HGCA

from theory to field

Trace benefit from trace elements?

Manganese deficiency in barley

Recent research has found little evidence that micronutrients bring a statistically significant yield response to cereals. *CPM* finds out what this means for identifying where they're needed.

By Tom Allen-Stevens

For many growers, micronutrients are a standard addition to the spray tank at this time of year — manganese may be applied because of issues of lock-up, or zinc to improve rooting, for example. But where's the trials evidence to show they're needed? And do we actually know how reliable the soil and tissue threshold values are for micronutrients?

"Chances are, more micronutrients are applied than are necessary, and some products may be doing nothing at all," says James Holmes of HGCA. "We need some reliable independent information and a firm basis for accepted threshold levels."

But this isn't just about identifying where micronutrients may be needlessly applied, to help save growers unwarranted inputs, he says. "Visual symptoms attributed to micronutrient deficiencies could be down to an underlying soil-structure issue that goes unaddressed, for example.

"There are places where micronutrients are needed, however, so it's important to have a reliable route to identify these so growers understand these specific situations better."

Law of the minimum

So a three-and-a-half-year project started in Oct 2009 to set about answering some of these questions, led by Prof Steve McGrath of Rothamsted Research. "The law of the minimum — commonly known as the leaky barrel — states that the nutrient that's in shortest supply is the one that limits yield. So we looked first at whether trace elements are becoming limiting, particularly on high-yielding crops.

"Another aspect we were keen to explore was grain quality. With higher yields, could there be a lower concentration of some essential nutrients coming through into the grain?" There could also be a human or animal nutritional issue to address, he adds.

Most of the work on micronutrients was done 30-40 years ago, he notes, so there was a need to bring this up to date. The first aspect the research team looked at was the micronutrient status of various soils. The analyses of around 1800 samples taken from 1978 to 1982 were compared with 132 samples taken in 2009/10, to determine whether levels of manganese (Mn), copper (Cu) and zinc (Zn) had actually fallen at all.

"There were a lot more samples in the old set of data than the new, so the spread of values was greater. You could say levels have fallen slightly, but it's only a slight drop, and may be due to the difference in the size of the two datasets."

The bulk of the project focused on three years of trials across five sites in each year. The aim of the trials was to test whether foliar-applied Mn, Cu and Zn would bring about a yield benefit for winter wheat (Solstice was the variety chosen). Soil, tissue and grain samples at each site were analysed to see what relationship, if any, could be drawn between these analyses and the harvested results.

"We deliberately chose sites that would be likely to be deficient in trace elements — primarily sandy, calcareous or organic soils. There were two sets of untreated

> *"Crops aren't quite as responsive in terms of yield as we're led to expect."*

There's a lack of independent information on micronutrients, points out James Holmes.

plots at each site, to improve the statistical robustness of the data. In each case, the treated plots received two doses of the micronutrient product recommended for a severe deficiency to encourage a response. We tried hard to get the trials to exhibit the sort of response you hear about from applied micronutrients."

But across all 15 experiments, each of which trialled three micronutrients, there was just one case where a trial yielded a statistically significant positive grain-yield result. This was an organic soil at Waterbeach in the Fens, north of Cambridge, where Cu applications brought about a 1.4t/ha (19%) yield benefit in 2012.

"It was a real surprise," comments Steve McGrath. "We weren't expecting massive responses, but did think we'd get more than one. What's more, it's possible that this benefit was down to the fungicidal properties of the particular Cu product used — copper oxychloride.

"It shows that crops aren't quite as responsive in terms of yield as we're led to expect. Even in 2011, when some sites were producing high-yielding crops of 10-11t/ha, the addition of the micronutrients on these high-risk sites didn't seem to be doing anything."

That's not to say there was no yield response at all. The research team analysed the variance of each field trial, in terms of its yield and by looking at the coefficient of variation (CV), they could determine what sort of yield response could conclusively be attributed to a micronutrient application.

"The mean CV over the three years ranged from 0.37-0.58t/ha, so you'd need about a 0.5t/ha yield improvement in order to see a difference," he notes. Each trial looked at single nutrient applications — the combined effect of several trace-element applications weren't investigated. "You'd need a highly complex set of trials in order to analyse this thoroughly, assuming there was any combined effect."

Type of soil

So what about the criteria growers use to gauge if their crops are suffering a nutrient deficiency, or could benefit from an application of trace elements? "Firstly, there's the type of soil in question, and some types, such as light, organic or high pH soils, are inherently at risk due to low bioavailability of micronutrients.

"Then there's soil analysis, and the EDTA extracts are commonly used across the UK. For Mn, this varies so much depending on the dryness of the soil and a range of other factors, that there's no minimum value stated. So soil analysis isn't a good measure of Mn availability. There's not a lot of UK data on Zn, but we think the minimum value is around 1mg per kg of soil (1ppm). There are also minimum values for Cu, ranging from 1-2.5ppm, depending on soil type."

Growers often rely on visible symptoms, says Steve McGrath, and these were assessed in the trials in 2011 and 2012 at GS33 — although none were found. "They can very easily be confused with other problems, and a crop may exhibit a nutrient deficiency that's only transitory."

Tissue analyses, of leaf and grain, are based on thresholds of 20ppm for Mn and Zn, 4ppm for Cu in plant leaves and 2ppm for Cu in grain. "But the basis for these thresholds is quite old, and the evidence is misty — shaky at best," he reveals. "So we put them to the test in our trials." ▸

Soil testing is the most reliable route to pick up a copper deficiency, but the trials showed little crop response to applications.

Steve McGrath notes that most of the work on micronutrients was done 30-40 years ago, and the evidence on thresholds is misty.

▸ Across the trials, soil analysis suggested a Cu deficiency in only three instances — a light soil at Morley, Norfolk, in 2010, a chalky soil at Rothamsted, and the Waterbeach site in 2012. Leaf analysis results suggested that no sites were deficient in 2010. Three deficiencies were suggested in 2011, and seven in 2012, including Cu at the Waterbeach site. But only the Waterbeach site in 2012 showed a statistically significant yield response, suggesting other results were false positives.

"Despite what the critical analyses tell us about the crops and their nutrient contents, it can often vary from year to year depending on climate and other factors without any noticeable effect on crop performance."

For grain analyses, the research team assessed whether applications of a micronutrient to the crop significantly boosted levels found in the grain. "For Cu and Mn, no detectable differences were found. We think that Cu is very tightly controlled in the plant, so it's unlikely any applications would make any difference.

Different story

"But it was a different story for Zn — there were a number of instances where an application boosted the grain content, particularly on light and calcareous soils where levels of the nutrient were low. Although this isn't very significant for the UK, across the world about 1bn people suffer Zn deficiencies, so it's great news for those who want to biofortify grain Zn."

The results from the Rothamsted work are among those that have been reviewed during a recent, five-month project undertaken by ADAS. "As well as including published and unpublished independent research, we invited micronutrient producers and distributors to submit their own data to the review, although very few did," reports Susie Roques of ADAS.

The data went as far back as the 1950s and as recent as 2012, with UK, New Zealand and Canadian results included. "We only looked at data from climates comparable to the UK, and focused on results that were independent and objective.

"We did some meta-analysis of the results to compare yield responses against soil and tissue test results — the first time such a review has been done, we believe — and that's when some really interesting patterns emerged."

They found a strong correlation between yield response to Cu applications and EDTA-extractable soil Cu status — below 1mg/l in the soil, large yield responses

Susie Roques found strong correlations for manganese and copper, but conclusions on other micronutrients were less clear cut.

Still much to learn on micronutrients

A better understanding of micronutrients is long overdue, according to David Robinson of Frontier. "It's pretty clear when a crop's short of a major nutrient. But a micronutrient deficiency is very much harder to pick up. Often, by the time it's noticed, the damage to crop potential has already been done."

This is one of the reasons Frontier has been including micronutrients in trials for a number of years. "There are some instances where you see results on farm, but this varies from year to year, and there are many variables that affect the response. We're trying to pick out those aspects in our trials and looking more closely behind what's happening."

One example is in oilseed rape, where trials are looking at how a range of micronutrients and different varieties behave, he says. "We believe there may be a difference between how hybrids and conventional varieties process micronutrients. With boron, we've noticed the benefit of applications tails off — too much boron can have a negative impact.

"But research in general into micronutrients is a bit haphazard — we need to nail down exactly what levels of each micronutrient is needed by the crop, how to measure it and detect where it's limiting. The HGCA research has taken an important step in that direction.

Frontier trials aim to look more closely behind instances where good results have been found on farm, to get a better understanding of why, says David Robinson.

However what it means in practical terms is harder to gauge, he believes. "There are situations where growers get results from using micronutrients, and the effect of not using them is very clear — those who have problems with manganese lock-up, for example.

"But as we grow crops more intensively and soil organic matter decreases, the ability of the soil to process micronutrients may become more restricted, and supply may be more limiting."

The benefit a crop may exhibit may be too marginal to measure, however, he points out. "Much of good crop management comes down to doing many little things right in great detail, which add up to an overall benefit."

Refined sampling practice will help identify where these opportunities to bring a yield benefit lies, he says. "But appropriate use of micronutrients still relies heavily on historical knowledge of how a field and a crop behaves, and a grower's or agronomist's own experience."

HGCA project 3508, Current status of soils and responsiveness of wheat to micronutrients, runs from Oct 2009 to April 2013. Its aim is to update information on micronutrients that's now 30-40 years old to ensure it's relevant for high-yielding modern wheat varieties and to gain information on yield responsiveness in order to provide guidelines for farmers. Its total cost is £170,806, of which £160,306 is funded by HGCA. The research is led by Rothamsted Research, with partners NIAB TAG and Hill Court Farm Research.

HGCA project 3783, a review of non-NPKS nutrient requirements of UK cereals and oilseed rape, ran from Nov 2012 to March 2013. Its aim was to review the importance of non-NPKS fertilisers in cereal and oilseed rape production and consider crop requirements, taking account of increased yields, other sources of these elements and recent data on soil fertility. It considered occurrence and diagnosis of nutrient deficiencies and strategies for avoiding/rectifying them, with the aim of identifying knowledge gaps requiring further research and updating recommendations to growers and consultants. Led by ADAS, its total cost was £23,810, funded equally by HGCA and Defra.

Zinc deficiencies, like this one in barley, are unlikely in UK crops, but grain content can be boosted through foliar applications – good news for those who want to biofortify grain.

were common, but over 2.0mg/l they were very rare. "We concluded that soil testing is the best way to predict Cu deficiency, and should be used on soil types with a high risk — shallow chalks with high organic matter, sands, peats and heathland soils."

Soil Mn status proved to be a poor indicator for predicting deficiency, but large yield responses were common when tissue Mn was below 20mg/kg. Yield responses to Mn treatment were also more common at a higher pH. "We think the best diagnostic method would be to test both soil pH and tissue Mn, and have a tissue threshold that varies with pH, but more research is required to confirm this and determine appropriate thresholds," says Susie Roques.

The best diagnostic method to test for manganese deficiency would be to test both soil pH and leaf tissue.

Conclusions for other micronutrients were less clear cut, however. "Zn deficiencies are extremely rare in the UK, and there was no correlation between yield response and soil or tissue Zn status. Given that magnesium (Mg) is a major nutrient, there was surprisingly little data on crop response. An Mg deficiency is often caused by compaction or drainage problems that limit rooting, so diagnosis should take soil conditions into account."

The ADAS team invited labs to provide information about their soil and tissue-testing methods, and the thresholds used to interpret the test results. They found moderate, but not total agreement, between the labs.

There's a lack of good data for oilseed rape, points out Susie Roques. "There also may be a need for improved methods of field experimentation, to allow accurate measurement of smaller yield responses. A particular problem with micronutrients is that the products can be paid for by yield responses of around 0.1t/ha, or even less, but the 'least significant differences' in classic plot experiments are usually 0.3-0.5t/ha."

The conclusions of the micronutrient work are being drawn together into an HGCA information sheet that should be available for growers later this year, says James Holmes.

"Growers should carefully consider the use of micronutrients, using both soil and tissue analysis, and other field factors should always be taken into account," he advises. ■

Summary of field experiment results

Soil type and site		Soil analysis – below criteria?		Leaf analysis – below criteria?		Grain concentration boosted by spray?			Yield response
Year		2010	2012	2011	2012	2010	2011	2012	2012
Organic	Waterbeach	x	Cu	x	Cu, Mn	x	x	x	Cu, 1.4t/ha
	Bardney	x	x	Cu	x	x	x	x	x
	Prickwillow	x	x	Mn	x	x	x	x	x
Light	Morley	Cu	x	x	x	x	x	x	x
	Caythorpe	x	x	x	Cu, Zn	x	x	x	x
	E Harling	x	x	x	x	Zn	x	x	x
	Woburn	x	x	Mn, Zn	Mn, Zn	Zn	Zn	Zn	x
Calc	Rothamsted	x	Cu	x	Zn	Zn	x	Zn	x

Source: Rothamsted Research; only significant results shown; trial sites also at Ely (organic) and Stretham (organic); winter wheat, variety Solstice