1-1-1987

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Variation in wheat protein content -
the effect of environment

By Graham Crosbie, Officer in Charge, Grain Products Laboratory and Harry Fisher, Senior Research Officer, Division of Plant Production

Over the past 20 years, the average protein content of Western Australian wheat has ranged from 9.3 to 12.0 per cent, with a mean level of 10.4 per cent. At most grain receival points, in any one season, individual loads often vary in protein content by as much as 5 per cent protein or more. Rainfall and soil fertility account for much of this variation.

Seasonal trends
The amount and distribution of rainfall during the growing period of the wheat crop has a marked effect on the final protein level in the grain. During grain development, protein and starch accumulate in the grain at different rates. By the time the bulk of the protein has been translocated from the plant to the grain, much of the starch has yet to be formed. The effect of further accumulation of starch is to dilute the protein; however an early finish to the season will limit the amount of starch formed, leading to reduced yield and higher than average protein content. The effect may be more pronounced under increased moisture stress, such as with higher temperatures or the incidence of root diseases.

Figure 1 shows the relationship between yield of wheat and protein content. Average yield and wheat protein levels for Western Australia are graphed separately over the period 1935/36 to 1986/87. An additional graph shows the yield of grain protein per hectare (the product of yield and protein per cent) over this period.

During the period 1935/36 to 1955/56 there was a general upward trend in average yield per hectare which corresponded with a fall in protein level. Wheat protein levels were above 10.0 per cent in the three year period to 1940/41 but fell to between 9.0 and 10.0 per cent from 1941/42 to 1955/56. Wheat yields showed little or no upward trend from 1955/56 to 1986/87; however the graph highlights sharp upward and downward seasonal changes during this period. The inverse relationship between yield and protein level is apparent, with high peaks for yield generally corresponding with low points for protein level and vice versa. A notable exception was the 1963/64 season, when both average yield and grain protein levels were low. In that season, the State's last major stem rust epidemic reduced the mean yield to only 0.76 tonnes per hectare. The areas worst hit were mainly those that usually produced a high proportion of the State's high protein grain. Grain from other higher yielding and lower protein areas therefore made a higher contribution to the State's wheat production than usual in 1963/64, the net result being lower than average protein levels.

Above: Frank Martinek using a near-infrared reflectance (NIR) analyser to test for protein content of wheat. Ground samples of wheat are loaded into a sample cup (opposite page) and inserted into the analyser. A new type of NIR analyser which measures protein content of whole grain wheat samples is being assessed in Western Australia this season. The NIR method requires calibration of the instrument, using samples of known protein content.
Over the 20 year period 1967/68 to 1986/87, years when either or both Gamenya and Halberd were dominant varieties, a significant inverse correlation between yield and protein content was observed \( r = -0.76, P < 0.01 \). About 58 per cent of the variation in protein content was accounted for by variation in yield. The regression analysis indicated that an increase in yield of 0.1 tonne per hectare was associated with a 0.28 per cent fall in protein content.

It has been suggested that wheat protein levels may be declining in this State. Although the apparent trend has been downward since the record high protein season of 1977/78, it appears to be associated mainly with several seasons of above average yield, particularly 1984/85 and 1986/87. The graph of grain protein yield in Figure 1 shows that grain protein yield in each of these seasons was at a relatively high level, thus the low protein levels could be largely explained by dilution of protein by starch in these high yielding crops.

**Effect of soil type**

Variations in soil fertility (particularly soil nitrogen level) and the moisture status of different soil types can substantially influence wheat protein levels.

Note

1. Average wheat protein for each season is the weighted mean protein content of all receivals in Western Australia into ASW (formerly FAQ). A. Hard and A. Soft grades, expressed as N x 5.7 on an 11 per cent moisture basis. Protein data for minor grades, for example, General Purpose are not available for all seasons and have been omitted from calculations; in most seasons this would have minimal or no effect on the overall average. The effect would have been greater in seasons when these other grades represented a higher proportion of total receivals. For example, in the 1963/64 and 1983/84 seasons, quantities downgraded because of low hectolitre weight and high screenings accounted for about 25 per cent and 23 per cent, respectively, of total receivals. Inclusion of minor grades in the calculation for 1983/84 would have increased the overall protein average from 10.3 to 10.8 per cent.

The protein analyses for seasons up to 1975/76 were carried out by the Western Australian Department of Agriculture, and in later seasons by the Bread Research Institute of Australia. Weightings for the calculations were based on information supplied by Co-operative Bulk Handling Ltd and the Australian Wheat Board.

2. Average grain yields for individual seasons were obtained from publications of the Australian Wheat Board and Australian Bureau of Statistics. Yields are expressed as tonnes per hectare.

3. Average grain protein yield is the product of average grain yield and average wheat protein, expressed as kilograms of protein per hectare.
Highest soil nitrogen levels are found in the heavy soil types—loam, clay loam and alkaline (morrel) soils—which are more commonly located in drier areas. High yields and moderately high protein levels can be achieved on these soils in favourable seasons. In dry seasons however, crops on heavy soils may suffer more moisture stress during the grain filling stage than those on lighter textured soils, resulting in substantially reduced yields and increased grain protein levels.

On the lighter soils, such as the sandy loams, loamy sands and duplex soils (sand or gravel over clay) which occur in most parts of the wheatbelt, grain protein content is generally lower than on the heavy soils. Lowest protein levels are found in wheat produced on the most infertile soils such as deep sands and shallow gravelly soils.

The effects of soil type on wheat protein level have been measured in several studies. Parish and Jones (1971) reported the results of field surveys carried out in 1959 and 1968.

In the 1959 survey, protein levels were assessed in samples taken from "heavy" (clay loam) and "light" (sandy) soils in seven districts. Samples from the heavy soils averaged about 1 per cent actual protein higher than those from the "light" soils, but the difference varied according to climatic conditions.

In the 1968 survey, wheat crops grown on clay, loam, sandy loam and sandy soils were sampled in eight districts. The effect of soil type, in that year, was found to be greatest in the Merredin district, where grain from crops grown on clay soils averaged 2.7 per cent more actual protein than grain from sandy soils. In the Narrogin and Katanning districts, protein levels in grain produced on sandy and sandy loam soils were slightly higher than those from clay and loamy soils. These results were attributed in part to better nitrogen availability on the light soils, associated with the development of legume pastures in these higher rainfall areas.

Interaction of soil type and moisture

Soil type and soil moisture were considered by Parish (1963) to have a major influence on protein variation in a wheat crop in paddock 5C at Merredin Research Station in 1962. In this study, 233 wheat samples harvested by hand throughout the paddock ranged in protein content from 7.1 per cent to 17.6 per cent.

### Table 1. Wheat protein and yield levels (cv. Gamenerya) in trials at Merredin Research Station

<table>
<thead>
<tr>
<th>Season</th>
<th>Station rainfall</th>
<th>Light land trials</th>
<th>Heavy land trials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May-Oct (mm)</td>
<td>Soil type applied</td>
<td>Yield (kg/ha)</td>
</tr>
<tr>
<td>1981/82</td>
<td>212</td>
<td>Us(gr)</td>
<td>1884</td>
</tr>
<tr>
<td>1982/83</td>
<td>196</td>
<td>Cls</td>
<td>1349</td>
</tr>
<tr>
<td>1983/84</td>
<td>183</td>
<td>Agras #1-154</td>
<td>1193</td>
</tr>
<tr>
<td>1984/85</td>
<td>200</td>
<td>Nps</td>
<td>1336</td>
</tr>
<tr>
<td>1985/86</td>
<td>176</td>
<td>Us(gr)</td>
<td>738</td>
</tr>
<tr>
<td>1986/87</td>
<td>249</td>
<td>Super-phosphate-160</td>
<td>1480</td>
</tr>
</tbody>
</table>

(1) Soil type key:
- Cls = Collgar loamy sand
- Mf = Merredin sandy loam
- Nps = Norpa loamy sand
- Npl = Norpa sand (Wodgil deep acid sand)
- Us(gr) = Ulva sandy loam (gravelly phase)

(2) Fertilizer key:
- Superphosphate = 9.1% P
- Agras #1 = 17.5% N/7.6% P
- Agras #2 = 12.0% N/10.4% P

(3) Protein = N x 5.7, expressed on an 11% moisture basis

Martin Walsh analysing wheat samples for protein content, using the standard Kjeldahl method. This method allows us to assess the total nitrogen content in the ground sample. Protein is calculated as nitrogen x 5.7 on an 11 per cent moisture basis.


The State's last major stem rust epidemic in 1963/64 reduced mean wheat yield to 0.76 t/ha.

cent (values adjusted to 11 per cent moisture content). Other samples representing 240 m lengths of a harvester-run around the outside of the paddock varied from 7.5 to 16.3 per cent protein. Parish observed that, in 1962, protein levels tended to be higher on the heavier soil types in this paddock, where the effects of moisture stress were more severe and yield was lower than on lighter soils.

Table 1 shows more recent data from trials at Merredin Research Station on various "light" and "heavy" soils. Protein levels were generally higher in wheat grown on heavier soils than on light soils. Wheat protein levels on both soils were highest, and differences between the two soil types greatest, in the seasons with lowest rainfall.

Receival point surveys

Surveys carried out by the Western Australian Department of Agriculture in collaboration with Co-operative Bulk Handling Ltd (Parish 1965a, b; Parish and Jones 1971) provided detailed information on the distribution of protein content in the Western Australian wheat crop. These surveys included an analysis of representative samples of wheat from each receival point in each season from 1956/57 to 1970/71. Toms and Parish (1971) combined data from these seasons to delineate areas on a map having different average protein content. Figure 2 shows a similar map, for the more recent period 1965/66 to 1979/80.

The map shows that, on average, wheat with a higher grain protein content is grown in northern and north-eastern areas, which have a shorter growing season and lower rainfall; and in the more fertile, lower rainfall areas of the south-east. Conversely, lower protein levels are found in wheat grown in southern and western areas, consistent with longer growing season and higher rainfall.

Conclusion

Variation in the protein content of wheat in Western Australia is associated largely with natural environmental conditions, particularly soil type and rainfall, which influence nitrogen supply and crop yield.

Various surveys have recognized the pattern and extent of this variation and have provided much of the basic information which led to the development of the higher protein Australian Hard (A. Hard) and lower protein Australian Soft (A. Soft) segregations in this State. Results from those surveys will continue to assist in defining suitable areas of application for new varieties and in pinpointing areas where new segregations may be worthwhile.

Acknowledgement

We thank the staff of the Merredin Research Station for their contribution to results reported in this article.

References


