Recognizing Copper Deficiency in Small Grain Cereal Crops

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Wheat, barley, oats, triticale and rye listed in this order, reflect their decreasing sensitivity to soil available copper. All wheat including winter, and spring types are highly sensitive to low or deficient levels of copper in soil whereas rye is highly tolerant of low soil copper levels. Copper deficiency, particularly in wheat, can result in catastrophic losses in yield and quality especially under high yield management systems. Most barleys are sensitive but cultivars may vary considerably in degree, a few oat cultivars respond to copper amendments in deficient soil while triticale responses seem small.

The factors that contribute to copper deficiency in sensitive cereal cultivars are numerous and frequently additive. Copper deficient soils are most frequently sandy to sand loam soils, soils high in organic matter and neutral peat (fen type) soils. Factors that can induce or contribute to copper deficiency in susceptible cereal crops are a) naturally deficient soils below 0.6 ppm available copper; b) high rainfall seasons that encourage shallow rooting of cereal crops where copper levels are lowest or less available; c) certain foliar cereal weed control herbicides that interfere with copper mobility in the cereal plant; d) soil residual herbicides such as those used in canola crops that may restrict or inhibit proper root development in the cereal rotation crop that follows; e) heavy applications of livestock manure that can biologically tie-up the available copper; f) peaty soils that naturally sequester copper; g) high levels of N, P, Zn or Mn naturally present or applied as fertilizer that either tie-up or competitively interfere with copper availability to the cereal crop. Resulting yield and quality problems in affected cereal crops were previously always vaguely blamed on an assortment of infectious diseases.

A relatively simple solution, never pursued by Canadian plant breeders, lies in the work done in Australia by Graham et al (1987) specifically the transfer to wheat of the copper efficiency factor gene carried in rye.

Many of the copper deficiency symptoms in wheat and barley in the text that follows had in past years been previously ascribed to bacterial and fungal diseases, herbicide and frost injury, wind lodging and soil “unsuitable” for cereal production.

1. Yields of Wheat and Barley – wheat and barley crops having much lower yields than expected based on soil fertility and soil moisture levels. In wheat, yields may be much less than half of expected. (Evans and Solberg 1999). The yields of wheat and barley have been as much as tripled along with major quality improvement in and around central Alberta on copper deficient soils, particularly sandy loams (chemozems) and peats (basic fenland) when adequate copper has been applied to the soil. In peatland adequate copper may mean 10 to 15 lbs of actual copper per acre – good for 5-10 years. In sandy loams and other mineral soils 2 to 5 lbs of actual copper may be necessary but yield and quality results are most immediate when the higher levels are used even if the lower application may become adequate over time. Such applications to mineral soils may be good for 10-15 years. Foliar applications to copper deficient
cereals are highly effective at the late tillering or early boot stage and are only effective in the year of application due to the minor amounts applied per acre; i.e. 2-4 ozs. Late applied copper, after anthesis, may actually decrease yields and increase ergot infection levels.

2. **Quality** – perhaps the most subtle Cu deficiency symptoms are low bushel weight, small kernel size and high protein levels. When copper is marginally deficient the movement of carbohydrates to the seed head is reduced and smaller kernels result. This translates into low bushel weights and concentrated protein.

3. **Colour** – the mature standing wheat crop (HRS) may have a brown or patchy brownish colouration, intensity depending on cultivar, especially on the upper stems and heads; i.e. head melanosis, these colour changes have not been observed in barley or oats.

4. **Ergots** – normally wheat, barley and oat flowers are fully self-pollinated. Copper deficiency results in pollen sterility (Azouaou and Souvre 1993) which induces normally closed flowers to open exposing them to ergot infestation and potential cross pollination. (Mantle and Swan 1995) (Simojoki 1991). Rye, like many grasses, is an open pollinated cereal crop which is why it is so susceptible to ergot infection. Pedigreed rye crops must be grown at least 2 miles away from any other rye crop.

5. **Take-all like symptoms** – unthrifty patches appear in the wheat crop in which all heads of entire plants are poorly filled and crop height may be very uneven and tillers thinned out. Examination of the roots does not confirm take-all, common root rot or any other root infesting fungus damage present in sufficient amount to cause such yield or quality problems.

6. **Lodging** – the wheat or barley crops may be badly lodged in a haphazard way indicating that a wind storm was not the cause. A deficiency of copper results in a failure of lignin formation which depends on adequate copper levels the very material that gives cereal straw its standing strength and rigidity.

7. **Tough swathing** – common in barley. Crops of barley that are copper deficient are very difficult to swath since the stems lack rigidity; i.e. failure of lignin formation which depends on adequate copper levels.

8. **Uneven Heading, Excessive Tillering and Irregular Maturity** - all three may sometimes be a consequence of copper deficiency in both wheat and barley crops. Research has shown that heading is delayed and crop maturity may be 10 to 14 days later in copper deficient crops of wheat and barley. In some barley cultivars increased tillering is an obvious consequence of low or deficient copper fertility which leads to high levels of “thins” in the harvested grain.

9. **Lot of Straw** – large volumes of straw are produced particularly in barley crops, but grain yields are disappointingly low and again with lots of thins present. This often happens after heavy applications of livestock manures to cropland. This condition has previously been blamed on excess nitrogen excess rather than induced copper deficiency caused by microbial activity biologically binding copper and making it unavailable for crop growth. The nitrogen excess blamed on manure was a common, unsubstantiated myth.

10. **Empty Heads – Frosted Bran** – examination of the grain heads in wheat and barley at crop maturity reveals missing grains, ergots and shriveled grain (frosted bran)
reminiscent of frost damage but weather records show no evidence of frost (Evans et al. 2000). Copper plays a key role in pollen fertility and stigmatia viability as well as in effective grain filling. Copper deficient wheat, in addition to ergot formation may also have the potential to out-cross with other nearby wheat crops, i.e. spring wheats crossing with bread wheats which may be very important for pedigreed seed growers.

11. **Pigtailing or Frost Injury at the Early Tillering Stage** – this symptom is present in wheat, barley and oats. The young leaf tips turn brown and resemble sharp frost damage but weather records show an absence of frost. Application of certain herbicides greatly exacerbates this condition. Foliar application of copper at this stage or prior to early boot stage is highly beneficial and may greatly reduce yield loss, improve grain quality and reduce or eliminate ergot infestation. (Evans et al. 1994).

12. **Frizzy Awns in Barley** – previously thought to be phenoxy-type herbicide injury especially prevalent on the later developing tillers of the barley plant grown on land low to deficient in copper. Not a condition often seen in wheat heads.

13. **Supplementing Cattle Feed with Copper** – somewhere around 60 to 70% of cattle slaughtered on the prairies are low to deficient in blood copper levels. All well managed livestock [hogs, elk, sheep, poultry as well as beef and dairy cattle] are fed copper supplements (minerals that contain copper). Further evidence that copper availability is somewhat limited in prairie soils.

14. **Certain Broad Leaf/Wild Oat Control Combination Herbicides** – used for weed control in wheat and barley can severely impact the cereal crops copper metabolism when this element is in low or deficient supply. Trifluralin type herbicide residues from the previous canola crop can greatly exacerbate the problem by restricting or injuring the cereal roots possibly further impairing copper uptake. Those same herbicides work perfectly well as weed control chemicals if and when adequate soil copper levels are present and readily available for the cereal crop. Herbicide injury patterns with certain specific herbicides are very obvious if the wheat or barley crops are examined for overlaps and misses around headlands or field obstructions. Injury only occurs as a consequence of using these herbicides if copper levels are low or deficient in all or only in part of the field.

**The Biggest Loss**

The bulk of yield and quality loss in Alberta soils is likely in the range of 10 to 20% of yield and a 1 grade drop in quality. Its not the obvious copper deficiency that continues to result in grower losses but that which is unsuspected and unseen. This relatively unnoticed yield and quality loss resulting from marginal copper deficiency may emerge as a problem in some years in up to 40% of Alberta cereal cropland.

**References**


