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In-season nitrogen prediction for the quality protein maize using the pocket hand-held NDVI sensor on farmers' field around Ilu-Gelan and Bako-Tibe, Ethiopia

Tolera Abera[1], Ernest Semu[1], Tolessa Debele[2], Haekoo Kim[3] & Dagne Wegary[3]
[1]Department of Soil Science, Sokoine University of Agriculture, P. O. Box 3008, Chuo Kikuu, Morogoro, Tanzania
[2]Wheat Project (SARD-SC), ICARDA c/o ILRI P.O. Box 5689 Addis Ababa, Ethiopia
[3]International Maize and Wheat Improvement Centre (CIMMYT), Global Conservation Agriculture Program, P O. Box 5689. Addis Ababa, Ethiopia

Corresponding author: thawwii@yahoo.com, thawwii2014@gmail.com

Abstract

The "pocket" hand-held Normalized Difference Vegetative Index (NDVI) sensor for in-season highland quality protein maize nitrogen rate determination for side-dressing was conducted in 2013cropping season on seven farmers' field around Bako-Tibe and Elu-Gelan districts. Six rates of N ranging from 0-150 kg ha^{-1}were applied to a long season quality protein maize (QPM) hybrid, Webii (AMH-760Q). Increased mean grain yield of was obtained with increasing application rate of Nitrogen. Mean grain yield of quality protein maize positively correlated with mean in season estimation of yield (INSEY). Significant relationship was observed between mean leaf area and NDVI reading. Promising result was obtained in current study, but further investigation needed for side dressing of nitrogen determination and N use efficiency of quality protein maize.

Key words: INSEY, NDVI, nitrogen, Quality protein maize

Résumé

Le détecteur de l'Indice de Différence Végétative Normalisée de « poche » (NDVI) pour la détermination du taux de la qualité d'azote dans le protéine de maïs en cours de saison des hautes terres a été réalisé en 2013pour la saison d'inter cultures sur le terrain de sept agricultures autour des districts de Bako-Tibe et d'Elu-Gelan. Six taux de N allant de 0 à 150 kg ha^{-1}ont été appliqués sur une longue saison de protéines de qualité du maïs (QPM) hybride, Webii (AMH-760Q). L'augmentation de rendement moyen de graine a été obtenue avec une augmentation de l'application du taux d'azote. Le rendement en grains de maïs à haute qualité protéique positivement corrélée avec une moyenne en saison, estimation du rendement (INSEY) moyenne. La relation significative a été observée entre la surface foliaire moyenne et les résultats de NDVI. Le résultat prometteur a été obtenu dans l'actuelle étude, mais des recherches futures sont nécessaires pour la couverture latérale de la détermination de l'azote et de l'utilisation efficace de la qualité protéinique de la de qualité du maïs.

Mots clés: INSEY, NDVI, l'azote, qualité protéinique du maïs

Background

Soil fertility depletion is considered as the major threat to crop production, and food security in Ethiopia. Low soil fertility is the greatest factor to increased productivity of maize in Western Ethiopia. However, decreasing productivity can be alleviated by use, among others, of inorganic nitrogen fertilizer. NDVI is one of the options used to indicate the amount of available and optimum nitrogen to apply. It can help smallholder farmers to produce maize at relatively low level of nitrogen and make productivity of maize sustainable. These technologies provide an opportunity for the producer to apply only the needed N fertilizer on their farms, thereby maximizing their production and reducing their cost of production.

Literature summary

The Green Seeker optical sensor technology enables researchers to measure, in real time, a crop's nitrogen levels, and variably apply the "prescribed' nitrogen requirements. The use of sensors holds great promise for implementation of improved precision of maize management. Filella *et al*. (1995) proposed the use of remote sensing to determine the N status of crops, and thus improving the accuracy of fertilizer N input. The benefits of using the optical sensor system in agriculture reaffirm that the development of this technology can be very useful in detecting plant N status and making fertilizer recommendations (Kanke *et al*., 2012). Optical sensors function on the basis that a beam of light that can be absorbed or reflected, depending on the characteristics of the material that is illuminated (Kenyon, 2008). Both the morphological and physical characteristics of plants, such as area of leaves, will influence the absorption or reflectance of the light beam (Araus *et al*., 2001). Li *et al*. (2009), Raun *et al*. (2005) and Zillman *et al*. (2006) reported increased nitrogen use efficiency by the use of spectral radiance, including the NDVI. The NDVI measurements can be used as an objective parameter for crop performance judgment, both in time and space, giving more dynamic and immediate information than does the static end-of season yield results (Govaerts, 2007). Li *et al*. (2009) and Tubaña *et al*. (2008) showed the Green Seeker sensor to be an N management tool that can improve NUE with significant increase in net profits for cereal and grain crops. Therefore, this technology provides an opportunity for the producer to apply only the needed N fertilizer on their farms, thereby maximizing their production and reducing their cost of production. Production and productivity of maize and soil health will be improved to result in a sustainable cropping system. There is no information on sensor based nitrogen determination in the country. Therefore, the objective was to investigate the "pocket" hand-held NDVI sensor for in-season nitrogen status of highland quality protein maize on farmers filed around Ilu-Gelan Bako-Tibe-.

Study description

The experiment was conducted on seven farmers' fields in Bako Tibe and Ilu-Gelan districts of West Shewa Zone in the main season of 2013. The areas lie between 8'59'31''N to 9'01'16 ''N latitude and 37'13'29 E to 37°21'xx''E longitude and at altitude range of 1727 to 1778 meter above sea level. Mean annual rainfall is 1239 mm with unimodal distribution (NMSA, 2013). The experimental areas are characterized by warm and humid climate with

mean minimum, mean maximum and average air temperatures of 13.2, 28 and 21°C, respectively (MBARC, 2003). The soil type is brown clay loam Nitisols (Mesfin, 1998). The experiment was laid out in randomized complete block design with three replications, and plot size was 5.1m x 4.5m. Six rates of nitrogen (0, 10, 25, 50, 100 and 150 N kg ha^{-1}) were used for QPM hybrid (Wabii or AMH-760Q). The hybrid was planted in rows spaced at 75 cm between rows and 25 cm between plants. The nitrogen rates were applied at planting. One hundred kg ha^{-1} of diammonium phosphate (DAP) was applied for all treatments uniformly during planting. All other agronomic management practices were applied as per recommendation for the hybrid, in each locality. Normalized difference vegetative index (NDVI) values were recorded in spectral radiance readings using a green seeker sensor at the vegetative growth stages during node initiation and elongation of the QPM. Thus, nitrogen readings at vegetative growth stages and in the grain will be computed for optimum grain yield of maize. Other relevant traits were recorded at appropriate growth stages of the maize plant.

In-season estimation of yield (INSEY) vs. grain yield relationship was established for the area as: INSEY= NDVI/GDD, where, GDD is the number of growing degree days greater than zero from seeding (or seed emergence) to sensing. The INSEY provides an estimate of daily biomass production or growth rate (Raun *et al.*, 2005) and is therefore an important determinant of final grain yield. Growth degree day (GDD) = (T maximum + T minimum/2)-base temperature for maize). The base temperature for maize is 10^0c. The collected data were analyzed using (SAS, 2010). Mean separation was done using least significance difference (LSD) at 5 % probability level (Steel and Torrie, 1980).

Research application

Use of nitrogen fertilizer significantly increased mean NDVI reading, yield and yield components of quality protein maize variety (Tables 1 and 2). Mean NDVI reading, leaf area, and In Season Estimation of Yield (INSEY) were increased with N rates up to 50 kg ha^{-1}, then decreased (Table 1). Significantly increased mean dry biomass, harvesting index and grain yield were observed as nitrogen rate increased. NDVI data were significantly different among farmers, date of measurements, and nitrogen levels (Table 1). Significantly higher NDVI reading and INSEY were recorded at node elongation as compared to node initiation stage (Tables 1 and 2). This might be due to higher leaf number (vegetative growth) at F6 growth stage of the QPM. The INSEY and NDVI readings at node elongation had a better indication for yield estimation and side dress nitrogen application of quality protein maize. Mean grain yield and plant characteristics variations were observed from one farmer's field to another farmers field (Table 2), indicating soil fertility management and soil fertility status difference among farmers' fields.

There was correlation between INSEY and mean grain yields of maize (Fig. 1). Similarly, higher correlation between NDVI reading and leaf area were observed, with correlation coefficients of 0.4641 (Fig. 2), indicating that improvements in leaf area with increasing N rates. It can be noted that leaf area peaked at 50 kg N ha^{-1}, implying that greater NUE is achieved at 50 kg N ha^{-1}. Application of 50 kg N ha^{-1} was more responsive to maize at

Table 1. NDVI reading and in season estimation of yield (INSEY) at Node initiation (F4) and Elongation (F6) stage of quality protein maize on farmers' field around Ilu- Gelan and Bako- Tibe, Western Ethiopia.

N kg ha^{-1}	NDVI		INSEY		Mean grain yield (kg ha^{-1})
	Node		Node		
	initiation	Elongation	initiation	Elongation	
0	0.52	0.66	0.050	0.063	2200
10	0.60	0.69	0.058	0.067	2857
25	0.62	0.72	0.060	0.069	3564
50	0.64	0.74	0.062	0.071	4217
100	0.62	0.74	0.059	0.071	4785
150	0.57	0.71	0.057	0.067	5227
LSD (5%)	0.0239	0.0196	0.0023	0.0019	64.475
CV (%)	6.52	4.51	6.52	4.51	2.76

Table 2. Effects of nitrogen rate on plant height, leaf area, leaf area index, harvesting index, and thousand weight of Quality protein maize on farmers' field around Ilu-Gelan and Bako Tibe, Western Ethiopia.

N kg ha^{-1}	Plant height (cm)	Leaf area (cm)	Leaf area index	Dry biomass (kg ha^{-1})	Harvesting index (%)	Thousand seed weight (g)
0	253	3119	1.52	11295	22.66	372
10	274	4588	2.18	12955	25.18	371
25	282	4626	2.19	13328	32.08	360
50	289	5974	2.87	14701	33.24	391
100	298	5313	2.55	15791	34.87	403
150	297	5478	2.71	17950	32.21	415
LSD (5%)	9.4981	924.8	0.4768	2887	8.2988	28.29
CV (%)	5.48	31.06	33.24	32.8	24.74	11.96

vegetative growth of maize. This method of nitrogen management for maize production provides an opportunity for the producer to apply only the needed N fertilizer on their farms, thereby maximizing their production, reducing their cost of production and reducing the incidence of environmental pollution. In conclusion based on promising result validation of nitrogen rate for side dressing and N use efficiency of quality protein maize production in the area is needed.

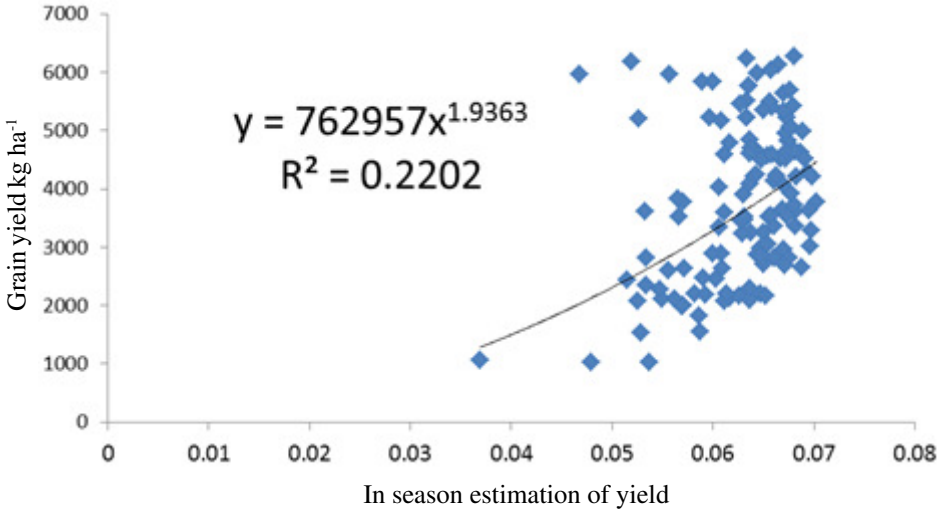

Figure 1. Relationship between maize mean grain yield Vs. INSEY (in-season-estimated-yield) at Ilu-Gelan and Bako Tibe.

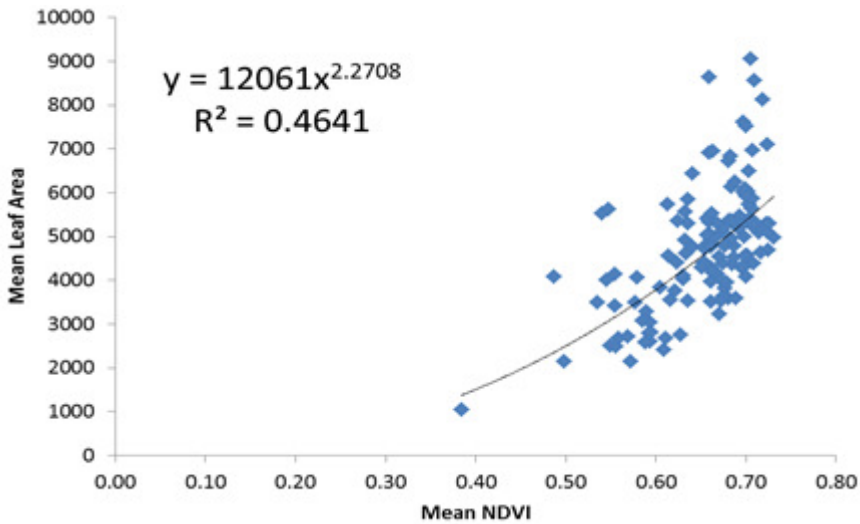

Figure 2. Relationship between maize mean leaf area Vs. NDVI at Ilu-Gelan and Bako Tibe.

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