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Crop Sensor as a Tool for Nitrogen Fertilizer Management for Hybrid Maize: A Study in Gobu-Seyo District on Farmers Field, Western Ethiopia

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Abstract: Though maize is the leading cereal crop in the national diet of Ethiopia; its present productivity is limited by blanket use of Nitrogen (N) fertilizer; without considering farm variability of soil in nutrient supply. Agricultural crop sensors are among the recent technologies developed to assess the actual crop Nitrogen (N) status in the field. In this view, a field trial was conducted on three farmers' fields in Gobu-Seyo district, Ethiopia in 2018 and 2019 to determine the best N rate for side-dressing and validate the N application using crop sensor. The treatment consisted of three N rates (0, 25 and 50 kg ha^{-1}) applied at planting and four rates of N (19, 38, 56 and 75 kg ha^{-1}) used in side-dressed. The field experiment was arranged in randomized complete block design with three replications. Significant variations were observed between the applied treatments on yield and yield traits of maize. The Correlation coefficients of 0.24 and 0.60 were observed among normalized difference vegetative index value and yield of maize at leaf four and eight growth stages. Higher grain yield (8.6 t ha^{-1}) was achieved at N rates of 50 kg ha^{-1} applied at planting and 75 kg ha^{-1} side-dressed at 35 days after emergence. Maximum net benefit, ETB 65343.36 ha^{-1} with acceptable marginal rate of return were achieved when 50 kg N ha^{-1} was used during planting and 75 kg N ha^{-1} was used as side-dressed. In conclusion, 50 kg N ha^{-1} during planting and 75 kg N ha^{-1} for side-dressing is the optimum N rate and economically viable for maize production in the study area.

Key words: Applied · Maize · Nitrogen · Planting · Side-Dressing · Sensor · Yield

INTRODUCTION

In Ethiopia, more than 80% of the population is reliant on agriculture, which is the engine of economic development and contributes to more than 80% of the country's export earnings [1, 2]. The country is endowed with an immense potential for agricultural crops such as grain crops are produced in various agro-ecologies of the country [3, 4].

To this, maize is one of the strategic crops to supply food for the ever-growing population of the country due to its various benefits as food for human beings and as well as for feed and even for fuel purposes [4-7]. According to FAO [8] reports, Ethiopia is the fourth in Africa and the leading country in the East Africa in producing maize crops. It is also the foremost crops leading other cereal crops in terms of production and productivity, while the second in area coverage following *tef*. The year 2020/21 sample survey results of post-harvest crop production of the Ethiopia Central Statistical Agency indicated that a total crop land areas of 12,979, 459.91 ha were under grain crops of which maize accounts of 19.46% (2,526,212.36 ha) area. As to production maize contributed 30.88% (10,557,093.6 tons) of grain production [4]. Because of its various benefits, more than 88% of produced maize crop is used at home and it is therefore, the major crops for population of the country [9, 10].

In spite of its significant contribution to food and produced on a huge area, its present yield in Ethiopia is only 3.9 t ha^{-1}. This is far below the grain yield potential of the crop. For instance, the hybrid maize, BH661 can produce from 9.5 to 12 and 6 to 8.5 t ha^{-1} at the research field and farmers' field, respectively [11]. Even though many constraints can contribute to these large yield gaps, declining soil fertility and inappropriate use of plant nutrient are the foremost major constraints to low productivity of maize [12-14].

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Nitrogen (N) fertilizer in the maize farming system is the main concerns as the productivity of maize is more limited to N fertilizer than other plant nutrients, since it is the major plant nutrient for growth and development of the crop [15]. Nevertheless, the majorities of the farmers in the western Oromia specifically in Gobu-Seyo district and the surrounding area fertilize their maize crop following blanket recommendations. This blanket application consists of 92-150 kg N ha^{-1}. Furthermore, appropriate N application rates have not been devised with the newly recommended NPS (blended of 19% N, 38% P_2O_5 and 7% S) fertilizer to increase the productivity of maize and fertilizer use efficiency in the study area. Moreover, farmers refine from using adequate amount of N fertilizer because of its skyrocket price of inorganic fertilizers, or lack of knowledge as to which application rates and time are appropriate [16]. On the contrary, the excessive application is wasteful, worsens the environmental contamination and potent to the crop [17]. Research scholars reveled that 30 to 70% the applied N fertilizer possibly lost in various forms within 7-10 days after application and this may lead to an increase in NO_3 level in the soil [18, 19]. Also, Martinez *et al.* [20] showed that more than 50% of applied N fertilizers are not available to a crop due to losses through runoff or leaching.

Crop canopy sensors are among the recent technologies developed to help researchers as well as growers in N management. The sensors are a convenient and rapid method to measure plant N status to match the requirement of N by crop during the growing season as per crop requirement. It measures crop spectral reflectance and generate vegetative indexes like the normalized difference vegetation index (NDVI) [21, 22]. The Green-Seeker integrated optical sensor that displays a NDVI was developed at Oklahoma State University and licensed to N Tech Industries in 2001 [23], a real step towards popularizing precision agriculture. When upon pulling the trigger, the sensor turns on and emits brief bursts of red and infrared light and then measures the amount of each that is reflected back; green plants absorb most of the red light and reflect most of the infrared light. They are placed about 0.60 cm above the crop canopy and collect valuable data as the device moves through the maize field and allows the device to cover larger area in a short period that allows us to made supplemental fertilization of N on a field scale. This is non-sampling, not requiring laboratory analysis and safe time, energy and inexpensive method used for large-area estimation of crop N status within a limited time. Many scholars reported that the use of NDVI sensor could bring precision agriculture to African smallholder, improving crop productivity, increasing returns on N fertilizer and reducing the risk of environmental pollution [24]. The NDVI value associate with various crop variables such as plant N content (deficiencies/excess), yield, crop disease and water stress [25]. There is also a higher correlation coefficient of 0.80-0.97 between crop vegetation cover and values of NDVI [26]. Likewise, higher leaf area and green leaf plant give a greater sensor values as the reading values are directly related to the leaf N content of the crop [27]. A higher NDVI value indicates higher plant N content. Unlike in maize, there was also evidence that the prediction of the bread wheat response to application of N detected using crop sensor was positively related to determined N and resulted in increased NUE [28, 29]. Raun *et al.* [30] reported that the predicted yield, as measured by NDVI obtained by the Green-Seeker sensor, was directly associated to the final yield of wheat.

This technology is the present inclusion to the list of crop sensors in African agriculture. There was an effort by researchers on in-season N prediction using Green-seeker sensors, which will be used by validating the results [31]. Thus, in addition to releasing high yield hybrid maize, BHQPY545 [32], it is vital to making N fertilizer recommendation using modern approaches like crop sensors to lift-up productivity and improve environmental health of the area. Therefore, the objective was to study the relationships of NDVI value measured by the sensor with crop growth and final yield in maize and to determine the optimum N fertilizer for maize production in the study area.

MATERIALS AND METHODS

The study was carried out in a sub-humid climate of Western Oromia, Ethiopia. The field trial was executed on three farmers' fields in Gobu-Seyo district in the 2018 and 2019 rainy seasons. The three farmers' field previously planted by maize crop, as the area is predominantly maize based mono-cropping with low soil fertility problem. (Table 1). The area located between 8'59'31"N to 9'01'16 ''N latitude and 37'13'29 E to 37°21''’E longitude and at an altitude ranged from 1727 to 1778 meter above sea level. The ten years, 2010 to 2019, weather data at nearby study area, Bako Agricultural research center indicated a uni-modal rainfall with a mean annual rainfall of 1240.5 mm and higher precipitation received in June to August [33]. The experimental area is characterized by warm and humid agro-ecologies with the minimum, maximum and mean

Table 1: Soil physicochemical characterization of the study sites before planting in Gobu-Seyo district, Western Oromia, Ethiopia

Soil parameters	Farmer-1	Farmer-2	Farmer-3
pH (1:2.5 H_2O)	5.1	4.8	5.3
Available P (ppm)	3.9	3.5	4.0
Total N (%)	0.15	0.13	0.19
Organic carbon (%)	2.4	2.2	2.7
Organic matter (%)	4.1	3.9	4.6
Ex. Acidity (cmol(+) kg^{-1})	0.2	0.1	0.2
Ex. Ca (cmol(+) kg^{-1})	3.0	2.5	3.1
Ex. Mg (cmol(+) kg^{-1})	1.8	1.5	2.0
Ex. Na (cmol(+) kg^{-1})	0.05	0.04	1.0
Ex. K (cmol(+) kg^{-1})	0.4	0.35	0.39
CEC (cmol(+) kg^{-1})	18.0	15.3	21.0
Texture	Clay loam	Clay loam	Clay loam
Previous crop	Maize	Maize	Maize

N= nitrogen, P = Phosphorus, Ex= Exchangeable and CEC= Cation Exchangeable Capacity.

temperatures of 14, 28.5 and 21.2°c to 13.4, 28.49 and 20.95°C, correspondingly (WWW.IQQO.ORG). The soil type of the area is brown clay loam Nitisols and Alfiso [34, 35]. The study area is the major maize growing belts in Ethiopia and finger millet, soybean and hot pepper commonly produced there. The field experiment was laid out in a randomized complete block design with three replications and the gross plot area was 5.1m length with 4.5m width. Three levels of N (0, 25 and 50 kg N ha^{-1}) which is all applied during planting and four N levels (19, 38, 56 and 75 kg N ha^{-1}) that is applied as side dressing were used as treatments. For this experiment, medium maturing hybrid maize, BHQPY545 was used as a test crop. The variety is well growing if planted at an altitude of 1000-1800 meter above sea level with an annual rainfall of 500-1000 mm with uniform distribution in its growing seasons and has an attainable yield ranges between 8.0 to 9.5 t ha^{-1} on research field and 5.5-6.5t ha^{-1} on farmers field. It performs better if planted during end of May to mid-June. Recommended pre-emergence and post-emergence herbicide can be used for weed control for the variety. The variety was planted in inter-rows spaced at 75 cm and intra-rows at 30 cm. Recommended phosphorus (46 kg P_2O_5 ha^{-1}) was uniformly used to all plots during planting. Urea was used for the source of N which was applied at different levels as constituted in the treatments. All other non-treatment management practices were practiced uniformly to all experimental plots as per recommendation for the cultivar.

The NDVI values were recorded from the central four rows of net plot area using hand-held Green-Seeker sensor at leaf four (V4), six (V6) and eight (V8) growth stages of maize crop. The NDVI values can ranged from 0.00 to 0.99; the higher reading, the healthier the plant, the healthier the plant canopy has a higher NDVI reading/value (23).

Phonological, yield and yield trait data and other relevant agronomic data of maize were also collected. To this, plant height (m) was measured from the soil surface to the base of the tassel of ten randomly taken plants from the net plot areas. While thousand kernel weights (g) was determined from 1000.00 randomly taken kernel from each plot and weighed using Sensitive Balance. In addition ear weight was measured using electronic balance during harvesting. Grain yield $plot^{-1}$, however, determined following the standard procedures: ear weight x 0.81) x ((100-M.C) ÷ 100-12.5)); where ear weight = Actual ear weight measured (in kg/plot) at harvesting, M.C= Actual grain moisture content at harvesting, 12.5 = standard moisture content for maize and 0.81 = correction factor. The obtained yield (kg/plot) converted to per hectare basis. On the other hand, above ground dry biomass was determined by harvesting the entire net plot area and converted in to t ha^{-1}. While harvest index (%) was determined as the ratio of grain yield (t ha^{-1}) to total above ground yield biomass (t ha^{-1}).

Harvesting was done from central rows by excluding two border rows from each side. A net plot area for each plot was 11.475 m^2. A pre-planting and treatment application composite samples were collected at a depth of 0-30 cm following the standard method and analyzed for some selected physiochemical properties of the soil (Table 1). Finally, all the collected data were analyzed using Gen-Stat software. Mean separation was done using Duncan's multiple range tests at $P < 0.05$ [36]. Regression analysis was also done to see the relationship among different variables.

RESULTS AND DISCUSSION

Soil Physicochemical Properties of the Experimental Fields Before Planting: The physiochemical testes of the soil are indispensable for the further development of plant nutrient management. As indicated in table 1, the textural classes of the experimental sites were clay loam and the pH values of the sites were 5.1. 4.8 and 5.3, which are found in strongly to very strongly acid ranges. While the total N contents of the experimental fields were ranging between 0.13% and 0.19% which is considered in the low to medium ranges. The total N levels between 0.1% and 0.2% values are found in the low rang, while those below 0.1% are very low for tropical soils. It, therefore, the study areas are low to medium in their total N status which could limit maize production and needs improvement with plant nutrient that contain N. Over all, the physiochemical tests of the study area indicated that the soil of the area is poor in chemical fertility.

Table 2: Analysis of variance for yield and yield traits as affected by nitrogen rates and interaction effects in the 2018 and 2019 rainy seasons in Gobu-Seyo district, Western Ethiopia

	MS					
Source of variation	D.f.	GY	DB	HI	TKW	PH
Nitrogen at planting(N)	2	42.38**	298.47**	14.85ns	361.5ns	0.298**
Nitrogen for side dressing (SD)	3	20.03**	94.85**	60.70*	688.2ns	0.117**
Location (Loc)	2	20.60**	333.79**	602.80**	6295.3**	0.324**
Year (Yr)	1	45.31**	3345.82**	2841.65**	103889.3**	12.06**
N * SD	6	1.81**	29.54**	104.41**	422.5ns	0.020*
N * SD*Loc	12	1.90**	27.00**	67.82**	848.9*	0.013ns
N * SD*Yr	6	1.31*	11.88ns	65.85**	638.1ns	0.004ns
N * SD*Loc*Yr	12	1.42**	18.55*	58.35**	1015.7**	0.006ns
Replication	2	1.15*	2.71ns	11.72ns	1488.8*	0.026ns
Residual	142	0.42	7.15	11.42	296.3	0.009
Total	215	-	-	-	-	-

* and ** = significant difference at 5% and 1% probability level, ns = non-significant difference, d.f. = degree freedom, PH = Plant height (m), GY = grain yield (t ha^{-1}), DB = dry biomass (t ha^{-1}), HI = Harvest index (%) and TKW = thousand kernel weight (g).

Table 3: Analysis of variance for NDVI value as influenced to different rates of N application rates in 2018 and 2019 cropping season in Gobu-Seyo district, Western Ethiopia

	MS			
		NDVI at node		
Source of variation	D.f.	V4	V6	V8
Nitrogen at planting (N)	2	0.00826**	0.01587**	0.01767**
Nitrogen for side dressing (SD)	3	0.00047ns	0.00208ns	0.00269*
Location (Loc)	2	0.028107**	0.01667**	0.04162**
Year (Yr)	1	0.232395**	0.24911**	0.10701**
N * SD	6	0.00173*	0.00095ns	0.00179*
N * SD*Loc	12	0.00082ns	0.00093ns	0.00089ns
N * SD*Yr	6	0.00097ns	0.00044ns	0.00065ns
N * SD*Loc*Yr	12	0.00123*	0.00095ns	0.00089ns
Replication	2	0.00332*	0.01428**	0.00518*
Residual	142	0.00060	0.00106	0.00073
Total	215	-	-	-

* and ** = significant difference at 5% and 1% probability level, ns = non-significant difference at 5% and 1%, MS Mean square, V4, V6 and V8 = vegetative growth stages at leaf four, six and eight, respectively.

Analysis of Variance for Grain Yield and Yield Components of Maize: The mean analysis of variance showed that applied N rates during planting and side dressed at 40 days after emergence significantly ($P<0.01$) affected yield, dry biomass and harvest index (Table 2). A significant ($P<0.05$) difference was observed between the applied N rates on plant height, NDVI-V4 and NDVI-V6 (Table 2 and Table 3). Besides, applied N fertilizer rates at planting showed a significant ($P<0.01$) differences on NDVI at V4. On contrary, the response of thousand kernel weight and NDVI at V6 to N rate did not show significant variations. On the other hand, grain yield and all yield parameters of maize were significantly differed among farmers' fields, indicating soil fertility variation in the farmers' fields.

Crop Phenology, Growth and Yield Traits of Maize: All yield parameters, except for plant height, were significantly affected by applied N rates in each farmer field and year. The yield components and growth parameters were showed a significant increase up to 56 kg N ha^{-1} and then minimal increment after that (Table 4 and 5). This might be some amount of applied N fertilizer was not utilized by the maize crop due to losses through a different process. Teboh *et al*. [37] stated that recommendations of fertilizers in Sub-Saharan Africa are mainly inefficient since application amounts are neither specific to plant requirement nor current with related yields which reduce the influence of temporal changes that affect actual yields. Hence, the result magnifies the significance of crop sensor-based N management for maize production.

Table 4: Effects of N rates on grain yield, dry biomass, harvest index and thousand kernel weight of maize in Gobu-Seyo district, Ethiopia.

Nitrogen rates at planting (kg ha^{-1})	Nitrogen rates for side-dressing (kg ha^{-1})	Dry biomass (t ha^{-1})	Harvest index (%)	Thousand Kernel Weight (g)
0	19	17.9a	28a	273a
0	38	20.1b	34e	288bc
0	56	21.5bc	33de	290c
0	75	22.6cd	30ab	286abc
25	19	21.3bc	31bcd	282abc
25	38	24.3def	29ab	281abc
25	56	23.4de	33cde	277abc
25	75	25.1ef	33cde	283abc
50	19	23.8def	31bcd	274ab
50	38	22.8cd	32cde	284abc
50	56	25.7f	31abc	2823abc
50	75	25.3ef	35 e	279abc
LSD (5%)		1.76	2.2	NS
CV (%)		11.7	10.7	6.1

Table 5: Plant height and NDVI reading of hybrid maize in 2018 and 2019 cropping season at Gobu-Seyo district, Western Ethiopia

Nitrogen rates at planting (kg ha^{-1})	Nitrogen rates for side-dressing (kg ha^{-1})	Plant Height (m)	NDVI at V4	NDVI at V6	NDVI at V8
0	19	2.29a	0.335ab	0.411abc	0.670ab
0	38	2.32ab	0.333a	0.400a	0.657a
0	56	2.44defg	0.351abcde	0.424bcde	0.682bcd
0	75	2.36bc	0.338abc	0.409ab	0.670ab
25	19	2.39cd	0.351abcde	0.441de	0.687bcde
25	38	2.41cde	0.365e	0.437de	0.698cdef
25	56	2.47efgh	0.360de	0.437de	0.696cdef
25	75	2.50gh	0.363e	0.446 e	0.697cdef
50	19	2.47efgh	0.369e	0.439de	0.713 f
50	38	2.43cdef	0.353bcde	0.417abcd	0.678bc
50	56	2.49fgh	0.354cde	0.434cde	0.705ef
50	75	2.53h	0.343abcd	0.423abcde	0.699def
LSD (5%)		0.06	0.016	NS	0.018
CV (%)		3.9	7.0	7.6	3.9

As indicated in table 4, higher dry biomass (25.7 t ha^{-1}) was attained from the use of 50 kg N ha^{-1} at planting and 56 kg N ha^{-1} as side-dressed at 40 days after emergence. Whereas, maximum harvest index (35 %) was obtained from the treatment applied by 50 and 75 kg N ha^{-1} at planting and side-dressing, correspondingly. On the contrary, minimum dry biomass (17.9 t ha^{-1}) and harvest index (28%) were attained from plots receiving sole 19 kg N ha^{-1} as side-dressed compared to other treatment combinations. Higher plant height (2.5), however, recorded when 50 kg N ha^{-1} at planting and 75 kg N ha^{-1} side-dressed was practiced. On the other hand, the highest NDVI reading at V_4 (0.369) was observed at 50/19 kg N ha^{-1} followed by 25/38 kg N ha^{-1} application rates, but statistically at par (Table 5). The maximum NDVI value at V8 (0.713) was, however, recorded from the use of 50/19 kg N ha^{-1}. Conversely, the lowest NDVI (0.333, 0.400 and 0.657) at V4, V6 and V8, respectively were observed from the practice of 0/38 kg N ha^{-1} rates than other treatments. In general, the NDVI values were very low at the early growth stages (Figure 1 and Table 5). However, it becomes higher after V4 as the growth progressed and reaching a maximum. This might be due to the initial growth stages of maize or possibly the failure of the maize canopy cover over the space between plants and lack of N deficiency at an early stage [24, 31]. At later growth stages, however, the reading value gradually increasing probably due to a more canopy cover of maize over the space. A similar result was reported by Tolera *et al.* [38] and on quality protein maize. Another author, Govaerts [39] reported that the NDVI value at the early vegetative growth is very low, but gradually enhanced as the growth progressed and reaching a maximum and decreasing gradually as the grain starts to ripening. There was evidence that an increase in N rates improved spectral vegetation indices which is helpful in indirectly obtaining information on plants' nutrient status such as potential yield and photosynthetic efficiency of

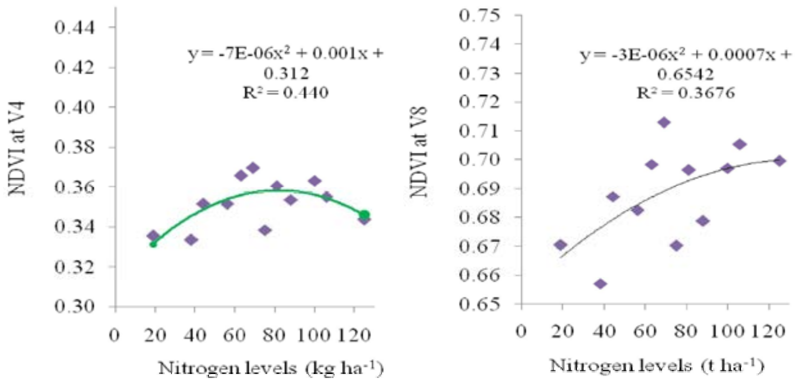

Fig. 1: Nitrogen level vs. NDVI at V4 (lef) and V8 (right) in 2018 and 2019 in Gobu-Seyo district, Ethiopia

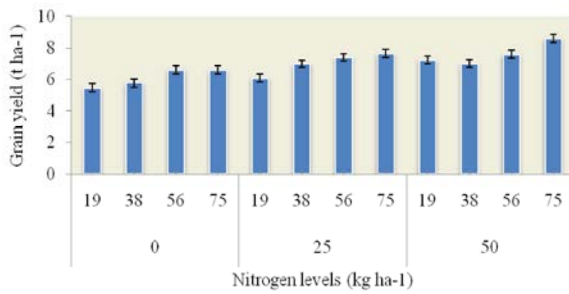

Fig. 2: Influence of N fertilizer rate on grain yield of hybrid maize in 2018 and 2019 at Gobu-Seyo district, Ethiopia

target crop [31]. There was also a correlation between applied N and NDVI observed in the 2018 and 2019 cropping seasons. A higher correlation between NDVI reading and applied N was observed with 0.44 and 0.37 at V4 and V8 vegetative growth, correspondingly (Figure 1). This indicates that the NDVI value at different growth stages correlated to plant physiological parameters [24].

Grain Yield of Maize: As depicted in Figure 2, applied N rates significantly effects on the yield of the maize crop. Higher significant grain yield (8.6 t ha^{-1}) was attained when 50 kg N ha^{-1} applied at planting with 75 kg N ha^{-1} side-dress at 40 days after emergence followed by 25/75 kg N ha^{-1} at planting/side-dress (Figure 2). Also, the comparable yield was attained when 50/56 kg N ha^{-1} was practiced. Minimum yield (5.5 t ha^{-1}) was, however, obtained from treatments receiving 19 kg N ha^{-1} which applied as side-dressed as other treatment combinations. On the other hand, the yield obtained from all farm fields (three farmers' fields) was less to the yield recorded at research fields (8-9.5 t ha^{-1}) for the variety used as a test crop. This is most likely due to better soil fertility management and fertilizer application over time in research stations. Various reports indicated research stations are mainly characterized by relatively high-level plant nutrient renewal or accumulation and better agronomic practices [40]. Similarly, Zingore *et al.* [41] and Rusinamhodzi [42] reported that smallholder farming fields are characterized by infertile soil rate and poor level of agricultural field management activities. In addition, the grain yield of maize response to N application depends on various factors such as the past time soil fertility management practices, soil type, amount and rain fall distribution and form of the N fertilizer [43].

In addition, the response of yield to applied N rates was significantly varied among farms (Table 5). This might be attributed to variability's between farm fields in soil fertility condition (Table 1), levels of land-use intensity and the capacity of farmers to apply farm inputs (crop residues, manure, refuse, fertilizer) to their fields over long time [44]. Likewise, Vanlauwe *et al.* [45] indicated that the long-time interaction of geological and landscape situation and plot-specific practices have created variations within farm soil fertility gradients.

Another author, Schmid *et al*. [46] indicated that a highly variable amount of nutrient was required to bring any given subplot of maize within a farm field to the highest yield. A wide range of farm-field management practices and long-term production history at each site subsequently affects the response of applied treatments to on-farm research [47]. This indicates the call for site based fertilizer management for maize production.

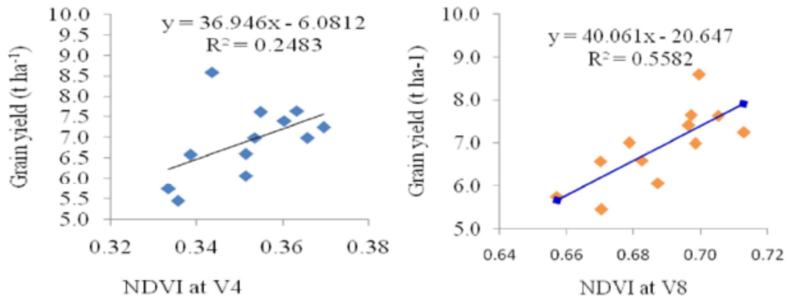

Fig. 3: Grain yield vs. NDVI at V_4 (left) and V_8 (right) in 2018 and 2019 in Gobu-Seyo district, Western Ethiopia

Table 6: Influence of nitrogen rates on grain yield of hybrid maize conducted on farmers' field in 2018 and 2019 cropping season around Gobu-Seyo district, Western Ethiopia

Nitrogen levels at planting (kg ha^{-1})	Nitrogen rate for side dressing (kg ha^{-1})	Grain yield (t ha^{-1}) Farmer-1	Farmer-2	Farmer-3	Mean
0	19	4.7	5.6	6.0	5.4a
0	38	5.7	5.5	6.1	5.8ab
0	56	5.7	6.7	7.4	6.6c
0	75	5.4	6.7	7.6	6.6c
25	19	5.4	5.7	7.1	6.1b
25	38	6.8	6.5	7.7	7.0cd
25	56	7.3	6.9	8.1	7.4de
25	75	7.9	7.0	8.0	7.6e
50	19	6.9	7.2	7.6	7.2de
50	38	6.4	7.2	7.4	7.0cd
50	56	8.5	6.2	8.2	7.6e
50	75	8.9	7.7	9.2	8.6f
LSD (5%)					0.43
CV (%)					9.4

Table 7: Partial budget analysis as affected by the applied N rates for hybrid maize in 2018 and 2019 rainy season

NL (Kg ha^{-1})	Treatments GY	Adj. GY	TC	GB	NB	CR	MRR
0/19	5.5	5.0	1104.62	44550.0	43445.38	39.30	
0/38	5.8	5.2	1769.56	46980.0	45210.44	25.50	265.4
25/19	6.1	5.5	1828.40	49410.0	47581.60	26.60	4029.8
0/56	6.6	5.9	2384.04	53460.0	51075.96	21.40	628.9
25/38	7.0	6.3	2465.94	56700.0	54234.06	22.00	3856.0
50/19	7.2	6.5	2667.00	58320.0	55653.00	20.90	705.73
0/75	6.6	5.9	2986.16	53460.0	50473.84	16.90	D
25/56	7.4	6.7	3025.12	59940.0	56914.88	18.80	352.4
50/38	7.0	6.3	3225.64	56700.0	53474.36	16.60	D
25/75	7.7	6.9	3602.04	62370.0	58767.96	16.30	321.2
50/56	7.6	6.8	3713.22	61560.0	57846.78	15.60	D
50/75	8.6	7.7	4316.64	69660.0	65343.36	15.10	920.2

NL= Nitrogen Levels (kg ha^{-1}), Gy = grin yield (t ha^{-1}), Adj. GY= Adjusted yield (t ha^{-1}), TC = Total variable costs that varied between treatments, GB = Gross Benefit, NB = Net Benefit, CR = Value to Cost ratio, MRR = Marginal Rate of Return, D = Dominated and 1 USD = 25.0 ETB.

Higher grain yield of maize was attained at the use 50 kg N ha^{-1} during planting and 75 kg N ha^{-1} side dressed at 40 days after emergence (Table 6) for maize around Bako, Western Ethiopia. There was also a correlation between applied N and yield of maize, 0.44 and 0.37 at V_4 and V_8 vegetative stages, respectively (Figure 3). This shows the NDVI value at different growth stages correlated to plant physiological parameters and crop yields. Likewise, Moges [48] showed that NDVI value was positively correlated to actual yield of maize. Govaerts [39] also reported that measured NDVI value using handheld crop sensor correlated well with the final grain yield of maize.

Hence, sensor-based N management is one of the best tools in optimum N fertilizer application for maize production. Mamo *et al*. [49] showed that optical sensor-based N application according to variability in soil N content which can minimize the whole N fertilizer application and enhance productivity when contrast with a uniform N application. Thus, the hand-held green seeker sensor is a very crucial instrument in monitoring the real-time maize growth under different levels of N application and detecting crop health and lack of stress which intern shows higher yield and reduce environmental pollution because of over application of nitrogen.

The Economic Feasibility of Nitrogen Application Rates on Maize: Economic feasibility for means of treatments was also assessed. The partial budget analysis indicated that the responses of grain yield to applied nitrogen rates were varied. As depicted in Table 7, maximum net benefit of ETB 65,343.36 ha^{-1} and value to cost ratio ETB 15.10% of expenditure were attained, when 50 and 75 kg N ha^{-1} was used at planting and side-dressing at 40 days after emergence, correspondingly, followed by application of 50 kg N ha^{-1} at planting combined with side-dressed of 56 kg N ha^{-1} which gave the next maximum net benefit (ETB 58,767.96 ha^{-1}). On the contrary, minimum net benefit (ETB 43,445.38) was achieved from using of 19 kg N ha^{-1} as side-dressed only. However, the acceptable marginal rate of return 920.2% with maximum net benefit of ETB 65,343.40 was attained when 50 kg N ha^{-1} was applied at planting combined with application 75 kg N ha^{-1} at 40 days after emergence.

CONCLUSIONS

Crop sensor technology such as the Green-seeker is among the new approach/ technologies for N management in maize producing farmers in western Oromia. From the present study it was observed significant difference among applied N fertilizer rates phonological parameters, yield and yield components of hybrid maize. In addition, higher relationship of 0.25 and 0.56 was observed between yields and used N fertilizer rates at V4 and V8 respectively. Maximum grain yield of 8.6 t ha^{-1} was achieved when 125 kg N ha^{-1} (50 kg N ha^{-1}) at planting combined with 75 kg N ha^{-1} that used as side dressing at 40 days after emergence. The value to cost ratio ranged from ETB 15.10-39.30 per unit investment of nitrogen fertilizer used. However, the highest yield (8.6 t ha^{-1}) and net benefit ETB 65343.36 $ha^{-1}$with acceptable marginal rate of return (920%) were attained at N application rates of 50 and 75 kg N ha^{-1} at planting and side-dressing at 40 days after emergence. Therefore, application rate at 50 kg N ha^{-1} during planting and 75 kg N ha-1 for side-dressing is the best N rate and economically viable for hybrid maize production in the study area and similar agro-ecologies in the country.

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REFERENCES

1. Lulseged Temene, Tilahun Amede, Job Kihara, Degefie Tibebe and Steffen Schulz, 2017. A review of soil fertility management and crop response to fertilizer application in Ethiopia. International Center for Tropical Agriculture (CIAT) Publication, 443: 2-6.
2. Birar Endalew, Mequanent Muche and Samuel Tadesse, 2015. Assessment of food security situation in Ethiopia. World Journal of Dairy and Food Science, 10(1): 37-43.
3. Woktole Mosisa, Legesse Wolde, Berhanu Tadesse, Girma Demissie, Wonde Abera, Tolera Keno, Gezahegn Bogale, Dagne Wegary, Solomon Admassu, Zelalem Habtamu, Y. Kassa, Temesgen Chibsa, Habte Jifa, Demoz Nuguse and Getachew Biru, 2011. Status and future direction of maize research and production in Ethiopia. In Proceedings of the third National maize workshop In Meeting the challenges of global climate change and food security through innovative maize research of Ethiopia, pp: 17-2011, Addis Ababa, Ethiopia.
4. Central Statistical Agency (CSA), 2020/21. Agricultural Sample survey: report on area and production of major crops (private peasant holdings, Meher season). Statistical Bulletin 590, Addis Ababa, Ethiopia.
5. Hailu Feyisa and Tolera Abera, 2020. Sensor-based validation of nitrogen fertilizer for quality protein maize variety using a handheld normalized difference vegetative index sensor at Bako, Western Ethiopia. African Journal of Plant Science, 14: 289-296.

6. Zerihun Abebe and Hailu Feyisa, 2017. Effects of Nitrogen rates and time of application on the yield of maize: Rainfall variability influenced time of N application. International Journal of Agronomy, 2017. Available at: https://doi.org/10.1155/2017/1545280.
7. Hailu Feyisa, 2020. The Response of maize yield to Blended NPS fertilizer rates: seasonal rainfall variation affected fertilizer application rates. Middle-East Journal of Scientific Research, 28(5): 401-408.
8. FAO, 2006. The role of Agriculture and rural Development in Revitalizing Abandoned/ Depopulated areas. Food and Agriculture Organization of the United Nations, Rome.
9. Madefro Nigssie, D. Tanner and S. Twumasi-Afriyi, 2001. Enhancing the contribution of maize to food security in Ethiopia: Proceedings of the second national maize workshop of Ethiopia, 12-16 Addis Ababa, Ethiopia.
10. Zerihun Abebe, Chela Dabala and Tadesse Birhanu, 2016. System productivity as influenced by varieties and temporal arrangement of bean in maize-climbing bean intercropping. Agronomy Journal, 16: 1-11.
11. Variety Register for crops, 2012. Crop variety registration, in CVR, Addis Ababa, 2012.
12. CIMMYT, 2004. CIMMYT's work for Maize systems and farmers in Sub-Saharan Africa report. CIMMYT, Mexico. Available at: http:// hdl.handle.net/ 10883/3716.
13. Mourice, S.K., S.D. Tumbo, A. Nyambilila and C.L. Rweyemamu, 2015. Modeling potential rain-fed maize productivity and yield gaps in the Wami River Sub-basin, Tanzania. Soil and Plant Science, 65: 132-140.
14. Achalu Chimdi, Heluf Gebrekidan, Kibebew Kibret and Abi Tadasse, 2012. Status of selected physiochemical properties of soils under different land use systems of Western Oromia, Ethiopia. Biodiversity and Environmental Science, 2: 57-71.
15. Blumenthal, J., D. Baltensperger, K.G. Cassman, S. Mason and A. Pavlista, 2008. Importance and effect of nitrogen on crop quality and health, Nitrogen in the environment: Sources, Problems and Management. 2nd ed. Elsevier, Oxford, England.
16. Hopkins, B.G., C.J. Rosen, A.K. Shuffler and T.W. Taysom, 2008. Enhanced efficiency fertilizers for improved nutrient management of potato. United States Department of Agriculture, National Agriculture Library. Crop management, 7(1): 0. 10.1094/CM-2008-0317-01-RV
17. Westermann, D.T. and G.E. Kleinkopf, 1985. Nitrogen requirement of potatoes. Agronomy Journal, 77: 616-671.
18. Canfield, D.E., A.N. Glazer and P.G. Falkowski, 2010. The Evolution and future of earth's nitrogen cycle Science, 330: 192-196.
19. Xue, L.H., X. Qin, G.H. Li and L.Z. Yang, 2010. Effect of basal and tiller nitrogen rates on population dynamics, nitrogen uptake and utilization and yield formation of direct-seeded early rice. Journal of Soil, 42: 681-688.
20. Martinez-dalmau, J., J. Berbel and R. Ordonez-Fernandez, 2021. Nitrogen Fertilization. A review of the Risks Associated with the Inefficiency of its Use and Policy Responses. Sustainability, 13: 5625.
21. Sripada, R.P., R.W. Heiniger, J.G. White and R. Weisz, 2005. Aerial color infrared photography for determining late-season nitrogen requirements in corn. Agronomy Journal, 97: 1443-1451.
22. Chang, J., D.E. Clay, K. Dalsted, S. Clay and M.O'Neill, 2003. Corn (*Zea mays* L.) yield prediction using multispectral and multi-date reflectance. Journal of Agronomy, 95: 1447-1453.
23. Trimble Navigation Limited, 2012. Trimble and the Globe & Triangle logo are trademarks of Trimble Navigation Limited, registered in the United States and other countries. Version 1.00. PN 022503-1124-1 (01/14).
24. Addis Teshome, HaeKoo Kim and Adugna Debala, 2015. Calibration of Nitrogen Fertilizer for Quality Protein Maize based on In-season estimated yield using a hand-held NDVI Sensor in the Central Rift Valley of Ethiopia. Asia Pacific Journal of Energy and Environment, 2: 25-32.
25. Ngie, A., F. Ahmed and K. Abutaleb, 2014. Remote sensing potential for investigation of maize production: review of literature. South African Journal of Geomatics, 3: 163-184.
26. Lukina, E.V., K.W. Freeman, K.J. Wynn, W.E. Thomason, R.W. Mullen, A.R. Klatt, G.V. Johnson, R. L. Elliott, M.L. Stone, J.B. Solie and W.R. Raun, 2001. Nitrogen fertilization optimization algorithm based on in-season estimates of yield and plant nitrogen uptake. Plant Nutrition, 24: 885-898.
27. Getinet Alemaw and Getachew Agegnehu, 2019. Precision Agriculture and the need to introduce in Ethiopia. Ethiopian Journal of Agricultural Science, 29(3): 139-156.

28. Raun, W.R., J. B. Solie, G.V. Johnson, M.L. Stone, R.W. Mullen, K.W. Freeman, W.E. Thomsan and E.V. Lukina, 2002. Improving nitrogen use efficiency in cereal grain production with optical sensing and variable rate application. Agronomy Journal, 94: 815-820.
29. Li, F., Y. Miao, F. Zhang, Z. Cui, R. Li, X. Chen, H. Zhang, J. Schroder, W.R. Raun and L. Jia, 2009. In-season optical sensing improves Nitrogen Use Efficiency for winter wheat. America Soil Science Society, 73: 1566-1574.
30. Raun, W.R., G.V. Johnson, M.L. Stone, J.B. Sollie, E.V. Lukina, W.E. Thomason and J.S. Schepers, 2001. In-Season prediction of potential grain yield in winter wheat using canopy reflectance. Agronomy Journal, 93: 131-138.
31. Tolera Abera, Ernest Semu, Tolessa Debele, Dagne wegary and Hae Koo Kim, 2015. Sensor-based in-season nitrogen prediction for quality protein maize varieties on farmers' field around Bako-Tibe, Western Ethiopia. America-Eurasian Journal of Agriculture and Environmental Science, 15: 1556-1567.
32. Adefris Teklewold, Dagne wegary, Abraham Tadesse, Birhanu Tadesse, Kassahun Bantte, Dennis Friesen and B.M. Prasanna, 2015. Quality Protein Maize: A Guide to the Technology and its Promotion in Ethiopia. CIMMYT: Addis Ababa, Ethiopia.
33. MBARC, 2014. Meteorological data of Bako area for 1960-2014. Bako, Oromia, Ethiopia.
34. Mesfin Abebe, 1998. Nature and Management of Ethiopian Soils. Haramaya University of Agriculture, Ethiopia.
35. Tolera Abera, Dagne wegary, Tolessa Debele, Ernest Semu and Hae Koo Kim, 2016. Pedological characterization, fertility status and classification of some typical soils of Bako-Tibe and Toke Kutaye districts of western Showa, Ethiopia. Ethiopian Journal of Applied Science, 7: 49-67.
36. Duncan, D.B., 1955. Multiple range and multiple F tests. Biometrics, 11: 1-42.
37. Teboh, J.M., B.S. Tubana, T.K. Udeigwe, Y.Y. Emendack and J. Lofton, 2012. Applicability of ground-based remote sensors for crop management in sub-sharan Africa. Journal of Agricultural Science, 4: 175-188.
38. Tolera Abera, Dagne wegary and Hae Koo Kim, 2020. In-season nitrogen determination for quality protein maize using Normalized difference vegetation index on-farmers field around Toke Kutaye, Oromia region, Western Ethiopia. World Journal of Agricultural Science, 16: 180-194.
39. Govaerts, D.B., 2007. Conservation agriculture, a sustainable production alternative for the (sub) tropical highlands: Toward an integrated evaluation of the system. Ph.D. Thesis, Katholieke Universiteit Leuven.
40. Tittonell, P., B. Vanlauwe and M. Corbeels, 2008. Yield gaps, nutrient use efficiencies and response to fertilizers by maize across heterogeneous smallholder farms of western Kenya. Journal of Plant and Soil, 313: 19-37.
41. Zingore, S., R.J. Delve, J. Nyamangara and K.E. Giller, 2008. Multiple benefits of manure: The key to the maintenance of soil fertility and restoration of depleted sandy soils on African smallholder farms. Journal of Nutrition Cycling Agro-ecosystem, 80: 267-282.
42. Rusinamhodzi, L., M. Corbeels, M.T. Van Wiik, M.C. Rufino, J. Nyamangara and K.E. Giller, 2011. A met-analysis of long-term effects of conservation agriculture on maize grain yield under rain-fed conditions. Agronomy for Sustainable Development, 31: 657-673.
43. Gotosa, J., J. Kodzwa, J. Nyamangara and G. Gwenzi, 2019. Effect of nitrogen fertilizer application on maize yield across agro-ecological regions and soil types in Zimbabwe. International Journal of Plant Production, https://doi.org/10.1007/s42106-019-00045-9.
44. Tittonell, P., A. Muriuki, C.J. Klapwijk, K.D. Shepherd, R. Coe and B. Vanlauwe, 2012. Soil heterogeneity and soil fertility gradients in smallholder farmers of the East African highlands. American Soil Science Society, 77: 525-538.
45. Vanlauwe, B., D. Coyne, J. Gochkowski, S. Hauser, J. Huising, C. Masso, G. Nziguheba, M. Schut and P. van Asten, 2014. Sustainable intensification and African smallholder farmer. Current Opinion in Environment Sustainability, 8: 15-22.
46. Schmidt, J.P., A.J. DeJoia, R.B. Ferguson, R.K. Taylor, R.K. Young and J.L. Havlin, 2002. Corn yield response to nitrogen at multiple in-field locations. Agronomy Journal, 94: 798-806.
47. Mack, C.J., 2006. Validation of nitrogen calibration strip technology for prescribing accurate top-dresses nitrogen fertilizer. M.Sc. Thesis, Oklahoma State University, United States.
48. Moges, S.M., 2004. Evaluation of Green, Red and Near Infrared bands for predicting winter wheat biomass, Nitrogen uptake and final grain yield. Plant Nutrition, 27: 1431-1441.
49. Mamo, M., G.L. Malzer, D.J. Mulla, D.R. Huggins and J. Strock, 2003. Spatial and temporal variation in economically optimum nitrogen rate for corn. Agronomy Journal, 95: 958-964.