CHLORIDE DEFICIENCY IN WHEAT

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Take home message

- *Chloride deficiency causes leaf spotting similar to that observed in several paddocks of durum grown in northwest NSW in 2007 and 2008.*
- *Initial field trials did not respond to added chloride fertiliser, probably because the soil supplied sufficient chloride from below a metre depth.*
- *Glasshouse wheat grown in sand and chloride-deficient nutrient solution reproduced the leaf spotting symptoms observed in the affected durum paddocks. Spots are very similar to yellow spot caused by the fungus Pyrenophora tritici-repentis.*
- *Whole plant tissue chloride concentration <0.1% should indicate when spots are related to chloride deficiency and save on unnecessary fungicide sprays.*

Background to the issue in northern NSW

Local agronomists observed severe leaf spotting symptoms on Jandaroi durum wheat near Breeza during the 2007 winter cropping season, believing it to be a leaf disease such as yellow leaf spot. However, no pathogens were found on samples from the affected paddock. Further discussion amongst agronomists and pathologists revealed that similar symptoms had been noticed for several seasons at various localities. An internet search discovered previous research from north America that suggested the cause may be nutritional, rather than pathological – "chloride deficient leaf spot syndrome" of wheat. GRDC funded field and glasshouse trials through an e-concept proposal aiming to confirm whether chloride deficiency was indeed the cause of the leaf spotting symptoms.

Chloride – an essential element for plant growth

Chloride (Cl-) is the natural stable ionic form of the element chlorine (Cl). The name chlorine comes from the greek word "Khloros" meaning "greenish-yellow" – the colour of chlorine gas. Chlorine is an essential plant nutrient, without which the plant cannot complete its life cycle. It is required for a range of major plant functions, such as water-splitting to liberate oxygen during photosynthesis, enzyme activation, nutrient transport, water and ion movement in the vacuoles of cells, and stomatal regulation of plant moisture content.

Since the 1980's, more than 200 trials in 7 north American states have evaluated chloride fertiliser response in wheat and barley. Responses in grain yield were measured in 48% of trials. Average yield increase was 350 kg/ha (response ranged from 0 - 1.2 t/ha). Responses were cultivar specific. There was a 70% chance of yield response to Cl fertiliser if the soil test was less than 34 kg Cl/ha to a depth of 60 cm. At responsive sites, chloride treated plants were more erect at mid-day, developed faster, had less disease, less lodging, and higher kernel weight. Diseases suppressed by chloride addition include take-all root rot, tan spot, stripe rust, leaf rust, Septoria, plus stalk rot in sorghum and corn. Chloride yield responses were also measured in corn, sorghum, lucerne, and millet, but not oats.

Some of the wheat and barley varieties that responded to chloride fertiliser exhibited a "physiological leaf spot syndrome" in the untreated plots. This leaf spotting had been observed in the US since the 1940's and was thought to be a metabolic or genetic dysfunction as no pathogens could be identified. The spots were renamed "chloride deficient leaf spot syndrome" when it was demonstrated that the spots only appeared on specific wheat varieties when tissue chloride concentration fell below 0.1% (0.09% for barley).

2008 field trials

Two field trials were conducted near Breeza (Liverpool Plains) adjacent to where symptoms were observed in a 2007 durum crop. The first trial was a variety x chloride addition split-plot experiment featuring 3 durum (Jandaroi(D), Bellaroi(D), Arrivato(D)) and 3 bread wheat (Gregory(D), Sunvale, Crusader(D)) varieties, with or without 40 kg Cl/ha (potassium chloride) surface spread pre-sowing. The second trial was a chloride fertiliser rate and application method experiment using Jandaroi. Chloride was applied as potassium chloride at 10, 20, 40, 60 kg Cl/ha at sowing, and as a foliar spray (magnesium chloride) at 10, 20, 30 kg Cl/ha during vegetative growth. Potassium additions were balanced with potassium sulphate.

There were no plant establishment, biomass, chlorophyll density, grain yield or grain quality responses to chloride fertiliser treatments in either trial. Leaf spotting was not evident in any treatment. Yields averaged 6.3 t/ha across both trials; ranging from 5.6 t/ha for Gregory to 7.0 t/ha for Crusader. Chloride fertiliser did raise tissue chloride concentrations in whole plant samples collected at flowering, but all results from the trial plots, including the untreated control, were well above the US critical level of 0.1% (our range; 0.34 -1.20% Cl).

Pre-trial soil testing to 150 cm found soil chloride concentrations to be below laboratory reporting level (<10 mg Cl/kg) from the surface down to 90 cm. However, chloride was present at lower depths; 27 mg Cl/kg in 90-120 cm, and 150 mg Cl/kg in 120-150 cm. We think that this deep chloride was sufficient to prevent any treatment response. The soil profile was fully wet at sowing so the plant had access to the whole profile. US soil testing guidelines only refer to the top 60 cm of the soil profile, which may explain why some of their sites did not respond to chloride fertiliser when the guidelines indicated a likely response.

Severe leaf spotting symptoms were observed upslope from the trial area in the commercial Jandaroi crop. We collected whole plant samples at flowering from an affected area 1 km upslope (shallower soil). Chloride concentration averaged 0.09%, which supports chloride deficiency as the cause of the spots and apparent reduced yield from the affected area.

In a previous soil survey of 60 Liverpool Plains paddocks, one “plains” and four “slopes” paddocks were below US chloride deficiency guidelines indicating a likely response to chloride fertiliser. Another twelve “plains” and sixteen “slopes” paddocks were in the “possible response” range. However, chloride in “possible response” paddocks may actually have been much less as many of the samples tested were reported as “<10 mg Cl/kg” so we don’t know whether the actual concentration was 9 mg Cl/kg or 0 mg Cl/kg or in-between.

2008 glasshouse trial

We reproduced the field-observed symptoms in a glasshouse trial by growing a range of durum and bread wheat varieties in sand and nutrient solutions containing nil chloride. Other treatments included low chloride added (0.125mM), medium chloride added (0.25mM), and full rate chloride added (2mM). All durums showed severe spotting and reduced total plant growth when grown in the nil chloride solutions (Table 1). Symptoms appeared first on the lower leaves one month prior to flowering, and rapidly spread up the plant in the following weeks. Initial lesions were only a few mm across, but eventually covered the oldest leaves so that they died. Spots developing on the middle leaves tended to be larger, irregular shaped, and had a more defined yellow margin and a red-brown dot in the centre of each spot. Spots on the upper leaves were smaller and thinner than those in the middle leaves. Some plants grown with low chloride added also showed spotting, but at a less severe scale.

Table 1. Glasshouse measurements affected by not adding chloride to nutrient solutions.

	Durum variety					Bread wheat variety				
	Arrivato	Bellaroi	Hyperno	Jandaroi	Kyle[1]	AC KArma[1]	Crusader	Gregory	Strzelecki	Sunvale
Leaf spotting score	✓[2]	✓	✓	✓	✓	✓	✓	✓	×[3]	×
Days to flowering	✓	✓	✓	✓	✓	✓	✓	×	×	✓
Total plant weight	✓	✓	×	✓	✓✓[2]	×	✓	✓	✓	✓✓
Number of heads	×	×	×	×	×	×	×	✓	✓	✓✓
Grain yield[4]	-	-	-	✓	✓	✓	✓	✓	-	✓✓
Kernel Weight	✓	✓	✓	✓	✓	✓	×	✓	✓	✓

[1] north American varieties known to be chloride sensitive

[2] tick = nil chloride treatment different to full chloride treatment; double tick = low chloride treatment also different from full rate treatment.

[3] cross = nil chloride treatment no different to full chloride rate treatment

[4] dash indicates grain yield results not reliable due to poor grain fill across all nutrient treatments of this variety

Some chloride-deficient bread wheat varieties also showed leaf spots, but these spots were smaller and less prominent than those on the durum varieties. Tips of the youngest leaves of Gregory and Strzelecki grown in the nil chloride solution became soft, floppy and some even withered at about the stage that the durums spotting began.

Severe chloride deficiency delayed flowering in all varieties except Gregory and Strzelecki, by up to 12 days in the case of Jandaroi, but generally between 4.5 and 6.5 days for all other varieties. Total plant biomass at maturity was reduced in all varieties but Hyperno and AC Karma. For Kyle and Sunvale, the treatments with low chloride added also grew less biomass, but still more than that in the nil chloride treatments. Fewer heads developed in chloride-deficient plants of Gregory (from 26 to 14 per 3 plants), Strzelecki (from 20 to 16), and Sunvale (from 32 to 29), but other varieties were not affected.

Grain yield results were not reliable for Arrivato, Bellaroi, Hyperno and Strzelecki due to poor grain filling but grain yield of all other varieties was 40 to 80% less when chloride was withheld from the nutrient solution. Kernel weight was reduced by chloride-deficiency in all durum varieties plus AC Karma and Gregory, but not Crusader, Strzelecki or Sunvale.

Summary

Chloride deficiency does cause leaf spotting in locally grown durum and some bread wheat varieties, similar to that observed in several commercial paddocks over the past 3 seasons. The limited nature of the sightings of these symptoms suggests that it may not be a very widespread problem, but then not all wheat varieties exhibit “chloride deficient leaf spot syndrome” when chloride is deficient. Using US soil test guidelines, around half of the Liverpool Plains paddocks tested previously were potentially chloride deficient. However, these guidelines do not account for deep chloride which may prevent deficiency occurring.

At present, we do not know the yield impact of chloride fertiliser added to a deficient soil as we had no wheat yield response at our first trial site. If farmers observe this leaf spotting on durum or bread wheat crops, a whole plant tissue test should be done. A chloride concentration of <0.1% should indicate that the spots are likely due to chloride deficiency rather than disease, therefore saving unnecessary fungicide applications. Further work is needed to establish critical soil and plant tissue test levels for local conditions and varieties.

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