Map-based Variable Rate Application of Nitrogen Using a Multi-Spectral Image Sensor

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Abstract

Site-specific N application for corn is one of the most commonly used precision crop managements in USA. To implement the site-specific N application, various nitrogen stress sensing methods, including aerial image, tissue analysis, soil sampling analysis, and SPAD meter readings, have been used. Use of side-dressing, an efficient nitrogen application method than a uniform application in either late fall or early spring, relies mainly on the capability of detecting nitrogen deficiency. This paper presents a map-based variable rate nitrogen application using a multi-spectral corn nitrogen deficiency (CND) sensor. This sensor assess the nitrogen stress by means of the estimated SPAD reading calculated from the corn leave reflectance. The estimated SPAD value from the CND sensor system and location information form DGPS of each field block were combined into a field map using the ArcView program. Then this map was converted into a raster file for a map-based variable rate application software. The relative SPAD (RSPAD = SPAD over reference SPAD) was investigated 2 weeks after the map-based variable rate nitrogen application. The results showed that the map-based variable rate application system was feasible.

Keywords: Precision crop management, Nitrogen deficiency, Multi-spectral image, SPAD, Reflectance, Map-based application

1. INTRODUCTION

Among all precision crop-production management (PCM) activities, nitrogen management is one of the most frequently practiced operations. Nitrogen is an essential nutrient for plant growth. However, excessive use of nitrogen fertilizers would have adverse effects on environmental qualities (Schepers et al., 1991). Because of the spatial variability in soil properties, different locations in a field may require different amounts of nitrogen to achieve a high yield. One of the major functions of PCM is to determine the optimum amount of nitrogen for a specific location in the field based on the yield potential at this location.

Conventional nitrogen management for corn production is characterized by uniform rate application across the field in the Fall, or early Spring, or in some cases as a side-dress. Side-dressing of nitrogen fertilizer in the early growing season for corn has less potential for nitrogen leaching than conventional methods because of drier soil conditions and deeper roots which would prevent water from percolating to depths below the root zone (Van Es and Trautmann, 1990). However, the efficiency and effectiveness of side-dressing heavily rely on the capability of detecting crop nitrogen deficiency variations in the field during the application.

Soil sample analyses, plant tissue analyses, SPAD (Soil Plant Analysis Development) meter readings, and aerial images.
have been used to assess the crop nitrogen stress (Piekielek and Fox, 1992; Thorp et al., 2002; Waskom et al., 1996; Gitelson et al., 1997). A SPAD meter measures corn nitrogen stress indirectly by measuring the light transparency of corn leaves. Because of the labor-intensive process required to perform field measurement, the SPAD meter nitrogen stress assessment is normally based on only a limited number of corn plants, which may result in inaccurate measurement of nitrogen stress for the entire field due to under-sampling. Aerial images could provide crop nitrogen stress information over the entire field, but its low resolution and background noise may affect the accuracy in interpreting the images to obtain plant nitrogen stress.

The correlation between reflectance from individual channels of the multi-spectral image sensor or different vegetation indices and the SPAD readings were studied in previous research (Noh et al., 2003). The results indicated that there existed some approximate linear relationships between leaf reflectance (or vegetation indices determined based on such reflectance) and SPAD readings.

Map-based variable rate application is useful when the site-specific field information is not provided in real-time, especially when N deficiency was calculated from the soil sampling, tissue analysis, and aerial image. Even if the site-specific information is provided in real-time for small area such as SPAD reading and ground based CND sensor image, it is desirable to use map-based variable rate application because the application coverage width of sprayer in one travel is wider than the width of N deficiency sensing area. A field map including the site-specific information, such as location, and N recommendation, is necessary to perform a map-based variable rate application. Also a control system was needed to control the application rate of the sprayer.

This paper reports development of a map-based variable rate application system using a multi-spectral image sensor. The following sections describe system design, sensor calibration, signal processing methods, and system validation test results in the field.

2. MATERIALS AND METHODS

A map-based variable rate application system was mounted on a sprayer with a Duncan MS2100, a multi-spectral charged couple device (CCD) camera for a real time crop nitrogen deficiency sensor. This sensor assess the nitrogen stress by means of the estimated SPAD reading of the corn based on the corn leave reflectance sensed using three channels (green, red, and near-infrared) of a multi-spectral camera. The method included a map creation from data sets such as calculated SPAD, GPS location coordinates, and nozzle control commands.

A. Research Platform

A Patriot XL sprayer (Tyler industries, Inc., Benson, MN, USA) was used as a mobile platform having a high clearance of 1.8 m in order to travel in corn fields during the growing seasons. The sprayer had 25 nozzles for liquid fertilizer application on a 23 meter (nozzle spacing: 76 cm) boom. A multi-spectral corn nitrogen deficiency (CND) sensor was installed in the front of the sprayer platform to acquire crop images in the field. Fig. 1 shows the research platform and its schematic illustration.

A GPS receiver having a position accuracy of 0.4 m in circular error probable (CEP), and an update rate of 100 Hz (AgGPS 132, Trimble, Sunnyvale, CA, USA) was installed on the top of the cab near the sprayer center of gravity to

![Fig. 1 Research platform (left) and its schematic illustration (right).](image-url)