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Improving Nutrient Management Via Evolving Strategies and New Technologies

Nebraska studies focus especially on nitrogen and its impact on the environment.

Summary: *Synchronizing soil nutrient availability with crop use is an ongoing process involving studies of nutrient uptake patterns and developing new and better ways of monitoring plant nutrient status.*

Nitrogen (N) is the most abundant nutrient in plants, which explains why its management has important implications on productivity and profitability of production systems. The fact that aerobic N transformations in soil ultimately produce nitrate, which is soluble in water, makes nitrate a potential contaminant of surface and ground water. The reality of the situation is that emphasis placed on N management is typically related to the profitability of the fertilizer user unless other segments of society are negatively impacted. In the long run, suppliers and growers have a vested interest in doing what they can to promote the efficient use of N, and this includes the scientific community. For it is now clear that whenever soil N availability is not synchronized with crop use, environmental impact is possible.

The purpose of this article is to discuss evolving nutrient management strategies and new technologies in light of the needs of corn in its different growth stages.

Uptake patterns

Problems with the occurrence of higher-than-acceptable concentrations of nitrate in groundwater during the '70s in Nebraska prompted many questions about synchronizing soil N availability with crop use. After going through a denial stage for a decade or so, irrigated corn producers in the Central Platte River Valley of Nebraska were finally forced by the Natural Resources District to implement selected management practices to protect groundwater resources. Although the need to improve synchronization between soil N availability and crop use emerged as an early priority, literature was not able to document if current N uptake patterns were applicable for modern hybrids.

Unpublished data generated during the 1993 and 1994 growing seasons showed that N uptake patterns before silking for five modern hybrids were statistically similar to a common hybrid grown in the '60s. However, after silking the N uptake patterns followed divergent patterns. Francis et al. (1997) found that up to 7 percent of the N applied before silking and up to 10 percent after silking, was lost from the leaves as ammonia during reproductive growth. They also found that 89 percent of K uptake occurred before silking but only 41 percent of P uptake occurred during the same time (Table 1). Prior to silking, dry matter accumulation for irrigated corn amounted to 37 percent of the total dry matter accumulated at harvest. Only 58 percent of final N accumulation had occurred by silking. This fact means that there is an opportunity for improved N management both before and after silking. Cumulative N uptake starts slowly but then gradually increases until silking, at which time N accumulation falters for a few days before again increasing (Figure 1). Expressing the same data in terms of N uptake rates shows that uptake can reach 4 lbs/A/day shortly before silking (Figure 2). During the pollination process, daily N uptake declines to a very low rate until after anthesis when translocation of photosynthates to the ear shoot begins. The second phase of rapid N uptake reaches a peak rate at about the R2 growth stage. Shortly thereafter, senescence can be observed in some hybrids, especially when grown under N deficient conditions. The loss of volatile N from leaves is associated with the senescence process and represents a component that is not accounted for when measuring total N uptake at harvest.

Monitoring nutrient status

Color patterns. Fortunately several key nutrient deficiencies are associated with distinct color patterns within a leaf. Detection of nutrient deficiency symptoms within a crop provides an early warning of pending problems and an opportunity to use tissue testing to verify the cause and magnitude of a stress. In some cases, other plant colors and pigments may mask deficiency symptoms. For example, nearly every nutrient deficiency affects leaf chlorophyll content, which is typically expressed as greenness. Yet, some nutrient stresses, such as P, also affect other parts of the photosynthetic process. Insufficient plant P results in the accumulation of sugars in leaves (i.e., reduced phosphorylation to build structural components) which prompts the synthesis of anthocyanin (reddish-purple color). This purplish color on the margins of corn leaves also can be induced by cold or wet soils and various kinds of plant damage.

Biomass/photosynthesis. Two major plant processes are worthy of further discussion when it comes to N management. Collectively, these two processes are sometimes discussed in terms of plant vigor. Sometimes it is convenient to think of plant biomass as it relates to size of the factory (i.e. exterior view), and photosynthesis as to how fast the factory is working (i.e., interior view). The SPAD chlorophyll meter is essentially a potential photosynthesis meter because it measures how much radiation can be used under excess light conditions. The device, however, is not able to assess leaf area index (LAI) or biomass. When observing corn plants for biomass, we must scan the object for spatial details and interpret these details according to established criteria. Essentially, human vision and our reasoning ability are roughly equivalent to what should be possible with remote sensing and a closely coupled decision aid.

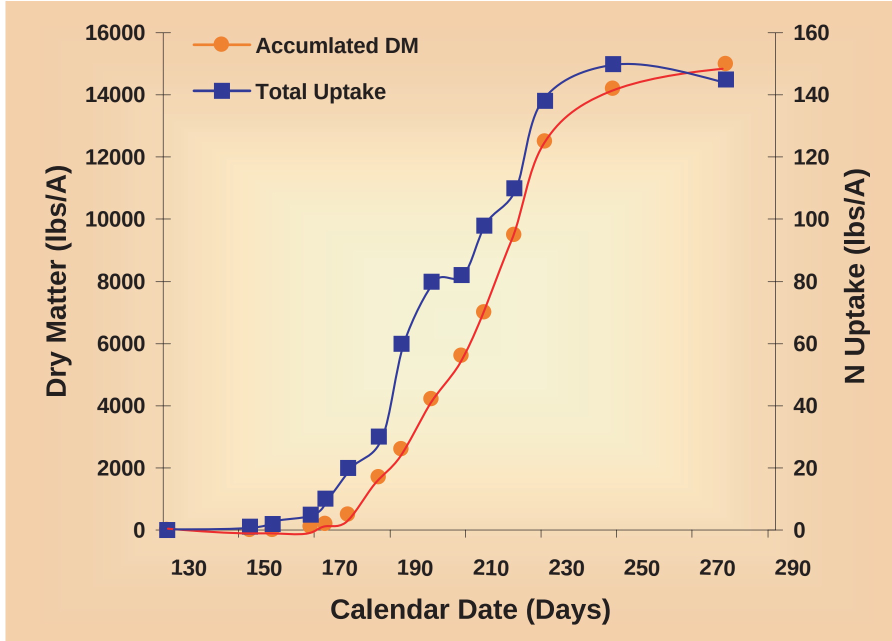

Figure 1. ***Cumulative dry matter production and total N uptake for irrigated corn. Average yield of 178 bu/A across six hybrids and three replications.***

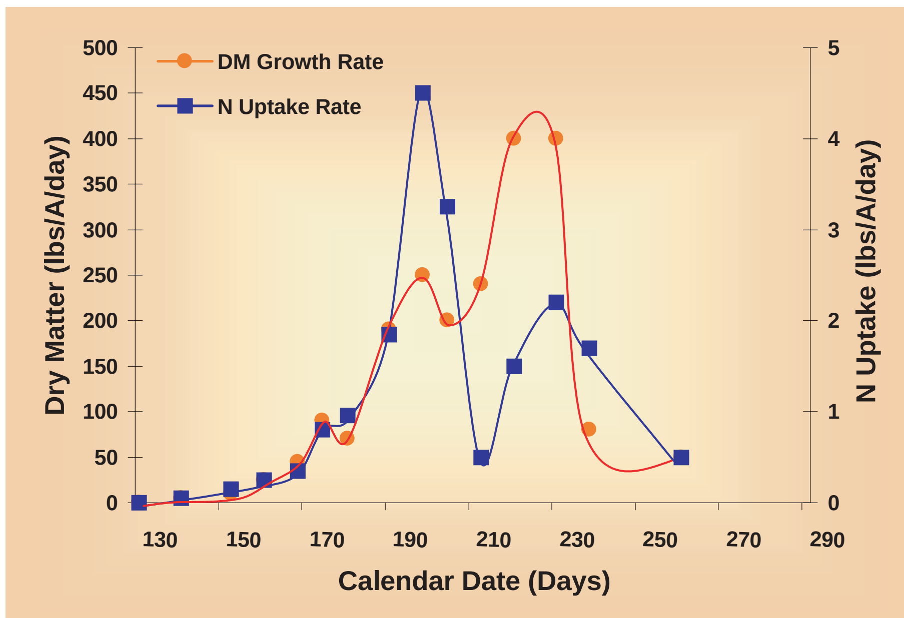

Figure 2. ***Dry matter production and N uptake rates for irrigated corn in Nebraska.***

Canopy reflectance. History has provided considerable information about the relationships between plant canopy reflectance and biophysical processes such as photosynthesis and plant biomass production. It has been well documented that near-infrared

(NIR) reflectance is highly correlated with the amount of living vegetation in the field of view (i.e., more living biomass results in more NIR reflectance). Concurrently, diminished blue and red reflectance is closely associated with the harvest of light in these visible wavelengths by chlorophyll molecules during photosynthesis (i.e., less blue and red reflectance translates into more photosynthesis and biomass). Thus, healthy and vigorous corn plants appear deep green in color while nutrient-deficient plants often appear yellow, purple or otherwise discolored. Likewise, the presence of vegetation causes the reflectance of large amounts of NIR radiation even though it cannot be detected by the human eye. Spectral procedures to differentiate between anthocyanin and chlorophyll related reflectance have been developed. The potential exists, therefore, for appropriate optical and NIR sensors to measure both biomass and photosynthetic activity.

Various approaches for measuring crop canopy reflectance have been developed and tested using remote sensing data for differing spatial resolution. Because of the diverse range in crops, situation, and intended application of the information, no single technique has emerged as working the best. Space-based platforms generally lack the desired spatial resolution and timeliness required for most site-specific management applications. Aircraft platforms offer an appropriate level of spatial resolution and provide a "whole-field" glimpse of the situation, but are plagued by problems with clouds, high winds, and time of day restrictions (i.e., sun angle). Mobile, ground-based sensors offer excellent spatial resolution and can be integrated with material delivery systems to facilitate real-time applications.

Remote sensing. The problem with remote sensing tools is that they rely on natural radiation to generate the reflectance that is then measured by a sensor and interpreted by a human. As such, light intensity, viewing angle, time of day, shadows, atmospheric interference, crop growth stage, and weather conditions are all factors that must be considered. In the mid-'80s, technologies were introduced to provide auxiliary light and thereby extend the useful period of operation for specialized applications such as weed detection and spot spraying. In the early '90s, the concept of using modulated or pulsed auxiliary light was introduced to differentiate between reflectance attributed to natural radiation and that coming from auxiliary light. Improvements in these technologies have led to the products such as the Patchen weed sprayer system and the GreenSeeker developed to make site-specific N applications to wheat.

In some cases, remote sensing or other techniques might be useful to estimate the optimum yield and related spatial variability. The use of remote sensing for monitoring some specific types of crop stresses is currently not possible with existing technologies. Even the most sophisticated sampling or imaging techniques available today are unable to accomplish the spatial integration of colors and patterns that humans can accomplish in a fraction of a second. We believe these limitations will be overcome as technologies advance, though it still will require the human touch to make instantaneous sense of any patterns within leaves. Put

Table 1. Quantity of nutrients in corn plants and nutrient uptake at silking and harvest.

Nutrient	Silking lbs/A	Silking % of total	Grain lbs/A	Grain % of total
Dry matter	4,199	37	8,428*	55
N	81	58	103	70
P	12	41	30	83
K	125	89	33	22
Zn	0.13	47	0.15	53
S	5.5	51	7.5	58
Mg	5.8	34	10.8	57
Ca	9.90	61	0.23	1
Mn	0.21	88	0.03	12
Cl	13.1	58	4.5	19
Cu	0.03	59	0.02	21

*Irrigated corn population of 30,000 plants/A. Data averaged across six hybrids and with three replications. Average yield of 178 bu/A at 15.5% moisture.

another way, almost anything that can be accomplished with a visible light sensor will contain diluted information compared to what can be seen by the human eye.

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