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Grain analysis for cereals

Summary

- **Grain analysis does not replace the need for soil analysis. Soil analysis is an essential tool, which tells us the status of nutrients in the soil, giving us a target to base nutrient applications from bagged fertiliser, organic manure and composts.**
- **Grain analysis does tell us much more about the actual capture of these nutrients and how well they have been taken up by the plant. It should be considered as a post-mortem of the crop, ultimately helping you to assess if your nutrient programme has been successful.**
- **Low concentrations of nutrients highlighted by grain analysis will need additional investigation. It does not necessarily mean you need to increase application of nutrients in the field. There are many factors which can reduce the ultimate capture of nutrients in the grain. These factors can be related to management (a pH which is below target) or environmental (wet weather at establishment, spring drought conditions or root and stem-based disease).**
- **Repeated use of grain analysis over different seasons, provides a much better assessment of actual nutrient uptake within a field. Repeated analysis allows you to assess, which nutrients might be yield limiting (low concentration in the grain) and which nutrients might be over supplied (high concentrations in the grain).**
- **Most importantly, repeated use of grain analysis helps the grower to identify the limiting factor within a field, for example is a low nutrient concentration the result of poor product choice, under application, low soil pH, poor soil structure or is it simply the result of a poor growing season (repeated wet autumns, dry springs, or seasonal disease pressure).**
- **In summary, grain analysis improves your understanding of nutrient uptake across your farm, allowing you to make better informed decisions.**

1. Introduction

Testing the nutrient content of harvested grain provides you with:

- **An accurate measurement of nutrient take-off**
- **An opportunity to identify nutrient deficiencies in the harvested grain which might be yield limiting.**
- **An opportunity to assess the impact of management changes on nutrient availability i.e., winter wheat fields which are ploughed vs min till or wheat which received organic manure vs wheat which received more inorganic fertiliser.**

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Taking a grain sample

- **Grain samples must be collected during harvest while trailers are being tipped.**
- **Grain from different fields must not be mixed.**
- **Labeled sample buckets left in the unloading area allow operators to collect grain from the appropriate field.**
- **Take x2 half cupfuls from each trailer as it is being tipped and place them in the labelled bucket for the correct field.**
- **When the whole field is harvested, mix the grain in each bucket and bag-up a sub-sample (~200g; 8oz) with its correct label.**
- **Record the harvest moisture content & yield.**
- **Store in a dry vermin proof room and when all fields have been harvested send to your chosen lab for analysis.**

Above: Field sample being collected Source: ADAS, YEN nutrition sampling procedure

Interpretating grain results

Grain nutrient concentrations are normally displayed in terms of percentage (%) or quantity (mg/kg) per kg dry matter (moisture removed), which means results from fields harvested at varying moisture contents are comparable.

Because grain analysis is relatively new, critical values (the point at which a grain nutrient concentration becomes yield limiting) are uncertain, with some more reliable than others.

AHDB-funded research on phosphorus (P) nutrition has shown that the critical level of grain P in winter wheat is 0.32%. The research has suggested that grain P contents repeatedly below this level indicate crop P uptake is deficient enough to reduce grain yield.

YEN nutrition (an ADAS funded initiative) has been recording grain nutrient results across the UK since 2016 and have established some critical value benchmarks. Based on this recording they have critical value benchmarks for phosphorus (P) nitrogen (N), manganese (Mn) and sulphur(S), which are classified as being reliable. potassium (K), copper (Cu), magnesium (Mg) and Zinc (Zn) have been classified as uncertain, while critical values for iron (Fe), calcium (Ca), boron (B) and molybdenum (Mo) unknown. These critical values are therefore subject to change as the data set develops.

Table 1: ADAS/YEN nutrition estimated critical values for cereals, 2020, listed in order of reliability.

	Reliable				Uncertain				Unknown			
Results/Kg DM	**N%**	**P%**	**Mn (mg/kg)**	**S%**	**K%**	**Cu (mg/kg)**	**Mg%**	**Zn (mg/kg)**	**Fe (mg/kg)**	**Ca%**	**B (mg/kg)**	**Mo (mg/kg)**
est Critical value (ADAS 2020)	1.90%	0.32%	20	0.12%	0.38%	2	0.08%	15	N/A	N/A	N/A	N/A

Using critical values to analyse individual field results

Grain analysis can be used as a way of identifying potentially yield limiting nutrients at the farm gate.

Table 2 shows the individual winter wheat, harvest results for anonymised farm A, which is part of the FAS funded Scottish Borders soil and nutrient network (arable) group. Table 2 below shows harvest year 2020 compared against the ADAS, YEN nutrition critical value benchmarks for 2020.

Table 2: Farm A (part of Borders Nutrient network group) winter wheat harvest results 2020 vs ADAS estimated critical values for cereals.

Farm A	Reliable				Uncertain				Unknown			
Harvest year 2020	**N%**	**P%**	**Mn (mg/kg)**	**S%**	**K%**	**Cu (mg/kg)**	**Mg%**	**Zn (mg/kg)**	**Fe (mg/kg)**	**Ca%**	**B (mg/kg)**	**Mo (mg/kg)**
Critical value	1.90%	0.32%	20	0.12%	0.38%	2	0.08%	15	N/A	N/A	N/A	N/A
Field 1 (8.0t/ha)	2.09%	0.29%	32	0.14%	0.48%	4	0.10%	26	39	0.04%	0.8	0.16
Field 2 (7.8t/ha)	2.00%	0.29%	32	0.13%	0.47%	4	0.10%	26	37	0.03%	0.8	0.24
Field 3 (6t/ha)	2.12%	0.28%	33	0.13%	0.44%	4	0.08%	23	77	0.05%	0.9	0.05
Average	2.07%	0.29%	32	0.13%	0.46%	4	0.09%	25	51	0.04%	0.8	0.15

Table 2 above suggests that although phosphorous deficiency Is yield limiting and requires further investigation, it should not be interpretated to mean increase phosphorus fertiliser applications on the next crop.

The reality is that there are many other variables, which might have restricted phosphorous uptake by the plant. Soil pH, soil health, drainage, establishment conditions, disease pressure and weather during the growing season are factors which can limit nutrient uptake by the plant.

In this growing season, a spring drought was a major limiting factor, which might have delayed and restricted the uptake of spring applied fertiliser.

The dry spring might also explain why the grain nitrogen values are very high as there was more nitrogen applied than was required for the yield potential which was limited by drought.

Caution should be taken when identifying management weaknesses using one year of results, however repeated testing over different growing seasons, will allow you to start building up a more accurate data set and evidence base for making decisions. This is discussed in the next section.

Using grain analysis to build an evidence base for changes in nutrient management of individual fields

Using Field 1 (Farm A), from the previous section, grain analysis was repeated in harvest years 2021 and 2022, to try and build up an evidence base for identifying nutrient deficiency or potential over supply of nutrients, which could be addressed by changing management or adjusting nutrient application rates.

Table 3: Field 1 – Farm A (part of Borders Nutrient network group) harvest results 2020 – 2022 vs ADAS estimated critical values for cereals (2020)

Field 1.	Reliable				Uncertain				Unknown			
Harvest 20-22	**N%**	**P%**	**Mn (mg/kg)**	**S%**	**K%**	**Cu (mg/kg)**	**Mg%**	**Zn (mg/kg)**	**Fe (mg/kg)**	**Ca%**	**B (mg/kg)**	**Mo (mg/kg)**
Critical value	1.90%	0.32%	20	0.12%	0.38%	2	0.08%	15	N/A	N/A	N/A	N/A
2020* (8.0t/ha)	2.09%	0.29%	32	0.14%	0.48%	4	0.10%	26	39	0.04%	0.8	0.16
2021* (9t/ha)	1.84%	0.23%	27	0.13%	0.45%	3	0.08%	20	36	0.03%	0.8	0.05
2022* (9.7t/ha)	1.61%	0.25%	14	0.13%	0.67%	4	0.11%	20	42	0.05%	1.1	0.10
Average	1.85%	0.26%	24	0.13%	0.53%	4	0.10%	22	39	0.04%	0.9	0.10

**2020 = Winter wheat yielding 8.0t/ha, 2021 =winter wheat yielding 9t/ha. 2022 = spring barley yielding 9.7t/ha*

Unlike table 2 from the previous section, table 3 displays a much stronger argument to suggest that phosphorous is limiting crop yield potential, as in all three years the grain nutrient concentration is below the critical value. The results also suggest that nitrogen is yield limiting.

There are many factors which might be limiting the uptake up phosphorous & nitrogen to the plant. Below is a list of some factors (not all) which Farmer A might want to consider based on the results in table 3.

- **Is there an issue with the soil pH?:** Soil pH enhances the availability of nutrients in fertiliser and encourages the microbial activity of the soil. Soil pH is affected by leaching, crop removal and nitrogen application. For cereal crops in Scotland, the target pH is 6.0-6.2 depending on soil type. **https://www.fas.scot/downloads/technical-note-tn656-soils-information-texture-liming/**

- **Is there an issue with the soil structure/drainage?** Soil health refers to the biological, chemical and physical components of the soil. Physical factors which will influence nutrient uptake include soil compaction, water logging and poor drainage, while repeated cultivations and low input of organic manure will impact organic matter and the biological health of the soil. **https://ahdb.org.uk/knowledge-library/principles-improve-soil-health**

- **Is there an issue with the nutrient application rate or application timing?** It is important to apply nutrients, based on estimated crop offtake and recent soil results. Soils which are low in phosphorous, will have a much greater requirement for phosphorous compared to a field which is high. In Scotland the phosphorous sorption capacity of soil will also influence the required application rate. Further guidance can be found in TN 715-718 **https://www.fas.scot/crops-soils/soils/nutrient-planning-useful-resources/**

- **Is there an issue with root and stem-based disease?** Eyespot and take-all are common in intensive cereal rotations. Both diseases result in restricted water and nutrient flow to the plant, resulting in significant yield losses. **https://Ahdb.org.uk/cereal-dmg**

The results above also suggest that unlike harvest year 2020, where drought was yield limiting and nitrogen was over supplied, in 2021 and 2022, nitrogen appears to be below the critical value, suggesting that in a year where the yield potential of the crop is good, it is limited by either the supply of nitrogen or the efficiency of the nitrogen uptake.

When deciding on nitrogen applications for the season ahead, it Is important to remember that increasing nitrogen applications to increase yield is not always economically justified. Cereal nitrogen recommendations in TN731 are based on a standard nitrogen response curve, with a break-even ratio of 3:1 (i.e., 3kg grain needed to pay for each 1kg of nitrogen). It is also important to keep within NVZ regulations, where set NMAX limits cannot be exceeded.

TN731 – Nitrogen recommendations for cereals, oilseed rape & potatoes **https://www.fas.scot/publication/technical-note-tn731-nitrogen-recommendations-for-cereals-oilseed-rape-and-potatoes/**

NVZ's – Practical guide **https://www.fas.scot/downloads/nvz-rules-refresher/**

Using critical values to benchmark group harvest results

Another benchmark, which can be used alongside critical values is the local average grain yields and nutrient concentrations for your local area.

Local average results can be more representative of local soils and climatic conditions and weather patterns in the area and allow you to better understand the effect of these local factors on nutrient uptake (non-free draining soils or soils with a high phosphorous sorption capacity).

Sharing information with others, through discussion groups or benchmarking groups, ultimately allows for a better understanding of what is achievable and realistic in a local area.

Table 4 below shows the Borders nutrient network (arable) group winter wheat average grain results for 2020, 2021 & 2022 compared against the ADAS, YEN nutrition critical value benchmarks for 2020.

Table 4: Borders NNG winter wheat results vs critical values for cereals.

	Reliable				Uncertain				Unknown			
Group results	**N%**	**P%**	**Mn (mg/kg)**	**S%**	**K%**	**Cu (mg/kg)**	**Mg%**	**Zn (mg/kg)**	**Fe (mg/kg)**	**Ca%**	**B (mg/kg)**	**Mo (mg/kg)**
Critical value	1.90%	0.32%	20	0.12%	0.38%	2	0.08%	15	N/A	N/A	N/A	N/A
2020 (8t/ha)*	1.88%	0.34%	29	0.14%	0.47%	4	0.11%	25	42	0.04%	0.9	0.16
2021 (9t/ha)*	1.73%	0.25%	35	0.13%	0.44%	4	0.08%	19	30	0.03%	0.9	0.24
2022 (10.5t/ha)*	1.81%	0.30%	32	0.14%	0.46%	4	0.10%	22	36	0.04%	0.90	0.20
3 Year average (9.16t/ha)	1.81%	0.30%	32	0.14%	0.46%	4	0.10%	22	36	0.04%	0.90	0.20

**The Borders nutrient network (arable) group is a group of 15 farmers in the Kelso region of the Scottish Borders. 2020 = 10 fields tested, with an average harvest yield of 8.0t/ha. 2021 = 12 fields tested, with an average harvest yield of 9.0t/ha 2022 = 10 fields tested with an average harvest yield of 10.5t/ha.*

The results above suggest that for this group of farmers over three years of grain testing, the average 3-year average wheat yield is 9.16t/ha, with the data suggesting a trend of below critical values for both nitrogen and phosphorous.

This group data is useful, because it allows participants to discuss their farm management practices and learn from each other. For example, in 2022 farmer A achieves a yield of 9.7t/ha, while farmer B achieves a yield of 10t/ha. Both crops received a similar amount of nutrients through bagged fertiliser and manure, however Farmer B's grain results show higher nutrient concentrations of phosphorous along with a higher yield.

This evidence can then allow farmer A to identify possible limiting factors within the field. This could be a low soil phosphorous status, poor timing of fertiliser application or a below target pH.

Small changes in organic matter between farms and fields can also have big changes in nutrient availability, so this is something worth focusing on. The value of returning straw to arable systems can be underestimated and is likely to pay dividends in the long term.

Conclusions

Grain analysis should form only one part of your overall analysis for cereals.

- **Part 1 – Soil planning:** Use your soil test results and FAS technical note for cereals to calculate your crop nutrient requirement for nitrogen (N) phosphorus (P) and Potassium (K) and Sulphur(S) based on crop type, market, soil nutrient status, soil type, rainfall, and estimated crop yield. FAS Technical notes are available from **https://www.fas.scot/crops-soils/soils/nutrient-planning-useful-resources/**
- **Part 2 – Field management:** Tailor your granular and foliar fertiliser applications and timings based on weather, yield potential & plant tissue status.
- **Part 3 –** Grain analysis: Review the success of the strategy (post-mortem).

References

- **AHDB –** Review of AHDB funded research on phosphorus management in arable crops, Ian Richards, April 2019 **https://projectblue.blob.core.windows.net/media/Default/Research%20Papers/Cereals%20and%20Oilseed/rr93-final-report.pdf**
- YEN Nutrition benchmarking report **https://yen.adas.co.uk/resources/yen-nutrition-example-benchmark-report-2**
- FAS Borders nutrient network (Arable) group.

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