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Research Article

Growth, Yield Components, and Yield Parameters of Maize (*Zea mays* L) as Influenced by Unified Use of NPSZnB Blended Fertilizer and Farmyard Manure

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A two-year field experiment was carried out to scrutinize the integrated use of NPSZnB blended fertilizer and farmyard manure (FYM) on maize growth and yield components at Koga and Bachima villages in Mecha district and Geray and Jiga villages in Jabi Tehran district. Factorial combinations have five levels of NPSZnB (100, 150, 200, 250, and 300 $kg{\cdot}ha^{-1}$), and four rates of FYM (0, 12, 16, and 20 $t{\cdot}ha^{-1}$), plus one blanket recommendation (200 $kg{\cdot}ha^{-1}$ DAP and 150 $kg{\cdot}ha^{-1}$ Urea). A randomized complete block design with three replications was used to set up the studies. Except for days to silking and leaf area index at both locations, and days to physiological maturity, and ear length at Mecha, main and interaction effects on all parameters were detected at both locations. The only main effect of NPSZnB was detected on the harvest index at Jabi Tehnan. Generally, the results achieved from the interaction effect were better and greater than those obtained from the blanket recommendation although this was not the case for the main effects. Grain yields at Jabi Tehnan and Mecha were 5618.5 and 5421 $kg{\cdot}ha^{-1}$, respectively, as a result of the unified use of 250 $kg{\cdot}ha^{-1}$ NPSZnB and 20 $t{\cdot}ha^{-1}$ FYM and shortened days to 50% tasselling by 3.46 days and delayed 90% physiological maturity by 2.95 days than the blanket recommended fertilizer at Jabi Tehnan. As the main effect, compared to the blanket recommendation, 250 $kg{\cdot}ha^{-1}$ at Jabi Tehnan and 300 $kg{\cdot}ha^{-1}$ NPSZnB at Mecha reduced the days to 50% silking by 0.225 and 0.292 days, respectively. Contrasted with the conventional recommendation, the application of 300 $kg{\cdot}ha^{-1}$ NPSZnB minimizes days to 90% physiological maturity by 0.89 at Mecha, and the rise in FYM level from 0 to 20 $t{\cdot}ha^{-1}$ caused 0.832 and 0.279 extra days to reach 50% silking at Jabi Tehnan and Mecha, respectively. The yield had a very strong correlation that is positive with growth and yield components. Economic study: the use of 200 $kg{\cdot}ha^{-1}$ NPSZnB with 20 $t{\cdot}ha^{-1}$ FYM resulted in the maximum net benefit of 36221.06 and 35431.04 ETB ha^{-1} at Jabi Tehnan and Mecha, respectively. Thus, 250 $kg{\cdot}ha^{-1}$ NPSZnB with 20 $kg{\cdot}ha^{-1}$ FYM and 200 $kg{\cdot}ha^{-1}$ NPSZnB with no FYM application were the most acceptable rates at both locations with a low cost of production to small-scale farmers. For resource-rich farmers, 200 $kg{\cdot}ha^{-1}$ NPSZnB with 20 $t{\cdot}ha^{-1}$ FYM was also favorable, with the best net benefit at both locations.

1. Introduction

Several developing countries depend heavily on agriculture to promote economic development including Ethiopia. Ethiopia's economy is based mostly on agriculture, which contributes to around 41.4 percent of the gross domestic product, 83.9 percent of all exports, and 80% t of total employment [1]. So, it is not unexpected that a major focus of Ethiopian policy is on enhancing the dynamism of the agricultural area.

Ethiopia, with a fertility rate of 4.2 children born per woman, is the continent's second most populous nation after Nigeria an existing population of 102.4 million [2]. Ethiopia is expected to be among the top eight in the world in terms of population growth between 2017 and 2050, with a total estimated population of 190.9 million [3]. The country must increase food grain production by increasing production per unit area in addition to nutritional value to feed and satisfy the needs of such a big population.

The main source of food in Sub-Saharan Africa is maize (*Zea mays* L.), and its area coverage increased by nearly 60% between 2007 and 2017 [4]. Nowadays, Ethiopia has the fifth-largest area dedicated to maize cultivation, but it has the second-highest yields (after South Africa) and the third-largest production areas (behind South Africa and Nigeria) [5]. Not only is it abundantly produced, but it is also the highest-yielding cereal in Ethiopia, ranking first in productivity per hectare (4.2 tonnes, accounting for 30.88 percent of cereal production) and second in production area (2.5 ha, accounting for 19.46 percent of total cereals) [6, 7]. More than 9 million small-holders growers cultivate maize on approximately 2 million hectares (14 percent of Ethiopia's total land area), with approximately 88 percent of the crop's output going toward food consumption [8]. Maize accounts for 42.79 percent of cultivated land and 64.27 percent of cereal grain production in the west Gojam highlands, with a yield of $4.573\,t{\cdot}ha^{-1}$ on average (9). In the 2020/21 summer planting season, 10,189,355.00 and 649,991.00 small-holder farmers, respectively, reportedly grew maize in the nation generally and in the West Gojam zone specifically. National (Ethiopia) and regional (Amhara) yields of 4.179 and 4.272 tone ha^{-1}, respectively [9], are significantly inferior to the average for the world yield ($57547\,kg{\cdot}ha^{-1}$) [10].

These high yield gaps are most probably caused by many abiotic factors including practical effectiveness gaps (i.e., limitations in crop management that result in production inefficiencies), economic constraints (i.e., financial limitations to expand input utilization), and technology gaps (i.e., inability to access advanced technologies modern technologies) and biotic factors (disease and weed) [11].

Mineral nutrition by itself has made a substantial contribution to about 50% of crop yield increment during the 20th century, everywhere, and is anticipated to be the single biggest factor reducing crop production in the twenty-first century [12]. But frequent use of chemical fertilizer can alter the soil's pH, disrupt beneficial microbial communities, aggravate pest problems, and potentially contribute to the release of greenhouse gases [13].

It is essential to establish a balanced fertilization program with macro and micronutrients in plant nutrition for plants to yield significant amounts of high-quality products by including microelements such as boron and zinc [14, 15]. Macro- and micronutrient deficiencies have been reported for different soils and crops [16]. Using organic fertilizer improves crop output per unit of nutrients supplied by creating a better physical, chemical, and microbiological environment [13]. Unless it is integrated with inorganic fertilizers, because of its comparatively small nutrient content, excessive application rates, and high labor needs, using organic fertilizer alone may not be sufficient to completely meet crop nutrients demand [17]. In addition to improving the chemical, biological, and physical characteristics of the soil, applying organic fertilizer (farmyard manure) in combination with chemical fertilizers ensured a steady supply of nutrients [18], and it promoted better growth and increased crop output. Relative to using only chemical fertilizers, integrated nutrient management (NPK + FYM) increases corn output [19–21]. Thus, exploiting the integrated practice of natural and artificial fertilizer appears to be the paramount alternate for sustainable crop production while preserving the soil fertility condition in farming systems based on maize and other cereals [17].

In the 1960s, higher education institutions introduced commercial fertilizer in Ethiopia, primarily in the form of urea and DAP through limited laboratory and research operations [22]. Beginning in the early 1970s, this was followed by extensive on-farm demonstration experiments across the country, and a general rate of $100\,kg{\cdot}ha^{-1}$ urea + $100\,kg{\cdot}DAP{\cdot}ha^{-1}$ was advised, regardless of crop or soil type [23]. As a result, the soil's nutrition levels gradually fall in nutrient levels in the soil and fail to address the nutrient requirements of specific crops, including maize [24]. Currently, Ethiopia has begun utilizing blended or compound fertilizers, which can be used to supplement inadequate nutrients, and NPSZnB blended fertilizer is one of them. Also, due to the high fertilizer costs and the farming community's low purchasing power, in the country, including the experimental area, a low rate of inorganic fertilizer application has been practiced which necessitates an alternative option such option is the unified use of inorganic fertilizer and farmyard manure. Not only the above reason but also due to a long-term imbalanced fertilization approach, a lack of other nutrients, particularly, potassium (K), sulfur (S), zinc (Zn), and boron (B), has begun to become clear [23, 25, 26].

Research findings on soil fertility management utilizing farmyard manure and mineral fertilizer are currently inaccessible and have not been carried out in the selected district (Jabi Tehnan and Mecha District Agriculture Office report), and the soil in the experimental area has insufficient nutrients including zinc, boron, phosphorus, sulfur, and nitrogen, as indicated by the Ethio-SIS map https://www.researchgate.net/profile/Tadele-Amare-Kassie [27]. Hence, this experiment was conducted in the Jabi Tehnan and Mecha district, which is one of the main maize preproduction belt regions of the country, to determine the most effective combination rate of NPSZnB blended fertilizer and farmyard manure that improved growth, yield, and define the optimal economic threshold of NPSZnB blended fertilizer and farmyard manure.

2. Materials and Methods

2.1. Site Description. Two years of field research (2016/17-2017/18) were conducted in two different locations in Amara National Regional State, Ethiopia: Jabi Tehnan district (at the Farmer's Training Centre (FTC) and Mecha district (at the substation of the Adet agricultural research centre and Farmer's Training Centre (FTC) (Figure 1). Jabi Tehnan is situated at latitude 10.6794°N and longitude 37.2598°E, at an altitude of 1,500–2,300 m.a.s.l, and encompasses an area of 116,954 hectares. The average annual rainfall in the city is 1250 mm, with minimum and maximum daily temperatures

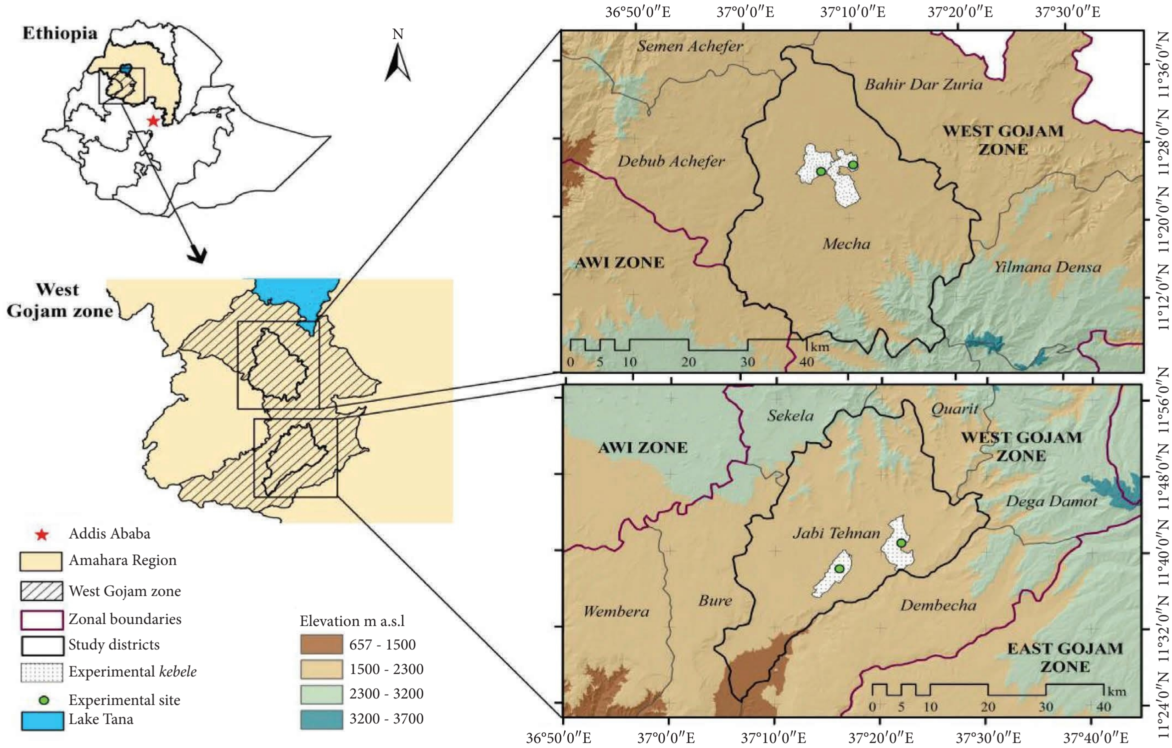

Figure 1: Study area map.

of 14 and 32°C, respectively, and a mean annual rainfall of 1,885 mm (Figure 2). The soil type is classified as 60% red soil, 25% brown, and 15% black soil [28]. The soil fertility is classified as 27% fertile, 71% medium, and 2% infertile. Agro-ecologically, Woyina Dega accounts for 88 percent of the district, while Kola accounts for the remaining 12% [29].

Mecha is situated at 11.4130°N, 37.1553°E and has an altitude of 1800–2500 meters above sea level. The region experiences yearly rainfall averaging between 820 and 1250 mm. The area's daily low and high temperatures are 17 and 30 degrees Celsius, respectively. The soil is 93% red, 3% black soil, and 4% grey soil. The main crops produced in the area are wheat (*Triticum aestivum*), barley (*Hordeum vulgare* L.), finger millet (*Eleusine coracana* L.), Teff (*Eragrostis tef*), and maize [30].

In each of the corresponding years, soil samples were taken at five places diagonally between 0 and 20 cm of soil depth to identify the general soil characteristics of both experimental sites before planting. The soil and farmyard manure samples were air-dried, crushed, and sieved through a 2 mm sieve before being analyzed to determine some selected chemicals for both soil and farmyard manure and physical characteristics for soil only. Tables1 and 2 present selected soil analysis parameters, methods, and results. Before the experiment start, soil analysis revealed that both study sites have clay texture and soil properties that are relatively comparable.

2.2. Experimental Design, Treatments, and Procedure. BHQPY545, a variety of maize noted for its high protein content, was employed as the planting material in this experiment. The treatments included five levels of NPSZnB blended fertilizer (16.9% N-33.8% P-7.3% S-2.23% Zn-0.67% B) (100, 150, 200, 250, and 300 kg·ha^{-1}) and four levels of well-decayed, from cattle source, aged three to six months of manure (0, 12, 16, and 20 t·ha^{-1}) and one blanket recommended 150 kg·ha^{-1} urea (69 kg·N) and 200 kg·ha^{-1} DAP (40 kg·P and 18 kg·N). Since the N content of NPSZnB blended fertilizer is lower than N derived from the blanket recommended urea and DAP, where the N content of 100 kg NPSZnB blended fertilizer is 16.9 kg, the blended fertilizer was adjusted with N to N of the recommended urea and DAP. This shows that 87 kg·N·ha^{-1} of conventional fertilizer, excluding DAP and Urea, was administered to all treatments [11]. Three replications of the experiment were conducted using a randomized complete block design (RCBD) with a factorial arrangement. The size of every plot was 4 by 4 m (16 m^2) and contained five rows, each with ten plants, a total of 50 plants per plot. Plots were 0.5 m apart, while blocks were separated by 1 m. Borders were described as the outermost single row from both sides of the plots and one plant at both ends of each row. As a result, the net plot used for data collection was 3.2 × 2.4 m (7.68 m^2), and the gross area for the experiment was 14 m × 94 m = 1316 m^2. All recommended agronomic activities were carried out. NPSZnB blended fertilizer was applied by drilling once at sowing time and was well incorporated with the local soil. While only a 1/2 amount of urea and all of the DAP fertilizer were applied as a base application at sowing, the remainder N was top-dressed at 35 days (knee-height stage) later sowing for the nitrogen adjusted and the blanket recommended. Throughout the cropping seasons, the experimental plots were managed using all of the improved

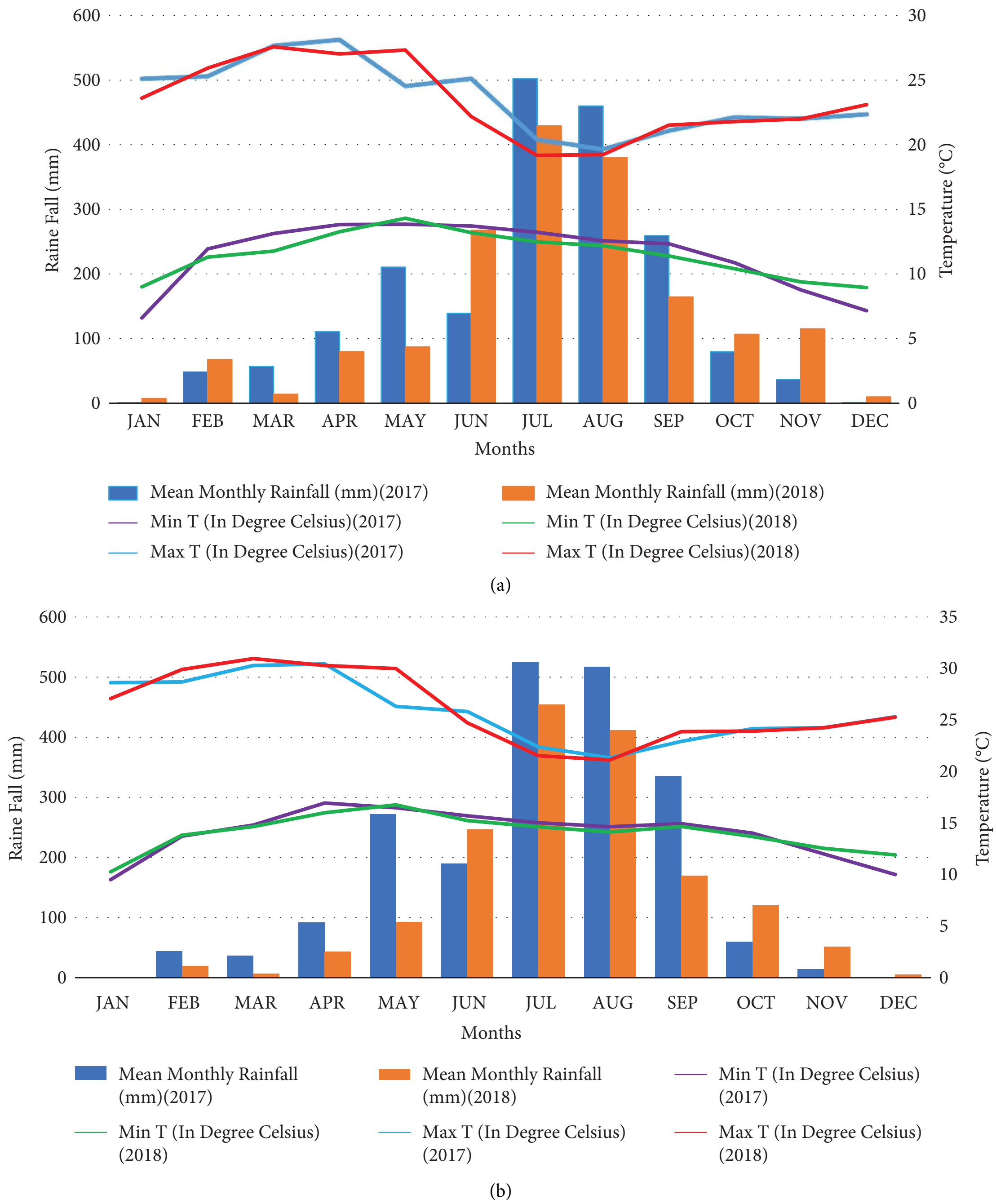

Figure 2: Monthly rainfall (mm), highest and lowest temperatures (°C) in Jabi Tehnan (a) and Mecha (b) districts in the experimental years of 2017 and 2018 (where Max T = maximum temperature and Min T = minimum temperature). Source: National metrological data agency.

culturally practiced methods for hybrid maize cultivation. From all collected farmyard manure, nondecomposable and unused components were isolated and removed and then dispersed on a plastic sheet in the shade to minimize its moisture, keeping the moisture content below 22%, and all different levels of farmyard manure were randomly applied one month before sowing and thoroughly mixed with the soil.

2.3. Data Collection and Measurement. Data for the trial were gathered from days to 50% (tasselling, silking), leaf area index, plant height, and days to 90% physiological maturity (cm), and yield and yield components such as ear length, number of kernels per ear, 100 seed weight (g), grain yield (kg ha^{-1}), above-ground biomass (kg ha^{-1}), and harvest index (%) were recorded. By calculating the conversion factor for each treatment to get the adjusted yield, the grain yield for each treatment was adjusted to the recommended moisture level of 12.5% [47].

$$\text{Conversion factor (C.F)} = \frac{100 - Y}{100 - X}, \tag{1}$$

Table 1: Soil properties of the study locations, including analysis methods and findings, before the experiment were conducted.

Parameters	Experimental location					
	Jabi Tehnan		Mecha		Soil analysis method	Rating
	2017	2018	2017	2018		
Textural class	Clay loam	Clay loam	Clay loam	Clay loam	Bouyoucos hydrometer system	
pH	6.04	6.50	5.90	6.08	Glass-calomel combination electrode [31]	At both locations mildly acidic to nearly neutral [32]
CEC (cmol(+)kg^{-1})	24.7**	25.1***	15.26**	16.9**	Ammonium acetate method [33]	* = medium, ** = high [34]
OC%	1.6**	2.7**	1.5**	1.4**	Walkley and Black method [35]	* = medium [36]
TN%	0.12*	0.14*	0.06*	0.04*	Micro-Kjeldahl method [37]	* = low [37]
Av. P ppm	9.68**	8.77**	7.13**	7.02**	Olsen method [38]	* = medium [38]
Av.S mg/kg^{-1}	20*	10*	15*	16*	Turbidimetric method [39]	* = low [40]
Av.B mg/kg^{-1}	0.024*	0.016*	0.033*	0.042*	Hot water extraction procedure [41]	* = nearly low [42]
Av.Zn mg/kg^{-1}	0.22*	0.21*	0.24*	0.3*	Extracted with DTP Lindsay and Norvell [43]	* = deficient [34]

where CEC: cation exchange capacity; OC: organic carbon; TN: total nitrogen; Av. P: available phosphorous, Av. S: available sulphur; Av. B: available boron; Av. Zn: available zinc.

Table 2: Methods of analysis and results of major chemical characteristics of farmyard manure used in the areas.

Parameters	Experimental location				Rating	References
	Jabi Tehnan		Mecha			
	2017	2018	2017	2018		
pH	6.9	7.1	7.4	7.3	Slightly alkaline	Tekalign Tadesse [44]
CEC (cmol(+)kg^{-1})	32.4	29.4	29.0	31.3	High	Landon [45]
OC%	34.13	32.13	30.11	31.10	Very high	ATA [46]
TN%	0.468	0.441	0.463	0.453	Moderate	Tekalign Tadesse [44]
Av. P ppm	14.34	15.92	16.81	16.72	High	Landon [45]
Av. S mg/kg^{-1}	9.2	4.43	14.43	10.2		
Av. B mg/kg^{-1}	0.012	0.013	0.023	0.020		
Av. Zn mg/kg^{-1}	0.18	0.23	0.21	0.09		

where CEC = cation exchange capacity; OC = organic carbon; TN = total nitrogen; Av. P = available phosphorous; Av. S = available sulphur; Av. B = available boron; Av. Zn = available zinc.

where Y represents the actual moisture content and X; the target moisture content (which is 12.5% for cereals) to which the yield should be adjusted.

$$\text{Adjusted yield} = \text{C.F} \times \text{plot yield}. \quad (2)$$

To experiment, plot-based data on yield and yield related to its components were collected.

2.4. Economic Analysis. A financial study was conducted to determine commercially profitable treatments. The cost-benefit study was carried out at two separate sites (Jabi Tehnan and Mecha district) over the two growing years (2016/17 and 2017/18) by contrasting production costs and revenue derived from different treatment levels. The analysis was carried out by using input-output statistics of maize by the CIMMYT (International Maize and Wheat Improvement Centre) method [48]. Other costs such as fertilizer transportation, pesticide application, and different agronomy activities also were under consideration. The average yield was adjusted to 10% lower to account for the discrepancy between the experimental area and the anticipated output at farmers' fields and with farmers' behaviors under the same treatments [49]. For nondominated treatments, the marginal rate of return (MRR) was calculated, and MRRs were compared to a minimum acceptable rate of return (MARR) of 100 percent to determine the best treatments. The product of maize yield for each treatment-year-location combination was used to calculate revenue (R). Benefits were calculated using the difference between revenues and expenditures.

2.5. Data Analysis. The analysis of variance was carried out by Gomez and Gomez [50], using statistical analysis computer software SAS version 9.2 (Statistical Analysis System) [51]. Since the homogeneity test carried out using the F-test as described by [50], of the two years and locations for all parameters had shown homogenous and nonsignificance of the two years on each location and heterogenous and significance of the two locations, a combined analysis was used for the two years on each location and analysis of each location; data were analyzed separately. Whenever there were important treatment results, mean separations were performed using the least significant difference (LSD) at the 5% level of significance, and to facilitate factorial analysis, the control was excluded. Using SAS, 9.2 versions, a correlation analysis was also performed to define the association between plant growth parameters and yield and yield components as affected by rates of NPSZnB fertilizer and farmyard manure.

3. Results and Discussion

3.1. Correlation of Maize Growth, Yield, and Yield Components. Correlation analysis of maize growth parameters revealed that all were highly and positively correlated with grain yield at both experimental sites (Tables 3 and 4). A comparison of the correlation coefficients at Jabi Tehnan revealed that plant height had a higher correlation coefficient ($r = 0.966^{**}$) than the other yield components, followed by above-ground biomass ($r = 0.951^{**}$), ear length ($r = 0.932^{**}$), thousand kernels mass ($r = 0.921^{**}$), and the number of green leaves per plant. The above-ground biomass ($r = 0.935^{**}$) had the highest correlation coefficient at Mecha, followed by thousand kernels weight ($r = 0.934^{**}$), number of green leaves per plant ($r = 0.922^{**}$), plant height ($r = 0.685^{**}$), and ear length ($r = 0.541^{**}$) showed associations with grain yield with correlation coefficients of comparatively inferior extents as compared to the former yield components. Similarly, Selassie, [52] and Habtamu et al., [53] discovered that maize grain yields were positively and significantly associated with yield components.

3.2. Days till 50% Tasseling. Combined analysis of variance over years indicated that days till 50% tasselling were significantly ($P < 0.0001$) affected by the application of NPSZnB blended fertilizer, farmyard manure, and their interactions at Jabi Tehnan (Table5). However, only NPSZnB blended fertilizer ($P < 0.0001$) caused a significant difference on days to 50% tasselling at Mecha (Table 5).

Days till 50% tasselling generally decreased as the integrated application of farmyard manure, and NPSZnB mixed fertilizer was increased. By increasing the blended fertilizer rate from 100 to 250 kg·ha^{-1} NPSZnB blended fertilizer and farmyard manure rates from 0 to 20 t·ha^{-1}, days to 50% tasselling were shortened. At the Jabi Tehnan site, the integrated use of 250 kg·ha^{-1} NPSZnB and 20 t·ha^{-1}

Table 3: Correlation coefficient matrix of the relationship between selected growth, yield components parameters, and maize yield at Jabi Tehnan.

	AGBM	EL	TKW	PH	GY
AGBM	1.00				
ED	0.872				
NEPP	0.677				
NGLPP	0.922				
NKPR	0.926				
NKPE	0.926				
CW	0.790				
EL	0.925	1.00			
TKW	0.915	0.892	1.00		
PH	0.947	0.919	0.955	1.00	
GY	0.951	0.932	0.921	0.966	1.00

where AGBM = above-ground biomass; EL = ear length; TKW = thousand kernels weight; PH = plant height; GY = grain yield.

Table 4: Correlation coefficient matrix of the association between selected growth, yield components parameters, and maize yield at Mecha.

	AGBM	EL	TKW	PH	GY
AGBM	1.00				
ED	0.420				
NEPP	0.558				
NGLPP	0.953				
NKPR	0.932				
NKPE	0.930				
CW	0.865				
EL	0.550	1.00			
TKW	0.905	0.579	1.00		
PH	0.656	0.411	0.683	1.00	
GY	0.935	0.541	0.934	0.685	1.00

where AGBM = above-ground biomass; EL = ear length; TKW = thousand kernels weight; PH = plant height; GY = grain yield.

Table 5: *P* values of the effects of year, block, NPSZnB blended fertilizer, farmyard manure, and their collaborations on the phenology and growth variables were measured at the Jabi Tehnan and Mecha districts of Ethiopia.

Sources of variation	DF	Two years combined result					
		D50%T	D50%S	PH	AGBM	DT90%PM	LAI
Jabi Tehnan							
Y	1	0.6534	0.2262	1.0000	0.9921	0.0605	0.9527
BL	2	0.0649	0.0074	0.0004	<0.0001	0.0279	0.1649
BF	4	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
FYM	3	<0.0001	0.0009	<0.0001	<0.0001	<0.0001	0.0224
FYM X BL	12	<0.0001	0.7903	<0.0001	0.0003	0.0001	0.4646
Error			3.2	0.5	195533.6	2.1	0.4
Total	97		97	97	97	97	97
Mecha							
Y	1	0.9232	0.3029	0.7824	0.9907	0.2761	0.0443
BL	2	<0.0001	0.2246	0.9645	0.1444	<0.0001	0.9392
BF	4	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
FYM	3	0.5723	0.0003	<0.0001	<0.0001	0.0399	<0.0001
BF XFYM	12	0.4230	0.9166	<0.0001	<0.0001	0.8187	0.7576
Error		3.37	2.50	12.77	122797.70	6.73	0.2
Total		97	97	97	97	97	97

where Y: year; BL: block; BF: NPSZnB blended fertilizer; FYM: farmyard manure; DF: degree of freedom; D50%T: date to 50% tasselling; D50%S: date to 50% silking; PH: plant height; AGBM: above-ground biomass; DPM: date to physiological maturity; LAI: leaf area index.

farmyard manure shortened days to 50% tasselling by 3.46 days as compared to the blanket DAP and urea fertilizer recommendation/satellite control ($200\,kg{\cdot}ha^{-1}$ DAP and $150\,kg{\cdot}ha^{-1}$ urea) application (Table 6). The application of $100\,kg{\cdot}ha^{-1}$ NPSZnB without the application of farmyard manure prolonged days to 50% tasselling by 2.92 days in comparison to the blanket DAP and urea fertilizer recommendation/satellite control, and it was also statistically at par with $100\,kg{\cdot}ha^{-1}$ NPSZnB blended fertilizer and $12\,t{\cdot}ha^{-1}$ farmyard manure combination. The earliest days' reaching 50% of tasseling in response to the highest amount of blended fertilizer NPSZnB (250 kg ha-1) and farmyard manure (20 tha-1) could also be attributed to their synergistic effect on promoting vegetative growth, which resulted in preserving enough food reserves to allow buds to develop into flower buds. The prolonged vegetative phase of the plant could, on the other hand, be caused by the lack of nutrients or starving of the plant, which would result in delayed tasselling in response to the interaction effect of the minimum amount of blended fertilizer and farmyard waste.

This could also be attributed to their synergistic effect, as the application of farmyard manure along with NP fertilizers provides balanced micro and macronutrients. This would have aided in enhancing the assimilation process in the seedling growth stage, which in turn would have enhanced the overall growth and extended through the vegetative growth stage, resulting in a prolonged period for tasselling [54].

These results are in line with Tetarwal et al., [55] who discovered that raising fertilizer rates decreased the number of days for maize to 50% tassel. Melaku et al. [56] also reported similar results where the application of blended NPS fertilizers and farmyard manure significantly affected days to tasselling. These results showed that the combined application of $150\,kg{\cdot}ha^{-1}$ NPS fertilizer and $12\,t{\cdot}ha^{-1}$ FYM resulted in the shortest duration for 50% tasselling (61 days), whereas the control treatment resulted in the longest period for 50% tasselling (80 days).

Mean comparisons for blended fertilizer treatments at Mecha revealed that the use of $300\,kg{\cdot}ha^{-1}$ blended fertilizer shortened days to 50% tasselling (51.14) by 1.05 days than the blanket fertilizer DAP and urea (52.2 days) whereas the longest 55.26 days to 50% of tasselling were recorded from $100\,kg{\cdot}ha^{-1}$ of NPSZnB blended fertilizer (Table 7.

The earliness tasselling in response to the increasing amount of NPSZnB blended fertilizer could be attributed to the nutrients N, P, S, B, and Zn in NPSZnB blended fertilizer causes the crop to grow vigorously and more rapidly during the vegetative stage, which eventually causes the crop to tassel sooner rather than later. The same results were also reported by Hailu et al., [57] where the use of blended NPS fertilizers significantly affected days to tasselling. When nutrients are applied in sufficient amounts, growth is quick and tasselling is accelerated, but when nutrients are applied insufficiently or not at all, development is slow, and tasselling and silking are delayed [58]. These findings are consistent with those of Makinde et al. [59, 60], who found that maize silking and tasselling days were reduced by 50% when fertilizer rates were increased.

3.3. Days till 50% Silking. The combined analysis of variance over years for the days to 50% silking revealed that, at both locations, there was a significant difference on days to 50% silking of maize due to the main effects of NPSZnB blended fertilizer and farmyard manure. However, this parameter was unaffected by their interaction impact (Table 5).

The shortest days to 50% of silking 60.52 and 60.70 were gotten from the plots that received 250 and $300\,kg{\cdot}ha^{-1}$ NPSZnB blended fertilizer at Jabi Tehnan and Mecha, respectively, but it was significantly on par with $300\,kg{\cdot}ha^{-1}$ at Jabi Tehnan and $250\,kg{\cdot}ha^{-1}$ NPSZnB at Mecha. In the meantime, the maximum days to 50% silking 63.41 and 64.32 were recorded from the minimum rate of NPSZnB blended fertilizer of $100\,kg{\cdot}ha^{-1}$ at Jabi Tehnan and Mecha, respectively (Table 7).

It was recognized that NPSZnB blended fertilizers with varying concentrations of N, P, S, and Zn may have accelerated plant growth and development, reducing the time until silking. Hailu et al., [57] also discovered that the use of blended fertilizers greatly impacted the days of silking. In the interim, Kinfe et al. [67] found that 50% of silking is significantly influenced by the use of mixed fertilizer rates. The outcomes are consistent with those of Makinde and Ayoola [59]; Uwah et al., [60] noticed that maize's 50% silking days were shorter when fertilizer rates were higher. In contrast to the results of this experiment, results from several studies confirmed that NPSZnB blended fertilizer with varying amounts of N, P, S, Zn, and B had no discernible impact on the silking of the maize crop [61].

The rise in the rate of farmyard application from 0 to $20\,t{\cdot}ha^{-1}$ caused a reduction in days to 50% silking (60.80 and 61.17) as maximum numbers of days to 50% silking 62.71 at Jabi Tehnan and 62.90 at Mecha were obtained from no farmyard manure application which is statistically similar to the rate of $12\,t{\cdot}ha^{-1}$ of farmyard manure at both locations (Table 7).

Increased amounts of cattle manure make the soil nutrients balanced, create a favorable soil environment by improving soil porosity (water holding capacity), and minimize nutrient leaching. These favorable conditions increased nutrient availability, especially NPK. The plant tends to grow at its maximum capability resulting in shortening the days to silking. These increases in days to 50% silking coincide with Gurmu and Mintesnot's findings [62] who reported days to 50% silking were delayed by 10.67 days (12.81%) at the control treatment compared to the application of 2.3-ton ha^{-1} compost that takes 83.3 days to 50% silking.

3.4. Days till 90% Physiological Maturity. Analysis of variance over years revealed that days to 90% physiological maturity of maize were significantly ($P < 0.0001$) affected by the application of NPSZnB blended fertilizer, farmyard manure, and their interactions at Jabi Tehnan, while at Mecha, the main effects of NPSZnB blended fertilizer and farmyard manure significantly ($P < 0.05$) affected days to 90% maturity. However, their interaction results were not significant ($P > 0.05$) (Table 5).

Table 6: Interaction effects of days to physiological maturity and 50% tasselling combined over years 2016/17 and 2017/18 in the Jabi Tehnan district of Ethiopia.

Treatments	D50%T				DT90%PM			
BR kg ha^{-1}	53.2				142			
FYM tha^{-1}					FYM tha^{-1}			
BF kg ha^{-1}	0	12	16	20	0	12	16	20
100	56.13a	55.92a	55.50b	55.33b	131.7ll	135.30k	135.52jk	136.47i-k
150	54.83c	54.62cd	54.37de	54.23ef	136.49i–k	136.89h–k	137.79g–i	137.70g–i
200	54.02fg	53.78g	53.45h	52.78i	138.33gh	139.08fg	142.22cd	142.77bc
250	52.63i	52.32j	51.33l	49.73o	137.14h–j	140.70d–f	142.96bc	144.95a
300	52.15jk	51.93k	50.78m	50.42n	140.18ef	140.85de	143.92a-c	144.31ab
CV (%)	0.48				1.04			
LSD	0.29				1.72			
P value	<0.0001				0.0001			

There is no noticeable difference between means inside a column that is preceded by the same letter; D50%T = several days to 50% tasselling; DT90%PM: days to 90% physiological maturity; BR: blanket recommendation (200 kg·ha^{-1} DAP and 150 kg·ha^{-1} urea); BF: blended fertilizer; FYM: farmyard manure; CV: coefficient of variation; LSD: least significant difference.

Table 7: The main effects of NPSZnB blended fertilizer and farmyard manure on days to 50% silking, days to 50% tasselling, and days to physiological maturity over the Ethiopian years 2016-17 and 2017-18 were observed in the Jabi Tehnan and Mecha districts.

Treatments	Experimental locations			
	Jabi Tehnan		Mecha	
	D50%S	D50%T	D50%S	DT90%PM
BR kg ha^{-1}	60.3	52.2	61	142
BF kg ha^{-1}				
100	63.41a	55.26a	64.32a	137.25b
150	62.07b	52.48b	62.51b	137.74b
200	61.96b	53.08b	61.88b	138.40b
250	60.50c	51.22c	60.80c	140.64a
300	60.52c	51.14c	60.70c	141.10a
LSD	1.06	1.24	0.90	1.48
P value	<0.0001	0.0001	<0.0001	<0.0001
FYM (t ha^{-1})				
0	62.71a	52.92	62.90a	137.93b
12	61.79ab	52.63	62.37ab	138.93ab
16	61.48bc	52.27	61.73bc	139.74a
20	60.80c	52.50	61.17c	139.50ab
LSD	0.95	1.11	0.81	1.32
CV %	3.01	4.14	2.55	1.86
P-value	0.0009	0.5723	0.0003	0.0399

There is no noticeable difference between means inside a column that is preceded by the same letter. BR: blanket recommendation (200 kg·ha^{-1} DAP and 150 kg·ha^{-1} urea); BF: NPSZnB blended fertilizer; FYM: farmyard manure; CV: coefficient of variation; LSD: least significant difference; D50%S: days to 50% silking; D50%T: days to 50% tasselling; DT90%PM: days to 90% physiological maturity.

At Jabi Tehnan, maize on the plot which received 250 kg·ha^{-1} NPSZnB blended fertilizer and 20 t·ha^{-1} farmyard manure took the maximum days to 90% physiological maturity (144.95 days). Hence, 2.95 extra days were required to reach the maturity of maize as compared to the conventional fertilizer DAP and urea application. However, it was statically comparable to the application of 300 kg·ha^{-1} NPSZnB blended fertilizer integrated with 20 and 16 t·ha^{-1} farmyard manure. Conversely, the shortest day to reach 90% physiological maturity 131.71 was documented from both the minimum rate of NPSZnB blended fertilizer (100 kg·ha^{-1}) (Table 6).

It was known that increased nutrients especially nitrogen could have shortened the days to tasselling, silking, and maturity by encouraging the early establishment, rapid growth, and development of the crop, but the current outcome was inconsistent in this respect. This might be because of the increased rate of nitrogen from both sources (blended inorganic fertilizer and farmyard manure) especially the gradual discharge of nutrients from farmyard manure, which delayed physiological maturity by promoting/promoting the plants' vegetative growth and development. In addition, it could be positive interaction of nutrients in both fertilizer, and additional benefits from farmyard manure (increases the soil's ability to retain moisture, reduces nutrient leaching, and releases nutrients such as nitrogen and phosphorus) could encourage plant vegetative development, which would lengthen the time until maize plants reach maturity. This result is in contradicts the report by Gurmu and Mintesnot[62] [62], who notes that plants receiving lesser nutrient applications grew slowly due to a lack of nutrients, while plants receiving higher nutrient applications exhibited early maturity due to strong development, early tasselling, and early silking of the crop.

At Mecha, the maximum number of days to 90% physiological maturity was 141.1, at the rate of 300 kg·ha^{-1} NPSZnB blended fertilizer which was 0.89 days earlier than the use of DAP and urea. However, it was significantly on par with the plot treated with 250 kg·ha^{-1} NPSZnB blended fertilizer whereas the minimum days 137.3 to reach 90% physiological maturity were recorded from the lowest rate of blended fertilizer (100 kg·ha^{-1}), which was significantly on par with the application of 150 and 200 kg·ha^{-1} NPSZnB.

It was known that blended fertilizers with varied amounts of N, P, S, Zn, and B would have favored early establishment, quick growth, and development of the crop, shortening the days to tasselling, silking, and maturity. Nevertheless, the current outcome was inconsistent in this regard. Such dalliance of days to 90% of maturity might be because of the increased amount of nutrients, especially nitrogen extending the growing season and delaying crop maturation by promoting vegetative growth. Also, it might be because of the positive integrity between nutrients in blended fertilizer. Because they are required for the initial development of roots and the synthesis of chlorophyll, boron, phosphorus, and sulfur all enhance the usage of nitrogen [63]. B, K, and N fertilizers work well together to increase crop yields and maturity [64].

This result contradicts the finding of Hailu et al., [57] and Kinfe et al., [61] who stated that maturity is significantly affected by the application of NPSZnB blended fertilizer rates, and in contrast to the control, which took the longest days to reach maturity, short maturity days were observed with the administration of NPSZnB blended fertilizer.

Regarding the effects of farmyard manure, application at the level of 16 t·ha^{-1} resulted in the longest maximum days to reach maturity 139.74 which was delayed by 1.8 days on plots not receiving farmyard manure (137.93) (Table 7). However, it was significantly at par with all rates of farmyard manure except nil application. However, no farmyard manure application caused the shortest days to reach physiological maturity.

In addition to releasing nutrients such as nitrogen and phosphorus that encouraged vegetative growth, prolonged the growing season, and consequently delayed the maturity of the maze, increasing FYM dosage may also be caused by increases in soil moisture-holding capacity and decreased nutrient leaching. Due to their usage in the production of chlorophyll and the earliest stages of root development, phosphorus, sulfur, and boron promote the intake of nitrogen [65]. The findings of this investigation are consistent with those of Redda and Abay [66] who found that using a larger dose of FYM (9 t·ha^{-1}) recorded longer days (122, 5) to physiological maturity.

3.5. Plant Height (cm). The outcome of combined analysis of variance of two years of data, NPSZnB Blended fertilizer, farmyard manure as well as their interaction revealed significant differences ($p < 0.05$), in plant height of the maize crop at both experimental locations (Table 5).

The tallest plant height of 218.91 cm at Jabi Tehnan and 217.79 cm at Mecha was recorded from the combined application of 250 kg·ha^{-1} NPSZnB blended fertilizer and 20 t·ha^{-1} farmyard manure which showed an increment in length by 1.3 cm at Jabi Tehnan and by 1.79 cm at Mecha compared to the conventional DAP and urea fertilizers. However, at Mecha, the treatment combination level which was given the maximum plant height was significantly on par with 250 and 300 kg·ha^{-1} NPSZnB blended fertilizer integrated with 16 t·ha^{-1} farmyards and also 300 kg·ha^{-1} NPSZnB blended fertilizer integrated with 20 t·ha^{-1} farmyard manure application. The shortest plant measures 169.1 cm in height at Jabi Tehnan and 168.83 cm at Mecha were obtained from the lower level of NPSZnB blended fertilizer (100 kg·ha^{-1}) and nil farmyard manure application (Table 8).

Plants treated with the maximum blending of NPSZnB fertilizer and cattle manure showed that a substantial increase in plant height could be due to the role of nutrients individually and also their collaboration with nitrogen, which is one of the nutrients that contribute most to yield and, when present in sufficient amounts, encourages the creation of chlorophyll, which leads to better photosynthetic activity, stronger vegetative growth, and taller plants. Shoot and root tips, where metabolism is high and cell division is quick, require a significant amount of phosphorus. The same is true with sulfur, which encourages the production of chlorophyll, increased photosynthetic activity, robust vegetative development, and taller plants. Due to boron's crucial function in cell division and nitrogen absorption from the soil, which promotes plant growth and eventually increases plant height, the addition of boron in the NPSZnB blended fertilizer also considerably boosted plant height. Zinc promotes the production of chlorophyll, photosynthesis, nitrogen uptake, and metabolism [67].

3.6. Leaf Area Index. The combined analysis of variance over years exhibited that the impact of NPSZnB blended fertilizer and farmyard manure on leaf area index was significant ($P < 0.0001$) (Table 5), and their interaction results, however, were not significant at both locations.

The leaf area index (LAI) is a significant growth indicator that assesses a plant's ability to capture solar energy for photosynthesis. It has a significant impact on the plant's growth and output. Application of 300 kg·ha^{-1} NPSZnB blended fertilizer resulted in the highest leaf area index 3.93 and 3.37 at Jabi Tehnan and Mecha, respectively (Table 9), which shows a relative reduction of leaf area index by (8.23%) at Jabi Tehnan and (17.10%) at Mecha than the conventional DAP and urea, while the lowest leaf area index (2.92) at Jabi Tehnan and (2.6314) at Mecha was recorded from the least level of blended (NPSZnB) fertilizer (100 kg·ha^{-1}). However, at both locations, the NPSZnB

Table 8: Interaction effects of NPSZnB blended fertilizer and farmyard manure on plant height, combined over years 2016/17 and 2017/18 in Jabi Tehnan and Mecha districts of Ethiopia.

Treatments	Experimental locations							
	Jabi Tehnan				Mecha			
BR kg ha^{-1}	217.6				216			
FYM tha^{-1}					FYM tha^{-1}			
BF kg ha^{-1}	0	12	16	20	0	12	16	20
100	169.1p	181.01o	181.6o	188.85n	168.83l	180.74k	181.33kj	185.33ij
150	188.85m	190.19l	192.67k	195.93j	188.58ih	193.46g	192.4gh	195.66gf
200	199.03i	209.6g	212.54de	213.3d	198.76f	209.33dc	211.69b–d	212.27b–d
250	200.5h	211.9e	214.24c	218.91a	203.3e	211.49b–d	213.55a–c	217.79a
300	211f	212.02e	216.40b	217.01b	208.98d	211.88b–d	213.97ba	216.74a
CV (%)	0.34				1.78			
LSD	0.83				4.31			
P value	<0.0001				<0.0001			

There is no noticeable difference between means inside a column that is preceded by the same letter. BR: blanket recommendation (200 kg·ha^{-1} DAP and 150 kg·ha^{-1} urea); BF: NPSZnB blended fertilizer; FYM: farmyard manure; CV: coefficient of variation; LSD: least significant difference; PH: plant height.

Table 9: Main effects of NPSZnB blended fertilizer and farmyard manure on leaf area index, harvest index, and ear length, combined over years 2016/17 and 2017/18 in Jabi Tehnan and Mecha districts of Ethiopia.

Treatments	Experimental location			
	Jabi Tehnan		Mecha	
	LAI	HI	EL	LAI
BR kg ha^{-1}	3.94	50.50	16.42	3.82
BF kg ha^{-1}				
100	2.92c	44.97c	13.44b	2.63c
150	3.01bc	49.50b	13.83b	2.82bc
200	3.13bc	53.10a	15.23a	2.81bc
250	3.34b	52.82a	16.10a	3.03b
300	3.93a	52.59a	16.16a	3.37a
LSD	0.37	2.16	0.98	0.22
P value	<0.0001	<0.0001	<0.0001	<0.0001
FYM (t ha^{-1})				
0	3.01b	50.06	13.91b	2.69b
12	3.21ab	50.41	14.95a	2.80b
16	3.33ab	51.60	15.22a	3.07a
20	3.52a	50.32	15.73a	3.166a
CV %	19.79	7.48	11.52	13.65
LSD	0.33	NS	0.88	0.20
P value	0.0224	0.4081	0.0009	<0.0001

There is no noticeable difference between means inside a column that is preceded by the same letter. BR: blanket recommendation (200 kg·ha^{-1} DAP and 150 kg·ha^{-1} urea); BF: blende fertilizer (NPSZnB); FYM: farmyard manure; CV: coefficient of variation; LSD: least significant difference; LAI: leaf area index; HI: harvest index; EL: ear length.

blended fertilizer rate that resulted in the smallest leaf area index was statistically similar to the 150 and NPSZnB kg ha^{-1} application. The improved leaf area index with increased NPSZnB blended fertilizer rate could be attributed to the vigorous growth and leaf enlargement in length and width in response to the significant role of individual nutrients and their synergy as well. Nitrogen causes the production of more above-ground biomass with enlarged leaves. In addition, phosphorus encourages the rapid development of the canopy and aids in the division of root cells. Due to their roles in the synthesis of chlorophyll, activation of enzymes, increased resilience to biotic and abiotic stressors, and defense against oxidative damage, phosphorus, boron, sulfur, and zinc boost the uptake of nitrogen [68].

Farmyard manure (20 t·ha^{-1}) exhibited the greatest leaf area index (3.72) and (3.16), 16.73%, and 17.10% more compared to the blanket conventional recommended DAP and urea fertilizer at Jabi Tehnan and Mecha, respectively. However, the farmyard manure rate that resulted in the maximum leaf area index was statistically comparable to 16 t·ha^{-1} at both experimental location and also by 12 t·ha^{-1} at Jabi Tehnan while no farmyard manure application provided the lowest leaf area index (3.01) and (2.69) at Jabi Tehnan and Mecha, respectively (Table 9). However, it was statistically at par with all various rates, except the higher rate at Jabi Tehnan and with 12 t·ha^{-1} farmyard manure at Mecha. In addition, it also assisted in maintaining functional leaf area throughout the growth phase in a replay to N availability, which promotes root growth and may have improved plants' ability to obtain nutrients in response to increased physical qualities of the soil [69]. This finding agrees with the findings of Sanni [70] who observed that increased leaf area in soil amended with organic fertilizer could probably be attributed to N availability which promoted leaf area during vegetative development and also helped to maintain functional leaf area during the growth period.

3.7. Ear Length (cm). Based on data from a multiyear combined data analysis of variance, at Jabi Tehnan, ear length was significantly ($P < 0.001$) affected due to the applications of NPSZnB blended fertilizer, farmyard manure, and their interaction effect. At Mecha, the main factors NPSZnB blended fertilizer and farmyard manure application ($P < 0.001$) affected ear length; however, their interaction did not affect ear length (Table 10).

Ear length is a very vital yield contributive parameter of maize. It considerably contributes to the grain yield of maize by manipulating each number of grains and grain size. A combined application of 250 kg·ha^{-1} NPSZnB blended fertilizer and 20 t·ha^{-1} farmyard manure resulted in the longest ear length (17.47) at Jabi Tehnan, which is exceeded by 5.64% over the conventional urea and DAP application whereas 100 kg·ha^{-1} with no farmyard manure application recorded the shortest ear length 9.07 cm (Table 11).

The probable reason for the increment of ear length due to the increasing combined application of NPSZnB blended fertilizer with farmyard manure may be their integration creates the availability of both macro and micronutrients which encourage the growth and development of plant parts. The results are also consistent with Biramo [71] who stated that the use of NPSZnB Blended fertilizer in conjunction with farmyard manure may have been the supply of adequate micro and macronutrients, which most likely aided in improving metabolic activity during the early growth period, which in turn aided overall growth, including ear length.

At Mecha, NPSZnB blended fertilizer rate at 300 kg·ha^{-1} gave the longest ear length (16.16 cm) compared to the conventional fertilizer DAP and urea but statistically similar to 200 and 250 kg·ha^{-1} NPSZnB blended fertilizer. However, with no significant statistical variation with 150 kg·ha^{-1}, the application of 100 kg·ha^{-1} NPSZnB blended fertilizer gave the shortest ear length (13.44 cm) (Table 9).

These findings are in line with those of Fayisa et al., [72] [72] who discovered that the application of NPSZnB blended fertilizer rates had an impact on maize ear length that was extremely significant (P 0.01). His findings showed that the control had the least maize ear length (11.57 cm), while the application of 200 kg NPSZnB + 150.2 N produced the longest (16.10 cm) ear length 20 t·ha^{-1}. Farmyard manure application is caused by the longest ear length (15.73 cm) which is lower in length by 4.35% as compared with conventional fertilizer DAP and urea. However, there was no statistical difference with the rest rate of farmyard manure except for the plot treated with no farmyard manure which gives the shortest ear length of 13.91 cm (Table 9). The stimulating impact of farmyard manure, which provides the plant with nutrients needed for the improved length of the ear, may be the cause of increased ear length with an increase in the application rates of the manure. These results are in agreement with those of Eleduma et al. [73] who found that maize plants amended with the maximum farmyard manure rate (20 t·ha^{-1}) had superior cob length (17.38 cm) than the control (15.05 cm) which decreased with each decrease in the level of cattle manure applied.

3.8. Thousand Kernels Weight (g). Combined data over years indicated that thousand kernel weights were significantly ($P < 0.0001$). At both trial sites, NPSZnB mixed fertilizer, farmyard manure application, and their interaction all had an impact (Table 10).

The integrated application of 250 kg·ha^{-1} NPSZnB blended fertilizer and 20 t·ha^{-1} farmyard manure at Jabi Tehnan and 300 kg·ha^{-1} NPSZnB blended fertilizer with 20 t·ha^{-1} at Mecha had the higher thousand-grain weight of 292.6 and 290.8 g at Jabi Tehnan and Mecha, respectively, which were higher than the conventional fertilizers DAP and urea by 3.26% and 4.954%. Nonetheless, statistically speaking, it was statistically at par with the combined application of 300 kg·ha^{-1} NPSZnB blended fertilizer at Jabi Tehnan and 250 kg·ha^{-1} NPSZnB blended fertilizer at Mecha combined with 20 t·ha^{-1} farmyard manure. Lightweights of 253.814 and 252.629 g of thousand kernels were recorded from the combined application of 100 kg·ha^{-1} NPSZnB blended fertilizer with no farmyard manure application at Jabi Tehnan and Mecha, respectively (Table 12).

A significant rise in the weight of the thousands of kernels may be attributable to the synergistic effects of mixed fertilizers on maize grain filling and greater growth-promoting photosynthesis. The results of Malakouti [74] support the outcome of this investigation that integrated nutrient management significantly improves thousands of weight of kernels. The maximum (28.67 g) test weight is obtained after applying 75% RDF (75 N + 45 P_2O_5 + 30 K_2O kg·ha^{-1}) with FYM (5 t·ha^{-1}). On the other hand, the lowest (22.73 g) thousand weight of kernels were observed when just 50% RDF (50 N + 30 P_2O_5 + 20 kg K_2O kg·ha^{-1}) was applied.

3.9. Above-Ground Biomass (kg ha^{-1}). NPSZnB blended fertilizer and farmyard manure interacted and, in turn, stood alone to have a significant impact on above-ground dry biomass at both experimental locations, according to the result from combined data analysis of variance over years (Table 5).

In comparison to the conventional one, above-ground biomass yield compensations of 17.3% and 19.36% were found because of increasing NPSZnB blended fertilizer from 100 to 250 kg·ha^{-1} and farmyard manure from 0 to 20 t·ha^{-1} in a combined way at Jabi Tehnan and Mecha, respectively, than that of the conventional DAP and urea. The combination of 250 kg·ha^{-1} NPSZnB blended fertilizer and 20 t·ha^{-1} farmyard manure resulted in the highest above-

Table 10: *P* values of the effects of year, block, NPSZnB blended fertilizer farmyard manure, and their interactions on yield components and yield variables measured at Jabi Tehnan and Mecha districts in 2016/17 and 2017/18.

Sources of variation	Two years combined result				
	DF	EL	TKW	GY	HI
Jabi Tehnan					
Y	1	0.1006	0.2909	0.9714	0.9927
BL	2	0.0009	0.0610	<0.0001	0.0863
BF	4	<0.0001	<0.0001	<0.0001	<0.0001
FYM	3	<0.0001	<0.0001	<0.0001	0.4081
FYM X BL	12	<0.0001	<0.0001	<0.0001	0.0537
Error		0.2	7.8	18431.6	9.1
Total	97	97	97	97	97
Mecha					
Y	1	0.4291	0.2405	0.8873	0.1592
BL	2	0.0370	0.0594	<0.0001	0.0048
BF	4	<0.0001	<0.0001	<0.0001	<0.0001
FYM	3	0.0009	<0.0001	<0.0001	0.0071
BF XFYM	12	0.2381	<0.0001	<0.0001	0.0108
Error		2.97	7.96	19998.50	15.4
Total	97	97	97	97	97

where Y: year; BL: block; BF: NPSZnB blended fertilizer; FYM: farmyard manure; DF: degree of freedom; TKW: thousand kernels weight: GY: grain yield; EL: ear length; HI: harvest index.

Table 11: Interaction effects of NPSZnB blended fertilizer and farmyard manure on ear length, combined over years 2016/17 and 2017/18 in the Jabi Tehnan district of Ethiopia.

Treatments				
BR kg ha^{-1}		16.54		
FYM tha^{-1}				
BF kg ha^{-1}	0	12	16	20
100	9.07n	10.14m	10.37m	10.66lm
150	11.03kl	11.28jk	11.43jk	11.66j
200	11.80j	12.78hi	14.24de	14.54d
250	12.37i	13.53fg	15.10c	17.47a
300	13.14gh	13.71ef	15.29c	16.14b
CV (%)	3.611			
LSD	0.52			
P-value	<0.0001			

Means inside a column that begins with the same letter or letters do not significantly differ. BR: blanket recommendation (150 kg·ha^{-1} urea and 200 kg·ha^{-1} DAP); BF: NPSZnB blended fertilizer; FYM: farmyard manure; CV: coefficient of variation; LSD: least significant difference.

ground dry biomass 10895.0 kg and 10787.9 kg·ha^{-1} (Table 13). However, no statistical variations were observed with the integrated application of 300 kg·ha^{-1} NPSZnB blended fertilizer with 20 t·ha^{-1} farmyard manure at Jabi Tehnan.

Whereas the lowest above-ground biomass 4609.4 kg·ha^{-1} and 4896.9 kg·ha^{-1} were recorded from the application of 100 kg·ha^{-1} NPSZnB blended fertilizer at Tehnan and Mecha, respectively, it was significantly on par with 100 kg·ha^{-1} NPSZnB blended fertilizer integrated with 12 t·ha^{-1} farmyard manure at Mecha (Table 13).

A greater leaf area index, more grains per ear, longer ears, thicker stems, taller plants, and more grain could all have contributed to an increase in above-ground biomass when NPSZnB mixed fertilizer and farmyard manure application amounts were increased. The high biomass yield in the combined treatments may have been enhanced by photosynthetic production being promoted by an increase in the number of leaves and an increase in the leaf area index. The present results are supported by Yigermal et al., [75], and during two consecutive years (2005 and 2006), the influence of inorganic fertilizer and farmyard manure on above-ground biomass remained significant under different application levels and who attained the significant maximum biomass yield of maize 8579 and 8475 kg·ha^{-1}, respectively, from the combined application of NPK (60-45-30 kg·ha^{-1}) with FYM (10 t·ha^{-1}).

3.10. Grain Yield (kg ha^{-1}). Combined analysis of variance over years indicates that NPSZnB blended fertilizer, and farmyard manure, and their interaction had a significant ($p < .0001$) effect on maize grain yields at both locations (Table 10).

Table 12: Interaction effects of NPSZnB blended fertilizer and farmyard manure on thousands of kernels weight, combined over years 2016/7 and 2017/18 in Jabi Tehnan and Mecha districts of Ethiopia.

Treatments	Experimental locations							
	Jabi Tehnan				Mecha			
BR kg ha^{-1}	281.63				278.83			
FYM tha^{-1}					FYM tha^{-1}			
BF kg ha^{-1}	0	12	16	20	0	12	16	20
100	253.81j	266.48i	267.85i	271.11h	252.62k	264.63j	266ij	269.261hi
150	271.20h	272.40gh	275.62fg	276.44f	269.35h	270.55gh	273.76fg	274.59f
200	278.78ef	281.86e	288.05cd	288.43cd	276.93ef	280e	286.19cd	286.6b-d
250	276.02f	286.78cd	289.5a-c	292.64a	274.16f	284.93cd	286.6b-d	289.86ab
300	285.33d	287.42cd	288.79bc	291.74ab	283.4d	285.57cd	287.9a-c	290.81a
CV (%)	1.01				1.03			
LSD	3.25				3.29			
P-value	<0.0001				<0.0001			
P-value		<0.0001						

Means inside a column that begins with the same letter or letters do not significantly differ. BR: blanket recommendation (150 kg·ha^{-1} urea and 200 kg·ha^{-1} DAP); BF: NPSZnB blended fertilizer; FYM: farmyard manure; CV: coefficient of variation; LSD: least significant difference.

Table 13: Farmyard manure and NPSZnB blended fertilizers interactions effect on above-ground biomass, combined over years 2016/17 and 2017/18 in Jabi Tehnan and Mecha districts of Ethiopia.

Treatments	Experimental locations							
	Jabi Tehnan				Mecha			
BR kg ha^{-1}	9282.9956				9037.862			
FYM t ha^{-1}					FYM t ha^{-1}			
BF kg ha^{-1}	0	12	16	20	0	12	16	20
100	4609.4o	5612.7n	6080.4mn	6474.4lm	4896.9m	5099.6m	5562.6l	6301.2k
150	6745.7kl	6966.1kl	7245.9jk	7598.3ij	6741.9j	7296.7i	7462.0hi	7628.5g–i
200	7815.4hi	8518.1fg	9713.9de	9890.4c–e	7816.4f–h	8095.0ef	9099.0cd	9204.4cd
250	8182.1gh	8913.9f	10135.5b–d	10895.0a	7894.5fg	8355.1e	9393.7c	10787.9a
300	8 813.1f	9492.4e	10297.1bc	10686.6ab	8192.8ef	8913.1d	10063.0b	10366.4b
CV %		6.025247			4.423964			
LSD		568.3			403.29			
P-value		0.0003			<0.0001			

Means inside a column that begins with the same letter or letters do not significantly differ. BR: blanket recommendation; FYM: farmyard manure; CV: coefficient of variation; LSD: least significant difference; BR: blanket recommendation (150 kg·ha^{-1} urea and 200 kg·ha^{-1} DAP); BF: NPSZnB blended fertilizer.

The highest grain maximum grain yield 5618.5 and 5421 kg·ha^{-1} were observed in the integrated application of 250 kg·ha^{-1} of NPSZnB blended fertilizers and 20 t·ha^{-1} farmyard manure at Jabi Tehnan and Mecha, respectively. This is significantly higher than the blanket DAP and urea fertilizer recommendation/satellite control by 16.554% at Jabi Tehnan and 15.982% at Mecha. But the treatment combination level which gave the maximum result was statistically at par with 250 and 300 kg·ha^{-1} NPSZnB blended fertilizer integrated with 16 t·ha^{-1} farmyard manure at both locations and also 200 and 300 kg·ha^{-1} NPSZnB blended fertilizer combined with 20 t·ha^{-1} farmyard manure at Mecha. The lowest yield, on the other hand, was obtained at Jabi Tehnan (2218.6 kg) and Mecha (2091.29) from plots that received 100 kg·ha^{-1} of NPSZnB blended fertilizer but no farmyard manure application. At Mecha, however, there was no statistically significant difference between 100 kg·ha^{-1} NPSZnB blended fertilizer and 12 t·ha^{-1} farmyard manure combination at the treatment combination level that produced the lowest result (Table 14).

Increases in both NPSZnB blended fertilizer and farmyard manure have led to an increase in grain production, which may be ascribed to the good effects of yield-contributing traits and the beneficial interactions between nutrients in the NPSZnB blended fertilizer and farmyard manure. The mixture of inorganic fertilizer and organic manures may have enhanced nitrogen usage efficiency and recovered more micro and macronutrients, which is the other likely explanation. However, providing NPSZnB blended fertilizer at rates more than 250 kg·ha^{-1} with 20 t·ha^{-1} farmyard manure combinations tended to result in a decline in mean grain output (Table 14).

The decline in grain yield at the higher rate of NPSZnB blended fertilizer and farmyard manure could be caused by

Table 14: Interaction effects of NPSZnB blended fertilizer and farmyard manure on grain yield, combined over years 2016/17 and 2017/18 in Jabi Tehnan and Mecha districts of Ethiopia.

Treatments	Experimental locations							
	Jabi Tehnan				Mecha			
BR kg ha^{-1}	4688.4406				4554.608			
FYM tha^{-1}					FYM tha^{-1}			
BF kg ha^{-1}	0	12	16	20	0	12	16	20
100	2218.6n	2441.2m	2664.0l	2708.4l	2091.29m	2223.56m	2734.83l	2996.12k
150	3107.3k	3410.6j	3741.1i	3904.0hi	3248.50j	3377.42j	3715.42i	3847.47hi
200	3953.0h	4493.1f	5269.2c	5394.2bc	3909.81gh	4553.25f	5211.69bc	5321.05ab
250	4275.5g	4782.9de	5417.5a–c	5618.5a	4087.97g	4949.95de	5356.17ab	5421.00a
300	4638.5ef	4977.2d	5490.5ab	5518.5b	4786.97e	5044.05cd	5391.99ab	5401.03ab
CV (%)	4.31449				4.021951			
LSD	207.62				192.73			
P-value	<0.0001				<0.0001			

Means inside a column that begins with the same letter or letters do not significantly differ. BR: blanket recommendation; FYM: farmyard manure; CV: coefficient of variation; LSD: least significant difference; BR: blanket recommendation (150 kg·ha^{-1} urea and 200 kg·ha^{-1} DAP); BF: NPSZnB blended fertilizer.

more assimilated products going to the vegetative components that the grain or too much amount of nutrients especially N producing high tissue N concentration, and it can be detrimental to maze growth, causing slowed growth and a decrease in grain yield [76]. Wu et al., [77] discovered that combining organic manures with inorganic fertilizer could have improved nitrogen usage quality, micro and macronutrient recovery, Increased K supply, P Solubilization, and Plant Uptake, resulting in improved maize growth and yield. For enhancing nutrient recovery, plant growth, and final output, a combination of organic and inorganic fertilizers is recommended; in the absence of this, larger N and P treatment rates are anticipated to result in a higher yield in maize [78]. According to Ma et al.'s research [79], mixing organic and inorganic nutrient sources boosted the synergism and coordination between nutrient release and plant regeneration, which enhanced crop growth and production. In addition, Moe et al., [80] and Negassa et al., [81] discovered that combining organic and inorganic fertilizers efficiently improves nitrogen use efficiency, and integrating inorganic and organic nutrients improved maize yield by 35%.

3.11. Harvest Index (%). The pooled analysis of variance over years revealed that either the main effect of farmyard manure or its interaction with NPSZnB blended fertilizer did not exert a significant effect on the harvest index (HI) at Jabi Tehnan. However, only NPSZnB blended fertilizer caused a highly significant ($p < 0.001$) effect on this parameter (Table 10). At Mecha, both significant ($p = 0.0108$) interactions and the main effect of treatment on harvest index were observed (Table 10).

At Mecha, NPSZnB blended fertilizer values of 250 kg·ha^{-1} with a rate of farmyard manure of 12 t·ha^{-1} produced a maximum harvest index of 59.2 that exceeded by 14.9 percent over the conventional fertilizers DAP and urea. However, it was statistically equivalent to the application of 300 kg·ha^{-1} NPSZnB blended fertilizer combined with 12 and 16 t·ha^{-1} farmyard manure and without farmyard manure application, 200 kg·ha^{-1} NPSZnB blended fertilizer combined with 12, 16, and 20 t·ha^{-1} farmyard manure, and 250 kg·ha^{-1} NPSZnB blended fertilizer combined with 16 t·ha^{-1} farmyard manure. Whereas crops on a plot treated with the least rate of NPSZnB blended fertilizer (100 kg·ha^{-1}) along with no farmyard manure application recorded the lowest harvest index of 43.8, it was statistically on par with 100 kg·ha^{-1} NPSZnB blended fertilizer with 12 and 20 t·ha^{-1} farmyard manure application and also 150 kg·ha^{-1} NPSZnB blended fertilizer with 12 t·ha^{-1} and without farmyard manure application (Table 15).

The higher maize harvest index with increased NPSZnB blended fertilizer and farmyard manure application might be due to higher grain yield per plant. This might be a result of the fertilizer's ability to effectively ingest plant nutrients in response to the harmony of macro- and micronutrients and their interactions with one another (blended and farmyard manure). The increasing trend of harvest index with an increase of both NPSZnB blended fertilizer and farmyard manure rates up to a certain level, followed by a decrease with more increasing rates of both NPSZnB blended fertilizer and farmyard manure, is probably because of excessive application of NPSZnB blended fertilizer and farmyard manure promoted more vegetative growth than grain.

Other scholars have backed up the study's findings, according to Amanullah et al., [82], effective uptake in response to a balanced P and Zn diet increased photo assimilation and translocation to grains, resulting in a higher harvest index. According to Kugbe et al., [83], boron increases crop yield even in P-deficient soils due to synergy in phosphorus absorption through B. Contrarily, greater nutrient availability may have retarded senescence and lengthened the life cycle of the maize plant, leading to a better economic output and harvest index, according to Dong et al., [84]. Fantaye and Hintsa [85] reported that the supreme harvest index of maize was obtained from the application of 50 to 150 kg·ha^{-1} NPSZnB blended fertilizer,

Table 15: Interaction effects of NPSZnB blended fertilizer and farmyard manure on harvest index, combined over years 2016/17 and 2017/18 in Mecha districts of Ethiopia.

Treatments				
BR kg ha^{-1}		50.39475		
FYM tha^{-1}				
BF kg ha^{-1}	0	12	16	20
100	43.85h	44.285h	49.16e–g	47.75f–h
150	48.504f–h	46.391gh	49.8e–g	50.48e–g
200	50.05e–g	56.23a–d	57.297ab	57.815ab
250	51.834d–f	59.263a	57.017ab	50.27e–g
300	58.419a	56.64a–c	53.68a–e	52.215c–f
CV (%)	7.818230			
LSD	4.6609			
P-value	0.0108			

Means inside a column that begins with the same letter or letters do not significantly differ. BR: blanket recommendation; FYM: farmyard manure; CV: coefficient of variation; LSD: least significant difference; BR: blanket recommendation (150 kg·ha^{-1} urea and 200 kg·ha^{-1} DAP); BF: blended fertilizer (NPSZnB).

Table 16: Effects of combined use of NPSZnB blended fertilizer and fertilizer and farmyard manure on the economic profitability of maize production in the Jabi Tehnan district.

	AGY (kg ha^{-1})	GBV (ETB ha^{-1})	TVC (ETB ha^{-1})	NBV (EBB ha^{-1})	MRR%
150 kg·ha^{-1} urea ∗ 200 kg·ha^{-1} DAP	4219.60	50635.16	16632.00	34003.16	D
BF kg ha^{-1} with FYM t ha^{-1}					
200 ∗ 16	4742.28	56907.36	20930.25	35977.11	45.92
200 ∗ 20	4854.78	58257.36	22036.30	36221.06	22.06

Table 17: Effects of combined use of NPSZnB blended fertilizer and farmyard manure on the economic profitability of maize production in Mecha district.

	AGY (kg ha^{-1})	GBV (ETB ha^{-1})	TVC (ETB ha^{-1})	NBV (EBB ha^{-1})	MRR%
150 kg·ha^{-1} urea ∗ 200 kg·ha^{-1} DAP	4099.15	49189.77	16632.00	32557.77	D
BF kg ha^{-1} with FYM t ha^{-1}					
200 ∗ 16	4690.52	56286.25	20930.25	35356.00	65.10
200 ∗ 20	4788.95	57467.34	22036.30	35431.04	6.78

where ETB: Ethiopian birr (currency); BF: NPSZnB blended fertilizer; FYM: farmyard manure; AGY: adjusted grain yield, GBV: gross benefit value, TAVC: total variable cost; NBV: net benefit value; MRR: marginal rate of return.

as opposed to the conventional DAP, but further increasing the NPSZnB blended fertilizer rate above 150 kg·ha^{-1} became the cause for the reduction of harvest index.

At Jabi Tehnan, the maximum harvest index of 53.1 was obtained from 200 kg·ha^{-1} of NPSZnB blended fertilizer which was higher by 14.91% than the blanket rational recommended fertilizers DAP and urea treatment application. However, it was statistically on par with 250 and 300 kg·ha^{-1}. Meanwhile, statistically, the minimum harvest index of 44.97 was documented from the least level of NPSZnB blended fertilizer (100 kg·ha^{-1}) (Table 9).

Increases in HI and NPSZnB blended fertilizer can be correlated with nutrient availability, particularly N, which has a favorable impact on assimilate partitioning to grain yield. However, supplying NPSZnB blended fertilizer at a rate above 200 kg·ha^{-1} tended to cause mean HI to decline (Table 9). While vegetative biomass output is proportionally higher than grain yield at higher blended fertilizer rates, the decrease in HI at the higher rate of NPSZnB blended fertilizer may be explained by the development of more vegetative biomass than grain yield. This outcome is consistent with Gurmu and Mintesnot's [62] findings, according to which the harvest index of maize was determined to be maximum at a rate of 150 kg·ha^{-1} NPSZnB when compared to the control treatment. Moreover, Tekle and Wassie [86] revealed that when compared to the control, blended fertilizer treatments had the highest harvest index of Tef. In agreement with this finding, Taddesse et al.'s [87] study found that excessive nutrient treatment decreased the amount of HI in grain crops.

3.12. Economic Analysis. An economic analysis was carried out using partial and marginal analysis to determine the economic feasibility of the various prices of NPSZnB blended fertilizer and farmyard manure used in these studies. The marginal rate of return (MRR) was determined by dividing the successive net benefit and total variable cost ratios' change in net profit (NB) by the change in gross variable cost (TVC) [49]. Maize variable prices, total profits, and related net returns are influenced by various rates. Tables 16 and 17 show the marginal rate of maize returns as a function of the combination of NPSZnB blended fertilizer and farmyard manure at Jabi Tehnan and Mecha.

According to a partial budget study, with a rise in input price of 10% and a decrease in output price of 10%, the application of NPSZnB blended fertilizer combined with farmyard manure showed that the treatment combination of 200 kg·ha^{-1} NPSZnB blended fertilizer with 20 t·ha^{-1} farmyard manure yielded the highest net return of EB 36221.06 and 35431.04 with marginal rate returns of 22.05 and 6.78% at Jabi Tehnan and Mecha, respectively. This means that for every 1.00 birr invest in a 200 kg·ha^{-1} NPSZnB blended fertilizer application with 20 t·ha^{-1} farmyard manure, producers can expect to recover 1.00 birr and obtain an additional 0.46 and 0.65 birr at Jabi Tehnan and Mecha, respectively.

Therefore, in both experimental areas, it would be advisable for small-scale farmers with low production costs, and greater benefits, in this instance, were blanket recommendations (200 kg·ha^{-1} DAP and 150 kg·ha^{-1} urea). However, for farmers with unlimited resources (investors), a combination of 200 kg·ha^{-1} NPSZnB blended fertilizer and 20 t·ha^{-1} blended fertilizer was also profitable and recommended as the second option. According to Agegnehu and Fessehaie, [49], the marginal rate of return (MRR %) should have a minimum of 50% and a maximum of 100%. According to the current study, MRR for the first option is significantly higher than 100% at both locations. Overall, there is strong evidence from the cost-benefit analysis that applying NPSZnB mixed fertilizer and farmyard manure together considerably boosted maize production, leading to considerable economic benefits.

4. Conclusion and Recommendations

Maize is a cereal crop that Ethiopia is relying on more and more for food security, notably in west Gojam, one of the country's prospective growth regions; however, its production is facing critical problems. However, its production is facing critical problems. Critical issues with maize production have arisen in Ethiopia as a result of the steadily declining fertility of the soil, continuous cropping, use of residues and manure as fuel instead of recycling, and erosion coupled with poor intrinsic fertility and organic content of the soil.

At both locations, except for days to silking and leaf area index at both location and days to physiological maturity, ear length, at Mecha, almost all parameters were significantly hastened and improved/increased by the individual as well as combined application of NPSZnB blended fertilizer and farmyard manure. Exceptionally, the only main effect of NPSZnB blended fertilizer was observed on the harvest index at Jabi Tehnan. Generally, on all parameters, the maximum result obtained from the interaction effect was improved and greater than that of the blanket recommendation (DAP and urea) but less in the case of main effects. The plant's ability to develop and perform vegetatively was greatly aided by the accessibility of nutrients from both sources.

The results of phenology, growth, and yield parameters showed that the fertility of the soil in the experimental area was not satisfactory, as all fertilized treatments, particularly the combined application of NPSZnB blended fertilizer and farmyard manure, produced better results than the use of either of them alone did, which produced relatively poor results. Research suggested that the optimal strategy for the crop's development and production performance is comprehensive nutrient management. The integrated strategy also has a long-term advantage in that it enhances the soil's physicochemical characteristics for sustained crop production.

In general, this research contradicts prior findings that using farmyard manure reduced recommended inorganic fertilizer rates by half. Instead, a high rate (250 kg·ha^{-1}) combined with 20 t·ha^{-1} of farmyard manure is the most likely combination to achieve the best grain production and profit, and it can be a viable alternative to integrated soil fertility management.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] P. Matouš, Y. Todo, and D. Mojo, "Roles of extension and ethnoreligious networks in acceptance of resource-conserving agriculture among Ethiopian farmers," *International Journal of Agricultural Sustainability*, vol. 11, no. 4, pp. 301–316, 2013.

[2] A. Bekele and Y. Lakew, *Projecting Ethiopian Demographics from 2012–2050 Using the Spectrum Suite of Models*, EPHA, Addis Ababa, Ethopia, 2014.

[3] T. Woldehanna and M. Araya, "WPoverty and inequality in Ethiopia," in *The Oxford Handbook of the Ethiopian Economy*, F. Cheru, C. Cramer, and A. Oqubay, Eds., Oxford University Press, Oxford, UK, 2019.

[4] F. Faostat, "Food and agriculture organization of the united nations-statistic division," 2019, https://www.fao.org/faost%20at/en/#data.

[5] T. Abate, B. Shiferaw, S. Gebeyehu et al., "A systems and partnership approach to agricultural research for development Lessons from Ethiopia," *Outlook on Agriculture*, vol. 40, no. 3, pp. 213–220, 2011.

[6] A. Teklewold, D. W. Gissa, A. Tadesse et al., *Quality Protein Maize (QPM): A Guide to the Technology and its Promotion in Ethiopia*, CIMMYT: Addis Ababa, Ethiopia, 2015.

[7] CSA (Central Statistical Agency), *The Federal Democratic republic of Ethiopia central Statistical agency: Agricultural Sample Survey 2016/2017 (2009 E.C.). Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season) Statistical Bulletin 584*, Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia, 2017.

[8] F. N. Bachewe, G. Berhane, B. Minten, and A. S. Taffesse, "Agricultural growth in Ethiopia (2004–2014): evidence and drivers," *Gates Open Research*, vol. 3, no. 661, p. 661, 2019.

[9] CSA, "Central statistical agency of the federal democratic republic of Ethiopia, agricultural sample survey, 2018/19. Report on area and production of major crops (private peasant holdings, meher season," *Statistical Bulletin*, vol. 278, 2019.

[10] J. Gustavsson, C. Cederberg, U. Sonesson, R. Van Otterdijk, and A. Meybeck, *Global Food Losses and Food Waste*,FAO Rome, Rome, Italy, , 2011.

[11] T. Abate, B. Shiferaw, A. Menkir et al., "Factors that transformed maize productivity in Ethiopia," *Food Security*, vol. 7, no. 5, pp. 965–981, 2015.

[12] T. Dowswell, E. Towner, G. Simpson, and S. Jarvis, "Preventing childhood unintentional injuries--what works? A literature review," *Injury Prevention*, vol. 2, no. 2, pp. 140–149, 1996.

[13] K. Potla, S. Bornare, L. Prasad, R. Prasad, and A. Madakemohekar, "Study of heterosis and combining ability for yield and yield contributing traits in barley (Hordeum vulgare L.)," *The Bioscan*, vol. 8, no. 4, pp. 1231–1235, 2013.

[14] K. Tully, C. Sullivan, R. Weil, and P. Sanchez, "The state of soil degradation in Sub-Saharan Africa: baselines, trajectories, and solutions," *Sustainability*, vol. 7, no. 6, pp. 6523–6552, 2015.

[15] Z. Sawan, S. Hafez, and A. Basyony, "Effect of phosphorus fertilization and foliar application of chelated zinc and calcium on seed, protein, and oil yields and oil properties of cotton," *The Journal of Agricultural Science*, vol. 136, no. 2, pp. 191–198, 2001.

[16] A. Ilyas, M. Y. Ashraf, M. Hussain, M. Ashraf, R. Ahmed, and A. Kamal, "Effect of micronutrients (Zn, Cu, and B) on photosynthetic and fruit yield attributes of citrus reticulate Blanco var. know," *Pakistan Journal of Botany*, vol. 47, no. 4, pp. 1241–1247, 2015.

[17] N. Sanginga and P. L. Woomer, *Integrated Soil Fertility Management in Africa: Principles, Practices, and Developmental Process*, CIAT, Cali-Palmira, Colombia, 2009.

[18] J. Macholdt, H. P. Piepho, and B. Honermeier, "Mineral NPK and manure fertilisation affecting the yield stability of winter wheat: results from a long-term field experiment," *European Journal of Agronomy*, vol. 102, pp. 14–22, 2019.

[19] U. Sharma, S. Paliyal, S. Sharma, and G. Sharma, "Effects of continuous use of chemical fertilizers and manure on soil fertility and productivity of maize–wheat under rainfed conditions of the Western Himalayas," *Communications in Soil Science and Plant Analysis*, vol. 45, no. 20, pp. 2647–2659, 2014.

[20] R. Singh, P. Singh, H. Singh, and A. Raghubanshi, "Impact of sole and combined application of biochar, organic and chemical fertilizers on wheat crop yield and water productivity in a dry tropical agroecosystem," *Biochar*, vol. 1, no. 2, pp. 229–235, 2019.

[21] R. Sharma, N. Sankhyan, R. Kumar, and S. Sepehya, "Effect of a four-decade long application of fertilizers, farmyard manure and lime, on forms of soil acidity and their relationship with yield of wheat and maize in an acid Alfisol," *Journal of Plant Nutrition*, vol. 41, no. 11, pp. 1444–1455, 2018.

[22] H. F. Murphy, *A Report on the Fertility Status and Other Data on Some Soils of Ethiopia*, Imperial College of Agriculture and Mechanical Arts, Alemaya, 1968.

[23] W. Haile and T. Mamo, "The effect of potassium on the yields of potato and wheat grown on the acidic soils of Chencha and Hagere Selam in Southern Ethiopia," *International Potash Institute Research Findings*, vol. 35, pp. 3–8, 2013.

[24] G. Diriba-Shiferaw, R. Nigussie-Dechassa, W. Kebede, T. Getachew, and J. Sharma, "Growth and nutrients content and uptake of garlic (Allium sativum L.) as influenced by different types of fertilizers and soils," *Science, Technology and Arts Research Journal*, vol. 2, no. 3, pp. 35–50, 2013.

[25] G. Agegnehu, B. Lakew, and P. N. Nelson, "Cropping sequence and nitrogen fertilizer effects on the productivity and quality of malting barley and soil fertility in the Ethiopian highlands," *Archives of Agronomy and Soil Science*, vol. 60, no. 9, pp. 1261–1275, 2014.

[26] A. Astatke, T. Mamo, D. Peden, and M. Diedhiou, "Participatory on-farm conservation tillage trial in the Ethiopian highland Vertisols: the impact of potassium application on crop yields," *Experimental Agriculture*, vol. 40, no. 3, pp. 369–379, 2004.

[27] T. Amare, Z. Bazie, E. Alemu et al., "Crops response to the balanced nutrient application in Northwestern Ethiopia," *Amhara Agricultural Research Institute (Arari)*, vol. 17, 2018.

[28] M. Tafere, A. Hassen, B. Kassa et al., *Participatory Rural Appraisal Report: Dera District*, American Society of Composers, Authors and Publishers, New York, NJ, USA, 2011.

[29] Y. Abebe, M. Tafere, S. Dagnew et al., "Best fit practice manual for Rhodes grass (Chloris gayana) production. Capacity building for scaling up of evidence-based practices in agricultural production in Ethiopia," *BDU-CASCAPE Working. Paper*, vol. 10, 2015.

[30] H. A. Beyene, *Factors Affecting the Sustainability of Rural Water Supply Systems: The Case of Mecha Woreda, Amhara Region, Ethiopia*, Citeseer, Pennsylvania, PA, USA, 2012.

[31] G. W. Thomas, "Soil pH and soil acidity," *Methods of soil analysis: part 3 chemical methods*, vol. 5, pp. 475–490, 1996.

[32] M. J. Sanchez-Martin, M. Sánchez-Camazano, Adsorption and mobility of cadmium in natural, uncultivated soils," *American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America*, vol. 22, no. 4, pp. 737–742, 1993.

[33] H. D. Chapman, "Cation-exchange capacity," *Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties*, vol. 9, pp. 891–901, 1965.

[34] J. R. Landon, "Booker tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics," *Routledge*, 2014.

[35] D. L. Heanes, "Determination of total Organic-C in soils by an improved chromic acid digestion and spectrophotometric procedure," *Communications in Soil Science and Plant Analysis*, vol. 15, no. 10, pp. 1191–1213, 1984.

[36] A. Woldeab and T. Mamo, "Soil fertility management studies on wheat in Ethiopia," 1991.

[37] J. M. Bremner and C. S. Mulvaney, "Nitrogen-total," in *Methods of Soil Analysis, 2nd edition, Agronomy Monograph No. 9 Page A. L.*, pp. 595–624, American Society of Agronomy. Part 2, Madison, WI, 1982.

[38] S. Olsen, "REstimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939)," *US Department of Agriculture*, 1954.
[39] R. G. Hoeft, L. M. Walsh, and D. R. Keeney, "Evaluation of various extractants for available soil sulfur," *Soil Science Society of America Journal*, vol. 37, no. 3, pp. 401–404, 1973.
[40] EthioSIS (Ethiopia Soil Information System), "Soil fertility status and fertilizer recommendation atlas for Tigray regional state," Ethiopia. Addis Ababa, 2014.
[41] J. L. Havlin, J. P. Beaton, S. L. Tisdale, and W. L. Nelson, *Soil Fertility Dan Fertilizer. An Introduction To Nutrient Management*, Prentice-Hall, New Jersey, 1999.
[42] B. M. Shehu, R. Merckx, J. M. Jibrin, A. Y. Kamara, and J. Rurinda, Quantifying variability in maize yield response to nutrient applications in the Northern Nigerian Savanna," *Agronomy*, vol. 8, no. 2, p. 18, 2018.
[43] W. L. Lindsay and W. Norvell, "Development of a DTPA soil test for zinc, iron, manganese, and copper," *Soil Science Society of America Journal*, vol. 42, no. 3, pp. 421–442, 1978.
[44] T. Tadesse, I. Haque, and E. A. Aduayi, "Soil, plant, water, fertilizer, animal manure and compost analysis manual," 1991.
[45] J. R. Landon, "Booker tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics," *Routledge*, 1991.
[46] ATA, "Status of soil resources in Ethiopia and priorities for sustainable management: Gsp for eastern and southern Africa," Nairobi, Kenya, 2013.
[47] B. Abebe, *Agronomy Research Manual. Part III. Formula and Tables*, Institute of Agricultural Research, Addis Ababa, Ethopia, 2011.
[48] Cimmyt Economics Program, *From Agronomic Data to Farmer Recommendations: An Economics Workbook*, Cimmyt, Mexico, North America, 1988.
[49] G. Agegnehu and R. Fessehaie, "Response of faba bean to phosphate fertilizer and weed control on nitisols of Ethiopian highlands," *Italian Journal of Agronomy*, vol. 1, no. 2, pp. 281–290, 2006.
[50] K. A. Gomez and A. A. Gomez, *Statistical Procedures for Agricultural Research*, John Wiley and Sons, New Jersy, NJ, USA, 1984.
[51] S. Sas, *STAT User's Guide*, vol. 3,Cary: SAS Inst, Cary, NC, USA.
[52] Y. G. Selassie, "The effect of N fertilizer rates on agronomic parameters, yield components, and yields of maize grown on Alfisols of North-western Ethiopia," *Environmental Systems Research*, vol. 4, no. 1, pp. 21–27, 2015.
[53] A. Habtamu, G. Heluf, B. Bobe, and A. Enyew, "Effects of organic and inorganic fertilizers on yield and yield components of maize at Wujiraba Watershed, Northwestern Highlands of Ethiopia," *American Journal of Plant Nutrition and Fertilization Technology*, vol. 5, no. 1, pp. 1–15, 2015.
[54] B. Masrie, N. Dechassa, T. Tana, Y. Alemayehu, and B. Abebie, "The effects of combined application of cattle manure and NP fertilizers on yield and nutrient uptake of potato in North-Eastern Ethiopia," *Journal of Science and Sustainable Development*, vol. 3, no. 1, pp. 1–23, 2015.
[55] J. Tetarwal, B. Ram, and D. Meena, "Effect of integrated nutrient management on productivity, profitability, nutrient uptake, and soil fertility in rainfed maize (Zea mays)," *Indian Journal of Agronomy*, vol. 56, no. 4, pp. 373–376, 2011.
[56] Y. Melaku, S. Singh, and W. Wondimu, "Agrophysiological changes caused by farmyard manure and NPS fertilizer enhance yield and economic return from maize (Zea mays L.) cultivation in acidic soil," *Tropical Agriculture*, vol. 98, no. 1, p. 2021.
[57] A. Hailu, D. A. Dagne, and M. Boelaert, "Leishmaniasis," in *Neglected Tropical Diseases-Sub-Saharan Africa*, Springer, Berlin, Germany, 2016.
[58] R. Cock and B. Ellis, *Soil Management, a World View of Conservation*, Krieger Publishing Company, Malabar, Florida, 1992.
[59] E. Makinde and O. Ayoola, "Maize growth, yield, and soil nutrient changes with N-enriched organic fertilizers," *African Journal of Food, Agriculture, Nutrition and Development*, vol. 9, no. 1, pp. 580–592, 2009.
[60] D. F. Uwah, U. L. Undie, and N. M. John, "Comparative evaluation of animal manures on soil properties, growth, and yield of sweet maize (Zea mays L. saccharata Strut.)," *Journal of Agriculture and Environmental Sciences*, vol. 3, no. 2, pp. 315–331, 2014.
[61] T. Kinfe, T. Tsadik, B. Tewolde et al., "Evaluation of NPSZnB fertilizer levels on yield and yield component of maize (Zea mays L.) at Laelay Adiyabo and Medebay Zana districts, Western Tigray, Ethiopia," *Journal of Cereals and Oilseeds*, vol. 10, no. 2, pp. 54–63, 2019.
[62] S. Gurmu and A. Mintesnot, "Effect of combined application of NPS fertilizer and compost on phenology and growth of quality protein maize (Zea mays L.) at Jimma, southwestern Ethiopia," *International Journal of Research Studies in Science, Engineering, and Technology*, vol. 7, pp. 18–28, 2020.
[63] R. Uchida, "Essential nutrients for plant growth: nutrient functions and deficiency symptoms," *Plant nutrient management in Hawaii's soils*, vol. 4, pp. 31–55, 2000.
[64] N. K. Fageria, "Influence of micronutrients on dry matter yield and interaction with other nutrients in annual crops," *Pesquisa Agropecuária Brasileira*, vol. 37, no. 12, pp. 1765–1772, 2002.
[65] A. S. Rao and K. S. Reddy, "Nutrient management in soybean," *The soybean: Botany, Production, and Uses*, pp. 161–190, 2010.
[66] A. Redda and F. Abay, "Agronomic performance of integrated use of organic and inorganic fertilizers on rice (Oryza sativa L.) in the select district of north-western Tigray, Ethiopia," *Journal of Environment and Earth Science. ISSN*, pp. 2224–3216, 2015.
[67] J. Potarzycki, "Improving nitrogen use efficiency of maize by better fertilizing practices. Review paper," *Nawozy i Nawożenie/Fertilizers and Fertilization*, vol. 39, no. 5, 2010.
[68] J. Potarzycki and W. Grzebisz, "Effect of zinc foliar application on grain yield of maize and its yielding compone," *Plant Soil and Environment*, vol. 55, no. 12, pp. 519–527, 2009.
[69] L. Preisser, C. Miot, H. Guillou-Guillemette et al., "IL-34 and macrophage colony-stimulating factor are overexpressed in hepatitis C virus fibrosis and induce profibrotic macrophages that promote collagen synthesis by hepatic stellate cells," *Hepatology*, vol. 60, no. 6, pp. 1879–1890, 2014.
[70] K. O. Sanni, "Effect of compost, cow dung, and NPK 15-15-15 fertilizer on growth and yield performance of Amaranth (*Amaranthus hybridus*)," *International Journal of Advances in Scientific Research*, vol. 2, no. 3, pp. 76–82, 2016.
[71] G. Biramo, *Effects of Biogas and Chemical Fertilizer on Yield, Yield Components of Tomato, and Soil Properties in Arbaminch Zuria District, Gamogofa Zone, Southern Ethiopia*, Hawassa University, Awasa, Ethiopia, 2017.
[72] B. A. Fayisa, G. A. Jibat, and S. K. Abdella, "Maize response to blended fertilizer estimates through nutrient use efficiency and economic analysis from assosa," *Western Ethiopia*, 2021.

[73] A. Eleduma, A. Aderibigbe, and S. Obabire, “Effect of cattle manure on the performances of maize (Zea mays L) grown in forest-savannah transition zone Southwest Nigeria,” *International Journal of Agricultural Science and Food Technology*, vol. 6, no. 1, pp. 110–114, 2020.

[74] M. J. Malakouti, “The effect of micronutrients in ensuring efficient use of macronutrients,” *Turkish Journal of Agriculture and Forestry*, vol. 32, no. 3, pp. 215–220, 2008.

[75] H. Yigermal, K. Nakachew, and F. Assefa, “Effects of integrated nutrient application on phenological, vegetative growth and yield-related parameters of maize in Ethiopia: a review,” *Cogent Food and Agriculture*, vol. 5, no. 1, Article ID 1567998, 2019.

[76] D. Smith, M. Dijak, P. Bulman, B. Ma, and C. Hamel, “Barley: physiology of yield,” in *Crop Yield*, pp. 67–107, Springer, Berlin, Germany, 1999.

[77] Q. Wu, Z. Li, H. Hong, K. Yin, and L. Tie, “Adsorption and intercalation of ciprofloxacin on montmorillonite,” *Applied Clay Science*, vol. 50, no. 2, pp. 204–211, 2010.

[78] S. Mubeen, J. Lee, N. Singh, S. Krämer, G. D. Stucky, and M. Moskovits, “An autonomous photosynthetic device in which all charge carriers derive from surface plasmons,” *Nature Nanotechnology*, vol. 8, no. 4, pp. 247–251, 2013.

[79] Y. Ma, X. Ji, F. Xiang et al., “A cationic water-soluble pillar [5] arene: synthesis and host–guest complexation with sodium 1-octane sulfonate,” *Chemical Communications*, vol. 47, no. 45, pp. 12340–12342, 2011.

[80] K. Moe, K. W. Mg, K. K. Win, and T. Yamakawa, “Combined effect of organic manures and inorganic fertilizers on the growth and yield of hybrid rice (Palethwe-1),” *American Journal of Plant Sciences*, vol. 08, no. 05, pp. 1022–1042, 2017.

[81] W. Negassa, K. Negisho, D. Friesen, J. Ransom, and A. Yadessa, “Determination of optimum farmyard manure and NP fertilizers for maize on farmers’ field,” in *Proceedings of the Paper presented at the Seventh Eastern and Southern Africa regional maize conference*, Nairobi, Kenya, Febrauary 2002.

[82] H. Amanullah, K. Marwat, P. Shah, N. Maula, and S. Arifullah, “Nitrogen levels and their time of application influence leaf area, height, and biomass of maize planted at low and high density,” *Pakistan Journal of Botany*, vol. 41, no. 2, pp. 761–768, 2009.

[83] J. Kugbe, R. Kombat, and W. Atakora, “Secondary and micronutrient inclusion in fertilizer formulation impact on maize growth and yield across northern Ghana,” *Cogent Food and Agriculture*, vol. 5, no. 1, Article ID 1700030, 2019.

[84] H. Dong, W. Li, A. E. Eneji, and D. Zhang, “Nitrogen rate and plant density effects on yield and late-season leaf senescence of cotton raised on a saline field,” *Field Crops Research*, vol. 126, pp. 137–144, 2012.

[85] B. Fantaye and M. Hintsa, “Performance evaluation of sorghum [Sorghum bicolor (L.) Moench] hybrids in the moisture stress conditions of Abergelle District, Northern Ethiopia,” *Journal of Cereals and Oilseeds*, vol. 8, no. 4, pp. 26–32, 2017.

[86] L. Tekle and H. Wassie, “Response of tef (eragrostis tef (zucc.) trotter) to blended fertilizers in tembaro, southern Ethiopia,” *Journal of Biology, Agriculture and Healthcare*, vol. 8, no. 13, pp. 34–39, 2018.

[87] G. Taddesse, D. Peden, A. Abiye, and A. Wagnew, “Effect of manure on grazing lands in Ethiopia, east african highlands,” *Mountain Research and Development*, vol. 23, no. 2, pp. 156–160, 2003.