Grain Protein Content and Grain Yield in Western Australia

Key points

- Protein content is driven by environment and in crop management
- Yield has a strong 'dilution effect' on protein
- New high yielding variety Calibre$^{\Phi}$ has a higher protein yield (kg/ha) than older, lower yielding varieties Mace$^{\Phi}$ and Emu Rock$^{\Phi}$
- Yield remains the key driver of enterprise profitability

Background

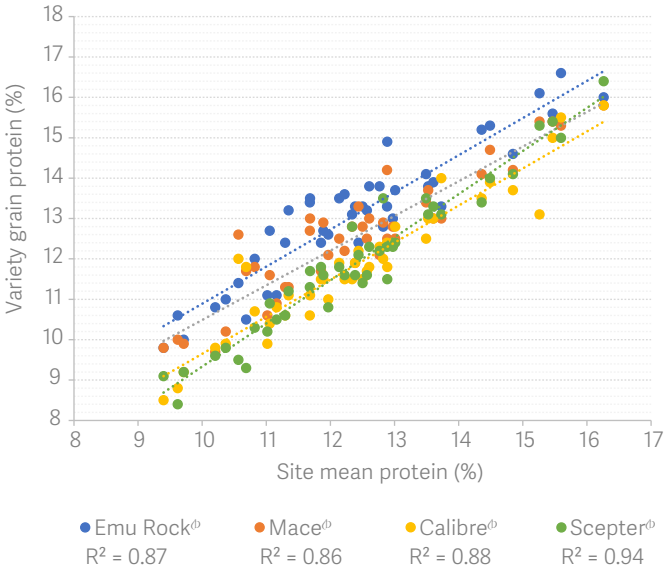
Grain protein is a key factor in baking and noodle quality, and the protein content of a wheat crop contributes to the grade it is accepted into at receival. Recently, there have been several new varieties with improved grain yield released which has generated discussion regarding grain protein and profit maximisation. Anecdotally it has been suggested that some varieties have a greater ability to accumulate grain protein than others. So how does this work and what evidence do we have to suggest some varieties achieve higher protein than others?

In wheat, nitrogen taken up by the plant is used for vegetative growth and reproductive development (grain formation). During grain fill nitrogen is either remobilised within the plant or directly transported to the developing grain to be stored as protein.

Understanding protein achievement

Figure 1 shows the 2020 WA National Variety Trial (NVT) protein content of four AH classified varieties plotted against the site average protein percentage. The first thing that we note here is that the protein content of a crop is overwhelmingly driven by environmental (nitrogen availability, soil type, temperature, and water availability) factors. Secondly, there are some varieties that have grain with higher protein concentration at most environments. For example, the protein percentage for Emu Rock$^{\Phi}$ on average was 13.1% while for Calibre$^{\Phi}$ it was 11.8%. However, as we know, this is only one (minor) part of the story, because Calibre$^{\Phi}$ had substantially higher grain yield (15%) than Emu Rock$^{\Phi}$ in the same dataset. This negative relationship between grain yield and grain protein content is often referred to as 'dilution effect'.

Figure 1 / Protein content of four varieties and corresponding average site protein percentage from 43 NVT sites across WA in 2020



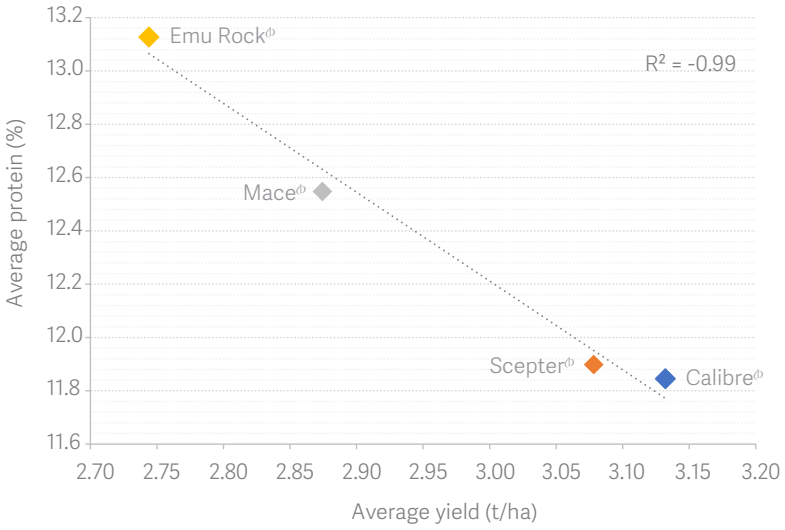
What is the grain protein ‘dilution effect’?

Grain yield in wheat is determined by the number of grains set and the size of those grains. Varieties that are higher yielding (more water-use efficient, stress tolerant, disease resistant etc) will fill a larger number of grains to a greater extent with the carbohydrates that have been generated by photosynthesis. In parallel to this, the plant takes nitrogen from the soil to make protein. The amount of protein that can be produced by the plant is limited by the amount of nitrogen available to the crop. Consequently, if a variety has higher water use efficiency and creates more carbohydrates to fill grain, the percentage of that grain that is protein is reduced.

This is known as the dilution effect, where the total amount of protein has not changed (or may even be higher), but the percentage protein drops because more carbohydrate (grain yield) has been loaded into the grain. This means that the varietal relationship between grain yield and protein percentage is almost always negative.

There are many studies globally that have investigated and demonstrated the ‘dilution effect’ (including Poudel et al. 2021, Zörb, Ludewig & Hawkesford 2018, and Simmonds 1995) of high yielding wheat varieties. This relationship between grain yield and protein content can also be clearly seen in NVT data (figure 2).

Figure 2 / Influence of grain yield on protein content (average grain yield and protein content from 43 NVT sites across WA in 2020)

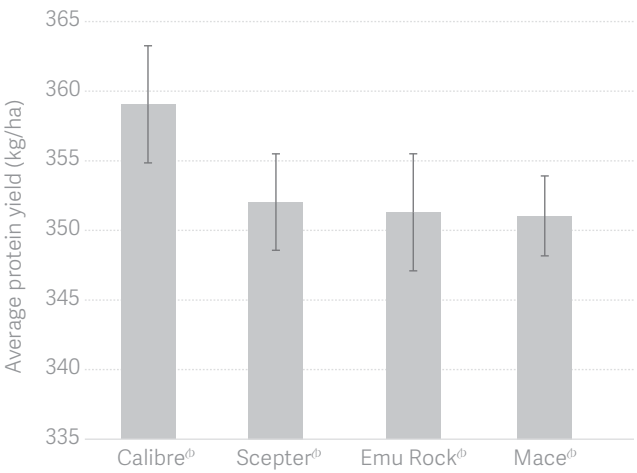


Yield and protein relationship

Given the strong negative relationship between grain protein percentage and grain yield (Zörb, Ludewig & Hawkesbury, 2018), protein content needs to be considered in conjunction with grain yield. It could be thought that if a variety has low protein content, it is a low protein achiever. This common assumption can be misleading and can have large financial ramifications if a variety of perceived high protein achievement, but lower yield, is adopted over the higher yielding but lower protein content variety.

A simple way to determine the real protein achievement of a variety is to look at protein yield. Protein yield is expressed in kilograms of protein per hectare. It is calculated by multiplying grain yield (kg/ha) by protein percentage. Figure 3 illustrates the average protein yield of some key varieties in WA, calculated from the 2020 NVT grain quality data set. In figure 1, Emu Rock$^{\Phi}$ appeared to have higher protein, but when compared to the newer higher yielding varieties it's true protein achievement (protein yield) is much lower.

Figure 3 / Average protein yield (kg/ha) of key main season varieties grown in WA (calculated from an average of 43 NVT sites across WA in 2020)

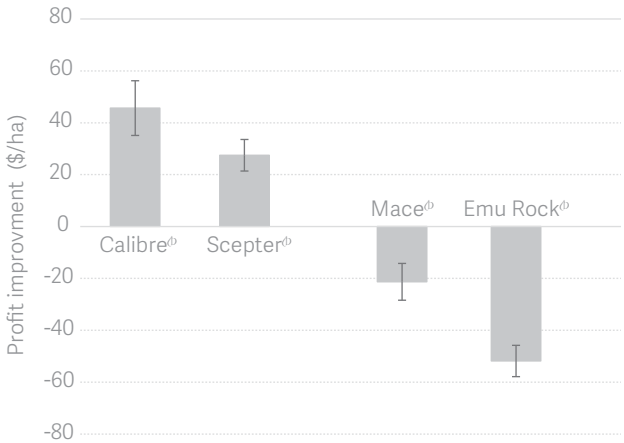


Profitability

The adoption of a variety which is perceived to have a higher protein content, could result in significant financial losses because the 'premiums' paid for protein are not sufficient to offset the lower grain yield. So ultimately, a gross value analysis would be more helpful when considering the impact of changing from one variety to another. First, we need to determine how much protein is worth in the market. Based on the historical prices paid for wheat delivered in the Kwinana Port Zone over the last four seasons, each percent of protein is worth on average $8 (Planfarm, 2021).

Gross income, taking into account both grain yield performance and value of the grain, is a more informative way to compare the value of wheat varieties. Figure 4 illustrates the gross profit change when moving from one variety to another. The higher yielding variety Calibre$^{\Phi}$ achieves a significantly larger gross return than the lower yielding Emu Rock$^{\Phi}$, despite its average protein being 1.3 units lower than Emu Rock$^{\Phi}$.

Figure 4 / Profit improvement ($/ha)



Conclusion

Grain protein percentage has the potential to influence a growers' financial return through determining the grade that grain can be accepted into. However, claims of high protein achievement should be treated with caution when assessing varietal performance, as high grain protein concentration (%) is usually associated with lower grain yield. Furthermore, the price paid for wheat protein of the past four seasons ($8 per % unit of protein) is not sufficient to offset the grain yield loss that is experienced when adopting 'high protein/low yield' varieties. However, it should be remembered that additional nitrogen application may still lead to greater returns in new elite, higher water use efficient varieties through supporting increased grain yield potential.

References

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Zörb, C., Ludewig. U., and Hawkesford, M.J. 2018. 'Perspective on wheat yield and quality with reduced nitrogen supply'. *Trends in Plant Science 23*(11) p1029-1037. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6202697/ (accessed 19th October 2021).

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Disclaimer: The information contained in this factsheet is based on the data, knowledge, and the understanding at the time of writing. Growers should be aware of the need to regularly consult with their advisor on local conditions influencing variety adoption and agronomic management.