Presentation 1

Tillage Machine Principles

Dick Godwin
Outline

• Effect of implement shape
  Depth/Width
• Rake Angle
• Speed
• Wings
• Shallower tines
• Spacing
• Discs
• Mouldboard Ploughs
• Concluding comments
Implement geometry and soil disturbance

2 key factors:

1. Rake angle
2. Depth/width ratio

After: Godwin, 1974
Soil disturbance by a vertical tine

25mm wide
215mm deep

After: Godwin, 1974
Soil failure patterns

- Depth/width = < 0.5
- > 1 to < 6
- > 6
Effects of rake angle on crescent geometry

After: Payne and Tanner, 1959
Effect of rake angle on soil forces

After: Godwin 1974
Effect of depth on soil forces

After: Godwin 1974
Effect of speed

After: Wheeler and Godwin, 1996
Selection of implement rake angle for tillage operations

Direction of travel

Soil surface

Operation: Loosening
Cutting
Inverting
Smoothing

Loosening

Low

Cutting

Inverting

Smoothing

Vertical

Sorting
Disintegrating
Rearranging
Consolidating

Sorting

Disintegrating

Rearranging

Consolidating

High

Compacting
Disintegrating

Compacting

Disintegrating

Rollers
Scrubber boards
Pneumatic tyres

Harrors - drag - power

Harrors - drag - power

e.g.: Chisel tines
Plough shares
Bulldozer blades

Plough shares
Bulldozer blades

After: Spoor, 1968
Soil failure and critical depth

Direction of travel

a. Soil surface
   Soil failure planes
   Undisturbed soil

b. Soil surface
   Critical depth
   Compacted zone

Side view  Cross section
Mole ploughs

Mole drains connect clay soils with perched water tables to gravel backfill over existing tile/plastic drains
Soil failure

Herringbone cracks

Horizontal cracks

After: Spoor and Godwin, 1978
Deep tine - 45° leg cracks
Lateral failure - Mole plough

After: Spoor and Godwin, 1978
Addition of Wings

- Tension crack
- Horizontal crack

Direction of travel

Tension cracks
Soil surface
Soil flow
Wing
Lift height

Godwin and Spoor, 2015
Effects of winged tines

Shear plane
Total soil disturbance

Tip

Wing
Effect of wings

<table>
<thead>
<tr>
<th></th>
<th>Conventional subsoiler</th>
<th>Winged subsoiler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draught</td>
<td>20.43 kN</td>
<td>26.58 kN</td>
</tr>
<tr>
<td>Disturbed area</td>
<td>0.098 m²</td>
<td>0.184 m²</td>
</tr>
<tr>
<td>Specific resistance</td>
<td>208 kN/m²</td>
<td>144 kN/m²</td>
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</tbody>
</table>

After: Spoor & Godwin, 1978
2.5 \(d\) \hspace{1cm} 1.6 \(d\)

Rear view

Side view

Godwin and Spoor, 2015
Leading shallow tines

After: Spoor & Godwin, 1978
Soil disturbance

<table>
<thead>
<tr>
<th>Draft Force (tonnes)</th>
<th>Area of disturbance (m²)</th>
<th>Specific resistance (tonnes/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.39</td>
<td>0.24</td>
<td>9.6</td>
</tr>
<tr>
<td>2.35</td>
<td>0.42</td>
<td>5.4</td>
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</tbody>
</table>

Similar: Almost double: 45% reduction

After: Spoor & Godwin 1978
Effects of tine spacing

Too close

Optimum

Too wide

Spacing

After: Godwin, Spoor and Soomro, 1984
Multiple tine spacing

- Simple tines  =  1.5 x depth of work
- Winged tines  =  2.0 x depth of work
- Winged tines + shallow leading tines  =  2.5 x depth of work (of deeper tine)

After: Spoor & Godwin, 1978
Effects of depth

\[ d \]

2cm
Subsoiler – Draught forces

Subsoiling after tracks at 350mm, 88hp

Subsoiling after tyres at 450mm, 240hp

63% Reduction

After: Ansorge and Godwin, 2007
Disc settings

< Passive soil failure

Scrubbing – compressive soil failure >
Effect of sweep angle on draught force

After Godwin, Sieg and Allott, 1987

Optimum
Implement adjustment
Clod size distribution and residue levels

- no discs, tines @ 150mm, plus wings, no packer.
- discs @ 60mm, tines @ 100mm, plus wings, hard packer.
- discs @ 60mm, tines @ 150mm, no wings, no packer.
- discs @ 60mm, tines @ 100mm, plus wings, no packer.
Black Grass Control by Cultivation

Black Grass Control (%)

Iṣd 8.38%, cv = 17.8%

<table>
<thead>
<tr>
<th>Method</th>
<th>Black Grass Ears/m²</th>
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</thead>
<tbody>
<tr>
<td>2 Pass Tillage</td>
<td>102</td>
</tr>
<tr>
<td>Shallow 1 Pass Tillage</td>
<td>108</td>
</tr>
<tr>
<td>Plough</td>
<td>5</td>
</tr>
<tr>
<td>Deep 1 Pass Tillage</td>
<td>27</td>
</tr>
<tr>
<td>Direct Drill</td>
<td>72</td>
</tr>
<tr>
<td>Early Direct Drill</td>
<td>199</td>
</tr>
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</table>

All Drilled 12th October

25th September
1. A plough anywhere in the system reduces black grass numbers.
2. Use good ploughing techniques. Poor ploughing is of little help as it will not bury the weed seeds.
3. Ploughing for a second year brings resistant black grass seeds back to the surface too soon for effective control.
4. Good ploughing followed by 2 years of direct drilling has reduced black grass and increased yields.
5. Continual direct drilling or shallow min till allows black grass numbers to increase. These systems work well if a good stale seedbed is achieved first and the herbicide chemistry works well.
6. With resistance issues, cultivations are having a greater effect on black grass control than current pre and post-emergence chemical options.
Mouldboard plough adjustment

- Work deep enough to bury all weed seeds
- Set skimmers to the correct depth
- Fully invert furrow slice
- Use a slatted mouldboard if soil is sticky
- Use a press to close the furrow
- Ensure the line of draft enables the tractor to pull effectively with the tractor on the land when ploughing with larger ploughs.

http://www.agrii.co.uk/blog/2013/10/24/the-good-ploughing-guide-from-agrii-and-lemken/
Conclusions

1. The effect of changes in geometry and speed on soil disturbance and soil-implement forces for a range of tillage tools are understood.

2. Minimising the draught force is not always the main issue and the correct “job” is the key requirement.

3. Reducing the magnitude of the specific resistance (draught force/disturbance) is a better indicator of overall tillage efficiency.

4. However, to minimise draught reduce both depth and rake angle (where possible).

5. Most tillage machines are designed to be adjusted!

6. Do not work with excessively worn implements.

7. Ploughs can be effective in managing Black Grass.

Photo Courtesy: Philip Wright