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Recommended Citation
Perry, Michael; Jarvis, Ron; Mason, Mel; and Tennant, David (1992) "Results of stubble research in Western Australia," Journal of the Department of Agriculture, Western Australia, Series 4: Vol. 33 : No. 1 , Article 6.
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Results of stubble research in Western Australia

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Few farmers would question the desirability of retaining stubbles, both for control of erosion by wind and water, and to return organic matter to the soil. While the present debate is focused on the short term management of stubbles, longer term effects also need to be considered.

The Department of Agriculture has several long-running trials intended to measure:

- the long term effects of retaining stubbles on soil organic matter,
- the long term effects of retaining stubbles on levels of soil nitrogen, and
- the effects of stubbles on the soil water balance.

It is through these soil factors that stubble retention influences grain yields.

Soil organic matter in stubble retention systems

The retention of stubbles in continuous cropping rotations can maintain or slightly increase soil organic matter. This is shown by results of long term trials comparing the burning of stubbles with methods of incorporating stubble into the soil on both sandplain and heavy soils.

Two trials comparing complete stubble retention, grazing to reduce stubble levels, and burning were started on sandplain soils at Wongan Hills and Merredin in 1979.

After eight years of stubble retention at Merredin and nine years at Wongan Hills, the levels of soil organic matter were tested by measuring organic carbon percentage. Carbon makes up about half the weight of soil organic matter, and the percentage organic matter can be found by multiplying the percentage organic carbon by 1.8.

Table 1. Organic carbon (per cent by weight) in two soil depth intervals after nine years of wheat sown into stubbles which were burnt, grazed or retained at Wongan Hills in April 1987

<table>
<thead>
<tr>
<th>Soil depth (cm)</th>
<th>Burnt</th>
<th>Grazed</th>
<th>Ungrazed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>0.92</td>
<td>0.87</td>
<td>1.04</td>
</tr>
<tr>
<td>5-10</td>
<td>0.91</td>
<td>0.87</td>
<td>0.93</td>
</tr>
<tr>
<td>Average</td>
<td>0.92</td>
<td>0.87</td>
<td>0.98</td>
</tr>
</tbody>
</table>

At Merredin, the soil organic carbon averaged 0.7 per cent and there were no differences in it between retaining stubble or burning it. At Wongan Hills, organic carbon was slightly higher in the ungrazed plots where all stubble was retained (see Table 1).

In a long term trial on red-brown earth (heavy land) at Merredin, results over the past few years have shown that stubble retention has less effect on organic carbon and soil structure than does reducing cultivation. Grain yield was reduced by both stubble retention and cultivation (see Table 2 on following page). The trial started in 1982 and the paddock has been continuously cropped each year.
Table 2. Organic carbon percentage and water stable aggregate percentage (WSA %) and wheat yield for two stubble and two tillage treatments on red-brown earth at Merredin

<table>
<thead>
<tr>
<th>Stubble</th>
<th>Tillage</th>
<th>Organic carbon %</th>
<th>WSA %</th>
<th>Grain yield t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burnt</td>
<td>Ploughed</td>
<td>0.81</td>
<td>4.7</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>Direct drilled</td>
<td>0.89</td>
<td>9.7</td>
<td>1.54</td>
</tr>
<tr>
<td>Retained</td>
<td>Ploughed</td>
<td>0.80</td>
<td>8.5</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>Direct drilled</td>
<td>0.89</td>
<td>14.5</td>
<td>1.41</td>
</tr>
</tbody>
</table>

The percentage of water stable aggregates is a good indicator of soil structure. Table 2 shows an improvement in water stable aggregate percentage of a red-brown earth where stubble was retained and with reduced tillage. Direct drilling (that is, no cultivation except for seeding) combined with stubble retention caused a further increase in water stable aggregate percentage. Direct drilling also increased the organic carbon percentage in the top 5 cm of soil irrespective of the stubble treatment.

Grain yields were slightly greater where stubble was burnt and greater with direct drilling. On these red-brown earths, which are highly susceptible to structural breakdown, waterlogging and water erosion, reducing tillage is the most important factor in attaining sustainable crop production.

On soils like the Merredin loams, it is important to have the machinery to handle the stubbles. If stubble clearance is poor and an extra cultivation is needed to chop it, substantial damage will be caused to the soil structure.

A similar trial on a red sandy loam at Chapman Research Station has shown that organic carbon percentage is greater where stubble was incorporated into the soil rather than being burnt. However, levels of organic carbon still decline under continuous crop rotations, despite the greater incorporation of organic matter as a result of cultivating in stubble. This is shown by results from this trial and others on sandplain at Merredin and Wongan Hills.

The conclusions from our long term stubble retention trials are:

The retention and incorporation of cereal stubbles can maintain or slightly increase soil organic matter and soil structural stability relative to burning.

These benefits can be important if stubble retention practices are combined with others, such as limited or no grazing and direct drilling.

**Stubble retention and nitrogen nutrition**

Incorporation of stubbles into the soil may tie up nitrogen, making it less available to plants. This prospect is often raised as a concern when cereal stubbles are retained.

Cereal stubble has a low nitrogen content (0.24 to 0.94 per cent) and as a result a high carbon to nitrogen ratio, usually about 100:1. The microorganisms that break down the stubble on the other hand have a low carbon to nitrogen ratio of about 20:1. When these microorganisms feed on the stubble residue, they take up nitrogen from the soil that would otherwise be available to the crop. This nitrogen is released later when the microbes die, but this may be too late for the crop.

This suggests that crops planted into retained stubbles would need higher rates of nitrogen than crops planted into stubbles that have been burnt.

Three long term trials were established in 1978 at Nabawa, Wongan Hills and Merredin to find out whether retaining stubbles changes the nitrogen requirement of a following wheat crop in a continuous wheat rotation. The stubbles were either incorporated by ploughing just before seeding, or were burnt; and were topdressed with various rates of ammonium nitrate.

In 30 comparisons (10 years at three sites), incorporation of stubble significantly reduced grain yield on only two occasions. In all but five of the 30 comparisons, there were no differences in the following crop’s need for nitrogen when stubble was incorporated or burnt. Even in these five cases, there was little difference in the most economic rates of nitrogen to apply.

Even in a continuous wheat rotation, the retention and incorporation of stubble will not significantly change the nitrogen requirement of a following crop.

Indeed, nitrogen may even be ‘saved’ from leaching for use later in the season by a crop. This is because the nitrogen used by soil microbes as they break down stubbles is later recycled when they die. The trend to move from continuous cereal cropping towards cereal-legume rotations further reduces the likelihood of nitrogen starvation when stubbles are retained.
Stubble and the water balance

The amount of water available to crops mainly determines cereal yields in the drier parts of the Western Australian wheatbelt. For rainfall to be useful, it must infiltrate into the soil and remain there until used by the crop. Stubble residues help to store more water in the soil in the following ways:

- The residues may act as pathways for rain to infiltrate into the soil. Anchored stubble and partly buried stubble are the most effective.
- Stubble protects the soil surface from the impact of raindrops. This impact causes surface sealing, which reduces infiltration and ponds water on the surface from where it can evaporate. Such protection is important on the unstable red-brown earths (heavy land) of the eastern wheatbelt.
- Stubble acts as a surface mulch, reducing evaporation from the soil.

In Western Australia, the first two mechanisms are likely to be the most important. Stubble is most effective in conserving substantial amounts of moisture if rainfall is frequent. The longer the period between rains the lesser the amount conserved. In the eastern wheatbelt, summer rain is small and irregular.

Conservation of summer rainfall

The effect of retaining stubble on water storage has been examined in trials at Merredin. In 1984, water contents were measured under no stubble and 8 t/ha of applied straw. Eighty-two millimetres of rain was received during April and May and of this 39 mm (48 per cent) was still stored at sowing under 8 t/ha stubble compared to 25 mm (30 per cent) under burnt plots.

In 1985, 50 mm of water was applied in February to plots either burnt or left with standing stubble, or with 1, 2, 4, or 8 t/ha of applied straw. When the amount of stored water was measured in April, burnt plots had retained about half the amount — 14 mm (28 per cent) of the applied water compared with 23 to 26 mm than where stubble was left or applied. In a dry season the additional 9 to 12 mm of stored water could be worth an additional 130 to 180 kg/ha of grain.

Winter water storage

In a second trial, yields of wheat grown for four consecutive years under standing stubble or with 2, 4, or 8 t/ha of applied stubble (applied in year 1 only) were compared with yields of wheat grown after stubbles were burnt. Additional straw was applied to a second 8 t/ha treatment to give a total of 16 t/ha for the second and subsequent years. Grain yields are given in Table 3.

In 1984, 14 mm more water was stored at sowing under the 8 t/ha stubble and the yield was 376 kg/ha greater.

In 1985, the 42 mm of summer rain was all lost, regardless of stubble cover. However, yields with retained stubble were on average 186 kg/ha greater than on the burnt treatment, suggesting that these crops had access to an additional 12 mm of water.

In 1986, water storage at sowing was again unaffected by stubble treatment, but the yields of wheat were on average 90 kg/ha greater than on the burnt plots. In 1987, there was no yield advantage from the stubble treatments.

The results of these trials show that on red-brown earths (heavy land) in the eastern wheatbelt the retention of stubble may have small beneficial effects on the water balance and on crop yield, through increased infiltration and reduced evaporation of water.
Table 4. Wheat grain yields from two stubble treatments in continuous cropping trials on sandplain at Merredin and Wongan Hills

Yields are 12 year averages (1979 -1990)

<table>
<thead>
<tr>
<th>Site</th>
<th>Wheat grain yield, t/ha</th>
<th>Burnt</th>
<th>Grazed</th>
<th>Ungrazed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merredin</td>
<td>1.13</td>
<td>1.05</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Wongan Hills</td>
<td>1.78</td>
<td>1.74</td>
<td>1.46</td>
<td></td>
</tr>
</tbody>
</table>

Although the irregular nature of summer rainfall, and the low levels of stubble in general, do not favour moisture conservation, even small increases (10 mm) in water storage at sowing may be worth an additional 150 kg/ha of grain in dry years. In practice, most cereal stubbles are retained over summer and only burnt in April or May as seeding approaches. Thus, paddocks in which stubbles are to be burnt achieve some conservation of summer rainfall.

On coarse-textured, sandy soils, infiltration of rain is not a problem. While stubble retention is critical for control of erosion by wind, it is unlikely to affect the water balance of a following crop.

Influence of stubble on wheat yield and protein content

Stubble retention on sandplain soil

Two long term stubble retention trials on sandplain soils susceptible to wind erosion were started at Wongan Hills and Merredin in 1979.

At Merredin, the previous year’s stubble was either burnt in April or retained after some post-harvest grazing. At Wongan Hills, the three stubble treatments were: burnt, grazed to about half the level of dry matter following harvest, or not grazed. The stubble-treated plots were cultivated to produce different levels of stubble incorporation.

In both trials there was little benefit in burning stubbles compared with grazing (see Table 4). At Wongan Hills ungrazed stubble treatments were consistently lower in yield due to weed infestation and crop establishment problems. In this trial weeds were much more difficult to control where stubble was retained. Both burning and grazing reduced reliance on post-emergence herbicides.

None of the stubble treatments affected the protein content of the wheat.

Table 5. Wheat yields and grain protein on a heavy soil continuously cropped with stubble and tillage treatments since 1982

<table>
<thead>
<tr>
<th>Stubble</th>
<th>Tillage</th>
<th>Yield (t/ha)</th>
<th>% protein*</th>
<th>Yield (t/ha)</th>
<th>% protein*</th>
<th>Yield (t/ha)</th>
<th>% protein*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burnt</td>
<td>Ploughed</td>
<td>1.65</td>
<td>9.6</td>
<td>1.34</td>
<td>10.9</td>
<td>0.50</td>
<td>11.4</td>
</tr>
<tr>
<td>Direct drilled</td>
<td></td>
<td>2.01</td>
<td>9.5</td>
<td>1.43</td>
<td>9.3</td>
<td>1.05</td>
<td>10.0</td>
</tr>
<tr>
<td>Retained</td>
<td>Ploughed</td>
<td>1.68</td>
<td>9.5</td>
<td>0.99</td>
<td>9.7</td>
<td>0.58</td>
<td>10.3</td>
</tr>
<tr>
<td>Direct drilled</td>
<td></td>
<td>2.12</td>
<td>9.1</td>
<td>1.27</td>
<td>9.0</td>
<td>0.71</td>
<td>9.5</td>
</tr>
</tbody>
</table>

* 11% moisture content

Although the irregular nature of summer rainfall, and the low levels of stubble in general, do not favour moisture conservation, even small increases (10 mm) in water storage at sowing may be worth an additional 150 kg/ha of grain in dry years. In practice, most cereal stubbles are retained over summer and only burnt in April or May as seeding approaches. Thus, paddocks in which stubbles are to be burnt achieve some conservation of summer rainfall.

On coarse-textured, sandy soils, infiltration of rain is not a problem. While stubble retention is critical for control of erosion by wind, it is unlikely to affect the water balance of a following crop.

The protein percentage measured in the past three years has been lower where stubble has been retained, and where the crop has been direct drilled (see Table 5). Generally, the higher the yield, the lower the protein within any one year.

Conclusions

Most Department of Agriculture research on stubble retention, to date, has been in the drier parts of the wheatbelt. These trials suggest that retaining cereal stubbles in continuous cereal rotations has little effect on wheat yield, provided the stubble can be handled adequately at seeding and weed control is satisfactory.

Weed control in stubble retention systems remains a potential problem, which may become more serious with the spread of herbicide resistance in weeds.

In higher rainfall areas, where we have undertaken little research on stubble retention, disease carry-over on stubble may also be important.

Trials in Western Australia have shown that retaining cereal stubbles can have small but beneficial effects on the soil organic carbon, water stable aggregate percentage and moisture conservation of continuous crop rotations compared with burning stubble.