Relationships of plant height and canopy NDVI with nitrogen nutrition and yields of corn

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Abstract
Measuring crop nitrogen (N) status during the growing season by remote sensing of the canopy seems to be a viable N management system for variable-rate N applications, emphasizing N application in the season, and minimizing the costs of N application. This study was designed to assess the relationships of plant height and canopy normalized differential vegetation index (NDVI) with crop N nutrition and yields of corn under different cropping and irrigation systems in Tennessee, USA. A field experiment was conducted near Milan, Tennessee from 2008 through 2009. Six N application rates of 0, 60, 120, 180, 240, and 300 kg N/ha were evaluated under four different cropping and irrigation systems: continuous corn under no irrigation, corn-soybean under no irrigation, corn-soybean under irrigation, and corn-cotton under no irrigation. A randomized complete block design was used with four replicates. Plant heights, canopy NDVI indices, and leaf N concentrations during the season and grain yields at harvest were measured on an individual plot basis each year. There were significant positive linear relationships between corn yields and plant heights and between corn yields and canopy NDVI indices at key growing stages regardless of crop rotations and irrigation systems. The relationships between corn yields and plant heights and between corn yields and canopy NDVI indices became stronger as the growing season progressed. The relationships of corn yields with plant heights were stronger than those of corn yields with canopy NDVI indices, respectively, at the same growing stage under all the crop rotations. The relationships of corn yields with plant heights and canopy NDVI indices were stronger with corn rotated after soybean than those in continuous corn and corn rotated with cotton. Our results suggest that plant heights and canopy NDVI indices at key growing stages can be used to develop algorithms for in-season variable rate N applications on corn under different crop rotations and irrigation systems.

Key Words
Relationship, plant height, NDVI, nitrogen, yields, corn.

Introduction

During the past few decades, the largest increase in the use of agricultural inputs has been fertilizer nitrogen (N) (Johnston, 2000). Nitrogen fertilizer is a key input for corn production. Production fields vary greatly in the native supplying capacity of N. With N fertilizer prices reaching an unprecedentedly high level during the last few years, N fertilization should be managed more efficiently. Observations from research plots and larger production fields have indicated that crop N response is very variable, and on some poor soils in some fields more N should be recommended and much less or none in other parts of the field. The presence of spatial variability within field is a critical issue demanding careful consideration for efficient use of N fertilizers.

Presently, N fertilizer is mostly recommended to be applied at a uniform rate across the entire field in many states of USA. Overall, there is a major factor limiting N use efficiency in the current N management systems for corn. As mentioned previously, the current N management systems were developed based on a state or regional scale, and they have no capability to cope with spatial variability within individual fields. Under the current systems, corn producers use a uniform N fertilizer rate for the entire field or even the entire farm, which often results in under- and over-application of N. Several research studies on corn and wheat have found large differences in crop yield and crop N response even within an individual field (Kitchen *et al.* 1995; Vetch *et al.* 1995); which confirms the need for reliable methods to generate site-specific variable-rate N recommendations (Hergert *et al.* 1997). Therefore, in order to solve the problem mentioned above, it is essential to develop innovative N management systems that can generate variable-rate N recommendations for different areas within individual fields.

Measuring crop N nutrition status during the season by optical sensing of crop canopy seems to be a viable precision N management tool for variable-rate N applications, and minimizing cost of N application (Raun *et al.* 2001; Raun *et al.* 2002; Teal *et al.* 2006; Tubana *et al.* 2008). This new precision technology allows us to variably apply N fertilizers at a less than one squared meter resolution. Researchers have utilized on-vehicle, real-time optical sensing of crop canopy to generate normalized differential vegetation index (NDVI) values to assess crop N status. This approach enables on-the-go diagnoses of crop N deficiency, real-time applying N fertilizer in variable rates to correct those deficiencies, and precisely treating each area sensed without processing data or determining location within a field beforehand. Research on corn and wheat has shown a 15% increase in N use efficiency and significant yield increases with this approach (Raun *et al.* 2002). So far, precision N management research has been focused on wheat and corn based on canopy NDVI, and is still at the beginning phase. Fewer investigations have been documented on precision N management based on plant heights.

The objectives of this study were to quantify the relationships of corn grain yields with plant height and canopy NDVI and the relationships of plant height and canopy NDVI with plant N nutrition status at different key growing stages throughout the season.

Methods

A field experiment was conducted near Milan, Tennessee, USA from 2008 through 2009. Six N application rates of 0, 60, 120, 180, 240, and 300 kg N/ha were evaluated under four different crop rotation and irrigation systems: continuous corn under no irrigation, corn-soybean under no irrigation, corn-soybean under irrigation, and corn-cotton under no irrigation. A randomized complete block design was used with four replicates. Plant heights, canopy NDVI indices, and leaf N concentrations at critical growing stages and grain yields at harvest were measured on an individual plot basis each year. Canopy NDVI readings were recorded using a GreenSeeker® NDVI hand unit (NTech Industries, Inc., CA, USA) in June and July. Relationships among grain yields, plant height, canopy NDVI, and crop N were examined using different models.

Results

There were significant positive linear relationships between corn yields and plant heights and between corn yields and canopy NDVI indices at key growing stages regardless of crop rotations and irrigation systems. The relationships between corn yields and plant heights and between corn yields and canopy NDVI indices became stronger as the growing season progressed regardless of crop rotations and irrigation systems. The relationships of corn yields with plant heights were stronger than those of corn yields with canopy NDVI indices, respectively, at the same growing stage under all the crop rotations. The relationships of corn yields with plant heights and canopy NDVI indices were stronger with corn rotated after soybean than those in continuous corn and corn rotated with cotton. Our results suggest that both plant heights and canopy NDVI indices at key growing stages can be used to develop algorithms for in-season variable rate N applications on corn under different crop rotations and irrigation systems.

Conclusion

Plant heights and canopy NDVI indices at key growing stages of the season can be used to develop algorithms for in-season variable rate N applications on corn under different crop rotations and irrigation systems.

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