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멀티스펙트랄 이미지 센서를 이용한 전자 지도 기반 변량 질소 살포

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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 optumum 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

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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., 2005). 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 corp 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

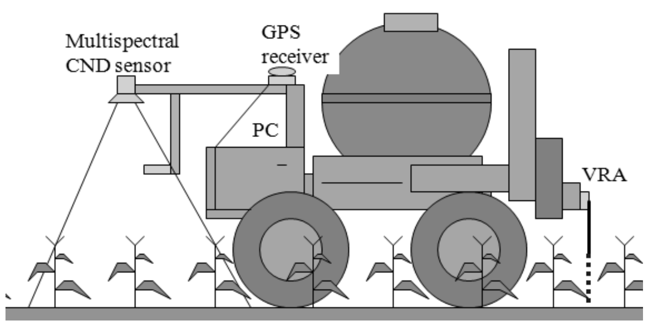

Fig. 1 Research platform (left) and its schematic illustration (right).

provide location information in the field for both field map creation and vehicle location. A desktop PC was installed in the cab to control the nozzles and to store the information obtained from the sensor.

B. Field Map Creation

Fig. 2 shows a variable rate application field map created using the ArcView software. In this figure, GPS data points displayed as dots to represent the test block and field boundary recorded using a computer through the Age132 DGPS.

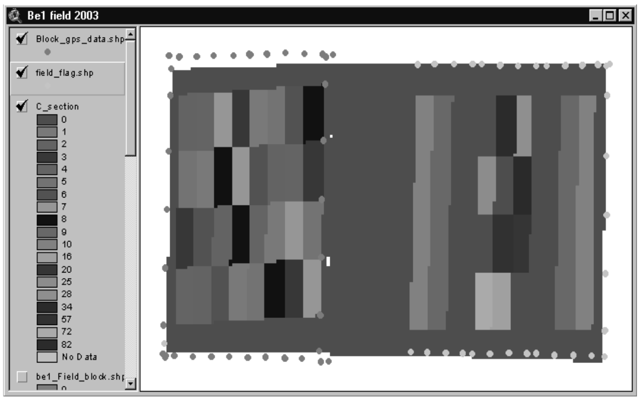

Fig. 2 Field map for variable rate application.

The collected data points contained longitude and latitude in an ASCII code in DDMM (Degree Minute) format. The positions expressed as longitude and latitude were converted to transverse Mercator projections (including Universal Transverse Mercator (UTM)).

The conversion into a point shape file was done in the ArcView program. The projections used in this data point conversion were UTM 1983 and Zone 16 (Illinois). Then based on the point shape file, the polygons were made as a field block in meter dimension. Each polygon on the field map had attributes of N treatment code and polygon ID.

Map-based application was performed using this field map data as an input map after finishing another conversion from raster to ASCII code. This ASCII code file was used to create a field map on computer screen and also real time GPS signal, sprayer's location was displayed on the monitor. When the sprayer reached in the experiment plot on the map, the N treatment code was read from the field map and the N rate (duty cycle) was then sent to the pulse width modulation (PWM) valve via a serial port.

C. Experimental Design

Fig. 3 shows a field block design for the map-based variable rate application. Each block has 24 rows (8 rows x 3 plots) and 75.9 m in length. For B block, the individual plots were 8 rows wide and 18.3 m long (with 0.9 m alleys cut between plots after emergence and before VRA).

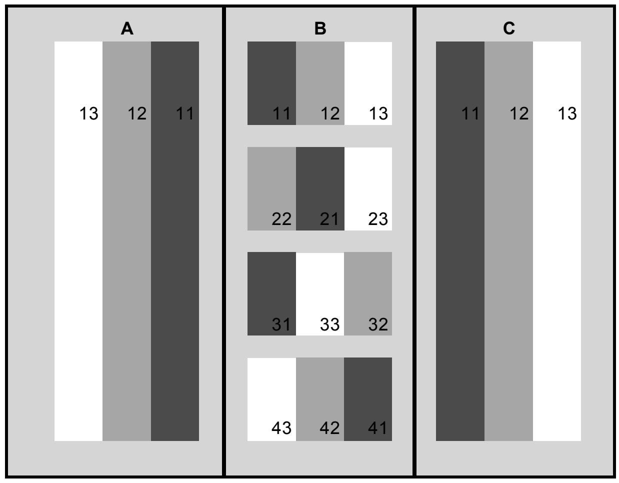

Fig. 3 Field map for map-based VRA.

The first number of the code in each block represents repetition and the second number of the code represents the N treatment applied by ammonia injection method before corn planting. The N treatment code 1, 2 and 3 represent 168, 84, and 0 kg/ha respectively. And various map-based variable rate application were performed in B field as shown in Table 1. Field A and C were used as a reference for yield monitor.

Treatment 1 was a conventional practice used as 'control treatment'. A uniform application rate was determined following recommendations of the Illinois Agronomy Handbook. Treatment 2 was half of the recommended nitrogen applied at the same time as in treatment 1. Additional nitrogen was variably applied in response to the canopy nitrogen stress from the CND sensor measurements. The rate was based on the predicted crop nitrogen needs at the time of application. Treatment 3 was no nitrogen application at the time of treatment 1. Additional nitrogen application was performed at the same time as in treatment 2. That means nitrogen was applied by variable rate application only in treatment 3. The rate was also based on the nitrogen recommendation based on the CND sensor system same as treatment 2.

Table 1 N application scheme of conventional methods vs. map-based VRA method

Field	Treatment	N application	
		Method	Amount [kg/ha]
A and C	1	Conventional N application	168
	2	Conventional N/2 application	84
	3	No applicaiton	0
B	1	Conventional N application	168
	2	Conventional N/2 application + map-basedVRA	84 + a*
	3	Map-based VRA	b*

a* b*: N application amount depend on map-based VRA using CND sensor system

Table 2 Site-specific information of field B for map-based VRA

ID	N_Tre [kg/ha]	Reflectance			R_SPAD	E_SPAD	D_SPAD	N_Rec [kg/ha]	D_CYCLE [%]
		G	NIR	R					
11	168	0.021	0.434	0.005	60	63.9	-3.9	0	0
22	84	0.056	0.388	0.023	60	52.2	7.8	34	25
31	168	0.055	0.412	0.031	60	56.7	3.3	0	0
43	0	0.088	0.400	0.077	60	41.6	18.4	116	72
12	84	0.093	0.425	0.088	60	39.9	20.1	133	82
21	168	0.022	0.374	0.002	60	63.5	-3.5	0	0
33	0	0.079	0.421	0.050	60	44.5	15.5	89	57
42	84	0.046	0.389	0.026	60	55.6	4.4	17	16
13	0	0.059	0.417	0.026	60	51.3	8.7	39	28
23	0	0.064	0.383	0.041	60	49.6	10.4	50	34
32	84	0.051	0.412	0.032	60	54.0	6.0	24	20
41	168	0.047	0.395	0.023	60	55.3	4.7	0	0

3. RESULTS AND DISCUSSION

The data used in the map were collected on July 14, 2003 by using the CNDS system on the sprayer. At that time the corn was VT stage (tasseling). On July 22 the map-based nitrogen variable rate application was performed, and the SPAD values were collected on August 1.

Table 2 shows the site-specific information of field B for map-based nitrogen VRA. The ID represents the treatment code. N_Tre means the nitrogen treatment before planting as a uniform application. The estimated SPAD (E_SPAD) values were calculated using the CND sensor. The reference SPAD value (as shown R_SPAD in the table) was calculated by averaging the SPAD values of the plots, where 168 kg/ha N was applied before planting. The difference between R_SPAD and E_SPAD was shown as D_SPAD. And this D_SPAD was used to calculate nitrogen recommendation using a N recommendation model based on SPAD difference.

Duty cycle (D_CYCLE) of the PWM valve finally calculated through the nozzle calibration equation, also the speed of sprayer used was 0.5 m/s. The duty cycle of block, N treatment code 1, was set to zero.

Fig. 4 shows the field map created for map-based VRA based on field block design (see Fig. 3) using the ArcView

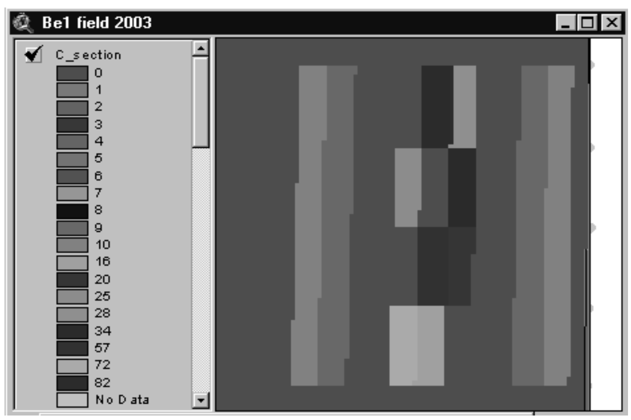

Fig. 4 shows the field map created for map-based VRA based on field block design (see Figure 3) using the ArcView program. And attributes of each block on the field map are shown in Figure 5.

program. And attributes of each block on the field map are shown in Fig. 5.

The value 82 represents the N application rate of the PWM valve, Count 132 means the block number automatically counted by the ArcView program, ID means treatment code of that block, Treatment 75 means the N amount applied before planting that is 84 kg/ha, and Field C means that this plot belongs to the field C on the map.

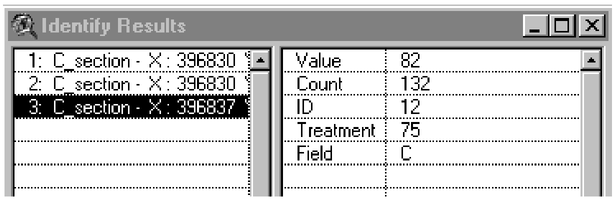

Fig. 5 Attribute of block on the field map.

As a map-based nitrogen VRA result, the measured SPAD value was used. The SPAD values of corn leave on each plot were measured using the multi-spectral CND sensor. Fig. 6 shows the comparison of the SPAD values before and after map-based variable rate application.

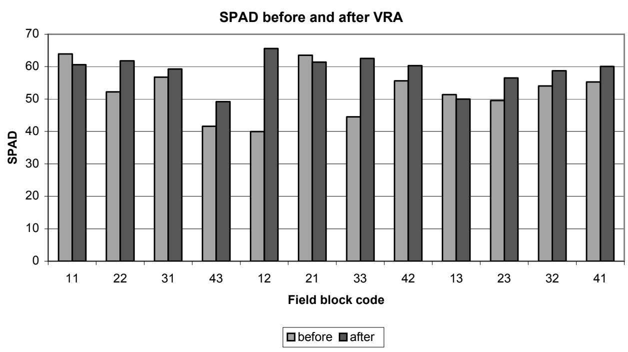

Fig. 6 SPAD value on the block in the field before and after the VRA.

As shown in Fig. 6, the SPAD values after VRA in treatment 1 (field block codes displayed as 11, 21 31, and 41. The number in front 1, 2, 3 and 4 mean the number of replication and in rear 1 means treatment 1), there was no clear pattern in SPAD values among different field block codes. This explains the each block needs different N treatments depengding on soil conditions of each block. On treatment 2 blocks the measured SPAD values after VRA were increased near to 60 SPAD (target SPAD value for map-based VRA) value, whereas the measured SPAD values after VRA did not reached 60 SPAD on treatment 3 blocks.

Fig. 7 shows the average SPAD values for different treatments. In treatment 1 (conventional uniform N application 168kg/ha) the average SPAD values were increased 2 weeks after the VRA treatment.

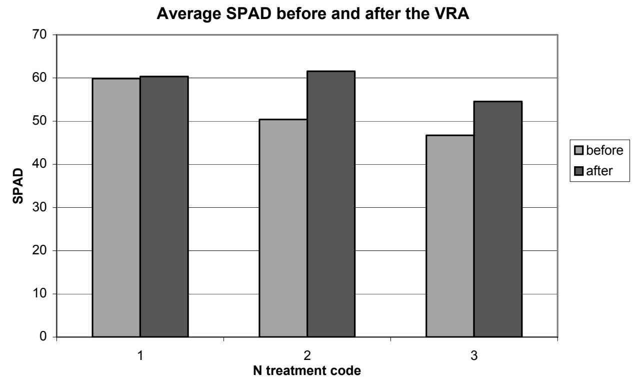

Fig. 7 Average SPAD value on the block in the field before and after the VRA.

In treatment 2 (conventional uniform N/2 application 84 kg/ha plus map-based VRA) the average SPAD values were increased by 10 SPAD value near to the target SPAD value (reference SPAD value 60). In treatment 3 (VRA only) the SPAD values were increased but did not reach to the target SPAD value.

The relative SPADs (RSPAD = SPAD over reference SPAD) 2 weeks after the VRA treatment was 1.03, and 0.91 for the treatment 2 and treatment 3, respectively, from this result we could conclude that the map-based variable rate application system was effective in managing corn because the RSPAD value was almost 1. The treatment 2, conventional half N application plus map-based VRA showed the best result in terms of measured SPAD value. However further studies are needed for determining optimum number of map-based N applications, but because frequent map-based VRAs during the growing season could cause stress and damage to corn. Even though map-based VRA would be better than conventional methods in environment.

4. SUMMARY AND CONCLUSIONS

This paper presents a VRA management of nitrogen that implements map-based application using a multi-spectral corn nitrogen deficiency (CND) sensor.

The main results of this research were summarized as follows

(1) The field map was created using an estimated SPAD value from the CND sensor system. The estimated SPAD value from the CND sensor system and location information from DGPS for each field block were combined into a field map using the ArcView program.
(2) The map was then converted into a raster file that could be used in a map-based variable rate application applicable to a field.
(3) The relative SPADs (RSPAD = SPAD over reference SPAD) 2 weeks after the map-based N application were 1.03, and 0.91 for the treatment2 (conventional uniform N/2 application 84 kg/ha plus map-based VRA), and treatment 3 (map-based VRA only) respectively. From this result we could conclude that the map-based variable rate application system was effective in managing corn because the RSPAD value was almost 1.

This map-based VRA method would be potentially useful for precision farming from an economic and environmental point of view.

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