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Corn stalk nitrate concentration profile: Implications for the end-of-season stalk nitrate test

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Corn stalk nitrate concentration profile: Implications for the end-of-season stalk nitrate test

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Abstract

The end-of-season corn (*Zea mays* L.) stalk nitrate-N test was developed as a post-mortem to determine if excessive or insufficient N was available to the corn crop during the latter part of the season. The stalk section specified for the test was very specific, the 20 cm-long section between 15 and 35 cm above the soil. Under production conditions, it may not always be possible to collect this precise stalk section. The objective of this study was to determine how nitrate concentration varied within the stalk from the soil level to the ear node, and how this variation could affect interpretations of the stalk nitrate test. Field grown (140 kg N ha^{-1}) corn stalks were collected and separated into phytomers (the node plus leaf, internode, and bud developing from it). Phytomers were further divided into six segments; the node and five equal length segments of the internode. All samples were analysed for NO_3-N with a nitrate-ion specific electrode after extraction with 0.04 *M* $(NH_4)_2SO_4$. Nitrate concentrations of individual samples varied from less than 100 to greater than 8000 mg NO_3-N kg^{-1} dry weight, and increased down the stalk from ear to soil. Generally, the nitrate concentrations of segments within a phytomer were similar. These results indicated new critical values, approximately 35% greater than the original ones, may be needed to determine if limiting or excessive amounts of N were available to the crop, i.e. 950 vs. 700 and 2700 vs. 2000 mg NO_3-N kg^{-1} for insufficient and excessive levels, respectively. However, the general interpretation of test would remain unchanged because stalk nitrate concentrations vary so widely under field conditions from less than 100 to greater than 5000 mg NO_3-N kg^{-1}.

Introduction

The end-of-season corn (*Zea mays* L.) stalk nitrate-N test (hereafter referred to as stalk nitrate test) was proposed by Binford *et al. (*1990) as a method of determining if excessive or insufficient N was available to the corn crop during the latter part of the season. In the test, 20-cm sections of corn stalks (between 15 and 35 cm above the soil) are collected from several plants, dried, ground, and analysed for nitrate-N. Nitrate-N concentrations less than 700 mg kg^{-1} dry stalk tissue indicated that available N limited grain yield whereas concentrations greater than 2,000 mg kg^{-1} indicated excessive N was available to the crop (Binford *et al.,* 1992). Other researchers have evaluated the test and concurred that stalk nitrate concentrations greater than 2000 mg kg^{-1} indicated that excessive N was available to the crop (Varvel *et al.,* 1997). These studies suggested that the stalk nitrate assay could be used as a post-mortem to determine if yield-limiting or excessive N was present to guide future fertilizer-N management, thereby improving profitability and reducing environmental degradation.

To be a useful crop management tool, methods for collecting and analysing samples must be straightforward and reasonably flexible so producers and consultants can adapt to field conditions as they gather samples. It is unrealistic to assume that samples will always be exactly 20 cm long and can always be collected between 15 and 35 cm above the ground under field situations. The objective of this study was to determine how stalk nitrate test results and interpretations would be affected if samples were collected from a portion of the stalk different from that specified by Binford *et al.* (1990).

Materials and methods

Stalks were collected, after physiological maturity, from a rain fed field of corn gown with 140 kg N ha^{-1}. Two plants were collected from each of 10 replications. Ears and leaf blades were removed from the stalks in the field and the portion of the stalk above the ear node was discarded. Stalks were cut at the soil surface, labelled and dried at 60° C. Leaf sheaths were removed from the stalks. Dried stalks were divided and numbered by phytomer unit (internode and subtending node, see Figure 1). Phytomer units were further divided into nodes and internodes, and internodes were subsequently divided into five equal length segments. Segments from the same relative position on the plant (i.e., same phytomer and same segment within the phytomer) from the two plants in each replication were combined and ground to pass a 2-mm screen. Nitrate-N concentration, in a 0.25 g samples, was determined with a nitrate-ion specific electrode after extraction with 50 mL of 0.04 *M* $(NH_4)_2SO_4$ (Wilhelm *et al.,* 2000). Analysis of variance (Proc MIXED, Littell *et al.,* 1996) was used to determine if phytomer, tissue type (node vs. internode), and segment within internode differed in nitrate-N concentration.

Results

Across all plant parts, nitrate concentrations varied from less than 100 mg NO_3-N kg^{-1} dry weight to greater than 8000 mg NO_3-N kg^{-1} dry weight. Analyses showed that

tissue types (node vs. internode), phytomers, and segments were significant sources of variation for nitrate-N concentration. Their interaction was not significant suggesting that although nitrate concentration differed with phytomer and segment, the pattern was similar among segments within all phytomers (Table 1).

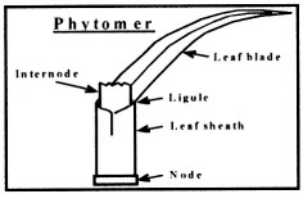

Figure 1. The phytomer is the basic repeating building block of the grass shoot and consists of four tissues, the node and leaf, internode, and axillary bud derived (above) from that node. The axillary bud in this diagram of the phytomer is hidden from view by the leaf sheath.

Table 1. Analysis of variance for nitrate-N concentration in several phytomers and segments of the corn stalks.

Source of variation	Degrees of freedom	F-value	Probability of a greater F
Phytomer	3	361	0.0001
Segment	5	4	0.0039
Phytomer x Segment	15	1	0.4751

Table 2. Mean nitrate-N concentration in several phytomers, divided into several segments, of corn stalks.

Segment[1]	Phytomer[2]				Mean
	S+1	S+2	E-2	E-1	
	Nitrate-N concentration (mg NO_3-N kg^{-1})				
5	3906	2261	126	146	1610
4	4456	2820	155	93	1881
3	4796	3304	189	105	2098
2	5026	3870	332	124	2338
1	4699	3628	423	163	2228
Node	4657	3643	382	175	2214
Mean	4590	3254	268	134	2061

[1] Stalk portions of each phytomer were divided into six segments, the node and five equal length segments of the internode. Segments were numbered upward from the node.
[2] Phytomer S+1 was the first phytomer above the soil surface, Phytomer S+2 was the second above the soil, Phytomer E-2 was second below the ear, and Phytomer E-1 was immediately below the ear.

Since not all plants within a sample had the same number of phytomers between the soil surface and ear, a continuous description of NO_3-N concentration for the entire stalk was difficult to produce. For comparison purposes, we report NO_3-N concentrations for only four phytomers, the two closest to the soil and the two immediately subtending the ear. Depending on the plant, zero to two phytomers may have existed between the phytomers near the soil and ear. As a result, nitrate profiles reported here (Table 2) appear to have a discontinuity that may not exist if data from all phytomers were available. Following the sampling procedures defined by Binford *et al.* (1990) for the stalk nitrate test, the second phytomer above the soil (S+2) would most likely be sampled.

The first two phytomers below the ear (E-1 and E-2) did not differ in nitrate concentration, but phytomers S+1 and S+2 differed from the former two and also differed from each other (Table 2). Nitrate concentration increased gradually moving down the stalk from the ear to the soil. Nitrate concentration in node tissue was similar to that of internode tissue in phytomers E-1, E-2, and S+1. However in phytomer S+2, the nitrate-N concentration in the upper two segments (4 and 5) was less than in the node tissue ($p < 0.05$). Nitrate-N concentration increased linearly as phytomers were further from the ear ($p < 0.0001$). Likewise, NO_3-N concentration of segments, within phytomers, increased linearly as they neared the node ($p < 0.001$).

Discussion

These results indicated that reasonable care must be taken in collecting field samples for the stalk nitrate test. If samples are collected closer to the soil than described in the original procedure (< 15 cm above the soil), the resulting analyses will likely produce greater nitrate-N concentrations. As a result, the critical values suggested by Binford *et al.* (1990, 1992) may have to be adjusted upward. Data from this initial study with an adequate to excessive N rate (N application, 140 kg ha^{-1}; yield 6.35 Mg ha^{-1}; stalk nitrate-N, 3254 mg NO_3-N kg^{-1}) suggests critical values may need to be increased by about 35% (comparison of S+2 to S+1 in Table 2). New critical values would be about 950 and 2700 mg NO_3-N kg^{-1} for yield-limiting and excessive levels of N [compared to 700 and 2000 mg NO_3-N kg^{-1}, respectively, as reported by Binford *et al.* (1990)]. Further research, with an array of N rates from yield limiting through excessive, will be required to accurately establish new values. However, interpretation and management decisions based on samples collected from stalk segments nearer the soil and new critical values would be similar to interpretations and decisions based on samples collected as described by Binford *et al.* (1990).

In fact, collecting samples from segments nearer the soil surface may offer a level of assurance because change in nitrate concentration was greater as samples were collected closer to the ear. Also because nitrate-N concentration declined rapidly in phytomers nearer the ear, field modification of collection procedures to acquire stalk sections more than 30 cm above the ground may result in inappropriate future N management procedures from a yield/profitability or environmental standpoint.

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