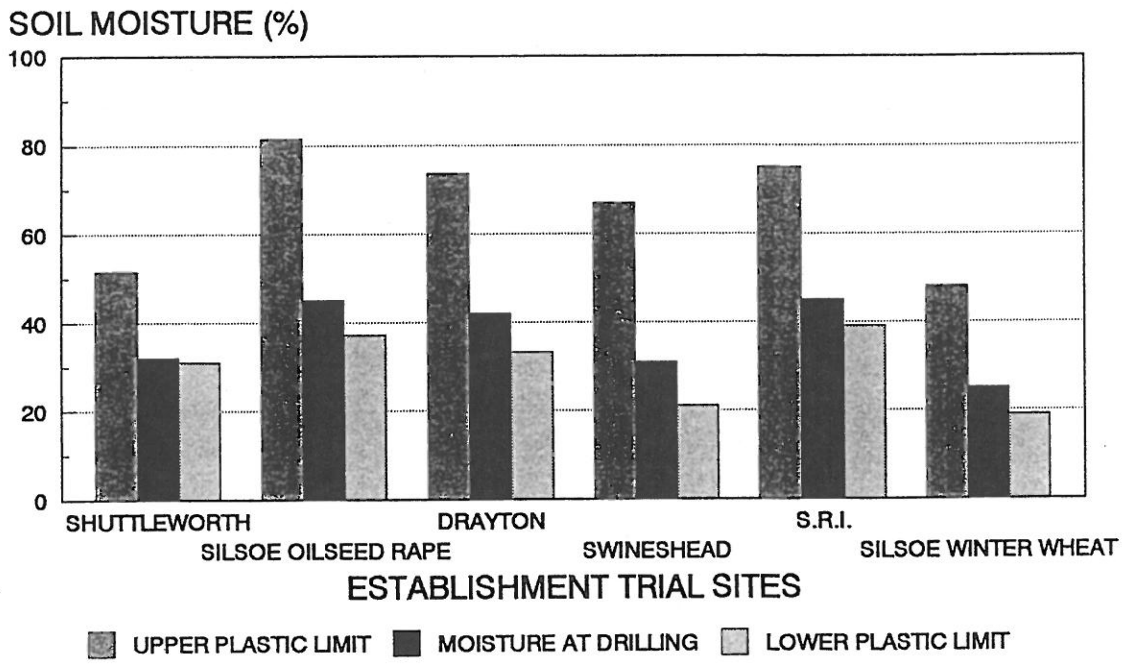


**Figure 7. Atterberg limits and moisture content at the time of drilling**

Figure 7 shows that the soil moisture content at drilling was greater than the plastic limit at all sites. This indicates that the soil was in a plastic, rather than a friable, condition. A friable (crumbly) state would have been preferable because it would have reduced the risk of smearing, and hence poor drainage, in the seed slot. The plots closest to this condition were located at the Shuttleworth winter wheat site. The presence of smear in the seed slot increases the vulnerability of the seed to prolonged waterlogging during the weeks immediately following drilling.

3.2.2. Oilseed rape sites

After drilling, four permanent $0.25m^2$ quadrats were established on each plot for crop growth analysis. Site layouts with explanations of treatments are presented in Appendix 1.

3.2.2.1. Results from the site at Swineshead

A summary of the results from the plots at Swineshead is presented in Figure 8.

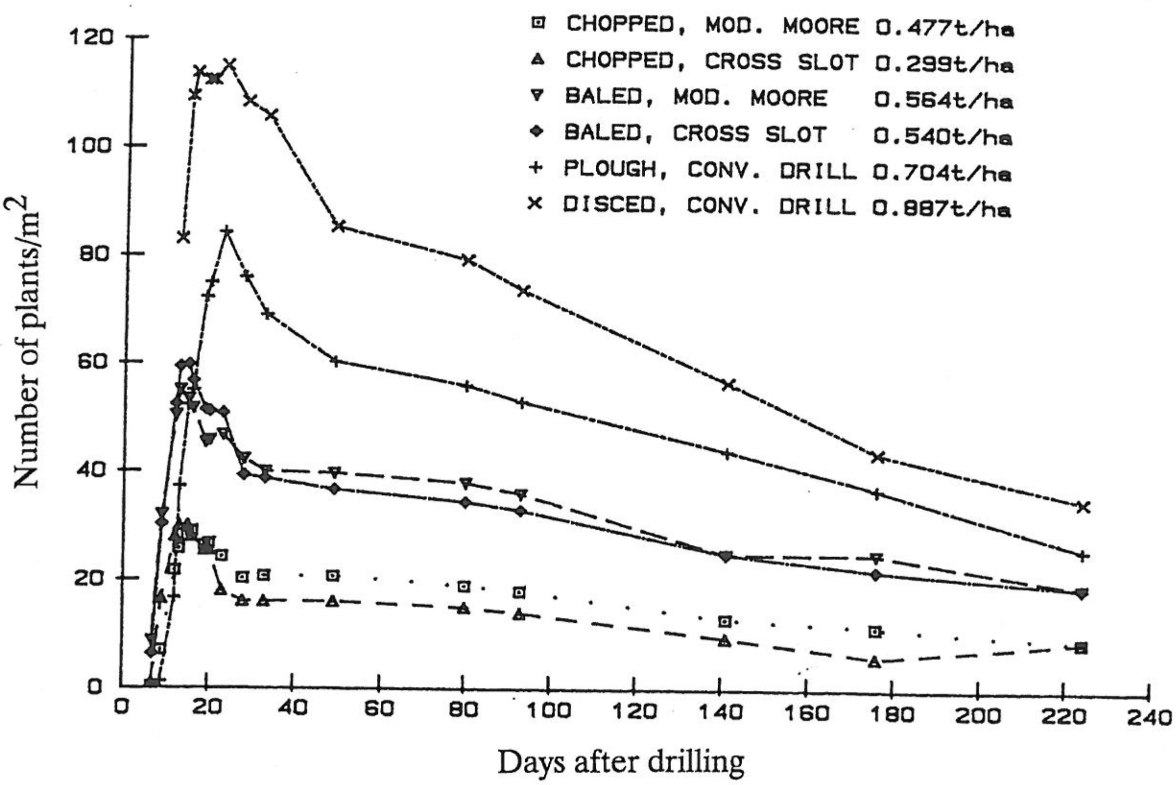


**Figure 8. Summary of oilseed rape data from the Swineshead site**

The rate of emergence on all direct drilled plots was higher than on conventionally cultivated, and minimum tillage, plots. The total number of plants to emerge was, however, lower particularly on plots where straw was chopped and spread rather than baled. Plant numbers on all plots decreased over the season and this was reflected in poor yield results.

3.2.2.2. Results from the site at Kneesall

This site was abandoned early on in the season due to severe slug damage resulting in low plant numbers and the plots were ploughed up in the spring. Results from the first two plant counts are presented in Table 3.

**Table 3. Oilseed rape plant numbers for the Kneesall site**

| Treatment | Drill | Plants/m² 7/10/92 | Plants/m² 10/11/92 |
|---|---|---|---|
| Chopped & spread straw | Direct drilled - mod. Moore | 11 | 15 |
| Chopped & spread straw | Direct drilled - cross-slot | 7 | 10 |
| Baled straw | Direct drilled - mod. Moore | 18 | 15 |
| Baled straw | Direct drilled - cross-slot | 17 | 15 |
| Ploughed | Conventionally drilled | 38 | 24 |
| Disced | Conventionally drilled | 61 | 51 |
| Tined | Conventionally drilled | 47 | 47 |
| Broadcast | | 37 | 26 |
| Farmer's field | Conventionally drilled | 42 | 36 |

Average of 10 random $0.25m^2$ quadrats.

At this early stage in the season, plant numbers were more depressed on direct drilled plots.

3.2.2.3. Results from the site at Drayton

A summary of the results is presented in Table 4.

**Table 4. Oilseed rape results for the Drayton site**

| Treatment | Drill | Plants/m² 2/10 | Plants/m² 10/11 | Plants/m² 15/3 | Yield t/ha |
|---|---|---|---|---|---|
| Chopped & spread straw | Direct drilled - std. Moore | 73 | 45 | 26 | 2.61 |
| Chopped & spread straw | Direct drilled - mod. Moore | 35 | 21 | 46 | 2.01 |
| Baled straw | Direct drilled - std. Moore | 85 | 78 | 19 | 2.52 |
| Baled straw | Direct drilled - mod. Moore | 60 | 45 | 32 | 2.27 |
| Ploughed | Conventionally drilled | 111 | 87 | 71 | 2.58 |
| Disced | Conventionally drilled | 95 | 82 | 72 | 2.66 |
| Tined | Conventionally drilled | 75 | 72 | 55 | 2.79 |
| Broadcast | | 44 | 42 | 16 | 2.14 |
| Chopped & spread straw | Std. Moore, power harrow | 52 | 38 | 28 | 2.50 |

Average of 10 random $0.25m^2$ quadrats.

| | |
|---|---|
| Mean yield (t/ha) | 2.45 |
| Standard deviation | 0.67 |
| Coefficient of variation (%) | 23.4 |

Autumn plant populations were markedly higher where straw was either removed by baling, or incorporated through cultivation. Despite widely varying plant populations between treatments, there was no statistically significant difference between yields.

3.2.2.4 Results from the site at Silsoe Research Institute

Plant counts were not carried out at this site until 3/2/92. A summary of plant population and yield is presented in Table 5.

**Table 5. Oilseed rape results for the Silsoe Research Institute site**

| | Stripped straw Block | | | | | Chopped and spread straw Block | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | Mean | Yield | A | B | C | Mean | Yield |
| Bettinson direct drill | 41 | 71 | 41 | 51 | 2.59 | 83 | 52 | 36 | 57 | 2.34 |
| M. Moore direct drill | 49 | 48 | 25 | 41 | 2.75 | 73 | 40 | 27 | 47 | 2.40 |
| Conv. establishment | 130 | 146 | 151 | 142 | 3.30 | 130 | 146 | 151 | 142 | 3.30 |

Yields from the conventionally established area were significantly higher than from either of the direct drilled treatments. This was likely to have been directly related to increased drainage and an absence of straw through cultivation.

3.2.3. Winter wheat sites

After drilling, four permanent $0.25m^2$ quadrats were established on each plot for crop growth analysis. Site layouts with explanations of treatments are presented in Appendix 1.

3.2.3.1. Results from the site at Shuttleworth

A summary of the results from the plots at Shuttleworth is presented in Figure 9.

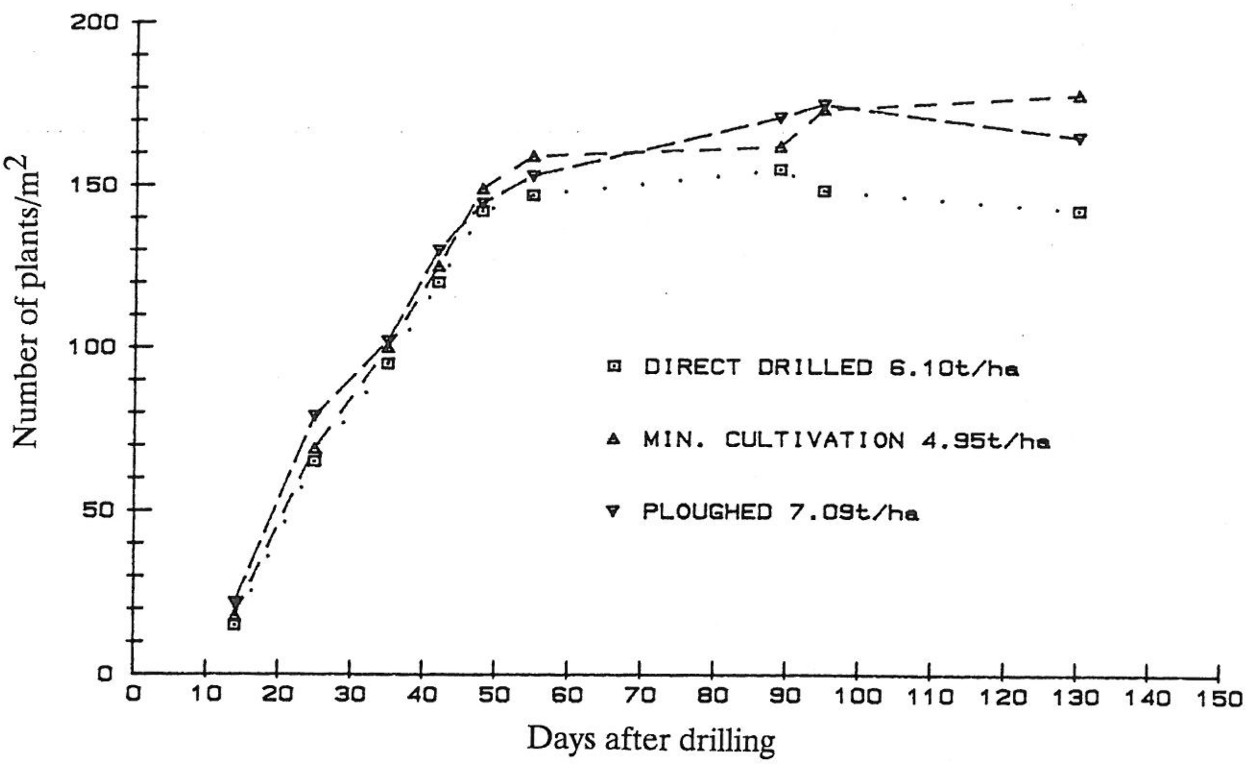


**Figure 9. Summary of winter wheat data from the Shuttleworth site**

The final yield results, following cleaning and adjustments for moisture content, show the plots direct drilled with the modified Moore to yield significantly higher than the minimal cultivation plots despite lower final plant numbers. The conventionally cultivated plots produced the highest yields by approximately 1t/ha.

Generally, the quantity of surface straw was low at Shuttleworth which appears to have favoured direct drilling during a wet autumn.

3.2.3.2. Results from the site at Boxworth

A summary of the winter wheat results from the Boxworth site is presented in Table 6.

**Table 6. Summary of winter wheat performance at Boxworth**

| Treatment | Drill | 9/3/93 (plants/m$^2$) | Yield (t/ha) |
|---|---|---|---|
| Straw burnt, 5cm tine | Conventionally drilled | 208 | 7.34 |
| Straw burnt, plough | Conventionally drilled | 198 | 7.93 |
| Staw chopped, plough | Conventionally drilled | 218 | 8.18 |
| Straw chopped, 10cm tine | Conventionally drilled | 182 | 7.06 |
| Staw chopped, plough | Conventionally drilled | 210 | 8.00 |
| Chopped, tine/disc combi | Conventionally drilled | 180 | 7.80 |
| Staw chopped, plough | Conventionally drilled | 223 | 7.50 |
| Straw chopped | Direct drilled - Moore | 73 | 7.30 |
| Straw chopped | Direct drilled - c-slot | 23 | 6.17 |
| Straw chopped, rotadigger | Conventionally drilled | 195 | 7.45 |
| Straw chopped, 10cm tine | Conventionally drilled | 177 | 7.51 |
| Staw chopped, plough | Conventionally drilled | 214 | 8.02 |

Average of 10 random 0.25m$^2$ quadrats.

| | |
|---|---|
| Mean yield (t/ha) | 7.52 |
| Standard deviation | 0.72 |
| Coefficient of variation (%) | 9.52 |

Resources did not allow the inclusion of baled direct drill plots which, if trends observed at other sites were followed, may have produced results comparable with those from the conventionally cultivated plots.

Plant numbers in March 1993 were low on direct drilled plots, however, this did not seriously affect yields due to the compensatory characteristics of winter wheat. Individual plots were assessed in terms of quantity of surface straw and its effect on crop performance and the data are presented in Table 7.

Table 7. Straw index, final plant numbers and yield for the winter wheat at Boxworth

| Straw Index | Plant numbers at harvest (plants/m$^2$ | Yield (t/ha) |
|---|---|---|
| 1 | 213 | 7.93 |
| 2 | 193 | 7.43 |
| 3 | 181 | 7.43 |
| 5 | 73 | 7.29 |
| 7-10 | 26 | 6.17 |

Where 1 = No straw
7 = 100% cover
7-10 = Increasingly thick

It appears that the greater the straw cover, the lower the plant numbers and final yield, however, the impact is greater on plant numbers.

## 4. Discussion

In general, direct drilled plots were less productive than conventionally established crops during a comparatively wet year. The results obtained were not unexpected when viewed in the context of the direct drilling suitability classifications - see Table 8.

**Table 8. Comparison of direct drilled and conventionally established yield data**

| Location | D. drill category | D. drilled Chop & spread | D. drilled Baled | Conv. drilled |
|---|---|---|---|---|
| | | **Oilseed rape** | Yield (t/ha) | |
| Kneesall | 3 | | | |
| Drayton | 2/3 | 2.01 | 2.27 | 2.58 |
| Swineshead | 3 | 0.48 | 0.56 | 0.70 |
| Silsoe Campus | 2/3 | | | |
| Silsoe Res. Inst. | 2/3 | | 2.75 | 3.30 |
| | | **Winter wheat** | | |
| Shuttleworth | 2 | | 6.10 | 7.09 |
| Boxworth | 2 | | 7.30 | 8.18 |
| Silsoe Campus | 3 | | | |

Better results were obtained where straw was removed prior to direct drilling, however, yields were still lower than those from conventionally established plots.

### 4.1 Factors affecting the performance of direct drilled crops

The poor performance of crops on some direct drilled plots can be attributed to a combination of the following factors:-

1) Slug damage
Slug attack was a serious problem in autumn 1992. Damage was particularly prevalent at Swineshead and Silsoe Campus. Slug pellets were applied immediately after drilling, however, our experience would suggest that pellets should be applied 5 days prior to drilling and afterwards as necessary. According to Prew (6), slugs favour direct drilled land and populations are likely to be twice those expected on cultivated areas. For a second year of direct drilling, up to five times the population is not uncommon.

2) Waterlogging
Waterlogging immediately after drilling was observed on direct drilled plots at Swineshead and Silsoe Campus. Ploughed plots, however, escaped prolonged saturation because of enhanced drainage promoted by cultivation. At both sites there was a marked difference in crop establishment on these plots compared with that on the direct drilled plots where the crop failed. According to Cannell (7), prolonged waterlogging during the first 9 to 16 days after drilling can seriously affect crop establishment. Adequate drainage, in close proximity to the seed, is clearly an important factor in

determining the success or otherwise of crops direct drilled in wet seasons on category 2 or 3 soils.

3) Anoxic conditions
The majority of poor establishment during the 1992/93 season was attributed to prolonged waterlogging, however, where straw was in contact with the seed under wet conditions, anaerobic zones developed in the soil further exacerbating the situation. During the autumn, a selection of plots were tested for anoxic conditions using a technique developed by Batey and Childs (8). A solution of $\alpha,\alpha'$ -dipyridyl was sprayed onto recently excavated soil and any anoxic zones reddened. Anoxic conditions were found to exist in the top 20mm of the direct drilled plots as illustrated in Figure 10.

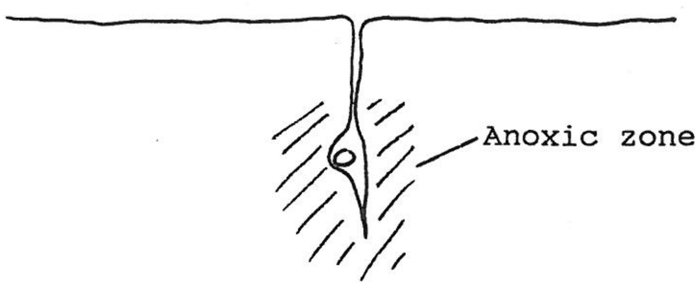


Figure 10. Schematic diagram of anoxic zones around direct drilled seed.

These conditions were particularly prevalent around direct drill seed slots where the disc coulter had forced straw down the slot prior to seed placement. Future drill development must ensure that surface straw must not be forced down the seed slot during drilling.

## 5. Conclusions

Investigations over the past two years have provided a valuable insight into factors affecting the performance of direct drilled crops in the presence of straw residue. The results suggest that direct drilling has considerable potential, however, due regard must be given to a soil's suitability for direct drilling particularly if the season proves to be wet.

The future development of direct drilling techniques should aim to extend the range of soil and climatic conditions under which crop establishment will be reliable, however, it must be accepted that this technique will never be suitable for certain extreme situations. Based on the results of two years of experimentation, future development must satisfy the following criteria:-

<u>In dry conditions</u>
1) good penetration,
2) minimal surface straw to discourage pigeons,
3) leave stubble standing to discourage pigeons, and
4) maximise moisture conservation through efficient slot closure.

<u>In wet conditions</u>
1) reduced smear in the coulter slot area,
2) enhanced drainage,
3) avoidance of straw-seed contact,
4) elimination of slug risk, and
5) minimise surface straw cover to reduce risk of frost heave.

There are important potential benefits to be gained from the development of a reliable direct drilling system. These can be summarised as:-

1) Reduced establishment time and costs.
Straw incorporation requires, in many cases, increased working depth with associated cost and output penalties. Considering a minimum working depth of 150mm to adequately handle straw, establishment costs with tillage are likely to be at least 30% higher than with direct seeding. The actual time required to establish a crop with tillage will be at least 3 times greater than with direct seeding, an important factor in a difficult season.

2) Increased reliability of establishment in dry years.
Soil moisture loss increases with intensity of cultivation, adding to the crop's reliance on subsequent rainfall for successful establishment. Moisture losses from direct seeding are minimal. Financial implications of this will be soil and weather dependent and may vary from zero in one year to a complete loss of crop in another.

3) Increased opportunity for crop establishment within optimum period.
The optimum period for establishment varies depending on the location and management objectives, eg whether the aim is to maximise yields, reduce inputs or minimise environmental impact. Whatever the objective, the high capacity of direct drilling systems considerably increases the possibility of being able to drill at the desired time.

4) Reduced soil erosion on light land.
The recent increase in winter cereals on light land has resulted in a greater incidence of soil erosion. This problem could be alleviated by allowing a proportion of the previous crop's residue to remain on the soil surface through direct drilling.

5) Reduced leaching of nitrates.
By avoiding cultivations, the quantity of nitrate released as a result of mineralisation can be reduced.

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# APPENDIX 1

# SWINESHEAD TRIAL SITE

## ESTABLISHMENT OF OILSEED RAPE (1992/93)

LIBRAVO SEED @ 7.8KG/HA

| PLOT NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STRAW | CHOP | CHOP | CHOP | BALE | CHOP | BURN | CHOP | BALE | CHOP | CHOP | BALE | VOID PLOT TOO WET | CHOP |
| CULT. | | | PLOUGH | | TINE | | | | DISC | TINE | | | |
| DRILL | MOORE | NEW Z. | CONV. | NEW Z. | CONV. | CONV. | BROADC | MOORE | CONV. | CONV. | MOORE | | MOORE |

18m

18m

| PLOT NO. | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STRAW | CHOP | CHOP | BALE | BURN | CHOP | CHOP | BALE | CHOP | CHOP | CHOP | CHOP | BALE | BURN | CHOP |
| CULT. | | DISC | | | | PLOUGH | | TINE | | PLOUGH | | | | DISC |
| DRILL | BROADC | CONV. | MOORE | CONV. | MOORE | CONV. | NEW Z. | CONV. | NEW Z. | CONV. | BROADC | NEW Z. | CONV. | CONV. |

Block 1 = plots 1 - 9
Block 2 = plots 10 - 18
Block 3 = plots 19 27

NEW Z. = NEW ZEALAND TYPE DRILL
CONV. = CONVENTIONAL DRILL
BROADC = BROADCAST SEED
MOORE = MODIFIED MOORE DRILL

# KNEESALL TRIAL SITE

## ESTABLISHMENT OF OILSEED RAPE (1992/93)

LIBRAVO SEED 7.8KG/HA

| PLOT NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| STRAW | CHOP | CHOP | BALE | BALE | CHOP | CHOP | FARMER'S CHOICE | CHOP | CHOP |
| CULTIVATION | | PLOUGH | | | TINE | | | DISC | |
| DRILL | BROADC | CONV. | MMOORE | NEWZ | CONV. | MMOORE | | CONV. | NEWZ |

| PLOT NO. | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|
| STRAW | CHOP | FARMER'S CHOICE | CHOP | CHOP | BALE | CHOP | CHOP | BALE | CHOP |
| CULTIVATION | | | TINE | DISC | | PLOUGH | | | |
| DRILL | NEWZ | | CONV. | CONV. | MMOORE | CONV. | BROADC | NEWZ | MMOORE |

| PLOT NO. | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|
| STRAW | CHOP | CHOP | CHOP | CHOP | CHOP | BALE | CHOP | FARMER'S CHOICE | BALE |
| CULTIVATION | | DISC | | PLOUGH | | | TINE | | |
| DRILL | MMOORE | CONV. | NEWZ | CONV. | BROADC | NEWZ | CONV. | | MMOORE |

| PLOT NO. | 27 | 28 | 29 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|
| STRAW | BALE | CHOP | CHOP | FARMER'S CHOICE | CHOP | CHOP | BALE | CHOP | CHOP |
| CULTIVATION | | TINE | | | | DISC | | PLOUGH | |
| DRILL | NEWZ | CONV. | MMOORE | | NEWZ | CONV. | MMOORE | CONV. | BROADC |

Plot dimensions: 12m × 12m

BLOCK 1 = PLOTS 1 - 9
BLOCK 2 = PLOTS 10 - 18
BLOCK 3 = PLOTS 19 - 27
BLOCK 4 = PLOTS 28 - 36

BROADC = BROADCAST
CONV.= CONVENTIONAL DRILL
MMOORE = MODIFIED MOORE DRILL
NEWZ = NEW ZEALAND DRILL

# DRAYTON TRIAL SITE

## ESTABLISHMENT OF OILSEED RAPE (1992/93)

LIBRAVO SEED @ 7.8KG/HA

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 25 | 21 | 17 | 13 | 9 | 5 | 1 |
| | CHOP | CHOP | CHOP | CHOP | CHOP | CHOP | BALE |
| | | | TINE | | | | |
| | MOORP | MOORE | CONV. | MOORP | MODM | BROAD | MODM |
| | 26 | 22 | 18 | 14 | 10 | 6 | 2 |
| | CHOP | BALE | CHOP | CHOP | CHOP | CHOP | CHOP |
| | DISC | | DISC | | PLOUGH | | PLOUGH |
| | CONV. | MOORE | CONV. | MODM | CONV. | MOORE | CONV. |
| | 27 | 23 | 19 | 15 | 11 | 7 | 3 |
| | CHOP | CHOP | CHOP | CHOP | BALE | CHOP | BALE |
| | | PLOUGH | TINE | | | DISC | |
| | MODM | CONV. | CONV. | BROAD | MOORE | CONV. | MOORE |
| PLOT NO. | | 24 | 20 | 16 | 12 | 8 | 4 |
| STRAW | | CHOP | BALE | BALE | CHOP | CHOP | CHOP |
| CULT. | | | | | | | TINE |
| DRILL | | BROAD | MODM | MODM | MOORE | MOORP | CONV. |

MOORE = STANDARD MOORE DRILL
MOORP = STANDARD MOORE + POWER HARROW
MODM = MODIFIED MOORE DRILL
CONV. = CONVENTIONAL DRILL
BROAD = BROADCAST SEED

Block 1 = plots 19 - 27
Block 2 = plots 10 - 18
Block 3 = plots 1 - 9

# SILSOE RESEARCH INSTITUTE TRIAL SITE
## ESTABLISHMENT OF OILSEED RAPE (1992/93)
BRISTOL SEED @ 8.8KG/HA

STRIPPED / CHOPPED

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLOT NO. | 1 | 2 | 3 | 4 | 5 | 6 | | 7 | 8 | 9 | 10 | 11 | 12 |
| DRILL | RAU | BETT. | BROAD | BROAD | BROAD | MODM | | BROAD | BROAD | MODM | BETT. | RAU | BROAD |
| CULTIVATION | | ROTARY HARROW | ROTARY HARROW | DYNA DRIVE | DISC HARROW | | | DYNA DRIVE | ROTARY HARROW | | ROTARY HARROW | | DISC HARROW |

CHOPPED / STRIPPED

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 14 | 15 | 16 | 17 | 18 | | 19 | 20 | 21 | 22 | 23 | 24 | PLOT NO. |
| BROAD | BROAD | BROAD | MODM | BETT. | RAU | | RAU | BETT. | MODM | BROAD | BROAD | BROAD | DRILL |
| DISC HARROW | DYNA DRIVE | ROTARY HARROW | | ROTARY HARROW | | | | ROTARY HARROW | | ROTARY HARROW | DYNA DRIVE | DISC HARROW | CULTIVATION |

STRIPPED / CHOPPED

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLOT NO. | 25 | 26 | 27 | 28 | 29 | 30 | | 31 | 32 | 33 | 34 | 35 | 36 |
| DRILL | RAU | BETT. | BROAD | BROAD | BROAD | MODM | | BROAD | BROAD | MODM | BETT. | RAU | BROAD |
| CULTIVATION | | ROTARY HARROW | ROTARY HARROW | DYNA DRIVE | DISC HARROW | | | DYNA DRIVE | ROTARY HARROW | | ROTARY HARROW | | DISC HARROW |

block 1 = plots 1 - 12
Block 2 = plots 13 - 24
Block 3 = plots 25 - 36

RAU = RAU ROTOSEM
BETT. = BETTINSON DRILL
BROAD = BROADCAST SEED
MODM = MODIFIED MOORE DIRECT DRILL

# SILSOE TRIAL SITE (MIDDLE FIELD)

## ESTABLISHMENT OF OILSEED RAPE (1992/93)

FALCON SEED 7.5KG/HA

| PLOT NO. | 1 | 2 | 3 | 4 | 5 | 11 | 12 | 13 | 14 | 15 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STRAW HT. | 14" | 8" | 8" | 8" | 8" | 14" | 8" | 8" | 8" | 8" | 14" | 8" | 8" | 8" | 8" |
| STRAW | CHOP | CHOP | CHOP | BALE | BALE | CHOP | CHOP | CHOP | BALE | BALE | CHOP | CHOP | CHOP | BALE | BALE |
| CULT. | LAID | | 13"SP | | | LAID | | 13"SP | | | LAID | | 13"SP | | |
| DRILL | NEWZ | MODM | NEWZ | NEWZ | MODM | NEWZ | MODM | NEWZ | NEWZ | MODM | NEWZ | MODM | NEWZ | NEWZ | MODM |

| PLOT NO. | 6 | 7 | 8 | 9 | 10 | 16 | 17 | 18 | 19 | 20 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STRAW HT. | 3" | 8" | 8" | 8" | 3" | 3" | 8" | 8" | 8" | 8" | 3" | 8" | 8" | 8" | 8" |
| STRAW | CHOP | CHOP | CHOP | CHOP | BALE | CHOP | CHOP | CHOP | CHOP | BALE | CHOP | CHOP | CHOP | CHOP | BALE |
| CULT. | | | | ROUGH | | | | | ROUGH | | | | | ROUGH | |
| DRILL | NEWZ | STDM | NEWZ | NEWZ | STDM | NEWZ | STDM | NEWZ | NEWZ | STDM | NEWZ | STDM | NEWZ | NEWZ | STDM |

BLOCK 1 = PLOTS 1 - 10
BLOCK 2 = PLOTS 11 - 20
BLOCK 3 = PLOTS 21 - 30

STRAW HT = HEIGHT OF STANDING STRAW
CULT.= CULTIVATION
STDM = STANDARD MOORE DRILL
NEWZ = NEW ZEALAND DRILL
MODM = MODIFIED MOORE DRILL
13"SP = 13 INCH SPACING ON DRILL
ROUGH = STRAW ROUGHENED

# SHUTTLEWORTH TRIAL SITE

## ESTABLISHMENT OF WINTER WHEAT (1992/92)

HAVEN SEED @ 184KG/HA

| PLOT NO. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| CULTIVATION | DIRECT DRILLED | MINIMUM CULTIVATION | PLOUGHED | MINIMUM CULTIVATION | PLOUGHED | DIRECT DRILLED |
| DRILL | MOD. MOORE | MOD. MOORE | MOD. MOORE | MOD. MOORE | MOD. MOORE | MOD. MOORE |

| PLOT NO. | 12 | 11 | 10 | 9 | 8 | 7 |
|---|---|---|---|---|---|---|
| CULTIVATION | MINIMUM CULTIVATION | PLOUGHED | DIRECT DRILLED | MINIMUM CULTIVATION | DIRECT DRILLED | PLOUGHED |
| DRILL | MOD. MOORE | MOD. MOORE | MOD. MOORE | MOD. MOORE | MOD. MOORE | MOD. MOORE |

MOD. MOORE = MODIFIED MOORE

Block 1 = plots 4,5 & 6
Block 2 = plots 7,8 &9
Block 3 = plots 1,2 & 3
Block 4 = plots 10,11 & 12

# BOXWORTH TRIAL SITE

## ESTABLISHMENT OF WINTER WHEAT (1992/93)

### SLEPNER SEED @ 172KG/HA

| PLOT NO. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| STRAW | CHOP | CHOP | CHOP | CHOP | CHOP | CHOP |
| CULT | TINE | | ROTADIG | PLOUGH | PLOUGH | |
| DRILL | CONV. | S.MOORE | CONV. | CONV. | CONV. | NEW.Z |

| PLOT NO. | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|
| STRAW | CHOP | CHOP | CHOP | BURN | CHOP | BURN |
| CULT | TINE | PLOUGH | PLOUGH | PLOUGH | TINE/DISC | TINE |
| DRILL | CONV. | CONV. | CONV. | CONV. | CONV. | CONV. |

| PLOT NO. | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|
| STRAW | CHOP | BURN | CHOP | CHOP | CHOP | CHOP |
| CULT | TINE/DISC | TINE | | TINE | ROTADIG | TINE |
| DRILL | CONV. | CONV. | NEW.Z | CONV. | CONV. | CONV. |

| PLOT NO. | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|
| STRAW | CHOP | BURN | CHOP | CHOP | CHOP | CHOP |
| CULT | PLOUGH | PLOUGH | PLOUGH | | PLOUGH | PLOUGH |
| DRILL | CONV. | CONV. | CONV. | S.MOORE | CONV. | CONV. |

| PLOT NO. | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|
| STRAW | CHOP | CHOP | BURN | CHOP | CHOP | CHOP |
| CULT | TINE/DISC | PLOUGH | PLOUGH | TINE | | PLOUGH |
| DRILL | CONV. | CONV. | CONV. | CONV. | NEW.Z | CONV. |

| PLOT NO. | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|
| STRAW | CHOP | CHOP | BURN | CHOP | CHOP | CHOP |
| CULT | ROTADIG | PLOUGH | TINE | PLOUGH | TINE | |
| DRILL | CONV. | CONV. | CONV. | CONV. | CONV. | S.MOORE |

CONV. = Conventional Drill
S.MOORE = Standard Moore Drill
NEW.Z = New Zealand Type Drill

Block 1 = plots 1 to 12
Block 2 = plots 13 to 24
Block 3 = plots 25 to 36

# SILSOE TRIAL SITE (MILBROOK)
## ESTABLISHMENT OF WINTER WHEAT (1992/93)
APOLLO SEED 173KG/HA

| PLOT NO. | 1 | 2 | 3 | 4 | 5 | 11 | 12 | 13 | 14 | 15 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STRAW HT. | 8" | 8" | 8" | 8" | 3" | 8" | 8" | 8" | 8" | 3" | 8" | 8" | 8" | 8" | 3" |
| STRAW | BALE | BALE | CHOP | CHOP | CHOP | BALE | BALE | CHOP | CHOP | CHOP | BALE | BALE | CHOP | CHOP | CHOP |
| CULT. | | | | | | | | | | | | | | | |
| DRILL | STDM | NEWZ | NEWZ | STDM | NEWZ | STDM | NEWZ | NEWZ | STDM | NEWZ | STDM | NEWZ | NEWZ | STDM | NEWZ |

| PLOT NO. | 6 | 7 | 8 | 9 | 10 | 16 | 17 | 18 | 19 | 20 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STRAW HT. | 8" | 8" | 14" | 8" | 3" | 8" | 8" | 14" | 8" | 3" | 8" | 8" | 14" | 8" | 3" |
| STRAW | BALE | BALE | CHOP | CHOP | CHOP | BALE | BALE | CHOP | CHOP | CHOP | BALE | BALE | CHOP | CHOP | CHOP |
| CULT. | | | LAID | | PLOUGH | | | LAID | | PLOUGH | | | LAID | | PLOUGH |
| DRILL | MODM | BETT | NEWZ | MODM | STDM | MODM | BETT | NEWZ | MODM | STDM | MODM | BETT | NEWZ | MODM | STDM |

BLOCK 1 = PLOTS 1 - 10
BLOCK 2 = PLOTS 11 - 20
BLOCK 3 = PLOTS 21 - 30

STRAW HT = HEIGHT OF STANDING STRAW
CULT. = CULTIVATION
STDM = STANDARD MOORE DRILL
NEWZ = NEW ZEALAND DRILL
MODM = MODIFIED MOORE DRILL
BETT = BETTINSON DRILL

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