

## Research Article

# Effects of Varieties and Nitrogen Fertilizer on Yield and Yield Components of Maize on Farmers Field in Mid Altitude Areas of Western Ethiopia

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Yield of maize hybrids could be low when grown below optimum management practices. Use of improved varieties and optimum nitrogen fertilizer application practices are unlocking the high yielding potential of hybrids maize. With these in view, a field experiment was executed on farmers' field to determine the effect of varieties and nitrogen fertilizer rate on yield and yield components of maize in two cropping seasons. It is laid out with randomized complete block design in factorial arrangement with three replications. Five maize varieties (BH-540, BH-543, BH-661, BH-660, and BH-140) as main factor and two levels of nitrogen (55 and 110 Kg N ha<sup>-1</sup>) as subfactor were used with one maize variety (BH-543) without fertilizer as control. Leaf area and leaf area index of maize varieties were significantly affected by application of nitrogen fertilizer rates. Interaction of maize varieties with nitrogen fertilizer rates significantly affected all yield and yield components of maize. Application of half and full recommended nitrogen fertilizer produced mean grain yield advantages of 31 and 41% over control. Therefore, application of half and full recommended nitrogen fertilizer for improved maize varieties has significantly improved grain yield and recommended for maize production in midaltitude area of western Ethiopia.

## 1. Introduction

Supplying nutritious, safe, and affordable food to a growing population is one of the far most burning issues currently facing Africa to fulfill food security in the region. Increase in soil degradation, salinization of irrigated areas, migration of youth to urban areas, and climate changes are among the many risks that are negatively affecting the agricultural production potential in Africa [1]. For agricultural production to keep pace with the growing global population, the use of chemical fertilizers will continue [2]. Adesemoye et al. [2] argued achieving sustainability; proper management techniques must be designed and implemented against the pollution potential of fertilizers. Despite the release of several

high yielding maize (*Zea mays* L.) varieties to smallholder farmers and its high adoption rate, maize production levels in sub-Saharan Africa remain low [3].

Currently, the rate of N fertilizer application has increased tremendously, a trend which is expected to continue [4]. Lassaletta et al. [5] reported that only 47% of the reactive nitrogen added globally onto cropland is converted into harvested products, compared to 68% in the early 1960s, while synthetic N fertilizer input increased by a factor of 9 over the same period. Nonetheless, in cereals, less than half of the applied N is recovered in the grain [6]. The remaining N is incorporated into soil organic matter or lost from farmlands through erosion, surface runoff, leaching, and gaseous (NH<sub>3</sub>, N<sub>2</sub>O, NO, NO<sub>2</sub>, or N<sub>2</sub>) emissions from

the soil and plants [7]. Freney [8] reported that nitrogen might be lost by ammonia volatilization, during nitrification, by biological denitrification, and by chemodenitrification, leached whenever rainfall exceeds evaporation, and lost by runoff. Losses of nitrogen by denitrification can also vary widely (2% to 73% of nitrogen applied) depending on farming system and management [6, 9]. More than half of the nitrogen used for crop fertilization is currently lost into the environment [5]. Thus, increasing N fertilizer use portends grave environmental consequences that are usually long-term and are seen as significant drivers of global change [10, 11].

Recently, concerns about unbalanced use of fertilizers leading to environmental pollution have been globally expressed [12]. van der Velde et al. [13] reported that imbalances with other nutrients such as P could limit yield responses to N addition. Oosterhuis and Howard [14] reported on how to use efficient methods to reduce nutrient applications at the same time increasing or maintaining crop yield, and reducing nutrient losses and improving nutrient use efficiency are imperative. Lassaletta et al. [5] suggested that a further increase of nitrogen fertilization would result in a disproportionately low increase of crop production with further environmental alterations, unless cropping systems improve their efficiency substantially. N is the major limiting factor in agricultural production among mineral fertilizers [10, 15–17] and NUE is estimated to be far below 50% in cereal grains [6], improving that NUE is essential for improving overall productivity in maize [18]. Lassaletta et al. [5] stated that nutrient use efficiency acts as the indicator to check the ability of a crop to convert available nutrients to economic yield. Due to environmental and economic concerns with N fertilizers, improvement in nitrogen fertilizer application to maize varieties has become a desirable option for sustainable maize production. Therefore, the objective was to investigate the effects of varieties and nitrogen rate on yield and yield components of maize and recommend for producers better maize varieties with better nitrogen rate in order to increase yield and reduce environmental problems.

## 2. Materials and Methods

The experiment was conducted on six farmers' field around Bako Tibe in 2013 and 2014 cropping seasons. The area lies 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 meters above sea level, receiving mean annual rainfall of 1265 to 1293 mm with unimodal distribution [19, 20]. It has a warm humid climate with the mean minimum, maximum, and average air temperatures of 13.4, 28.49, and 20.95°C, respectively [19], to 14, 28.5, and 21.2°C [20]. The soil type is brown clay loam Alfisol [21]. The experiment was laid out in factorial combinations with complete block design in three replications. Five maize varieties from subhumid mid altitude area were used as main factors. Two levels of nitrogen (half of the recommended (55 Kg N ha<sup>-1</sup>) and recommended (110 Kg N ha<sup>-1</sup>)) were used as subfactor. One maize variety (BH-543) without fertilizer was used as control treatments. The maize varieties were BH-540, BH-543, BH-661, BH-660, and BH-140. The total treatment combinations were 11. The

plot size was 5.1 m × 4.5 m. An improved seed each variety was planted in rows spaced at 75 cm between rows and 30 cm between plants. The weighed nitrogen rate was applied half at planting and remaining half at knee height. One hundred kilogram per hectare of Triple superphosphate (TSP) was applied for all treatments uniformly during planting. All other agronomic management practices were applied as per recommendation for the variety. The necessary data were collected at right time and crop growth stage.

*2.1. Soil Sampling and Analysis.* The soil samples were before treatment application from 10 sites randomly and composited one for analysis. The collected soil analysis was prepared following standard procedures and analyzed at Holleta and Debre Zeit Agricultural Research Center Soil and Plant Analysis Laboratory. Determination of soil particle size distribution was carried out using the hydrometer method [22]. The soil pH was measured with digital pH meter potentiometrically in the supernatant suspension of 1:2.5 soils to distilled water ratio. Organic carbon was determined following wet digestion methods as described by Walkley and Black [23] whereas Kjeldahl procedure was used for the determination of total nitrogen (N) as described by Jackson [24]. The available P was measured by Bray II method [25] and available potassium (K) was measured by flame photometry. The steam distillation method was used for determination of NO<sub>3</sub><sup>-</sup>N and NH<sub>4</sub><sup>+</sup>H as described by Keeney and Nelson [26].

*2.2. Crop Parameters.* Leaf area and leaf area index at 50% tasseling and plant height and grain yield after maturity and harvesting of maize were collected at respective stage of the crop. The grain yield was harvested from the net plot (3 m × 5.1 m = 15 m<sup>2</sup>). The harvested grain yield was adjusted to 12.5% moisture level [27, 28]. The adjusted seed yield at 12.5% moisture level per plot was converted to grain yield as kilogram per hectare.

*2.3. Plant Tissue Sampling and Analysis.* The tissue of maize was collected at 50% tasseling of maize from three replications and composited to after chopping. The grain of maize was collected after harvesting of the crop. The collected tissue and grain were prepared following standard procedures and analyzed at Holleta and Debre Zite Agricultural Research Center Soil and Plant Analysis Laboratory. The maize tissues and grain were subjected to wet digestion [29]. The N content of the plant tissue was determined by Kjeldahl procedure, whereas the P content was determined colorimetrically according to Murphy and Riley [30].

The N harvest index (NHI) at maturity was calculated by Jones et al. [31] and N accumulation (kg N ha<sup>-1</sup>) in the shoots or grains was calculated by Seleiman et al. [32] and Xu et al. [33] as follows:

$$\text{N harvest index} = \frac{\text{Grain N accumulation (kg ha}^{-1}\text{)}}{\text{Total N accumulation (kg ha}^{-1}\text{)}}, \quad (1)$$

TABLE 1: Some physicochemical properties soil of farmer's field before planting maize in Bako Tibe districts, western Ethiopia.

Farms	pH	N (%)	P (ppm)	OC %	OM %	CEC (meq 100 g soil <sup>-1</sup> )	K	Na	Exch. acidity	NO <sub>3</sub> <sup>-</sup> N (ppm)	NH <sub>4</sub> <sup>+</sup> N (ppm)	Texture
F-1	4.86	0.22	5.02	2.69	4.63	21.26	0.71	1.68	0.09	43.98	trace	clay
F-2	4.63	0.22	5.43	2.53	4.35	19.7	0.13	2.4	0.17	53.05	8.84	Clay
F-3	5.45	0.23	7.52	2.77	4.76	21.32	0.85	2.4	0.17	41.13	8.81	clay
F-4	5.4	0.17	6.27	2.07	3.56	38.12	0.85	1.68	0.08	30.17	6.03	clay
F-5	4.71	0.2	4.18	2.46	4.23	22.74	0.99	2.16	0.24	66.38	9.05	clay
F-6	5.44	0.18	5.67	2.22	3.82	36.5	0.56	1.44	0.12	41.13	11.75	clay

Farm 1–6 = farmers' names (Takele Uluma, Adisu Fufa, Adisu Likessa, Mulatu shukar, Tesfaye Tsagaye, and Gutu Tolera).

where the total N accumulation includes all N that accumulated in leaves, stem, shank, cobs, and husk organs in addition to the grain.

$$\begin{aligned} & \text{Shoot N accumulation (kg ha}^{-1}\text{)} \\ &= \frac{\text{shoot N content (g kg}^{-1}\text{)} \times \text{shoot DM (kg ha}^{-1}\text{)}}{1000} \end{aligned} \quad (2)$$

$$\begin{aligned} & \text{Grain N accumulation (kg ha}^{-1}\text{)} \\ &= \frac{\text{grain N content (g kg}^{-1}\text{)} \times \text{grain DM (kg ha}^{-1}\text{)}}{1000} \end{aligned}$$

The data analyses for agronomic data were carried out using statistical packages and procedures of SAS computer software [34]. Mean separation was done using least significance difference (LSD) procedure at 5% probability level [35].

**2.4. Economic Analysis.** Partial budget and marginal rate of return analysis and maize grain yield were valued at an average open market price of EB 375 per 100 kg for the last 5 years. Labour cost for field operation was EB 21 per man-day. The yield was adjusted down by 10% to reflect actual production conditions [36]. The cost of fertilizer (urea and DAP) was EB 1275 and 1500 per 100 kg with current market price.

### 3. Result and Discussion

**3.1. Some Soil Chemical and Physical Properties of the Study Area.** The result of soil chemical and physical properties of different farm field's soil has been indicated in Table 1. All the six-farm soil was clay in textural classes. The soil pH in H<sub>2</sub>O was ranged from 4.63 to 5.45 found in very strongly acidic to moderately acidic [37, 38].

Total N and P were ranged from 0.17 to 0.23%; and 4.18 to 7.52 ppm (Table 1). The total N concentrations for all six farms were found in very low, medium to high range [37–39]. The extractable phosphorus concentration was found in low to medium range [37, 38]. The different farm fields were needs different rates of nitrogen and phosphorous fertilizer management for maize. The organic carbon and organic matter concentrations were ranged from 2.07 to 2.77 and 3.56 to 4.76%, which is found low to medium range [37, 38]. The

CEC concentration was ranged from 19.7 to 38.5 cmol<sup>+</sup>kg<sup>-1</sup> and found in medium to high range [37, 38]. Horneck et al. [40] soils with high clay and/or organic matter content have high CEC. The different farm soil was varied in nutrient holding capacity and organic matter contents based on CEC of the soil. Therefore, the six-farm soil required different soil fertility management practices for crop productions. The NO<sub>3</sub><sup>-</sup>N concentration of the six-farm soil was ranged between 30.17 and 66.38 ppm (Table 1), found in high to very high range [41, 42]; excessive range [43]. The NH<sub>4</sub><sup>+</sup>N concentration of the soil was ranged from trace to 11.75 ppm (Table 1) found in optimum range [40]. The NO<sub>3</sub><sup>-</sup>N and NH<sub>4</sub><sup>+</sup>N concentrations of the soils were found in optimum range for sustainable maize production.

**3.2. Mean Leaf Area and Leaf Area Index of Maize.** Mean leaf area and leaf area index of maize were significantly affected by use of varieties in three farms (Table 2), indicating variations of leaf size of different varieties of maize among farmers' field. Higher leaf area and leaf area index of 7246 cm<sup>2</sup> and 3.86 followed by 7112 cm<sup>2</sup> and 3.79 were recorded from BH-661 followed by BH-660. This indicates that the two varieties were performed better than other varieties in leaf width and length and also capture more solar radiation to produce more carbohydrates. All varieties produced higher leaf area and leaf area index under nitrogen applications indicating significant role of nitrogen for leaf development of maize varieties. Consider that optimum nitrogen application was very crucial for maize production to capture light to produce more photosynthesis. Applications of different rates of nitrogen were nonsignificantly affected mean leaf area and leaf area index maize at individual farms (Table 2). Combined mean of leaf area and leaf area index were significantly affected by rates applied nitrogen. Significantly higher mean leaf area and leaf area index of 7156 cm<sup>2</sup> and 3.82 was recorded from application of recommended (110 kg N ha<sup>-1</sup>) applied compared to half recommended. Leaf area and leaf area index advantage of 5.73 and 5.82% was recorded from full recommended nitrogen applied compared to half recommended N. This indicates that application of nitrogen was contributed to higher leaf size to capture light for photosynthesis.

Interaction of maize varieties by nitrogen rates significantly affected mean leaf area and leaf area index of maize varieties (Table 3). Significantly higher mean leaf area

TABLE 2: Effects of varieties and nitrogen rate on mean leaf area and leaf area index of maize on farmers' field around Bako Tibe, western Ethiopia.

Varieties	Leaf area (cm <sup>2</sup> )												Leaf area index							
	2013			2014			2013			2014			2013		2014		Mean			
	F-1	F-2	F-3	F-4	F-5	F-6	F-1	F-2	F-3	F-4	F-5	F-6	F-1	F-2	F-3	F-4		F-5	F-6	
BH-540	6513	5243	6644	7746	6360	7734	6707	3.47	2.80	3.54	4.13	3.39	3.39	3.39	3.54	4.13	3.39	3.39	4.13	3.58
BH-543	7009	6347	7402	6876	6900	7193	6955	3.74	3.39	3.95	3.67	3.68	3.68	3.68	3.95	3.67	3.68	3.68	3.84	3.71
BH-661	7488	6489	7385	7342	7969	6800	7246	3.99	3.46	3.94	3.92	4.25	4.25	4.25	3.94	3.92	4.25	4.25	3.63	3.86
BH-660	7793	5935	7756	6171	6897	8122	7112	4.16	3.17	4.14	3.29	3.68	3.68	3.68	4.14	3.29	3.68	3.68	4.33	3.79
BH-140	7217	6965	6944	6162	6834	6630	6792	3.85	3.71	3.70	3.29	3.71	3.71	3.71	3.70	3.29	3.71	3.71	3.54	3.62
BH-543	6026	6390	6655	4837	6594	4315	5803	3.21	3.41	3.55	2.58	5803	5803	3.41	3.55	2.58	3.52	3.52	2.30	3.09
LSD (5%)	1128	1418.2	NS	NS	81797	NS	985.56	0.602	0.7564	NS	NS	0.602	0.7564	0.7564	NS	NS	0.4363	0.4363	NS	0.5257
CV (%)	12.91	18.87	14.53	18.64	9.64	25.61	16.48	12.91	18.87	14.53	18.64	16.48	16.48	18.87	14.53	18.64	9.64	9.64	25.61	16.48
N (kg ha <sup>-1</sup> )																				
50% RR	7234	6248	6922	6486	7094	6624	6768	3.86	3.33	3.69	3.46	6768	6768	3.33	3.69	3.46	3.78	3.78	3.53	3.61
100% RR	7174	6144	7530	7232	6890	7968	7156	3.83	3.28	4.02	3.86	7156	7156	3.28	4.02	3.86	3.67	3.67	4.25	3.82
Control	6026	6390	6655	4837	6594	4315	5803	3.21	3.41	3.55	2.58	5803	5803	3.41	3.55	2.58	3.52	3.52	2.30	3.09
LSD (5%)	NS	NS	NS	NS	NS	NS	383.05	NS	NS	NS	NS	383.05	383.05	NS	NS	NS	NS	NS	NS	0.2043
CV (%)	12.91	18.87	14.53	15.74	9.64	25.61	16.48	12.91	18.87	14.53	15.74	16.48	16.48	18.87	14.53	15.74	9.64	9.64	25.61	16.48

F-1-F6 = farmers' names (Takele Uluma, Adisu Fufa, Adisu Likessa, Mulatu Shukar, Tesfaye Tsagaye, and Gutu Tolera), NS = nonsignificant difference at 5% probability level; 50% and 100% RR = half and full doses (55 and 110 kg N ha<sup>-1</sup>) recommended for maize.

TABLE 3: Combination effects of varieties and nitrogen rate on mean leaf area and leaf area index of maize on farmers' field around Bako Tibe, western Ethiopia.

Varieties	Leaf area (cm <sup>2</sup> )												Leaf area index					
	2013			2014			2013			2014			2013			2014		
	F-1	F-2	F-3	F-4	F-5	F-6	F-1	F-2	F-3	F-4	F-5	F-6	F-1	F-2	F-3	F-4	F-5	F-6
BH-540 (50% RR)	6524	5245	6582	8447	5920	5880	3.48	2.80	3.51	4.50	3.16	3.14	3.48	2.80	3.51	4.50	3.16	3.14
BH-540 (100% RR)	6502	5241	6706	7046	6800	9589	3.47	2.80	3.58	3.76	3.63	5.11	3.47	2.80	3.58	3.76	3.63	5.11
BH-543 (50% RR)	6746	5223	7457	6851	7444	6589	3.60	2.79	3.98	3.65	3.97	3.51	3.60	2.79	3.98	3.65	3.97	3.51
BH-543 (100% RR)	7272	7472	7347	6901	6355	7797	3.88	3.98	3.92	3.68	3.39	4.16	3.88	3.98	3.92	3.68	3.39	4.16
BH-661 (50% RR)	7314	7096	7061	6769	8145	7188	3.90	3.78	3.77	3.61	4.34	3.83	3.90	3.78	3.77	3.61	4.34	3.83
BH-661 (100% RR)	7661	5882	7709	7915	7794	6412	4.09	3.14	4.11	4.22	4.16	3.42	4.09	3.14	4.11	4.22	4.16	3.42
BH-660 (50% RR)	8205	6181	7423	5494	7198	7348	4.38	3.30	3.96	2.93	3.84	3.92	4.38	3.30	3.96	2.93	3.84	3.92
BH-660 (100% RR)	7382	5690	8088	6847	6597	8897	3.94	3.03	4.31	3.65	3.52	4.74	3.94	3.03	4.31	3.65	3.52	4.74
BH-140 (50% RR)	7381	7496	6088	4872	6763	6118	3.94	4.00	3.25	2.60	3.61	3.26	3.94	4.00	3.25	2.60	3.61	3.26
BH-140 (100% RR)	7054	6434	7800	7452	6905	7143	3.76	3.43	4.16	3.97	3.68	3.81	3.76	3.43	4.16	3.97	3.68	3.81
BH-543	6026	6390	6655	4837	6594	4315	3.21	3.41	3.55	2.58	3.52	2.30	3.21	3.41	3.55	2.58	3.52	2.30
LSD (5%)	1638	2096.4	1881.8	1768.6	1275.7	3207	0.87	1.118	1.0036	0.943	0.681	1.710	0.87	1.118	1.0036	0.943	0.681	1.710
CV (%)	13.55	19.81	15.40	15.56	10.77	26.8	13.6	19.81	15.40	15.56	10.77	26.8	13.6	19.81	15.40	15.56	10.77	26.8

F-1-F6 = farmers' names (Takele Uluma, Adisu Fufa, Adisu Likessa, Mulatu Shukar, Tesfaye Tsagaye, and Gutu Tolera), NS = nonsignificant difference at 5% probability level; 50% and 100% RR = half and full doses (55 and 110 kg N ha<sup>-1</sup>) recommended for maize.



TABLE 4: Effects of varieties and nitrogen rate on mean plant height of maize on farmer's field around Bako Tibe, western Ethiopia.

Varieties	Plant height (cm)						Mean
	F-1	F-2	F-3	F-4	F-5	F-6	
BH-540	263	242	268	260	270	266	261
BH-543	266	258	271	268	278	267	268
BH- 661	301	279	306	288	308	312	299
BH-660	259	271	297	263	263	312	278
BH-140	258	242	263	284	266	266	263
BH-543	276	244	274	273	254	240	260
LSD (5%)	18.3	19.391	17.705	7.0071	15.804	19.931	8.1063
CV (%)	5.6	6.19	5.19	5.480	4.7	5.78	5.34
N (kg ha <sup>-1</sup> )							
50% RR	272	254	282	268	271	277	271
100% RR	267	263	281	277	283	292	277
Control	276	244	274	273	254	240	260
LSD (5%)	NS	NS	NS	NS	9.9955	12.605	4.4317
CV (%)	5.6	6.19	5.19	6.38	4.7	5.78	5.34

F-1–F-6 = farmers' names (Takele Uluma, Adisu Fufa, Adisu Likessa, Mulatu Shukar, Tesfaye Tsagaye, and Gutu Tolera), NS = nonsignificant difference at 5% probability level; 50% and 100% recommended nitrogen rate (110 kg N ha<sup>-1</sup>).

and leaf area index was achieved from all maize varieties applied with full recommended nitrogen rates. Furthermore, maize varieties planted with half and full recommended nitrogen applied nitrogen were given higher leaf area and leaf area index as compared to maize planted without nitrogen application. Significantly higher mean leaf area and leaf area index was ranged from 5803 to 7262 cm<sup>2</sup> and 3.09 to 3.87, respectively (Table 3). Application of optimum nitrogen to different maize varieties was desirable to have higher leaf size to capture solar energy for better photosynthesis to produce carbohydrate.

**3.3. Mean Plant Height of Maize.** Mean plant height of maize varieties was significantly different among varieties. Significantly higher, mean plant height of maize varieties were recorded from BH-661, BH-660, and BH-543 varieties of maize in descending order (Table 4). This specifies that morphological variation was observed among maize varieties on different farmer's field. Consider that height of maize varieties was crucial to make hybrid of maize to avoid logging of maize without windbreaks. Mean plant height of maize was significantly affected by application of nitrogen on farms 5 and 6 and combined over farms (Table 4). Significantly higher combined mean plant height was recorded from maize varieties planted with full recommended rates of nitrogen. Application of nitrogen had a significant role in height maize varieties.

Interaction of maize varieties by nitrogen rates was significantly affected mean plant height of maize varieties among farmers field and combined over locations (Table 5). Significantly a higher, mean number of plant heights of maize varieties were recorded from BH-661, BH-660, and BH-543 varieties of maize in descending order (Table 5). Backcrosses

of taller varieties were desirable to avoid logging of maize varieties in nonwindbreak farms.

**3.4. Mean Grain Yield of Maize.** Mean grain yield of maize was significantly different among varieties, across farms, and combined over farms (Table 6). This indicates that there were variations among farmers field with fertility status and management system applied to maize too. Raun et al. [44] reported that indigenous soil N across the landscape can vary severalfold, resulting in very different N recommendations depending on the location within the field. This indeed justifies the need site based fertilizer management and variety recommendation to farmers for sustainable maize production in the agroecology. Different varieties were given different yield across farms. Maize varieties BH-661 > BH-660 > BH-540 > BH-543 > BH-140 in order produced better mean grain yield. All varieties produced significantly higher mean grain yield as compared to maize varieties planted without nitrogen fertilizer application. Combined mean grain yield advantage of 24 to 66% was achieved from maize varieties planted with nitrogen application as compared to control (Table 6). BH-661 followed by BH-660 significantly produced higher combined mean grain yield maize and was recommended for farmers to produce higher mean grain yield in area. Farmers should use maize varieties BH-661 > BH-660 > BH-540 > BH-543 > BH-140, importance in descending order for alternative options.

Mean grain yield of maize varieties was significantly influenced by application nitrogen rates (Table 6). Significantly, higher mean grain yield was harvested from maize varieties planted with application of full recommended (110 kg N ha<sup>-1</sup>) nitrogen rate compared to half nitrogen rate. Higher mean grain yield of maize varieties was obtained from half and

TABLE 5: Combination effects of varieties and nitrogen rate on mean plant height of maize on farmer's field around Bako Tibe, western Ethiopia.

Maize varieties with N rates	Plant height (cm)						Mean
	2013		2014				
	F-1	F-2	F-3	F-4	F-5	F-6	
BH-540 (50% RR)	256	233	261	256	262	253	254
BH-540 (100% RR)	269	250	274	263	279	278	269
BH-543 (50% RR)	263	254	273	255	268	257	262
BH-543 (100% RR)	268	262	269	282	288	277	274
BH-661 (50% RR)	302	271	305	297	312	311	300
BH-661 (100% RR)	299	286	307	280	304	312	298
BH-660 (50% RR)	282	272	311	254	256	300	279
BH-660 (100% RR)	236	271	284	272	270	324	276
BH-140 (50% RR)	255	238	258	280	258	265	259
BH-140 (100% RR)	261	245	268	287	273	267	267
BH-543	276	244	274	273	254	240	260
LSD (5%)	24.904	33.317	24.512	NS	21.057	27.634	10.553
CV (%)	5.42	7.61	5.130	7.077	4.498	5.785	5.86

F-1–F6 = farmers' names (Takele Uluma, Adisu Fufa, Adisu Likessa, Mulatu Shukar, Tesfaye Tsagaye, and Gutu Tolera), NS = nonsignificant difference at 5% probability level; 50% and 100% RR = half and full doses (55 and 110 kg N ha<sup>-1</sup>) recommended for maize.

TABLE 6: Effects of varieties and nitrogen rate on mean number of grain yield of maize on farmer's field around Bako Tibe, western Ethiopia.

Varieties	Grain yield (kg ha <sup>-1</sup> )						Mean
	2013		2014				
	F-1	F-2	F-3	F-4	F-5	F-6	
BH-540	4114	2089	4751	2655	4518	5282	3901
BH-543	4988	2566	4644	2999	3731	4372	3883
BH-661	6546	3050	4691	4193	5643	6052	5029
BH-660	3216	2509	4425	3447	4972	5867	4073
BH-140	4113	1754	4878	3171	4411	4223	3758
BH-543	3796	1870	3659	3941	3350	1556	3029
LSD (5%)	841.3	176.7	349.1	178.72	327.97	549.58	196.27
CV (%)	15.54	6.07	6.27	5.84	5.81	8.71	5.68
N (kg ha <sup>-1</sup> )							
50% RR	4705	2208	4397	3159	4535	4806	3968
100% RR	4485	2579	4958	3427	4774	5513	4289
Control	3796	1870	3659	3941	3350	1556	3029
LSD (5%)	532.07	111.76	220.79	147.52	207.43	347.59	113.04
CV (%)	15.54	6.07	6.27	5.84	5.81	8.71	5.68

F-1–F6 = farmers' names (Takele Uluma, Adisu Fufa, Adisu Likessa, Mulatu Shukar, Tesfaye Tsagaye, and Gutu Tolera), NS = nonsignificant difference at 5% probability level; 50% and 100% RR = half and full doses (55 and 110 kg N ha<sup>-1</sup>) recommended for maize.

full recommended nitrogen fertilizer applied as compared to maize variety planted without nitrogen in all farms except farm 4. This indicates that maize planted in farm 4 was not responding nitrogen fertilizer application, which might be due to very poor fertility status of the soil and termite infestation problems observed in the farm. Higher mean grain yield advantages which were ranged from 18 to 209% were obtained among different farms with half recommended nitrogen as compared to maize variety planted without nitrogen (Table 6). Maize varieties planted with full recommended (110 kg N ha<sup>-1</sup>) were given significantly higher mean grain

yield advantages ranging from 18 to 254% among farms as compared to maize variety planted without nitrogen fertilizer (Table 6). Combined mean grain yield advantages of 31 and 42% across farms were produced from maize planted with half and full recommended nitrogen applied as compared to maize varieties planted without nitrogen. Furthermore, application of full recommended nitrogen across farms gave grain yield advantage of 8% as compared to maize planted with half recommended nitrogen applied.

Interaction maize varieties with nitrogen rate significantly affected mean grain yield of maize among farms and

TABLE 7: Combination effects of varieties and nitrogen rate on mean grain yield and thousand seed weight of maize on farmer's field around Bako Tibe, western Ethiopia.

Maize varieties with N rates	Grain yield (kg ha <sup>-1</sup> )						Mean
	F-1	F-2	F-3	F-4	F-5	F-6	
BH-540 (50% RR)	3633	1894	5057	2613	3904	4880	3663
BH-540 (100% RR)	4595	2283	4446	2696	5132	5684	4139
BH-543 (50% RR)	4516	2455	4141	2990	4043	4383	3755
BH-543 (100% RR)	5459	2678	5147	3009	3419	4361	4012
BH-661 (50% RR)	6719	2628	4323	4457	5472	5556	4859
BH-661 (100% RR)	6373	3472	5060	3928	5814	6548	5199
BH-660 (50% RR)	3872	2567	4107	3432	5042	5155	4029
BH-660 (100% RR)	2561	2451	4742	3462	4902	6579	4116
BH-140 (50% RR)	4788	1494	4359	2302	4216	4053	3535
BH-140 (100% RR)	3437	2013	5398	4039	4605	4393	3981
BH-543	3796	1870	3659	3941	3350	1556	3029
LSD (5%)	1154.8	242.2	537.8	361	456.19	960.75	656.99
CV (%)	15.41	6.05	7.01	6.33	5.9	11.45	10.08

F-1–F-6 = farmers' names (Takele Uluma, Adisu Fufa, Adisu Likessa, Mulatu Shukar, Tesfaye Tsagaye, and Gutu Tolera). NS = nonsignificant difference at 5% probability level; 50% and 100% RR = half and full doses (55 and 110 kg N ha<sup>-1</sup>) recommended for maize.

were combined across farms (Table 7). This is implying that the responses of different maize varieties to rates of N fertilizer were different. Le Gouis et al. [45] confirmed that there is a genetic variability for grain yield at a low N level and that the genotype × N level interaction is significant. Average mean grain yield was ranged from 2346 to 4832 kg ha<sup>-1</sup> among farms (Table 7). This indicates variation of soil fertility status and management practices applied among each farms. Farm and/or soil test based fertilizer recommendations were required for sustainable maize production in the area. Maize varieties planted with half (55 kg N ha<sup>-1</sup>) recommended nitrogen application were given mean grain yield advantages ranging from 16 to 60% as compared to maize planted without nitrogen application. BH-543, BH-660, and BH-661 varieties were better nitrogen efficient varieties among maize varieties used. Significantly higher mean grain yield advantages ranging from 31 to 72% were produced from maize varieties planted with full (110 kg N ha<sup>-1</sup>) recommended nitrogen fertilizer as compared to control. The grain yield of maize was increased as the rate of nitrogen fertilizer increased [46]. Maize varieties BH-661 followed BH-660 were ranked first and second among the maize varieties used. Higher mean grain yield and nitrogen use efficiency were obtained from BH-661 followed by BH-660 varieties of maize. This indicates that maize varieties with higher grain yield potential had higher nitrogen use efficiency.

**3.5. Shoot and Grain N Accumulation and N Harvest Index of Maize.** The mean shoot N accumulation, grain N accumulation, and N harvest index of maize varieties are indicated in Tables 8 and 9. Nitrogen harvest index of maize varieties was varied across farms, varieties, and nitrogen fertilizer application. Nitrogen harvest index of maize varieties was ranged between 0.16 and 0.23%. Farm one followed by

farm 4 produced higher nitrogen harvest index of maize varieties across farms. Higher nitrogen harvest index of maize varieties was obtained with half recommended nitrogen fertilizer as compared to maize varieties planted with full recommended nitrogen fertilizer application. Moser [46] found that maize varieties differed significantly in N harvest index and the N harvest index decreased as the rate of nitrogen fertilizer increased. Maize varieties planted with half recommended nitrogen fertilizer produced 1.06% nitrogen harvest index advantages over full recommended nitrogen fertilizer application. NHI reflects the grain protein content and thus the grain nutritional quality [47]. Maize varieties planted without nitrogen fertilizer application were given 16% nitrogen harvest index over maize varieties planted with half and full recommended nitrogen fertilizer application.

The mean shoot N accumulation of maize varieties was varied across farms and among varieties with nitrogen fertilizer application. Higher shoot nitrogen accumulation ranging from 40 to 87 was obtained from among all farms (Table 9). Except some farms, higher shoot accumulation was obtained from maize varieties planted with half and full recommended nitrogen fertilizer application as compared to maize planted without fertilizer application. Mean shoot N accumulation of 64 and 74 was obtained from maize varieties planted with half and full recommended fertilizer application. Application of half and full recommended nitrogen fertilizer to maize varieties was given higher shoot nitrogen accumulation of 56 and 881% over maize varieties planted without nitrogen fertilizer application. Similarly, Anbessa and Juskiw [7] found that biomass N yield was increased with the rate of N fertilizer. The correlation coefficients between maize productivity and N accumulated in shoots (leaves, corncobs, straws, and stems) were high [48]. Moser [46] found that maize varieties differed significantly in shoot N concentration and shoot N accumulation and shoot N concentration was increased with



TABLE 8: Effects of varieties and nitrogen rate on N harvest index of maize on farmer's field around Bako Tibe, western Ethiopia.

Maize varieties with N rates	N harvest index (kg ha <sup>-1</sup> )						Mean
	2013		2014				
	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	
BH-540 (50% RR)	0.18	0.11	0.19	0.21	0.25	0.22	0.19
BH-540 (100% RR)	0.22	0.27	0.11	0.21	0.18	0.16	0.19
BH-543 (50% RR)	0.35	0.19	0.13	0.15	0.19	0.21	0.21
BH-543 (100% RR)	0.15	0.16	0.15	0.19	0.11	0.14	0.15
BH-661 (50% RR)	0.34	0.26	0.11	0.22	0.17	0.18	0.21
BH-661 (100% RR)	0.30	0.29	0.31	0.22	0.24	0.14	0.25
BH-660 (50% RR)	0.21	0.18	0.20	0.17	0.27	0.11	0.19
BH-660 (100% RR)	0.17	0.12	0.17	0.25	0.21	0.24	0.19
BH-140 (50% RR)	0.20	0.11	0.18	0.16	0.13	0.13	0.15
BH-140 (100% RR)	0.13	0.15	0.15	0.20	0.21	0.13	0.16
BH-543	0.30	0.26	0.22	0.21	0.18	0.12	0.22

Farm 1–6 = farmers' names (Takele Uluma, Adisu Fufa, Adisu Likessa, Mulatu Shukar, Tesfaye Tsagaye, and Gutu Tolera); 50% and 100% RR = half and full doses (55 and 110 kg N ha<sup>-1</sup>) recommended for maize.

increased rate of nitrogen. The average of N accumulation in shoots collected at harvesting was 69.7 ha<sup>-1</sup> [48]. Total amount shoot N accumulation increased as the rate of nitrogen fertilizer increased [46]. Duete et al. [49] found N accumulation in the maize shoots after the harvesting of 33.2 to 58.2 kg ha<sup>-1</sup> relative to levels of 180 kg ha<sup>-1</sup> N implying nitrogen fertilizer contributed maize dry biomass.

The mean grain nitrogen accumulation was varied across farms, varieties, and nitrogen fertilizer application. Mean grain N accumulation of 9, 12, 15, 15, 16, and 17 was obtained from maize planted on farm 2, farm 4, farm 3, farm 5, farm 1, and farm 6, respectively. Farm 6 followed by farm 1 was given higher grain N accumulation as compared to other farms. This indicates that these two farms had better fertility potential to produce sustainable maize production in the region. All maize varieties were given higher N accumulation at full recommended nitrogen fertilizer application as compared to half recommended nitrogen application and without fertilizer N application. da Silva et al. [48] found that grain N accumulation was higher in all treatments with ammonium sulphate fertilization. The N accumulation in plants and grains was in agreement with the reports by Zotarelli et al. [50]. Grain N yield increased with the rate of N fertilizer and averaged over cultivars, and grain N yield was 94, 126, and 146 kg ha<sup>-1</sup> for the low, moderate, and high N regimes [7]. Mean grain N accumulation was ranged from 12 to 17 and 13 to 18 from maize varieties planted with half and full recommended nitrogen fertilizer application. The lowest and highest grain N accumulation were obtained from BH-140 and BH-661 with half and full recommended nitrogen fertilizer application. Higher mean grain N accumulation of 27 and 38% was obtained from maize varieties planted with half and full recommended nitrogen fertilizer application as compared to maize variety planted without nitrogen fertilizer application. This indicates that application nitrogen fertilizer significantly increased grain N accumulation of maize varieties. The N accumulation was higher when fertilization was

completely applied at maize sowing or side dressing [48] and the average of N accumulation grains collected at harvesting was 78.8 kg ha<sup>-1</sup>. Therefore, application of nitrogen fertilizer increased shoot and grain N accumulation of maize varieties. In conclusion, covering maize stalk after harvesting had a contribution to soil fertility management of the soil.

*3.6. Effects of Varieties and N Rates on Economic Viability of Maize Production.* The economic analysis results for interaction effects of maize varieties with nitrogen fertilizer were indicated in Table 10. The highest net benefit of EB 15011 ha<sup>-1</sup> and marginal rate of return 345% was obtained from planting of BH-661 maize varieties with application of half-recommended (55 kg N ha<sup>-1</sup>) rate. The marginal rate of returns 54, 76, and 143% was obtained from planting of BH-540, BH-543, and BH-660 maize varieties with application of half recommended nitrogen fertilizer. The values to cost ratio which were ranged from EB 2.32 to 10.81 per unit of investment were for recommended and half recommended nitrogen fertilizer rate. The economic net benefit of EB 13947, 12210, and 11285 ha<sup>-1</sup> was achieved from maize varieties BH-661 planted with full recommended; BH-660 and BH-543 with half recommended nitrogen fertilizer (Table 10). This indicates that planting of maize varieties with half recommended nitrogen fertilizer was given higher economic benefits. The mean grain yield and economic return from planting of maize varieties with the application of half recommended nitrogen fertilizer were significantly higher than recommended rate. There four maize varieties (BH-540, BH-543, BH-660, and BH-661) were nitrogen use efficient and reduced environmental pollution. In contrary due to continuous cultivation, maize varieties in the filed application of nitrogen fertilizer may cause no response, which might be due to soil acidity and shortage other secondary macronutrients. Currently the Ethiopian Ministry of Agriculture is dealing with blended fertilizer NPS rather than NP and application of

TABLE 9: Effects of varieties and nitrogen rate on shoot N accumulation and grain N accumulation of maize on farmer's field around Bako Tibe, western Ethiopia.

Maize varieties with N rates	Shoot N accumulation (kg ha <sup>-1</sup> )						Grain N accumulation (kg ha <sup>-1</sup> )					
	2013		2014		2013		2014		2013		2014	
	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
BH-540 (50% RR)	74	47	55	38	39	71	13.48	5.83	12.74	9.88	12.57	20.16
BH-540 (100% RR)	63	32	120	35	64	79	14.15	11.83	15.56	9.06	14.01	15.92
BH-543 (50% RR)	47	35	93	57	56	52	16.75	8.25	13.62	10.25	13.30	15.03
BH-543 (100% RR)	136	63	112	50	96	142	19.87	11.62	19.82	11.59	12.20	23.20
BH-661 (50% RR)	62	36	83	59	90	104	21.16	12.51	10.29	17.16	18.06	24.50
BH-661 (100% RR)	75	28	42	52	67	115	22.31	11.18	18.42	14.57	20.76	19.71
BH-660 (50% RR)	87	44	54	44	45	119	18.70	9.52	13.51	8.89	16.94	15.52
BH-660 (100% RR)	53	51	80	54	77	49	9.14	7.20	16.27	17.69	20.25	18.42
BH-140 (50% RR)	83	37	77	34	98	90	16.42	4.60	16.48	6.45	14.17	14.19
BH-140 (100% RR)	81	42	113	64	63	108	10.11	7.33	20.03	15.83	16.44	16.91
BH-543	44	20	43	56	51	30	13.02	6.94	12.30	15.17	11.49	5.56

Farm 1-6 = farmers' names (Takele Uluma, Adisu Fufa, Adisu Likessa, Mulatu Shukar, Tesfaye Tsagaye, and Gutu Tolera). 50% and 100% RR = half and full doses (55 and 110 kg N ha<sup>-1</sup>) recommended for maize.

TABLE 10: Mean interaction effects of varieties and nitrogen rate on partial budget and marginal rate of return mean grain yield of maize at Bako Tibe, western Ethiopia.

Items	Maize varieties + nitrogen kg ha <sup>-1</sup>									
	BH-543	BH-540 (50% RR)	BH-543 (50% RR)	BH-660 (50% RR)	BH-661 (50% RR)	BH-140 (50% RR)	BH-540 (100% RR)	BH-543 (100% RR)	BH-661 (100% RR)	BH-140 (100% RR)
Grain yield kg ha <sup>-1</sup>	3029	3663	3755	4029	4859	3535	4139	4012	5199	3981
Adjusted grain yield kg ha <sup>-1</sup>	2726	3297	3380	3626	4373	3182	3725	3611	4679	3583
Gross field benefit EB ha <sup>-1</sup>	10223	12363	12673	13598	16399	11931	13969	13541	17547	13436
Total field cost EB ha <sup>-1</sup>	0	1388	1388	1388	1388	1388	4050	4050	4050	4050
Net benefit EB ha <sup>-1</sup>	10223	10975	11285	12210	15011	10543	9919	9491	13497	9386
Values to cost ratio		7.91	8.13	8.80	10.81	7.60	2.45	2.34	3.33	2.32
Marginal rate of return (MRR)		54.16	76.53	143.16	344.97					

Note. Grain price = EB 3.75 kg<sup>-1</sup>, labour cost = EB 21.00/day, yield was down adjusted with 10% coefficient, cost of urea = EB 12.75 kg<sup>-1</sup>, DAP = EB 15.00 kg<sup>-1</sup>, RR = recommended rate of nitrogen fertilizer (110 kg N ha<sup>-1</sup>), and D = dominated treatment.

lime in acidity problem soil. Soil acidity, secondary nutrient limitations, and physical constraints problems which caused no response to NP fertilizer were stated by Vanlauwe et al. [51], and secondary macronutrients deficiencies in SSA is gradually becoming apparent. Soil acidification interferes with the availability of specific nutrients. Vanlauwe et al. [51] suggested that results from regional scale analysis have been valuable in informing policy on urgent need to support farmers to access improved seed and fertilizers to resolve soil fertility challenges underlying low crop productivity (e.g., increase fertilizer use to support crop production intensification, which led to the target of increasing fertilizer use in SSA to 50 kg nutrients per ha). Knowledge of integrating soil fertility management with varieties on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity Vanlauwe et al. [51, 52], was crucial for sustainable maize production. In addition assessing the blended application of secondary macronutrients into NP fertilizers and application of lime in acidity prone area like western Ethiopia at both regional and individual farm scales level would be recommended. Further investigation on recommended nitrogen fertilizer rate for maize production was advisable for agronomically, economical feasible and environmental sound sustainable maize production in western Ethiopia.

#### 4. Conclusion

Soil fertility problem was alleviated using improved crop management practices. Maize varieties produced significantly different biological and grain yield. Application of nitrogen fertilizer was given significantly higher mean grain yield maize. Application of nitrogen fertilizer was increased shoot and grain N accumulation of maize varieties. Higher nitrogen harvest index of maize varieties was obtained with half recommended nitrogen fertilizer as compared to maize varieties planted with full recommended nitrogen fertilizer application. Planting of BH-661, BH-660, BH-540, and BH-543 maize varieties with half recommended nitrogen fertilizer rate was agronomically given higher grain yield and economical feasible for sustainable maize production. Thus, planting of maize varieties with optimum nitrogen application was far most important for sustainable maize production in the agroecology. In conclusion, the results' empathy of improved maize varieties with half and full recommended nitrogen fertilizer is recommended for sustainable maize production in the area.

#### Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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