American-Eurasian J. Agric. & Environ. Sci., 15 (8): 1556-1567, 2015
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2015.15.8.12766

Sensor Based In-Season Nitrogen Prediction for Quality Protein Maize Varieties on Farmers' Field around Bako-Tibe, Western Ethiopia

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Abstract: The green seeker sensor reading of normalized difference vegetation index (NDVI) is highly related with leaf N content in quality protein maize (*Zea mays*). Mean yield components of quality protein maize were significantly affected by application of nitrogen rate in 2013 and 2014 cropping seasons. Increasing N rate from 0 to 100 kg ha^{-1} increased significantly all parameters of quality protein maize varieties. Significantly a taller plant height, higher leaf area and leaf area index was recorded from 50-100 kg N ha^{-1} than other treatments. Higher correlation between NDVI reading and leaf area were observed, with correlation coefficients of 0.46 and 0.47 at V4 and V6 growth stage in 2013 cropping season resulted in a good correlation between NDVI and leaf area. N application rates produced significantly higher increase up to 50-100 kg ha^{-1} and small increase after suggesting that the rate supplied sufficient N for maximum yield of maize. Significantly higher mean grain yield of quality maize varieties (AMH760Q and BH-545) was obtained between 50-100 kg N ha^{-1} in both cropping seasons. Better correlation coefficients of 0.36 and 0.60 in 2013 and 2014 cropping season between INSEY and mean grain yields of maize were observed, indicating that predicating grain yield with In Season Estimation of Yield of quality protein maize. The Normalized Difference Vegetative Index (NDVI) reading at V4 and V6 have 5 % and 1% positive meaningful correlation with grain yield (r=0.72 and 0.65), indicating, Normalized Difference Vegetative Index reading at V4 and V6 put positive impression in grain yield of QPM. In conclusion based on promising results validation of nitrogen rate for side dressing and N use efficiency of QPM varieties (AMH760Q and BH-545) production in the area is needed.

Key words: QPM · NDVI · INSEY · Nitrogen · Maize

INTRODUCTION

Nitrogen is an essential element and important constituent of many biomolecules in plants and low N is a limiting factor to high yields in a variety of agricultural systems [1]. Increased crop productivity has been associated with a 20-fold increase in the global use of N fertilizer use during the past five decades [2] and this is expected to increase at least 3-fold by 2050 [3]. Nitrogen (N) is an essential plant nutrient and is the most yield limiting factor in major hybrid maize production in Western Ethiopia. Pasuquin *et al.* [4] reported the total fertilizer N requirement is estimated from the expected grain yield response to fertilizer N and an expected AEN, with the assumption that a greater AEN can be achieved at higher yield responses. Currently, sky-rocketed prices of synthetic fertilizer have made it difficult for smallholder farmers to use inorganic nitrogen for crop production. Carranca [5] reported crops are often fertilized with large amounts of N fertilizer, but only a small fraction of this fertilizer (roughly 5% to 50%, is taken up by the plants. Furthermore, not all the nitrogen applied is taken up by

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the crop, since N can be lost by volatilization, gaseous plant emission, surface soil runoff, leaching and denitrification [6, 7]. N management for corn can be improved by applying a portion of the total N during the growing season, allowing for adjustments which are responsive to actual field conditions [8]. Sensors that estimate normalized difference vegetative index (NDVI) can increase nitrogen use efficiency and help meet the expected increased food demand. Green Seeker optical sensor technology enables you to measure, in real time, a crop's nitrogen levels and variably apply the "prescribed' nitrogen requirements. Li *et al.* [9], Raun *et al.* [10] and Zillmann *et al.* [11] 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 [12]. Li [9]; and Tubaña *et al.* [13] 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. Preseason blanket fertilizer recommendation of nitrogen fertilizer application rates for corn based on differences in soil and prior yields have been shown to be unreliable. While, yield potential and soil differences are important, many other factors such as rainfall and nitrogen leaching affects N loss and availability. Loss of fertilizer N results from gaseous plant emission, soil denitrification, surface runoff, volatilization and leaching [7]. Alleviating fertilizer N losses in agriculture can help farmers to apply the needed amount and reduce the environmental pollution. Raun and Johnson [7] reported increased cereal NUE is a systems approach is implemented that uses varieties with high harvest index, incorporated NH_4–N fertilizer, application of prescribed rates consistent with in field variability using sensor based systems within production fields, low N rates applied at flowering and forage production systems. Filella *et al.* [14] proposed the use of remote sensing to determine the N status of crops and thus improving the accuracy of fertilizer N. The benefits of using the optical sensor system in agriculture, reaffirming that the development of this technology can be very useful in detecting plant N status and making fertilizer recommendations [15].

Technologies which help producers better manage N fertilizer and to achieve maximum production with minimal inputs is for most importance. The Green Seeker crop sensor is measurement device that can be used to assess the health or vigor of a crop. It can be used to make non-subjective decisions regarding the amount of fertilizer to be applied to a crop, resulting in a more efficient use of fertilizer a benefit to both a farmer's bottom line and the environment. Better N management not only helps producers get more value for their N investment, but also reduces the risk of environmental pollution. Therefore the objective was to determine sensor based in-season nitrogen prediction and recommend for side dressing of quality protein maize varieties (AMH760Q and BH-545) on farmers' field around Bako-Tibe, western Ethiopia.

MATERIALS AND METHODS

The experiment was conducted on seven farmers' fields in Bako Tibe district of west Shewa Zone of Oromia national Regional state in the main season of 2013 and 2014 (Fig. 1). The areas lie between 8'59'31"N to 9'01'16 ''N latitude and 37'13'29 E to 37°21'''E longitude and at altitude range of 1727 to 1778 meter above sea level. Mean annual rainfall is 1265 to 1293 mm with unimodal distribution [16, 17]. The experimental areas are characterized by warm and humid climate with mean minimum, mean maximum and average air temperatures of 14, 28.5 and 21.2 to 13.4, 28.49 and 20.95$°_C$, respectively [16, 17]. The soil type is brown clay loam Nitisols [18]; and Alfisol [19]. The experiment was laid out in randomized complete block design with three replications and plot area was 5.1m x 4.5m. Six and eight rates of nitrogen (0, 10, 25, 50, 100 and 150 N kg ha^{-1}) and (0, 10, 25, 50, 75, 100,125 and 150 N kg ha^{-1}) in 2013 and 2014 cropping season were used for one QPM hybrid (Webii or AMH-760Q and BH-545) in 2013 and 2014 cropping season. The nitrogen rates and maize varieties were changed based on yield 2013 cropping season. The hybrid was planted in rows spaced at 75 cm x 25 cm and 75 cm X 30 cm in 2013 and 2014 cropping season. The nitrogen rates were applied at planting. One hundred kg ha^{-1} of Triple super phosphate (TSP) 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.

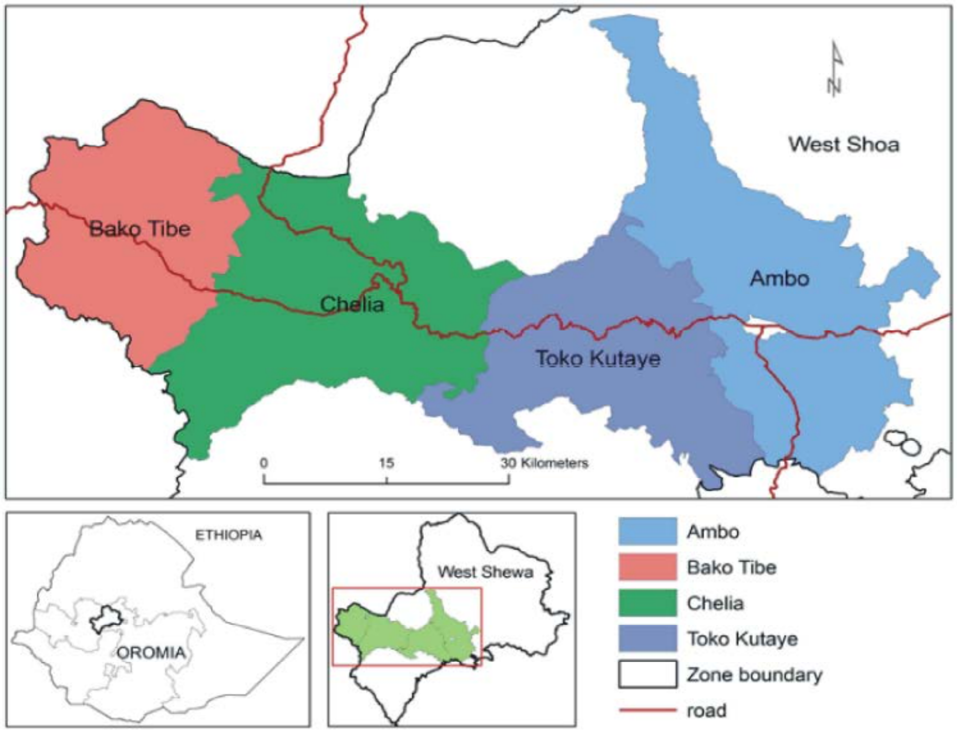

Fig. 1: Study district in West Shewa Zone of Oromia, Ethiopia

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 [10] and is therefore an important determinant of final grain yield. Growth degree day (GDD) = (T maximm + T minimum/2)-base temperature for maize). The base temperature for maize is 10°C. The collected data were analyzed using [20]. Mean separation was done using least significance difference (LSD) at 5 % probability level [21].

RESULTS AND DISCUSSION

Yield Components of Maize: The mean yield components of quality protein maize were significantly affected by application of nitrogen rate in 2013 and 2014 cropping season, except number of leaves plant^{-1}, thousand grains weight and harvest index of maize which was non-significant in 2014 (Tables 1 and 2). Significantly higher increase of mean yield components of quality protein maize parameters were obtained up to 50 kg N ha^{-1} and slight increase up to 100 kg N ha^{-1} then very minimum increase. Increasing N rate from 0 to 100 kg ha^{-1} increased significantly all parameters of quality protein maize varieties (Tables 1 and 2). Significantly a taller plant height, higher leaf area and leaf area index was recorded from 50-100 kg N ha-1 than other treatments. Similarly Liu and Wiatrak [22] found significantly taller plants height was recorded from treatments with 135 kg N ha^{-1} than treatments with 0 or 45 kg N ha^{-1}. All yield components of quality protein maize varieties (AMH760Q and BH-545) were obtained between 50-100 kg N ha^{-1} in 2013 and 2014 cropping season. There was correlation between NDVI reading and leaf area of quality protein maize (Fig. 2). Higher correlation between NDVI reading and leaf area were observed, with correlation coefficients of 0.46 and 0.47 at V4 and V6 growth stage in 2013 cropping season resulted in a good correlation between NDVI and leaf area. 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 vegetative growth of maize.

Grain Yield of Maize: Mean grain yield of maize was significantly increased by applied N fertilizer in all farms in both years (Tables 3 and 4) and (Figs. 3 and 4). Yields were highest in 2014 as compared to 2013 cropping season which might be due to maize variety used difference in both years. N application rates produced

Table 1: Effects of nitrogen rate on plant height, leaf area, leaf area index, dry biomass, harvesting index and thousand weight of quality protein maize (AMH760Q) on farmers' field around Bako Tibe, western Ethiopia in 2013 cropping season

N kg ha^{-1}	Plant height (cm)	Leaf area (cm)	Leaf area index	Dry biomass (kg ha^{-1})	Harvest index (%)	Thousand grains 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

Table 2: Effects of Nitrogen rate on mean number of leaf plant, leaf area, leaf area index plant height, thousand seed weight, dry biomass and harvest index of quality protein maize (BHQP-545) on farmers' field in Bako-Tibe districts, western Ethiopia in 2014 cropping season

N kg ha^{-1}	Number of leaves plant^{-1}	Leaf area (cm)	Leaf area index	Plant height (cm)	Thousand grains weight (g)	Dry biomass (kg ha^{-1})	Harvest index (%)
0	18	6304	2.82	263	290	17232	28.55
10	19	6866	3.05	267	287	19765	27.18
25	18	6917	3.07	277	287	23122	25.68
50	19	7864	3.50	295	286	24455	26.64
75	19	8405	3.74	288	291	25626	27.33
100	19	8347	3.71	297	287	26391	28.13
125	18	8581	3.81	292	305	28814	26.86
150	19	8735	3.88	292	292	28158	27.26
LSD (%)	NS	728.63	0.3241	12.086	NS	3601.3	NS
CV (%)	8.89	12.98	12.98	5.88	9.48	20.56	21.33

NS= Non-significant difference at 5 % probability level

Table 3: Effects of nitrogen rate on mean grain yield of quality protein maize (AMH760Q) on farmers' field around Bako-Tibe district, western Ethiopia.

	Mean grain yield (kg ha^{-1})							
N kg ha^{-1}	Farm-1	Farm-2	Farm-3	Farm-4	Farm-5	Farm-6	Farm-7	Mean
0	3904	1637	1042	2165	2219	2077	2356	2200
10	4693	2064	2150	2851	2716	2656	2872	2857
25	5224	2518	3271	3753	3221	3480	3485	3564
50	5535	2916	4456	4652	3657	4218	4088	4217
100	5787	3276	5422	5415	4140	4753	4699	4785
150	6028	3578	6210	5947	4534	5150	5144	5227
LSD (5%)	0.0468	147.35	214.52	251.93	128.98	234.38	146.86	64.475
CV (%)	2.17	3.04	3.14	3.35	2.076	3.44	2.14	2.76

Farm-1-6= farmers name (Takele Uluma, Adisu Fufa, Adisu Likessa, Mulatu Shuker, Shuker Gemechu, Tesfaye Tsagaye and Gutu Tolera)

Table 4: Effects of nitrogen rate on grain yield and thousand seed weight of quality protein maize (BHQP-545) on farmers' field in Bako-Tibe districts, western Ethiopia in 2014 cropping season

	Grain yield (kg ha^{-1})					
N kg ha^{-1}	Farm-1	Farm-2	Farm-3	Farm-4	Farm-5	Mean
0	4322	2213	5249	6158	4890	4566
10	5199	3334	5596	6578	5070	5155
25	5273	4612	6562	6916	5449	5762
50	5606	6176	6604	7680	5860	6385
75	6588	6200	6690	8154	5905	6707
100	6747	6678	6890	8177	6275	6953
125	6854	6920	7098	8474	6290	7127
150	7422	7205	7612	8798	6594	7526
LSD (%)	1767.1	1126.5	1852.6	1684.7	1441.8	676.93
CV (%)	16.81	11.87	16.18	12.63	14.22	14.9

Farm1-5= farmers name (Bekele , Woyessa adugna, Kisa Dhaba, Shugt Aboma and Fekadu)

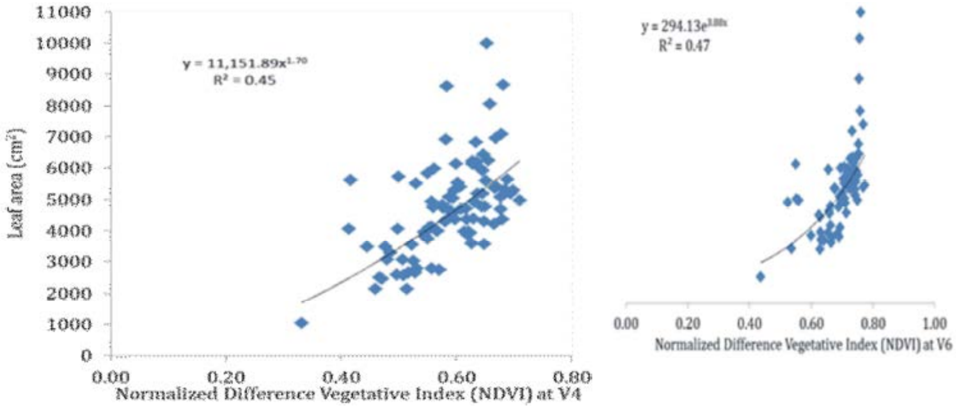

Fig. 2: Leaf area Vs. Normalized Difference Vegetative index of maize at V4 and V6 growth stage in 2013 cropping season, western Ethiopia

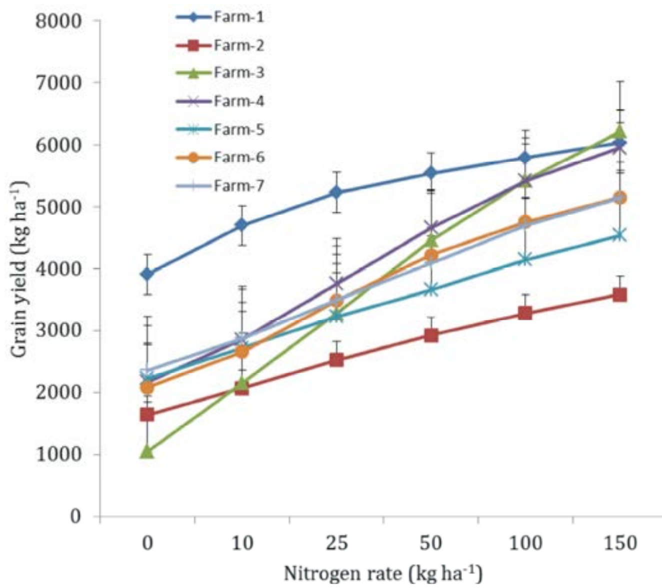

Fig. 3: Grain yield of maize vs. applied nitrogen rate on farmers' field in 2013 cropping season at Bako Tibe, western Ethiopia

significantly higher increase up to 50-100 kg ha^{-1} and small increase after suggesting that the 50-100 kg ha^{-1} rate supplied sufficient N for maximum yield of maize. Similarly Torbert *et al.* [23] reported that grain yield was increased with increasing N fertilizer up to 168 kg N ha^{-1} in wet years. All applied N rates yielded significantly more than the check (0 kg ha^{-1}). Yields increment produced in sites year one were similar to those in sites-year two between 50-100 kg N ha^{-1} rates. This again suggests that the N sufficiency level was reached at the 50-100 kg ha^{-1} rate. The mean grain yield of maize was varied among farms in both years. This might be due to variations among farmers field in soil fertility status and management practices applied. Similarly Raun *et al.* [24] reported indigenous soil N across the landscape can vary several-fold, resulting in very different N recommendations depending on the location within the field. The heterogeneity of smallholder farmers field were contributed much in yield variations of quality protein maize with similar nitrogen rate application in the soil during planting. A highly variable amount of N was required to bring any given subplot of corn within a farmer's field to maximum yield [25]. Similarly Vanlauwe *et al.* [26] found house-hold typologies based on resource endowments are useful for exploring and designing appropriate technologies congruent with those endowments. They further stated within farms variability caused by the different levels of land use intensity and the ability of farmers to apply inputs (crop residues, manure, refuse, fertilizer) to some fields (homestead), yet

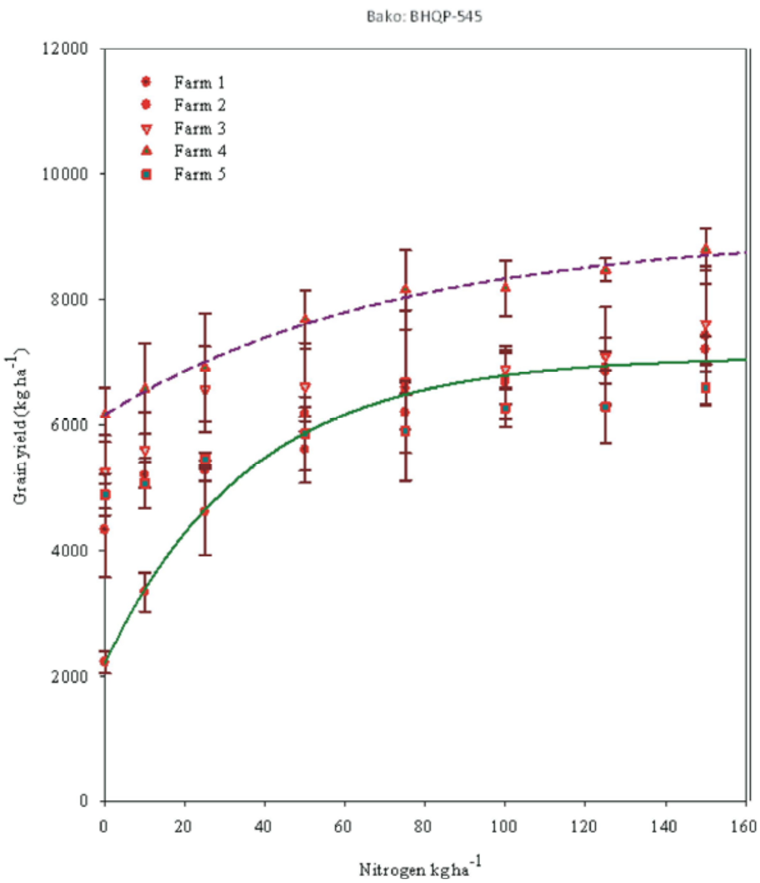

Fig. 4: Mean grain yield vs. nitrogen rate on farmers' field around Bako Tibe in 2014 cropping season, western Ethiopia

exploiting others (distant fields). Differences in soil variability between farms that vary in resource endowment are attributable to differential soil management between farms and fields over time [27]. Wibawa *et al.* [28]; and Penny [29] reported within-field yield variation is typically attributed to variability in soil texture, changes in landscape position, cropping history, soil physical and chemical properties and nutrient availability across fields. This indeed the need site based management nitrogen for maize production by maintain maize production levels, while reducing nitrogen input applied using sensor based N management. The NDVI handheld sensor is therefore an interesting tool in order to monitor efficiently and in real time crop growth under different management systems [12]. Similarly Kanke *et al.* [15] using the optical sensor system in agriculture can be very useful in detecting plant N status and making fertilizer recommendations within smallholder farmers field. Therefore the NDVI measurements can be used for crop performance judgment both in time and space, giving more dynamic and immediate information than static end-of season yield results to avoid the smallholder farmers field difference. Significantly higher mean grain yield maize of quality maize varieties (AMH760Q and BH-545) was obtained between 50-100 kg N ha^{-1} in 2013 and 2014 cropping seasons. Therefore application of 50-100 kg N ha^{-1} was profitable for quality protein maize varieties around Bako-Tibe western Ethiopia.

There was correlation between INSEY and mean grain yields of maize (Figs. 5, 6 and 7). Better correlation between INSEY and mean grain yields of maize were observed, with correlation coefficients of 0.36 and 0.60 in 2013 and 2014 cropping season (Figs. 5 and 6), indicating that predicating grain yield with In Season Estimation of Yield, resulted in a good correlation between INSEY and mean grain yields of quality protein maize. INSEY was found to be correlated to grain yield [8]. Significantly higher correlation coefficients between mean grain yields with In Season Estimation of Yield were obtained in 2014 cropping season indicating better predication mean grain yield of QPM (BH-545) with right niche of production area. In 2014 cropping season correlation coefficients of 0.25 was obtained at V6 and V8 growth stages of maize (Fig. 7). It can be noted that mean grain yield peaked

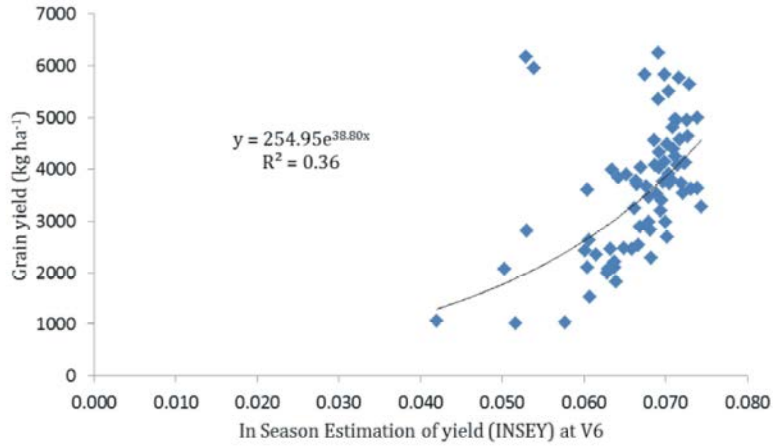

Fig. 5: Grain yield vs. In Season Estimation of Yield (INSEY) of maize in V6 growth stage of maize in 2013 cropping season at Bako Tibe, western Ethiopia

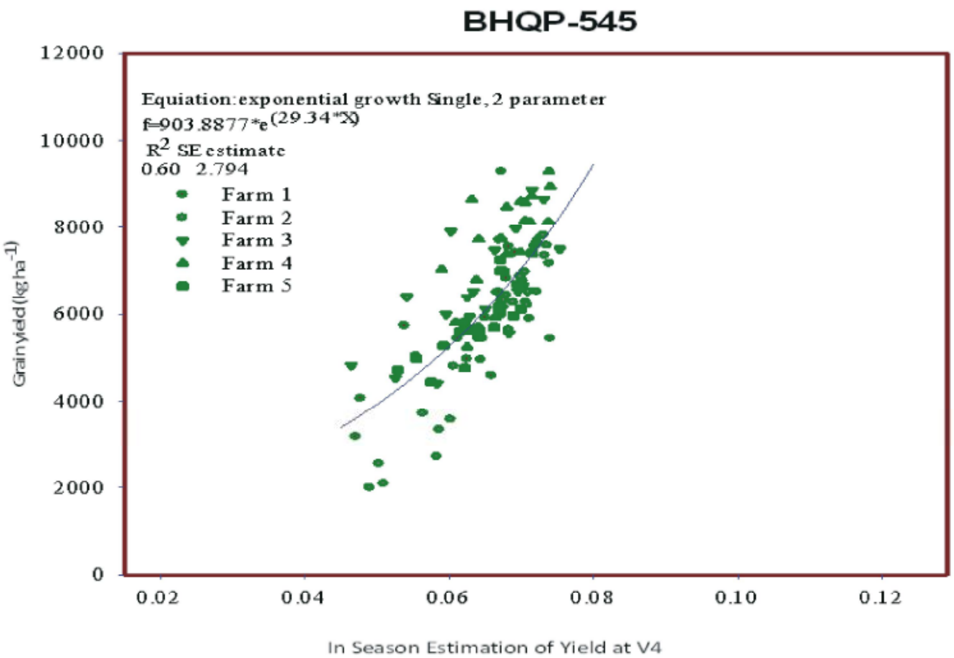

Fig. 6: Grain yield vs. In Season Estimation of Yield at V4 growth stage of maize on farmers' field at Bako Tibe in 2014 cropping season, western Ethiopia

between 50-100 kg N ha^{-1}, implying that greater NUE is achieved at 50-100 kg N ha^{-1}. Application of 50-100 kg N ha^{-1} was more responsive to maize at 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 varieties (AMH760Q and BH-545) production in the area is needed.

Interrelationships Between Growth Phenology and Yield Components of Maize: Application nitrogen rates were significantly positively associated with all growth phenology, yield and yield components of maize (Table 6). However, there were negatively significant associations between application nitrogen rates and number of dead leafs (r= -0.205) indicating application of higher nitrogen rates have directly reduced the number of dead leafs per plant^{-1}. Significantly higher positive association between application nitrogen rates and leaf area and leaf area index; between application nitrogen rates and grain yield; and between application nitrogen rates and plant height

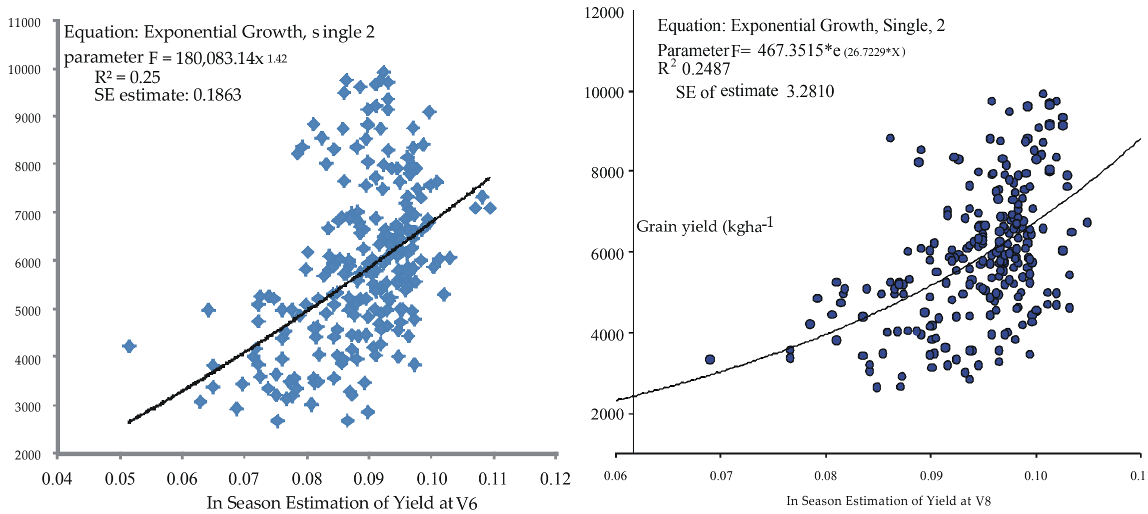

Fig. 7: Combined mean grain yield vs. In Season Estimation of Yield at V6 and V8 growth stage of maize on farmers field at Bako Tibe in 2014 cropping season, western Ethiopia

(r= 0.41, 0.43 and 0.57) were obtained indicating application of nitrogen rates directly increased leaf area, leaf area index, grain yield and plant height of quality protein maize varieties in 2013 cropping season (Table 6). Normalized difference vegetative index at V4 and V6 were showed significant positive association with plant height of quality protein maize in 2013 cropping season. This indicated that the normalized difference vegetative index measurements the higher will be the plant height of quality protein maize vice versa. Normalized difference vegetative index measurements with in season estimation of yield at 0.1 and 0.5 have positive meaningful perfect correlation it means that if the normalized difference vegetative index measurements increase, the In Season Estimation of Yield will be increase for quality protein maize in 2013 cropping season. Plant height and dry biomass of with in grain yield of quality protein maize at 0.1 and 0.5 have positive meaningful correlation (r= 0.55 and 0.69), indicating the higher plant height and dry biomass, the higher will be grain yield of quality protein maize in 2013 cropping season.

The character of leaf length and leaf width with quality protein maize leaf area plant^{-1} and leaf area index plant^{-1}, respectively, in possibility levels have 5 % and 1% positive meaningful correlation (r=0.76 and 0.82; and 0.73 and 0.81), it means that, if the leaf length and leaf width is further, the maize leaf area and leaf area index will be increased. The leaf area with leaf area index of quality protein maize, respectively in possibility levels have 5% and 1% positive meaningful perfect correlation (r=0.99). This indicated that the higher the leaf area the higher will be the leaf area index and *vice versa*. Harvest index was showed significantly positive association with mean grain yield of maize (r = 0.53), it means that if the grain yield was increased, the harvest index will be increase (Table 6). The calculated In Season Estimation yield at V4 with In Season Estimation yield at V6 in possibility level is 0.5 and 0.1 meaningful positive association (r=0.75), it means that, the higher In Season Estimation yield at V4, put positive increase on In Season Estimation yield at V6.

In 2014 cropping season application nitrogen with growth phenology, yield and yield components of quality protein maize, respectively in possibility levels have 0.1 and 0.5 positive meaningful correlation between (r=0.46 to 0.81) except thousand seed weight and harvest index which were non-significant and negative association (Table 7). It means that if the application of nitrogen rates increase, the growth phenology, yield and yield components of quality protein maize will be increased. Significantly higher positive association (r= 0.75 and 0.81) was obtained between application nitrogen and Normalized Difference Vegetative Index and In Season Estimation of Yield at V4 and V6 growth stage of quality protein maize, it means that, if the application of nitrogen rates is further, the Normalized Difference Vegetative Index and In Season Estimation of Yield at V4 and V6 growth stage of quality protein maize will be increased. Number of leaves plant^{-1} was negatively associated with leaf area (r= -0.078), leaf area index (r= -0.076) and harvest index (r= -0.26) of quality protein maize but positively associated with other parameters of maize. This may be attributed to the fact that increased in number of leaves plant^{-1} and might have directly reduced leaf area, leaf area index and harvest index (Table 7).

Table 5: Relationship between various phonological growth, yield and yield components of maize in Bako Tibe, 2013 cropping season, western Ethiopia

	N	NDVIF	NDVIS	DL	NL	PH	GY	TW	LL	LW	LA	LAI	DB	HI	INSEYS	INSEYS
N		0.217*	0.316*	-0.205*	0.137	0.573*	0.433*	0.330*	0.225*	0.336*	0.408*	0.412*	0.367*	0.224*	0.217*	0.316*
NDVIF			0.751*	0.179**	0.104	0.607*	0.302*	0.039	0.451*	0.507*	0.477*	0.423*	0.251*	0.164	1*	0.751*
NDVIS				0.079*	0.126*	0.660*	0.452*	0.224*	0.442*	0.501*	0.486*	0.447*	0.344*	0.274*	0.751*	1*
DL					0.122	-0.106	-0.341*	-0.187**	0.067	-0.058	-0.047	-0.088	-0.173**	-0.217*	0.179**	0.079
NL						0.183	0.111	-0.019	0.072	0.124	0.146	0.136	0.058	0.147	0.105	0.126
PH							0.551*	0.3389*	0.371*	0.487*	0.521*	0.495*	0.447*	0.308*	0.607*	0.660*
GY								0.425*	0.306*	0.363*	0.400*	0.395*	0.691*	0.530*	0.302*	0.452*
TW									0.199**	0.182*	0.256*	0.261*	0.294*	0.308*	0.039	0.224*
LL										0.444*	0.755*	0.731*	0.336*	0.054	0.451*	0.442*
LW											0.820*	0.810*	0.362*	0.120	0.507*	0.501*
LA												0.995*	0.361*	0.155	0.477*	0.486*
LAI													0.354*	0.154	0.423*	0447*
DB														0.182**	0.251*	0.344*
HI															0.164	0.274*
INSEYF															0.751*	
INSEYS																

N= Nitrogen rate, NDVIF= Normalized difference vegetative index at V4, NDVIS= Normalized difference vegetative index at V6, DL= number of dead leaf, NL= number of leaf plant-1, PH= Plant height, GY= grain yield, TW= thousand seed weight, LL= Leaf length, LW= Leaf width, LA= Leaf area plant-1, LAI= Leaf area index plant-1, DB= Dry biomass, HI= Harvest index, INSEYS= In season Estimation of Yield at V4, INSEYS=In season Estimation of Yield at V6, *and**= significant at 1 and 5 % probability level.

Table 6: Relationship between various phonological growth, yield and yield components of maize in Bako Tibe, 2014 cropping season, western Ethiopia.

	N	LN	LA	LAI	PH	NDVIF	NDVIS	GY	TW	DB	HI	INSEYF	INSEYS
N		0.060*	0.609*	0.606*	0.461*	0.809*	0.752*	0.621*	0.112	0.483*	-0.011	0.809*	0.753*
LN			-0.078	-0.076	0.379*	0.162	0.169	0.186**	0.036	0.298*	-0.264	0.163	0.169
LA				0.999*	0.396*	0.555*	0.503*	0.388*	0.001	0.316*	0.019	0.555*	0.503*
LAI					0.397*	0.556*	0.500*	0.388*	0.001	0.315*	0.019	0.556*	0.500*
PH						0.538*	0.507*	0.409*	0.031	0.361*	-0.076	0.538*	0.507*
NDVIF							0.855*	0.721*	0.056	0.569*	-0.072	1*	0.855*
NDVIS								0.648*	0.109	0.491*	-0.021	0.855*	1*
GY									0.035	0.668*	0.067	0.721*	0.648*
TW										0.090	-0.091	0.056	0.109
DB											-0.636	0.569	0.491
HI												-0.072	-0.021
INSEYF													0.855*
INSEYS													

N= Nitrogen rate, NL= number of leaf plant-1, LA= Leaf area plant-1, LAI= Leaf area index plant-1 , PH= Plant height, NDVIF= Normalized difference vegetative index at V4, NDVIS= Normalized difference vegetative index at V6, GY= grain yield, TW= thousand seed weight, , DB= Dry biomass, HI= Harvest index, INSEYS= In season Estimation of Yield at V4, INSEYS=In season Estimation of Yield at V6, *and**= significant at 1 and 5 % probability level.

Table 7: Rainfall, temperature and relative humidity data for the Bako Agricultural Research Center

	Rainfall (mm)												
Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
Mean	6.83	12.70	40.07	57.63	138.87	265.36	261.75	251.46	132.88	60.18	25.66	12.22	1266
	Temperature (0c)												Mean
Minimum	11.48	11.60	13.42	13.79	14.63	14.49	14.67	14.77	14.39	13.81	12.72	11.02	13.40
Maximum	30.37	31.84	31.92	31.57	29.50	25.83	24.65	24.43	25.30	27.75	28.91	29.84	28.49
Mean	20.93	21.72	22.67	22.68	22.06	20.16	19.66	19.60	19.85	20.78	20.81	20.43	20.95
Relative humidity (%)	49	46	47	51	53	65	64	62	64	55	53	50	54.80

Table 8: Rainfall and temperature data obtained from nearby weather stations.

	Rainfall (mm)												
Years	J	F	M	A	M	J	J	A	S	O	N	D	Total
Mean	13.8	7.3	33.2	59.0	127.6	212.5	241.3	301.1	207.6	48.9	36.6	3.9	1292.8
	Temperature (°C)												Mean
Minimum	12.3	13.8	14.8	15.4	15.3	15.2	14.6	14.7	14.3	12.6	11.7	12.5	14.0
Maximum	30.5	32.0	31.7	31.2	29.0	25.6	23.9	24.3	25.8	28.0	28.9	29.1	28.5
Mean	21.4	22.9	23.2	23.3	22.2	20.4	19.3	19.5	20.0	20.3	20.3	20.8	21.2

Leaf area was revealed perfect positive association with leaf area index (r = 0.99). This indicated that the higher the leaf area the higher will be the leaf area index and *vice versa*. Leaf area and leaf area index were significant positive association with Normalized Difference Vegetative Index measurements and In Season Estimation of Yield (r= 0.50 and 0.55) at V4 and V6 growth stage of quality protein maize. This indicates the higher leaf area and leaf area index the higher will be Normalized Difference Vegetative Index measurements and In Season Estimation of Yield.

Plant height have 5 % and 1% positive meaningful correlation with Normalized Difference Vegetative Index reading and calculated In Season Estimation of Yield at V4 and V6 (r= 0.50 and 0.54). This revealed if the plant height is further, the Normalized Difference Vegetative Index reading and calculated In Season Estimation of Yield will be increased. The Normalized Difference Vegetative Index reading at V4 and V6 have 5 % and 1% positive meaningful correlation with grain yield (r=0.72 and 0.65). It means that, Normalized Difference Vegetative Index reading at V4 and V6 put positive impression in grain yield of quality protein maize. The Normalized Difference Vegetative Index reading at V4 and V6 have 5 % and 1% higher and perfect positive meaningful correlation with In Season Estimation yield grain yield (r=0.85 and 1). This indicated that the higher the Normalized Difference Vegetative Index reading at V4 and V6 the higher will be the In Season Estimation yield and *vice versa*. Mean grain yield of maize was positively associated with dry biomass maize (r = 0.67). This may be attributed to the fact that increased grain yield might have directly increased dry biomass. Significantly positive correlation coefficients were observed between dry biomass and Normalized Difference Vegetative Index reading and In Season Estimation of Yield at V4 (r= 0.57) and dry biomass and Normalized Difference Vegetative Index reading and In Season Estimation of Yield at V6 (r= 0.49). This showed the higher biomass, the higher will be Normalized Difference Vegetative Index reading and In Season Estimation of Yield. Dry biomass was non-significantly negative association with harvest index (r= -0.64). This may be attributed to the fact that higher dry biomass might have directly reduced harvest index of quality protein maize. The NDVI has been correlated to plant physiological parameters, maize yield and biomass production (Govaerts, 2007). Govaerts (2007) found the highest correlation between NDVI and final maize yield was again obtained during the reproductive phase R1. Therefore there a strong relationship was observed between NDVI, INSEY and grain yield of quality protein maize.

CONCLUSION

The mean yield components of quality protein maize were significantly affected by application of nitrogen rate in 2013 and 2014 cropping season. Higher correlation between NDVI reading and leaf area were observed, with correlation coefficients of 0.46 and 0.47 at V4 and V6 growth stage in 2013 cropping season. N application rates produced significantly higher increase up to 50-100 kg ha^{-1} and small increase after suggesting that the 50-100 kg ha^{-1} rate supplied sufficient N for maximum yield of maize. Significantly higher mean grain yield maize of quality maize varieties (AMH760Q and BH-545) was obtained between 50-100 kg N ha^{-1} in 2013 and 2014 cropping seasons. Better correlation coefficients of 0.36 and 0.60 in 2013 and 2014 cropping season between INSEY and mean grain yields of maize were observed, indicating that predicating grain yield with In Season Estimation of Yield of quality protein maize. The Normalized Difference Vegetative Index (NDVI) reading at V4 and V6 have 5 % and 1% positive meaningful correlation with grain yield (r=0.72 and 0.65). Remotely sensed NDVI green seeker can provide valuable information about in-field N variability in maize and significant linear relationships between sensor NDVI and maize grain yield have been found suggesting that an N recommendation based on NDVI could optimize N application and N use efficiency. Therefore there a strong relationship was observed between NDVI, INSEY and grain yield of quality protein maize. In conclusion based on promising result validation of nitrogen rate for side dressing and N use efficiency of quality protein maize varieties (AMH760Q and BH-545) production in the area is needed.

ACKNOWLEDGEMENTS

The authors thank International Maize and Wheat Improvement Centre (CIMMYT), Regional University Fund for Capacity Building for Agriculture (RUFORUM), International Development Research Center (IDRC) and Carnegie Corporation of New York funding the experiment. I am very grateful to Ambo Plant Protection Research Center for providing me all necessary equipment's and logistics during the research work. All the technical and field assistants of Land and Water Resources Research Process are also acknowledged for unreserved effort during executing the experiment. Holleta and Debre Zeit Agricultural Research Center, Soil and Plant Analysis Laboratory are acknowledged for their provision of laboratory service for soil. I want to thank farmers at Bako Tibe for providing me their land for field research work.

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