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Effects of Integrated Nutrient Management on Maize (Zea Mays L.) Production and Soil Properties in North-Western Ethiopia

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COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES
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EFFECTS OF INTEGRATED NUTRIENT MANAGEMENT ON MAIZE (*Zea mays* L.) PRODUCTION AND SOIL PROPERTIES IN NORTH-WESTERN ETHIOPIA

Ph.D. DISSERTATION

BY

MITIKU ASHENAFI EJIGU

June 2023
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SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D.) IN AGRONOMY

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Bahir Dar, Ethiopia

DISSERTATION APPROVAL SHEET

We read and evaluated this dissertation prepared by Mr. Mitiku Ashenafi Ejigu, entitled "Effects of integrated nutrient management on maize (*zea mays* l.) production and soil properties in north-western ethiopia" as a member of the board of examiners for the degree of Doctor of Philosophy (Ph.D.) in agronomy dissertation open defence examination. We thus declare that the dissertation has been accepted for the award of the degree of Doctor of Philosophy (Ph.D.) in agronomy.

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DECLARATION

I, the undersigned, hereby declare that the dissertation submitted to the Department Council of Plant Sciences, College of Agriculture and Environmental Sciences, Bahir Dar University for the degree of Doctor of Philosophy (Ph.D.) in Agronomy is my work and has not previously been submitted to another university. The dissertation properly acknowledges the resources received from different sources.

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DEDICATION

This dissertation is dedicated to my mother W/ro Yeshi Bayu for her tender love and care for me, as well as her unwavering support and encouragement throughout my life and achievements.

ABBREVIATIONS AND ACRONYMS

ATA	Ethiopian Agricultural Transformation Agency
CV	Coefficient of variation
CIMMYT	Centro International de Mejoramiento de Maiz
CSA	Central Statistics Agency
DAP	Di-ammonium phosphate
BDZ D	Bahir Dar Zuriya Districts
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization of the United Nations
FTC	Farmers training center
FYM	Farmyard manure
GDP	Gross Domestic Product
HI	Harvest index
HQP	High-quality protein
INM	Integrated nutrient management
ODK	Open Data Kit
OM	Organic matter
PRA	Participatory rural appraisal
QPM	Quality protein maize
SOC	Soil organic carbon
STATA	Statistical software for data science
UNDP	United Nations Development Program

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GENERAL ABSTRACT

Maize (Zea mays L.) is one of the main and most popular cereal crops because of its high value as a stable food as well as its stover demand for animal feed, fuel, and even construction purposes. It is used as human food, a source of cash income, fuel, feed for livestock, and for industrial purposes. In Ethiopia, maize is a staple food and one of the main sources of calories in the major maize-producing regions. Approximately 88% of the maize produced in Ethiopia is used as food, in both green cobs and grain. In Ethiopia, maize is grown in 13 agroecological zones in the southern, south-central, and southwestern parts of the country. However, national (Ethiopia), regional (Amhara), and local (West Gojam) yields are 4.179, 4.272, and 2.5 tonnes ha^{-1}, respectively. These yields are significantly lower than the global average yield (5.8 t ha^{-1}), with yield gaps of 1.621, 1.528, and 3.3 t ha^{-1}, respectively. This low productivity in Ethiopia in general and in the study area in particular is caused by nutrient mining as a result of continuous cropping, abandoning fallowing, completely removing crop wastes, applying little or no manure, using crop and animal waste as fuel, and erosion. Declining soil fertility was the major factor in the lower productivity of maize, and to combat these problems, commercial fertilizers have been applied. However, the rising costs of inorganic fertilizers may not encourage smallholder farmers. Therefore, in sourcing an alternative that reduces the cost of production while increasing productivity in the research areas, the effect of integrated inorganic fertilizer and manure use on crop yield and soil quality indicators is ambiguous. Instead, producers rely heavily on chemical soil fertilization, which has a poor reputation in terms of long-term viability and cost-benefit ratio. There is little consistency in the research on the effects of combining organic and inorganic fertilizers. To address these limitations, in 2016/17 and 2017/18, an assessment survey was done in three sites (Bahir Dar Zuria, Jabi Tehnan, and Mecha) and field research was undertaken in two places (Jabi Tehnan and Mecha districts), with the objective of assessing the sustainability of maize production in North-Western Ethiopia by characterizationof maize production and evaluating the effects of integrated nutrient management on maize yield and soil properties. To characterized maize production, maize farm assessments and farmer interviews were carried out, and a field trial was conducted to investigate the integrated use of NPSBZn blended fertilizer and farmyard manure on maize growth parameters, yield, and yield components. A total of 250 farmers in the study area were selected and interviewed to gather data on demographic characteristics, land resource and agronomic practices, inputs, and pest management based on maize production capacity, coverage, and the importance of maize in farmers' lives. Three, two, and one 10-km by 10-km X and Y geographic coordinate regions have been transferred to the newly constructed main

grid from the districts of Mecha, Jabi Tehnan, and Bahirdar Zuriya, respectively. Within the main grid frame, a quadrangle was established, providing a grid cell 1 km by 1 km square. The field experiments were laid out in a randomized complete block design (RCBD) with three replications in a factorial arrangement: five NPSBZn blended fertilizer rates (100, 150, 200, 250, and 300 kg ha^{-1}), four cow manure rates (0, 12, 16, and 20 t ha^{-1}), one control (0, 12, 16, and 20 t ha^{-1}), and one blanket recommendation (DAP and Urea). A maize hybrid variety called "BHQPY-545" was used as a test crop. According to the survey findings in the three areas, the majority of respondents are married males of working age with substantial agricultural experience. Small, fragmented parcels placed close to the home were typical. Urea is the most commonly used fertilizer, but its availability from regular sources proved difficult at the right time of year. The majority of farmers in the study area use improved seeds rather than local seeds. Weed and insect pest infestations in corn fields were common. The field research result showed that, only the main effect of blended (NPSBZn) fertilizer and farmyard manure was significant at both locations for the days to silking, leaf area index, and ear diameter at both locations and the days to 90% physiological maturity, Number of ears per plant, and ear length at Mecha. While main and interaction effects on the remaining parameters were significant at both sites (Jabi Tehnan and Mecha). The main effects of NPSBZn blended fertilizer and farmyard manure were significant on days to physiological maturity, ear number per plant, ear length, and diameter at Mecha. Grain yield showed a positive correlation with growth and yield components, and the combined application of 250 kg $ha^{-1}$of NPSBZn blended fertilizer with 20 t $ha^{-1}$of yard manure resulted in grain yields of 5,618.5 and 5,421 kg $ha^{-1}$and above-ground dry biomass yields of 10,895.0 and 10,787.9 kg ha^{-1}at Jabi Tehnan and Mecha, respectively. Thus, 250 kg $ha^{-1}$of NPSBZn blended fertilizer with 20 t $ha^{-1}$of farmyard manure is recommended for effective maize production in both study areas.

Keywords:Blended fertilizer, farmyard manure, maize, nutrient management, survey, yields, productivity,Ethiopia.

CHAPTER 1. GENERAL INTRODUCTION

1.1. Background and Justification

Ethiopia is one of the world's least developed countries where the country ranks 164th out of 187 countriesin the World (Anteneh Mulugeta, 2020). Ethiopia, with a current population of 102.4 million people, is Africa's second-most populous country after Nigeria (Alemayehu Bekele and Yihunie Lakew, 2014). The country is expected to have a fertility rate of 4.2 children per woman between 2017 and 2050, ranking it among the top eight countries in the world in tems of population growth (Tassew Woldehana and Mesele Araya, 2019). Agriculture contributes significantly to Ethiopia's economy. In 2016 agriculture contributed 36%,75%, and 85% of the gross domestic product, employment, and foreign exchange profits, respectively (NBE, 2018).

In Ethiopia there is large yield gap between actual ad attainable yield.For the majority of key crops, closing yield gaps to 100% of achievable yields could boost crop output globally by 45% to 70% (with increases in maize, wheat, and rice production of 64%, 71%, and 47%, respectively). However, there are huge "low-hanging" intensification prospects for main cereals in Sub-Saharan Africa; if yields were boosted to 50% of feasible yields, this region might experience significant production gains(Mueller *et al.*, 2012). Determination of the potential yield and the gaps between potential and actual yields requires a thorough understanding of crop growth and development, which in turn depends on climatic, edaphic, hydrological, physiological, and management factors (Liu *et al.*, 2012).

Ethiopia has a diverse range of climatic and soil conditions that allow the cultivation of a variety of crops. The country grows a wide variety of grains, legumes, oil, horticulture, and industrial crops. In the country, of the total cultivated area, cereals cover about 81.19% of the total cultivated area, and maize, second only to teff in terms of area covered, is followed by sorghum, wheat, and barley, in that order. Regarding yield, maize, teff, wheat, and sorghum made up 30.88% (10557093.59 tone), 16.12% (550996.151 tone), 16.91% (5780130.596 tone), and 13.22% (4517.350218 tone) of the grain production (CSA, 2021). In the 2000s, the share of maize consumption among cereals more than doubled from the 1960s to nearly 30%, while the share of teff, Ethiopia's most widely grown cereal, fell from more than 30% to around 18% during the same era.

Even though agriculture is the country's economic engine, it is confronted with several challenges that are limiting agricultural yields. Poor soil fertility, severe land degradation, high reliance on rainfall, limited availability and poor quality of seeds and fertilizers, economic constraints such as low income and a lack of financial support, and insufficient policies and guidelines are only a few of the major constraints (Belay Kassa & Degnet Abebaw, 2004;Nakawuka *et al.*, 2018). Socio-economic problems such as ongoing conflicts, lack of strong institutions, ineffective policies, lack of incentives for professional workers, the presence of diseases and insect pests, and inefficient input and output markets are all contributing to the sector's poor growth (Asenso and Samson Jemaneh, 2012).

In Ethiopia, maize is mainly grown as a subsistence crop in the mid-altitudes (1500–2000 m.a.s.l.) in the southern, south-central, and south-western parts of the country. It is grown in 13 agroecological zones on about 2274306 ha (21.70 %) of the total cereal crop area (CSA, 2019). The popularity of maize in Ethiopia is partly because of its high value as a food crop, the ever-increasing market prices of another crop yield to both rural and urban communities, and the growing demand for the Stover as animal fodder and as source of fuel for rural families. Unlike its neighbor, Kenya, which imports a significant share of its consumption needs, Ethiopia has increasingly attained self-sufficiency in maize production since early this decade and even exports some quantities to neighboring countries (e.g., Sudan and Djibouti) in years of surplus production. If production can be significantly expanded, the potential for maize exports to all the neighboring countries, including Kenya is very high although the national demand is expected to continue to grow in the coming years (Abate Tsedeke *et al.*, 2015).

The primary effects of continuous N and P fertilizer application would be to increase the uptake and depletion of secondary nutrients like sulfur and micronutrients like zinc and boron (Mulema, A., & Damtew, Elias ,2016). In addition to nitrogen and phosphorus fertilizers, blended fertilizers with sulfur, zinc, and boron have recently been developed (Eyasu Elias*et al.*, 2019). However, continual use of chemical fertilizers is not a long-term answer as it may result in deterioration of soil quality, including an increase in soil acidity, loss of organic matter, and depletion of nutrients not included in the fertilizer formulation (Liu *et al.*, 2010). According to the available evidence, adding farmyard manure to soil can significantly improve soil qualities, such as increasing soil porosity, boosting soil fertility, and reducing soil erosion. The combination of farmyard manure and NPSBZn blended fertilizer hasn't been the subject of any research, though crop yields, organic matteravailability, nutritional status, soil bulk density, and crop yields are all enhanceddue to their combined application (Getachew Agegnehu *et al.,* 2014; Tesfu Mengistu*et al.,* 2017).

Due to a lack of organic resources, competing uses for farmyard manure, such as animal feed and fuel, and a labor shortage transport, small-scale farmers are unable to add the necessary amounts of farmyard manure to their soils. In order to satisfy the nutrient requirements of crops and maximize crop yields, using farmyard manure alone as a replacement for inorganic fertilizers is not a sustainable approach (Timsina, 2018). However, it is thought that the greatest method for enhancing soil fertility and raising crop yield is to use locally accessible organic inputs like compost, manures, and crop residues along with mineral fertilizers (GetachewAgegnehu *et al.,*2014). However, the study area has inadequate adoption of farmyard treatments combined with mineral fertilizers, particularly mixed NPSBZn fertilizer for enhancing soil fertility and maize output. The impact on soil fertility and maize yield needs to be examined in order to make more familiar farmers to combine the addition of farmyard manure and mineral fertilizers.

In addition, there aren't any guidelines for applying farmyard manure and blended mineral fertilizers together based on the soil type or the crops that would use them. Determining the impact of applying farmyard manure and mineral fertilizers on specific soil characteristics and maize yields in the highlands of northwest Ethiopia was the goal of this study.

1.2. Statement of the Problems

The yield gapof actual and attenable is especially remarkable for maize, with an average yield of 2.6 t ha^{-1} (CSA, 2016), which is much lower than its productivity in industrialized countries such as the USA (8–9 t ha^{-1}) (Beyene Seboka and Abera Deressa, 1996; De Fraiture, 2010). In Ethiopia, land degradation and nutrient depletion, lack of access to improved technologies such as seeds and fertilizers, and poor weed and pest control practices are among the major factors depressing the productivity of maize (Tolessa Debela *et al.,* 2002).

Declining land productivity in Ethiopia as a result of soil fertility reduction is a major problem facing smallholder farmers today. Currently, Ethiopia is among the countries with the highest rate of nutrient depletion in sub-Saharan Africa. Annual phosphorus (P) and nitrogen (N) losses nationwide from the use of dung for fuel are equivalent to the total amount of chemical fertilizers applied (MoARD, 2010). Because the country's topography is mountainous, with a variety of soil types, soil erosion produces poor soil fertility, especially in the highlands, where about 90% of the arable land is concentrated (Yebo Belay, 2015). The problem of diminishing soil fertility has worsened as a result of nutrient mining due to continuous cropping, abandonment of fallowing, reduced manure application, and use of wastes as fuel, and erosion, all of which are exacerbated by low intrinsic fertility (Wassie Haile and Shiferaw Boke, 2011). Fertilizer use in the country, on the other hand, is below the acceptable level, and farmers do not follow the suggested recommendation. Nonetheless, present soil fertility management in Ethiopia, where 50–80 percent of animal manure and 70–90 percent of crop wastes are removed from the farm and/or used for fuel, feed, and building (Chillot and Hassan, 2010), severely limits soil nutrient restoration. The inadequate usage of fertilizer can be attributed to several factors; including high fertilizer costs, marketing issues(lack of legal and regulatory frame work), and a lack of infrastructure (Achieng *et al.,* 2010).

Maize research, on the other hand, has primarily focused on the development of improved varieties, and quantifying blanket fertilizer recommendations of DAP and urea. And Crop residues are used as animal feed, and manure is used as fuel, resulting in a loss of soil fertility.

Because of the high expense of commercial fertilizers and their long-term negative impact on soil chemical characteristics, the value of FYM is being recognized once again. Aside from providing macro- and micronutrients to the soil (Wakene Negassa *et al.,* 2001), the physicochemical properties of the soil are also improved by farmyard manure (Tirol-Padre *et al.,* 2007). However, unless combined with inorganic fertilizers, FYM alone may not be sufficient to meet crop nutritional requirements, particularly in the year of application (Palm *et al.,* 1997).

Consistent application of unbalanced fertilizers depletes soil fertility and reduces yields. Farmers in the studied areas have low yields owing to a lack of vital soil nutrients (ATA,2013). In Ethiopia, including the soils of the study area, sub-optimal fertilizer use combined with unblended fertilizer (NPSBZn) use has favored the formation of multi-nutrient deficits (B,Zn). As a result, crop production has remained unchanged (Abiye Astatkie, 2004; Wassie Haile and Shiferaw Boke, 2011). Balanced fertilizers comprising

N, P, S, B, Fe, and Zn have been advised for site-specific nutrient deficits to boost crop yield and productivity, as well as water and labor productivity (EthioSIS, 2016).

In Ethiopia, the current fertilizer recommendation for maize is based on either extremely general crop-specific guidelines or, more commonly, a single recommendation for all crops (100 kg DAP (18-46-0) and 200 kg urea (46-0-0) (Ewnetu Teshale and Afework Legesse 2020) This blanket approach typically fails to account for variances in resource endowment (soil type, labor capacity, and climatic risk), as well as drastic fluctuations in the input/output price ratio, discouraging farmers from fertilizing (Yangge, *et al.*, 1998). Furthermore, the nutrients in the blanket suggestion are not agronomically balanced, and their continued usage would deplete soil nutrient stores. As a result of the uneven application of fertilizers, neither yields nor profits can be sustained, as the practice accelerates the depletion of other soil nutrients. S, B, and Zn shortages are common in Ethiopian soils today, in addition to N and P, while K, Cu, Mn, and Fe deficiencies are also present in some soils (Tamene Lulseged*et al.*, 2017).

There was little information about the influence of different types of fertilizers in Ethiopia in the past, except for nitrogen and phosphorus. Seven fertilizer types (NPS, NPSB, NPSZn, NPSBZn, NPSBCu, NPSBZnCu, and K) are advised according to deficiency laboratory results and the soil fertility map produced over 134 districts of Amhara National Regional State (ATA, 2013). According to the Amhara National Regional State's Soil Fertility Status and Fertilizer Recommendation Atlas (ATA, 2013), in addition to macronutrients, some micronutrients such as zinc and boron are depleted from the soil in the region's key crop-producing area due to long-term farming.

The optimum rates of the major suggested blended fertilizer types for different crops, agro-ecologies, and soil types have not yet been defined for the region, even though the types of blended fertilizers required for the region have been identified. Meanwhile, organic fertilizer supplies abound in the research region. Dung from larger animals (cattle, sheep, horses, donkeys, and mules) is frequently available in large quantities. However, crop residues are completely gathered and used for animal feed, whereas FYM is used for fuel in the research area, indicating that organic materials are underutilized.

In study districts, maize is one of the major and most widely cultivated cereal crops. It covers more area and produces more in the district than other crops; however, improving the productivity of maize through the integrated use of NPSBZn blended fertilizer via manure has not been known. Furthermore, there is no unified data available in the study district on the impact of integrated inorganic fertilizer and manure use on crop yield and soil quality metrics. Instead, growers rely primarily on chemical soil fertilization, which isn't well-known for its long-term viability or cost-benefit ratio.

To boost maize productivity in the research area, it is critical to identify the main maize production restrictions and validate integrated nutrient management, which includes the simultaneous use of both organic manures and inorganic fertilizers.

1.3. Objectives

1.3.1. General objective

To assess the sustainability of maize production in North-Western Ethiopia by characterizing maize production and evaluating the effects of integrated nutrient management on maize yield and soil properties.

1.3.2. Specific objectives

- To characterizesocio-economic factors in current maize production practices in North-Western Ethiopia
- To assess the current maize production practices in North-Western Ethiopia and identify areas for improvement.
- To investigate the effects of integrated nutrient management on maize yield and soil properties in the study area.
- To identify the optimum combinedrates of FYM and NPSBZn for sustainable maize production in North-Western Ethiopia.

1.4.Organization of the Dissertation

The dissertation is divided into six chapters. The first chapter addresses the general introduction;the second chapter include the general materials and methods. The following three chapters include the research results as threepublishable papers. Theconclusion and recommendations are covered in chapter six.

CHAPTER 2. GENERAL MATERIALS AND METHODS

2.1. Description of the Study Area

A two-year field experiment (2016/17-2017/18) was conducted in two different locations in Amhara 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 center and FTC). Geographically, both study areas are located in north-western Ethiopia. Jabi Tehnan is located at the latitude of 10.6794° N and longitude of 37.2598° E, at an altitude of 1,500–2,300 meters above sea level, and covers an area of 116,954 hectares(Figure 2.1). It is about 389 km northwest of Addis Ababa and 176 km southeast of Bahir Dar, the Amhara Region's capital.The average annual rainfall in the city is 1250 mm, with minimum and maximum daily temperaturesof 14 and 32°C, respectively, and a mean annual rainfall of1,885mm (Figure 2.1a). The experimental site was characterized by 65% plain, 15% mountainous, 15% undulating, and 10% valley (TibebuTaye,2016). Additionally, from a fertility point of view, it's classified as 27% fertile, 71% medium, and 2% infertile soil (Hassen *et al*., 2014).

Mecha is 146 km northwest of Addis Ababa and 30 km southwest of Bahir Dar, the capital of the Amhara Region. The area is located at 11.4130° N, 37.1553° E, and has an altitude of 1800–2500 meters above sea level (Figure 2.1). The region experiences yearly rainfall averaging between 820 and 1250mm.The area's daily low and high temperatures are 17 and 30 degrees celsius, respectively (Figure 2.1b).The most dominant is a nitisol that covers 92% of the area, and the remaining soils are vertisols and vertic nitisols. Seventy-five percent of the study area is gently sloping, 13% is moderately sloping and 8% is mountainous while 4% consists of valley soils. The major crops grown in the area are wheat, barley, finger millet, teff, and maize(Habtamu Addis, 2012).

In addition to the surveys study was conducted in Jabi Tehnan,and Mecha districts, Bahir Darzuriya, which covers the areas surrounding Bahir Dar, the capital city of the Amhara region, was also studied concurrently. It is situated at an altitude ranging from 1700–2300 m a.s.l. and has an area coverage of 151,119 ha (DOoARD, 2009). The area receives an average annual rainfall ranging from about 820 to 1250 mm. The minimum and maximum daily temperatures of the area are 10 and 32 °C, respectively. The district's topography includes Woina-Dega climatic zones. Soil types in the district are verity, clay loam, and clay, with dominating colors of black (3%), red (93%), and brown (4%) with heavy clay, medium clay, and loam texture (MoWR, 2002, Kassawmar,2017). In the Bahidar Zurya district, the major crops grown are maize, wheat, barley, millet, and tef (BDZD, 2000, unpublished).

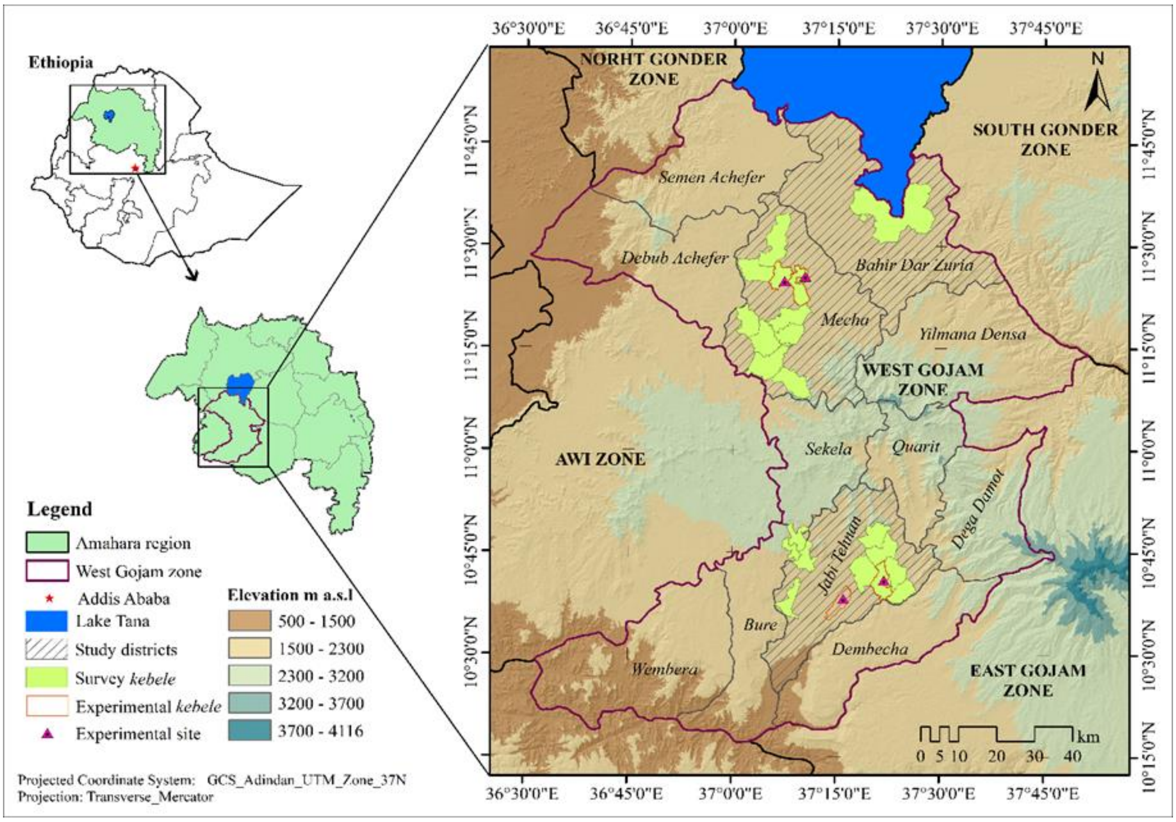
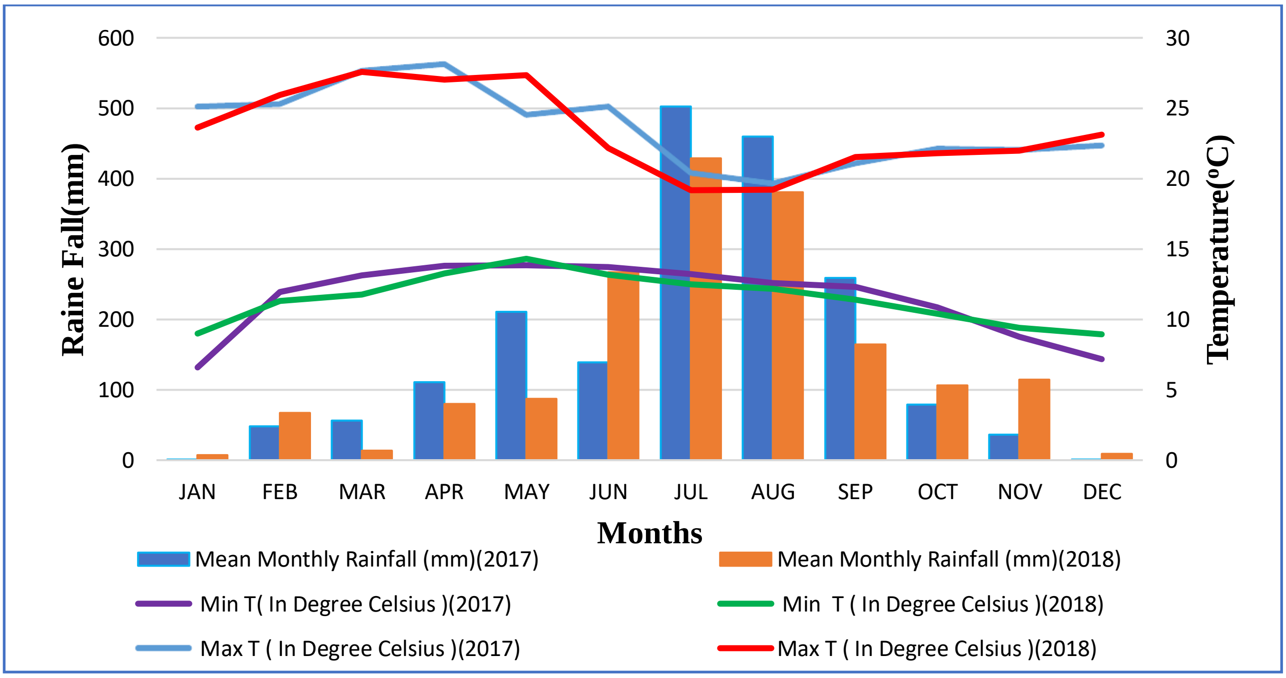
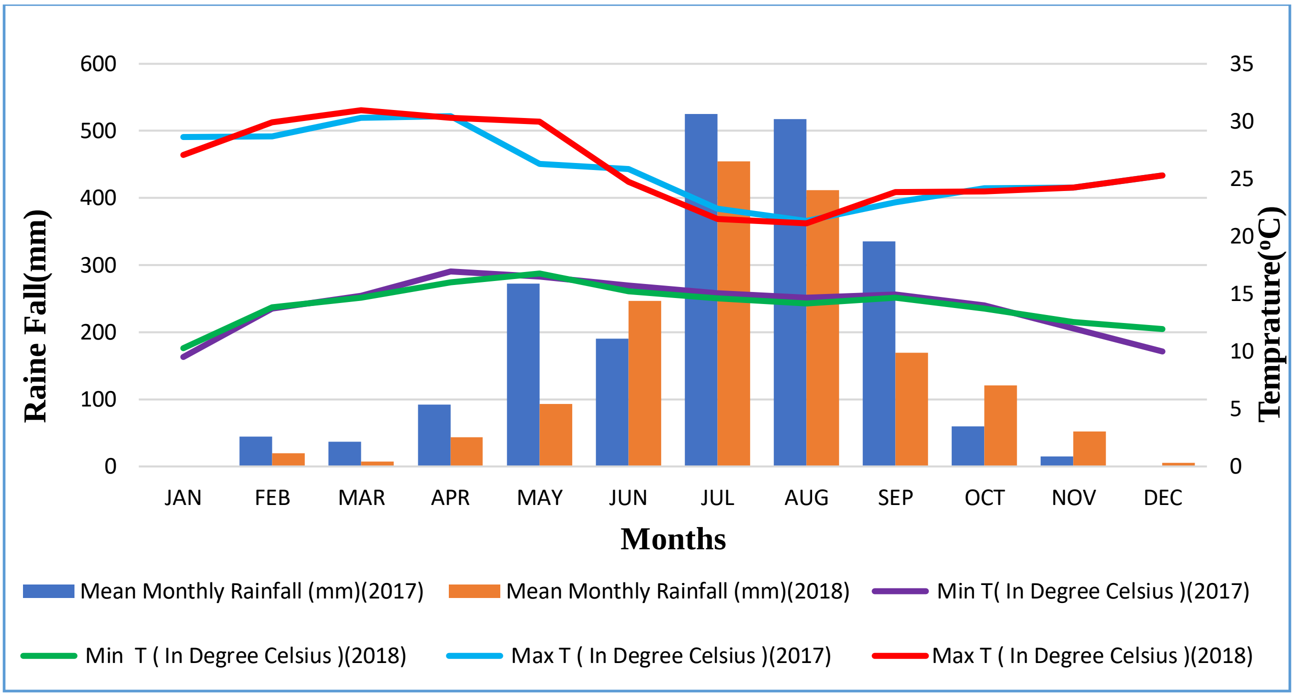


Figure 2.1. Location map of the study sit



a)



b)

Figure 2.2: Monthly rainfall (mm), and maximum and minimum temperatures (^oC) in Jabi Tehnan (a) and Mecha (b) districts during the experimental years of 2016/17 and 2017/18 (Where; Max T= Maximum temperature and MinT = Minimum temperature).

2.2. DataCollection

2.2.1.Soil and farmyard manure sampling and analysis

A soil sample was collected from five random spots diagonally in the experimental field from both sites in both years before and after planting on the top 0–30 cm using an auger. The soil samples that were obtained were composited into a single sample for each location.Local farmers provided us with well-decayed farmyard manure (from cattle). All non-decomposable and unused components were isolated and removed. All the collected farm yard manure was placed on a plastic sheet in the shade to dry. The sample of farmyard manure was collected and passed through a 2 mm sieve, weighing 1 kg, and used for physical and chemical property analysis.The soil and farmyard manure samples were analyzed in Debre Berhan university and Debre Berhan agricultural research Centre soil laboratories.

A glass electrode pH meter was used to measurethe soil pH in the supernatant suspension with a 1:2.5 soil-to-water ratio (Corwin & Rhoades, 1984). The Bouyoucos hydrometer system was used to assess soil texture (Bouyoucos, 1962). Furthermore, the electrical conductivity (EC) 1:2.5 soil to water suspension was determined using Jackson's (1967) method. Organic carbon was determined by the wet oxidation method (Walkley & Black, 1934). The Olsen method was used to determine available phosphorus using ascorbic acid as the reducing agent (Olsen, 1954). The Micro-Kjeldahl digestion method with sulfuric acid was used to determine total nitrogen (Jackson, 1967). Sulfur was determined by the turbidimetric method (Hoeft *et al.,* 1973). Boron was determined by the hot water extraction procedure (Havlin *et al., 2016)* and the exchangeable bases and CEC of the soil were determined by the ammonium acetate method (Batjes *et al.,* 2020). Available Zn was extracted with DTPA as described by Lindsay and Novell (1978) and B was measured by atomic absorption spectrophotometry.

2.2.2. Agronomic data collection and measurement

All the necessary data were collected timely from the experimental plots following their respective standard methods and procedures.The grain yield was adjusted to a moisture content of 12.5 percent. On a plot basis, data on yield and yield component-related parameters are collected and converted to a hectare basis. Data on vegetative growth and some yield-related parameters, on the other hand, were collected on a plant-by-plant basis by randomly selecting five plants in each net plot area.
The following are detailed collections of crop parameter data.

a) Phenological parameters

- **Days to 50% Tasselling:** Days to 50% tasselling (the number of days required from planting to the start of shedding of pollen by 50% of the maize plants) was recorded when 50% of plants in a net plot reached the respective phenological stage.
- **Days to 50% silking:** It was determined as the number of days taken from the date of planting to the stage when 50% of plants showed extrusion of silk.
- **Days to 90% physiological maturity**: were recorded as the number of days from the date of sowing till 90% of the plants change their green color to yellowish, and lose their water content in the net plot area.

b) Vegetative growth parameters

- **Plant height:** was measuredthe distance from the plant base to the point where the tassel starts to branchof five randomly selected plants, from two central rows. A carpenter’s tape was used for measuring the height from the ground level to the top-most leaf.

- **Number of green leaves per plant**: Total number of green leaves per plant at tasselling was counted from five randomly taken plants and their averages were taken as the number of green leaves per plant.
- **Leaf area and Leaf Area Index**:Leaf area was determined at 50% silking from five plants randomly taken per net plot by multiplying leaf length and maximum width adjusted by a correction factor of 0.75 (i.e., 0.75 x leaf length x maximum leaf width) as suggested by Francis *et al.* (1969). The leaf area index was then calculated by dividing leaf area per plant sampled ground area (Radford, 1967).

C. Yield-related parameters

- **The number of ears per plant**:It was recorded from the count of ten randomly taken plants in the central net plot area at crop harvest.
- **Ear length**:It was measured from the point where the ear is attached to the stem to the tip of the ear from randomly taken ten ears in the central net plot at crop harvest.
- **Ear diameter (cm):** The average thickness of the ear in the middle of the ear was measured from five randomly taken ears.
- **The number of kernels per ear**: It was recorded from the average of five randomly taken ears per plot. This will be done by manually shelling and counting the kernels and then their average was calculated.
- **Thousand kernel weight (TKW) (g**): A thousand kernels were counted from a bulk of shelled grains from a net plot and weighed up using a sensitive balance adjusted to a 12.5% moisture level.
- **Above Ground Biomass Yield (kg ha^{-1}):** Plants from the net plot area were harvested at physiological maturity and weighed after sun drying
- **Grain yield**: It was recorded from the net plot area and the grain yield of each treatment was adjusted to the standard moisture level of 12.5% by computing the conversion factor for each treatment to get the adjusted yield using the following formula (Biru Abebe, 1979)**:**

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

Where Y is the actual moisture content and X is the standard moisture content to which the yield is to be adjusted (for cereals the standard moisture content is 12.5%).

Adjusted yield = C.F × plot yield

Data were collected for the experiment on yield and yield-related parameters on a plot basis and converted to ha^{-1}.

- ❖ Harvest index (%): It was calculated as the ratio of grain yield to above-ground dry biomass per net plot and multiplied by 100.

2.2.3. Survey data collection and measurement

Both quantitative and qualitative data were collected.To collect primary data Personnel observation and key informant interviews, such as discussions with woreda and kebele level leaders and agricultural experts, wereemployed in the qualitative data collection techniques. The discussion was guided by a checklist that covered issues related to maize production, solutions for managing maize production constraints, characteristics preferred by farmers in summer rainfed maize production and agronomy activities that they would like to grow maize and extra general information. Data included household demographic characteristics (household head educational level, marital status, sex, age, family size, land resource data (land size, distance from home and year of production in the last ten years), agronomic practices and inputs (seed and its sources, field management).

2.3. Data Analysis

All the data, which were collected from experimental plots, surveys, and field assessment areas, were analysed using appropriate software. The data collected from the experimental plots were analysed using SAS software (SAS, 2004).During data analysis, whenever ANOVA was significant, mean separation was performed using the least significant difference (LSD) method at a 5% level (Gomez and Gomez, 1984), and the control was excluded to facilitate factorial analysis. Since the homogeneity test was performed using the F-test as described by Gomez and Gomez (1984) before combining over year and location, the two years and locations for all parameters had shown homogeneous and non-significance of the two years on each location and heterogynous and significant of the two locations, so a combined analysis was used for the two years on each location and data from each location were analysed separately. While the data collected from farm assessments and surveys were analysed using SPSS (Statistical Package for Social Scientists) and were subjected to descriptive statistics.

CHAPTER 3. CHARACTERIZATION OF MAIZE PRODUCTION IN JABI EHNAN, MECHA AND BAHIR DAR ZURIYA, DISTRICTS, NORTHWESTERN ETHIOPIA

ABSTRACT

Knowing the primary maize production constraints that could lead to poor productivity which in turn lower farm income is essential to close the gap between desire and actual yield. As a result, a household survey was conducted to assess the constraints on maize production across West Gojjam Zone in three districts: Jabi Tehnan, Bahir Dar Zuriya, and Mecha. Based on maize production potential, coverage, and the importance of maize in the livelihood of farmers in the study area, 10 km by 10 km X and Y geographical coordinate points as the main grid, and a quadrangle 1 km by 1km square grid was generated. Data were gathered from primary and secondary sources. We used both qualitative and quantitative data collection techniques to gather primary data. A structured questionnaire was administered to 252 randomly selected sample farmers and their farms as part of the quantitative data collection. According to the findings, farmers in all three districts were dominantly married, of working age, and with extensive farming experience. The smallest and most fragmented production land was located away from the house. The most common fertilizers were urea, DAP, and NPS, from which a large proportion of the farmers used urea more than others and there was difficulty in getting fertilizers from regular sources and at the right time at all of the study sites. The majority of farmers in the study area utilized local seeds than improved seeds. Weed and insect pest attacks in the maize field were very low. Furthermore, the largest portion of farmers had a very small production area which they plowed repeatedly. As a result of this study, it is possible to conclude that fertilizer, seed, and land preparation factors impact farmers in all three maize production systems. In this regard, it is suggested that more attention should be paid to these yield-limiting factors.

Keywords: Maize production, farming experience, *Zea mays*L., land distributions, Ethi

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3.1. Introduction

In Ethiopia, 25.5% of the population is food insecure, and around 18 million people live through emergency food assistance and productive safety net program (Jiren *et al.,* 2021). Agriculture is the backbone of the Ethiopian economy, where it contributes about 43% of the gross domestic product (GDP), employs 80% of the total labour force, which is more than two-thirds of Ethiopia's population and contributes to 70% of foreign exchange earnings (Gebrehaweria Gebregziabher & Regassa Namara, 2007). The poverty reduction efforts in Ethiopia have to put significant emphasis on improving agricultural productivity. Despite diverse crop and agro-ecological diversity, people have long faced food shortages and economic underdevelopment because production and productivity are remaining low for most of the country but there have been clear signs of improvement over the past decade (Fisher *et al.,* 2015).

In Ethiopia, smallholder farmers produce maize on 2,274,306 hectares (21.70%) of the total area used for grain crops and 30.88% of the cereals produced (CSA, 2019). In terms of yield, sorghum (*Sorghum bicolor*), wheat, teff (*Eragrostis tef* Zucc. Trotter), and maize (*Zea mays* L.) contribute 30.88% (105,570,935.92 quintals), 16.12% (55,099,615.14 quintals), 16.91% (57,801,305.96 quintals) and 13.22% (45,173,502.18 quintals) to the production of grains, respectively (CSA, 2016). Considering its importance in terms of wide adaptation, total production, and productivity, maize has been selected as one of the high-priority crops to feed the increasing population of Ethiopia (Mosisa Worku *et al.,*2002).

Approximately, 88% of maize produced in Ethiopia is consumed as food, both as a green and dry grain. Unlike its neighbor, Kenya, which imports a large portion of its food, Ethiopia has gradually increased its maize output self-sufficiency since the early 2000s (Abate Tsedeke *et al.,* 2015). It has even exported some surplus to neighbouring countries (such as Sudan and Djibouti) during years of surplus production (Milliman *et al.,*2012).

According to research findings, fertilizer may be responsible for 50% of the output difference in sub-Saharan Africa, which is one of the most important factors identified as impacting grain yield globally, along with irrigation and climate (Reynolds *et al.,*2015). However, these global factors may not always be the leading factors at the local level especially when agronomic management practices are not optimized.

Although the potential of maize production and productivity in Ethiopia is satisfactory, the national average yield, 3,430 kg ha^{-1}, is still far below the world average of 5,500 kg ha^{-1} (FAOSTAT, 2019). The yield of maize is less in Ethiopia (3,430 kg ha^{-1}) compared to other countries like Germany (8,828 kg ha^{-1}), Italy (8,899 kg ha^{-1}), Canada (9,988 kg ha^{-1}), Argentina (6,603 kg ha^{-1}) and China (6,016 kg ha^{-1}) (Mueller *et al.,* 2012). Due to the significant yield gap in Africa, particularly in Ethiopia, compared to global yield, there is the potential for production improvements (Birhane Gebrekidan & Bantayehu Gelaw,1989).

To develop intervention plans and focus on tangible investments and policy assistance on improving smallholder agricultural output, the government must first recognize basic production constraints and yield-enhancing variables at the farmer level. Because distinct constraints influence various regions' productivity and yield potential, region-specific management adjustments and interventions are necessary to reduce the observed yield gap (Birhane Gebrekidan & Bantayehu Gelaw,1989).

North-Western Ethiopia is one of the most important regions with great potential for maize production in the country (Kassawmar, 2017). These areas are categorized among the maize crop belt areas of the country. However, maize productivity has remained low, with an estimated local average yield of 2,500 kg ha^{-1} which is lower than the national (3,430 kg ha^{-1}) and also the world (5,500 kg ha^{-1}) due to several constraints: biotic (inadequate improved varieties, pests, and diseases), abiotic (low soil fertility, land and water degradation, and drought), and socioeconomic (input unavailability, lack of storage facilities, poor access to markets) (Reynolds *et al.*,2015). In addition, the low yield of maize is associated with low adoption, ignorance, and accessibility problem of productivity-improving technologies such as improved seeds and some agronomic activities [personal observation]. Farmers' low adoption of technologies developed by research institutions shows the need for client orientation in research. As a result, a wise understanding of the context is essential, such as agronomic activities, farmers' preference for improved varieties, and the adoption of technologies and farm inputs to identify the root problem and thus find ways to boost productivity and stabilize the situation. Furthermore, farming systems must be understood to identify and implement necessary interventions for increased maize productivity. A more detailed region-specific analysis of the maize system and its potential opportunities and possible constraints is required for the effective targeting of research and development efforts. Despite the fact that the likely production controlling factor for the observed yield gap has been identified, understanding contributing factors, as well as identifying the implications of agronomic management practices and low-cost approaches to take an important entry point towards increasing food production and reducing within-site yield gaps, has not been well documented. The current study is, thus, intended to draw together and document maize production systems through meticulous regard on agronomic management systems existing in the study area, household and farm characteristics, cultural practices, diseases and pests and their control, yield, and key general productivity constraints of maize.

3.2. Materials and Methods

3.2.1. Site description

The experimental sites are described in the general materials and methods chapter in chapter 2, sub-section 2.1, the locations of the study sites are given in detail(Figure 3.1) between 15th July and 24th October 2018

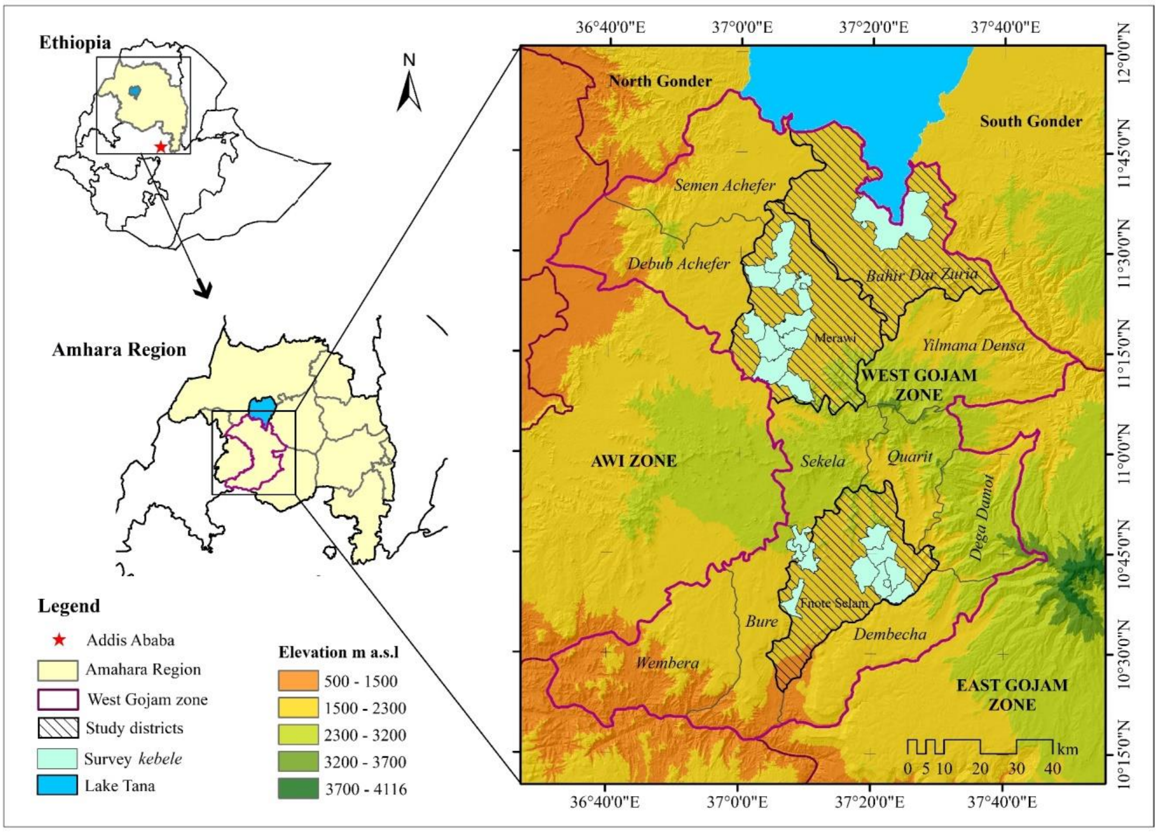

Figure 3.1: Location of the survey studied districts

3.2.2. Sampling procedure

The study was conducted in three districts from the West Gojam administrative zone. The districts are Jabi Tehnan, Mecha, and Bahirdar Zuriya, using a two-stage sampling technique. Representative farm households and farm plots in the study areas were selected. In the first stage, based on production coverage, agro-ecological uniformity, and clustering of maize production, three, two, and one 10-km by 10-km X and Y geographical coordinate points were taken from Mecha, Jabi Tehnan and Bahir Dar Zuriya districts, respectively, to develop the main grid frame by using the Global Positioning System (GPS). Finally, using ArcGIS software (10.5), a 1 km by 1 km sub-grid cell within the main grid frame was generated and numbered sequentially (1 through 100, starting from the top left corner and proceeding left-to-right, row-by-row), and then seven systematic unaligned samplings (sub-grid cells) from each main grid. Six respondents from each sampled sub-grid were selected using a simple random sampling method. Accordingly, 126, 84, and 42 respondents were selected from 21, 14, and 7 sub-grids, in Mecha, Jabi Tehnan, and Bahir Dar Zuriya, respectively. Finally, a total of 252 sample respondents of maize producers were interviewed (Table 3.1).

Farmers' selection was done in a group effort with village leaders and agricultural extension experts considering maize production and farmers' interests.

Table 3.1: The number of main and sub-grids, the number of sampled households, and the altitude range by district

Name of districts	No of sampled main- grid(10-km by 10-km)	No of sampled sub-grid (1-Km by1km)	Sample household		Altitude(m.a.s.l)
			Per sub-grid	Total	
Jabi Tehnan	2	7	6	84	1837.36 - 2171.90
Mecha	3	7	6	126	1908.30 - 2115.60
Bahirdar Zuriya	1	7	6	42	1916.30 - 2243.70

3.2.3. Data collection and analysis of the survey

3.2.3.1. Data collection

Both quantitative and qualitative data collection techniques were employed to collect primary data. Personnel observation and key informant interviews were conducted. The key informants were woreda and kebele level leaders and agricultural experts. Different ranking and scoring systems were also employed in focus group discussions. Focus group discussion was used to identify common problems facing the rain-fed maize small-scale farmers in the study areas. The discussion was guided by a checklist that covered issues related to maize production constraints, solutions for managing maize production constraints, characteristics preferred by farmers in summer rain-fed maize production and agronomy activities that they would like to grow maize, and extra general information. During the discussions, farmers also scored and ranked major maize production constraints in their areas. Preliminary Roost

Assessments (PRA) scoring and ranking aids were followed in identifying the group's priorities.

Each enumerator (person who assisted respondents in answering the questions and in completing the questionnaire) engaged in this survey monitored the focal persons and supervisors to ensure the correctness of collected data at the end of each day. The questionnaires loaded into the Open Data Kit (ODK) mobile application, included household demographic characteristics (household head educational level, marital status, sex, age, family size, land resource data (land size, distance from home, and year of production in the last ten years), agronomic practices and inputs (seed and its sources, field management). Before launching the survey, a questionnaire was pretested and was improved accordingly. Focal persons, supervisors, and enumerators had been trained and pre-tested with the tool by a group of experts before the actual data collection. The focal persons and supervisors made the survey work easier by establishing good relationships with district agricultural professionals, local agricultural extension agents, and village administrators. They also provided hard copy lists of farmers to be sampled for cross-checking, assisted the ODK on tablet phones whenever technical problems arose, and organized transportation for enumerators.

3.2.3.2. Data analysis

The data, which were collected from surveys and field assessments, were subjected to descriptive statistics. Results are presented in descriptive statistics such as percentages and frequency.

3.3. Results and Discussion

3.3.1. Household characteristics

3.3.1.1. Gender

The farmers' gender (Table 3.2) was a stand-in for their managerial skills, which they used to make farming decisions including what to plant, when and how much to sow, and how much to sell.

Out of the total respondents, smallholder farmers involved in maize production in the three districts headed households (95.23% at Jabi Tehnan, 95.24% at Bahir Dar Zuriya, and 97.6% at Mecha) were male-headed households. The share of female respondents at Jabi Tehnan, Bahir Dar Zuriya, and Mecha was 4.76%, 4.76%, and 2.38%, respectively (Table 3.2). This indicates that the participation of females in critical decision making in the area is minimal.

The outcome proves that male-headed households mainly dominate the area. Being dominated by male-headed households may not negate the adoption of technologies. Some research findings indicate that male-headed households have a higher adaption rate to technologies than female-headed households (Doss and Morris, 2000). However, in a country like Ethiopia, unless a cultural shift occurs that considers males as primary farm activators and women to be housewives, the situation will remain as it is. This will hamper maize production's technological adoption, efficiency, access, and technological use in the farming community (Girei *et al.*,2018).

Table 3.2: Gender, marital status, and household size of respondents by districts

Household characteristics		Jabi Tehnan (n=84)		Bahir Dar Zurita (n=42)		Mecha (n=126)	
		Freq.	%	Freq.	%	Freq.	%
Gender	Male	80	95.23	40	95.24	123	97.61
	Female	4	4.76	2	4.76	3	2.38
Marital status	Single	3	3.57	0	0.0	4	3.18
	Married	80	95.0	41	97.62	119	94.44
	Married (polygamous)	0	0.0	0	0.0	0	0
	Divorced	1	1.0	1	2.68	3	2.38
Household size	1-3	23	27.38	7	8.33	9	7.143
	4-6	38	45.24	52	61.91	72	57.14
	7-9	22	26.19	23	27.38	42	33.33
	10-12	1	1.19	2	2.38	1	0.79
	>12	23	27.38	0	0	2	1.59

3.3.1.2. Marital status and household size

The farm family is the primary source of labor for agricultural activities in subsistence agriculture. In all three districts, the proportion of married farmers was higher than divorced farmers, polygamous farmers, and single farmers. A higher number of married households (97.62%) were recorded at Bahir Dar Zuriya followed by Jabi Tehnan (95%) and Mecha (94.4%) (Table 3.2). A research report indicated that the dedication level of married farmers is higher than unmarried farmers, which can create an imperative impact on the production and productivity of maize (Ozor, 2010). The research areas have a fairly high number of married farmers, which could be advantageous for crop production in general and maize production in particular in the future. Oxen-drawn lowing is used by farmers, which was impossible for women to do due to widespread cultural norms. As a result, married women typically lost access to land when their husbands died or when they are divorced. Female heads of households were generally reduced to sharecropping (Mulema, A., & Damtew, Elias ,2016). They are in a collaborative relationship with their husbands, as women from every region face gender-specific constraints related to socio-cultural forces that serve to reduce their agricultural productivity and limit their ability to ensure production (Badstue *et al.*,2020). The average household size for the three districts was between 4 to 6. This range accounted for 45.24%, 61.9%, and 57.1% in Jabi Tehnan, Bahir Dar Zuriya, and Mecha districts, respectively. The second-highest household size was 7-9 in all three districts.

Mecha had the largest (> 12) household size of the three; 1.58% of the households registered a family size of more than 12, but none of the other districts did (Table 3.2). According to Oluwasola and Alimi (2008), having a larger family size can create better labor which can be put into the management of crops. Household size was positively associated with net farm revenue, implying that the larger the family, the more labor donated to the farm business. Thus, the larger the farm, the higher the farm income (Headey *et al.*,2014). According to Noack and Larsen (2019), while farm output per unit of land decreases with inc reasing farm size, farmer income, and consumption increase. Agricultural production decreas es with farm size, which harms consumers, whereas agricultural income increases with farm size, which has a positive impact on producers. A one percentage increase in farm size reduce s output per unit of land by 0.18% while increasing output per unit of labor by 0.22%, accordi ng to the results of this specification. In the study area, as the average household size was 4-6 and most of them were adults, it can create good working power, creating an atmosphere for further enhancement in maize production.

3.3.1.3. Age and educational level

The age of the household is considered a decisive factor because it determines whether the household benefits from experience or has a foundation for its decisions on risk-taking behavior. This study revealed that the average age of the respondents in the majority of households in Jabi Tehnan was 35-44 (highly productive), followed by 25-34 (more productive), and 45-54 (productive), (Table 3.3). According to Tauer (2017), farmers' productivity increased with age for the age groups of 25-34, 35-44, and 45-54, respectively, as did their output per dollar (15,593,301, 44,573,767 and 98,724,744). According to the survey results, the majority of households in Bahir Dar Zuriya and Mecha had an average age of 45-54 (productive), followed by 35-44 (highly productive), and > 55 (less productive).

Farmers producing maize in all three districts were in their active productive age. Farmers who are at a productive age are more likely to succeed in investing physical effort in improving productivity (Abate Habtemariam and Düvel, 2004). The farmer’s age also has a distinctive impact on adopting and using technologies. It is associated with farming experience and planning for the horizon. In such cases, young farmers have better adoption of technologies and are receptive to change. Whereas, older farmers have a characteristic of less disposition for change and adoption of new technologies (Alene *et al.*,2000). Because the age groups in the research areas are mostly young and productive, if the rate of technology adoption becomes high due to the impact of their age, it may be regarded as a benefit.

Education can encourage farming households to try out and adopt modern technologies that improve farm production. Most of the population in the surveyed districts had attended or completed high school (44, 47.6 and 45.24%) and followed by elementary (30.9, 33.3 and 34.13 in the Jabi Tehnan, Bahirdar Zuriya, and Mecha areas, respectively). Farmers who had not received any education were 14.28, 4.8 and 7.94% in Jabi Tehnan, Bahir Dar Zuriya, and Mecha, respectively (Table 3.3). In all study districts, a non-significant number had attended above high school and university (1.2, 2.4, and 3.2), in Jabi Tehnan, Bahir Dar Zuriya, and Mecha, respectively (Table 3.3). Hence, even if the other factors are on the positive side of increasing production, having less education will negate technology's use of efficiency, production, and the adoption rate of new technologies. In agreement with this, the researchers reported that there is a direct relationship between the educational levels of the household and improved maize technology adoption (Leake Gebresilassie and Adam Bekele, 2015).

Table 1.3:Age and educational status; farming experience of maize by districts

Parameters		Jabi Tehnan (n=84)		Bahir Dar Zuriya (n=42)		Mecha (n=126)	
		Freq	%	Freq.	%	Freq.	%
Age	<25 (less productive)	2	2.38	0	0	5	3.9
	25-34 (more productive)	21	25	6	14.29	16	12.8
	35-44 (highly productive)	23	27.38	10	23.81	32	25.4
	45-54 (productive)	20	23.81	12	28.57	44	34.9
	>**55** (less productive)	18	21.43	14	33.33	29	23.02
Educational level	No educated	12	14.28	2	4.8	10	7.94
	Elementary level or graduate (up to 6th)	26	30.95	14	33.3	43	34.13
	High school level or graduate(6-8thn)	37	44.05	20	47.6	57	45.24
	Secondary high school	8	9.524	5	11.9	12	9.5
	Above high school	1	1.2	1	2.4	4	3.2
For how many years have you been growing maize?	1-15	32	38.09	11	26.2	42	33.3
	16-30	44	52.38	12	28.6	62	49.2
	31-45	6	7.14	16	38.1	19	15.1
	>45	2	2.38	3	7.1	3	2.4

3.3.1.4. Farming experience

The farming experience of any crop is one of the measurements that can determine the success and productivity of the crop. The survey results indicated that at Jabi Tehnan most of the farmers (52.38%) had the farming experience of 16-30 years. Respondents with 31- 45 years of maize farming experience accounted for 7.14%. In Bahirdar Zuriya, (38.1%) of the respondents exhibited a farming experience of 31-45 years. The next percentage, 28.6%, was accounted for by farming experience of 16-30 years. As compared to the two zones, the lowest maize farming experience in years was recorded in Mecha (Table 3.3). The highest proportion was recorded at 16-30, which was 49.2%, followed by 1-15 years, which was

33.3%. Some farmers have more than 45 years of farming experience, even though the ratio is lower in all three study districts (2.3, 7.1, and 2.4% in Jabi Tehran, Bahirdar Zuriya, and Mecha, respectively) (Table 3.3). According to the (Läpple, 2010), based on their research work on the adoption of precision farming, they concluded that farmers with higher farming experience have a lower adoption rate of improved technologies than new farmers. This could be a negative indication of the adoption of new technologies in the future in research areas. But the verification of many research reports has indicated that having a higher farming experience enhances farmers' product knowledge and technical efficiency (Wondimu Tesfaye and Hassen Beshir, 2014). Across three districts, the farming experience can be counted as high and could give maize production the above-listed benefits.

3.3.2. Production land distance from home

When a farm's home and a production site are far apart, on-time plot preparation, weeding, harvest, and input utilization are less likely, and farm revenue is less likely (MelkamuAlebachew *et al.,* 2022). Out of the respondents at Jabi Tehnan, 97.6% indicated that maize production land distance from home was a 0-30 min walk. The time required for one round trip was about a maximum of 1hr (Table 3.4). Similarly, 92.9% of respondents in the Bahirdar Zuriya and 96.03% of respondents in Mecha reported that their home was within 0-30 minutes of walking distance of a maize farm. The influence of Production land distance from home is supported by research reports on the impact of farm distance on labor utilization and organic fertilizer use. According to Feng *et al.* (2010), there is a significant impact of land distance on labor use and green manure application. This indicates that there has been a reduction in the amount of working power. According to McCall (1985), farm distance from home is not a significant factor in farming systems but its effect is mainly on cropping choices, livestock integration, and input use. As a result, it is expected that the distance from home affects the determinant factors listed above in the study areas.

Table 3.4: Land size, maize producing land distance from home, and land preparation (soil test and tillage) by districts

Parameters		Jabi Tehnan (n=84)		Bahir Dar Zuriya (n=42)		Mecha (n=126)	
		Freq.	%	Freq.	%	Freq.	%
Areal of cropland- (ha)	0.125-0.25	51	60.7	27	64.3	66	52.38
	0.251-0.50	24	28.6	14	33.33	42	33.33
	0.51-2.00	8	9.5	1	2.38	17	13.5
	>2.00	1	1.2	0	0	1	0.79
Maize-producing land Distance from home (min)	0-30	82	97.62	39	92.9	121	96.03
	31-45	1	1.19	0	0	4	3.2
	46-60	1	1.19	2	4.76	1	0.79
	>60	0	0	1	2.38	0	0
Has soil testing been done on this field in the past 3 years?	No	82	97.62	42	100	115	91.27
	Yes	2	2.38	0	0	11	8.73
Mainland preparation type	Manual	0	0	0	0	0	0
	Oxen	84	100	42	100	126	100
	Tractor	0	0	0	0	0	0
Tillage frequency	One to three	59	70.24	23	54.76	86	68.25
	Four to six times	13	15.47	11	26.2	21	16.67
	Seven to nine times	12	14.3	8	19.05	19	15.08
Does this plot have any form of irrigation?	No	84	100	42	100	86	68.25
	Yes	0	0	0	0	40	31.75

3.3.3.Production land size

Due to the productive potential of huge farm sizes, larger farm holdings engage less frequently, which may limit off-farm involvement rather than diversify agricultural activities (Alaba and Kayode, 2014; Abebe Beyene, 2008).

A land plot size of 0.125-0.25ha was reported by 60.07% of respondents in Jabi Tehnan, 64.3% in Bahirdar Zuriya, and 52.3% in Mecha. Following this, 28.6% of farmers in Jabi Tehnan, 33.3% in Bahir Dar Zuriya, and 33.3% in Mecha possessed lands that were 0.25 to 0.50 hectares in size. Only 0.79% of respondents from Mecha reported owning land larger than 2 hectares, making up the final 1% of respondents (Table 3.4).

The results showed that the farmers across the study areas had a very small share of the land. Having such a small share could lead to a strong decision to select the crop with the most economic impact and a mainstay, which takes the largest share. This could affect maize production in the study areas. Due to the small size of the production land and its low production cost requirement, farmers may be motivated to exert maximum effort to maximize yield: renewable resources(human resources and seed) and non-renewable resources (human resources, chemical fertilizers, chemical pesticides, and electricity). A similar finding was reported by Fallahinejad *et al.*(2022), the share of purchased renewable and non-renewable resources were 50.61, 42.70 and 45.50% in small, medium, and large-scale farms, respectively. Contrasting research reports on the relationship between farm size and agriculture productivity are available.Liu (1999), reported that farm size and agriculture productivity have an inverse relationship. It was also indicated that after improved agricultural technologies, it looks like an increase in farm size enhances agriculture productivity to the maximum (Li *et al.*,2013). According to Paustian and Theuvsen (2017), labor productivity increases with an increase in farm size. Based on this evidence, the production of maize could be highly influenced by the land size of the respondents.

3.3.4. Land preparation

In Ethiopia, plowing by oxen has been a common farming system since unmemorable times. Tractors are now used by small-scale farmers in some areas of the country (Astewel Takele *et al.*, 2018). But, the farmers at Jabi Tehnan, Bahir Dar Zuriya, and Mecha districts seem like they have not yet started to use tractors in their farming. All of the respondents (100%) across the three districts responded that they plowed by oxen as a means of land preparation for maize production (Table 3.4). The system of oxen plowing has its disadvantages in terms of natural resource degradation, soil erosion, and uneven tillage depth (Astewel Takele *et al.*, 2018). But due to minimal availability and the high cost of plowing by tractors, farmers across different parts of Ethiopia prefer traditional plowing (Bezuayehu Tefera, 2002). The highest number of respondent farmers, 70.24%, 54.76%, and 68.25% at Jabi Tehnan, Bahir Dar Zuriya, and Mecha, respectively, tilled their land one to three times before sowing the maize crop (Table 3.4), followed by four to six times and seven to nine times, respectively in all three districts (Table 3.4).

Tillage frequency increases land degradation to a great extent and could be the main cause of land degradation in Ethiopia (Astewel Takele *et al.*, 2018). There was no soil testing of the farmers' fields in all three districts for the past three years. Maize land testing was not common among 97.6% of farmers in Jabi Tehnan, 100.0% of farmers in Bahir Dar Zuriya, and 91.25% of farmers in the Mecha field. Except for 31.75% of the farmers' fields in Mecha, the remaining two districts had no irrigable plots of land (Hailemariam Teklewold & Alemu Mekonnen, 2017).

3.3.5. Input used

3.3.5.1. Seed type and rate

Farmers in the study area grew hybrids and landraces and improved open-pollinated types of maize on the same or different fields. Landrace types were grown by a larger percentage of farmers, 77.38, 59.6, and 61.9 %, in Jabi Tehnan, Bahir Dar Zuriya, and Mecha, respectively. Whereas farmers who grew improved varieties were 22.62, 40.4 and 38.1% in Jabi Tehnan, Bahirdar Zuriya, and Mecha, respectively (Table 3.5). These are either local varieties or seeds from improved varieties that have been recycled. The maize production system, by improving seeds, enhances the technical efficiency of production (Kafle, 2010).

Out of the total respondent farmers, 71.43% of Jabi Tehnan, 90.48% of Bahir Dar Zuriya, and 79.4% of Mecha used a seed rate of 20-40 kg ha^{-1}per 0.5 ha of land. In the districts of Jabi Tehnan, Bahir Dar Zuriya, and Mecha, respectively, 15.4%, 4.76%, and 13.5% of farmers used a seed rate of 20-40 kg ha^{-1}(Table 3.5). In Jabi Tehran, Bahirdar Zuriya, and Mecha, the proportion of farmers who used a seed rate of 40-60 kg ha^{-1}was 9.5, 2.4, and 5.5%, respectively. However, some farmers in those three districts utilized more than 30 kg ha^{-1} of maize seed (3.6, 2.38, and 1.6% in the Jabi Tehnan, Bahirdar Zuriya, and Mecha areas, respectively). This indicates that a higher percentage of farmers across the study areas use seed rates abovethe national recommended rate of maize seeds, which is 25-30 kg ha^{-1}. This could cause yield reductions in the study areas. Most farmers used the local variety rather than the improved ones in the study areas. It could be attributed to the lack of availability of improved seeds, a poor research extension system, and farmers' preference for local varieties.

In agreement with this, Mutanyagw, *et al.*(2018), discovered that the adoption rate of improved maize varieties seed by farmers varied across the nation from 0 to 58%. In contrast, Yu *et al.*(2011), reported that the adoption rate of improved seeds in East Gojam was 58%, which is an indication that above half the maize-producing farmers are willing to take the improved maize seeds. The statistical reports summarized by Gecho and Punjabi (2011), indicated that the adoption of fertilizer combined with local seeds is the main mode of modern technology adoption.

Table 3.5: Seed type and rate of maize by districts

		Jabi Tehnan (n=84)		Bahir Dar Zuriya (n=42)		Mecha (n= 126)	
		Freq.	%	Freq.	%	Freq.	%
Seed type	Improved	19	22.62	17	40.4	48	38.1
	Local	65	77.38	25	59.6	78	61.9
Seed sown kg per 0.5 ha	0.5-10	60	71.43	38	90.48	100	79.4
	10.1-20	13	15.47	2	4.76	17	13.5
	20.1-30	8	9.5	1	2.4	7	5.5
	>30	3	3.6	1	2.38	2	1.6

3.3.5.2. Fertilizer accessibility and measures to mitigate its scarcity

Fertilizer access has been one of the limiting factors in cereal production all over Ethiopia. It is also one of the determining factors in maize production in research areas. According to the respondents, 57.1% of Jabi Tehnan, 57.1% of Bahir Dar Zuriya,and 69.05% of Mecha districts were not able to get fertilizers from the usual source. The lack of fertilizer supply is mainly due to delayed supply and national and stock shortages (Table 3.6). This could significantly reduce the production and productivity of maize across the study areas.

The non-availability of fertilizers on time significantly affects the yield of crops and the adoption of improved seeds (Wekesa*et al.*,2003). The delayed application also reduces the fertilizer use efficiency and productivity of the maize crop. At Jabi Tehnan a larger proportion of the respondents suffered from a delay in supply (48.8%) and a national shortage (27.4%). A higher proportion of maize-growing farmers in the Bahir Dar Zuriya faced fertilizer shortages due to a national shortage (38.1%) and a delay in supply (33.3%) (Table 3.6). The case in Mecha indicated that 100% suffered from a delay in supply and 11.1% of them from the national shortage. Farmers' reactions varied across districts when fertilizer was in short supply. As the shortage of fertilizers piles pressure on the farmers' maize production, their response is summarized as either they did nothing or they travelled to another location to find fertilizer. Some farmers bought and borrowed from other farmers. At Jabi Tehnan, 50% of the farmers travelled to other locations and 28.6% did nothing. Similar to Jabi Tehnan, the larger portion of farmers either travelled to other locations to find fertilizer or did nothing. The unique case in Mecha and Bahir Dar Zuriyais that the farmers borrowed fertilizer from each other, unlike in Jabi Tehnan (Table 3.6).One of the primary factors affecting fertilizer use in Ethiopia is the availability and cost of fertilizer. Similarly, respondents throughout the study area experienced a lack of fertilizer supply on time and in the required amount (MoA, 2014).

Table 3.6: Status of inorganic and organic fertilizer by the district

Parameters		Jabi Tehnan (n=84)		Bahir Dar Zuriya (n=42)		Mecha (n=126)	
		Freq.	%	Freq.	%	Freq.	%
Mostly get inorganic fertilizer at the usual source? (Cooperative, Unions, fertilizer distribution agent)	No	48	57.1	24	57.1	87	69.05
	Yes	36	42.9	18	42.9	39	30.95
The main reason for not getting fertilizer	Delay in supply	41	48.8	14	33.33	126	100
	Stocks out	20	23.8	12	28.57	72	57.14
	National shortage	23	27.4	16	38.1	14	11.11
	Other	0	0	0	0	40	31.75
Response to fertilizer shortage?	Did nothing	24	28.6	12	28.57	32	25.4
	Traveled to another location	42	50	15	35.7	52	41.3
	Purchased from other farmers	17	20.23	5	11.9	24	19
	Borrowed from other farmers	0	0	7	16.7	12	9.5
	Other location	1	1.19	3	7.143	6	4.8
Did you apply to Urea?	No	24	28.57	9	21.43	24	19.1
	Yes	60	71.43	33	78.57	102	80.9
Did you apply to NPS?	No	45	53.57	16	38.1	61	48.4
	Yes	39	46.43	26	61.9	65	51.6
Number of applications of NPS	At one time all	48	57.2	19	45.24	66	52.3
	Two times	36	42.8	19	45.24	48	38.2
	Three times	0	0	4	9.52	12	9.5
Do you apply cattle manure?	No	74	88.1	28	66.67	90	71.43
	Yes	10	11.9	14	33.33	36	28.57
Do you apply compost?	No	80	95.21	33	78.57	104	82.54
	Yes	4	4.8	9	21.43	22	17.46
Do you follow fertilizer recommendations?	No	47	55.95	22	52.38	77	61.1
	Yes	37	44.1	20	47.62	49	38.9

Low soil fertility, the lack of balanced fertilization, and ineffective soil management techniqu es have all contributed to the agriculture sector's historically low productivity. One majorimp ediment to increasing fertilizer use efficiency in the country has been a lack of information about the fertility status of the bicultural land (Tamrat Demissie, 2020). Assessing the soil fertility status is important so that fertilization recommendations can be based on soil test results. In Ethiopia's farming communities including the study area, the application of both organic and inorganic fertilizers is a common trend. Urea, DAP, and the recently introduced NPS fertilizers are the most commonly used inorganic fertilizers (Tolera Abera *et al.*, 2019). The organic fertilizers are mainly farmyard manure, compost, and in some areas, chicken manure.

Among farmers from the Jabi Tehnan district, 71.43% applied urea, 46.43% applied NPS, 11.9% applied manure, and 4.8% applied compost (Table 2.6). The use of these fertilizer categories could enhance the production and productivity of maize in the research areas (Habetamu Getinet, 2021). According to the findings of this study, the majority of respondents at Jabi Tehnan used inorganic fertilizers rather than organic ones. In the case of Bahir Dar Zuriya, 78.57% of the farmers applied urea, 61.9% applied NPS, 33.3% of respondents applied manure and 21.43% of them applied compost. This indicates that, even if the application of inorganic fertilizers at Bahir Dar Zuriya is higher, a large portion of farmers apply organic fertilizers for maize production. According to the respondents at Mecha, 80.9% of applied urea, 51.6% applied NPS, 28.57% applied manure, and 17.46% of respondents used compost (Table 2.6).

The dominance of inorganic fertilizers over organic fertilizers is also a common trend in Mecha. This research result agrees with the report byTollenaar *et al.* (1997), which indicated an increase in fertilizer use by maize farmers across the country. The newly introduced fertilizer NPS method is variable from area to area across the research districts. Most of the respondents at Jabi Tehnan (57.2%) and Mecha (52.3%) applied NPS fertilizer all at once. In the case of Bahir Dar Zuriya, half of the farmers (45.24%) applied NPS fertilizer all at once, and the other half (45.24%) of them applied it two times. This indicated that the farmers either did not know the recommended application method or did not follow it. Farmers who followed and applied the recommended rate were 44.1%, 47.62%, and 38.9% in Jabi Tehnan, Bahir Dar Zuriya, and Mecha, respectively.

3.3.5.3. Weeds, Diseases, and Pests

In the study area, weeds are the limiting factors in the production and productivity of maize than the disease. The farmers from the Jabi Tehnan district (96.43%) reported that diseases are not maize production problems. Similar reports were also obtained from the Bahir Dar Zuriya in which 97.6 % of the respondents indicated diseases as not the limiting factor in the production year. The percentage of farmers (10.32%) who indicated diseases as problems in maize production in the Mecha district was higher than in the other districts. It was expected that, with no disease problems, the application of pesticides would be very limited. Based on this, 88.1% of the farmers from Jabi Tehnan, 95.23% of the farmers from Bahir Dar Zuriya, and 89.68% of farmers from Mecha reported no use of pesticides for maize production (Table 3.7). Witch weed was not a problem in their maize farming, according to most respondents in Jabi Tehnan (97.61%), Mecha (94.4%), and the entire Bahir Dar Zuriya (100%). The farmers also indicated that they did not use herbicides to control weeds on their maize farms. The percentage of farmers who did not use herbicides accounts for 70.24%, 83.3%, and 72.2% of respondents in the Jabi Tehnan, Bahir Dar Zuriya, and Mecha districts, respectively. The respondents indicated that 59.59% of farmers from Jabi Tehnan, 61.9 % of farmers from Bahir Dar Zuriya, and 68.25% of farmers from Mecha used hand weeding two times per growing season. Some farmers weeded once or three times across their districts. The percentage of farmers who weeded once and three times at Jabi Tehnan was 28.9% and 11.08%, respectively. Bahir Dar Zuriya farmers who weeded once were 21.44% and 16.6% weeded three times. Mecha maize weeding was done once a season and three times a year, by 17.5% and 11.1%, respectively (Table 3.7). This could indicate that the land is free of weeds in which case farmers should weed less frequently. Hand weeding and cropping systems could be the possible reasons for the limited availability of weeds, diseases, and insect pest attacks (Aune, 2001).

The farmers from the Jabi Tehnan district (96.43%) reported that diseases are not maize production problems. Similar reports were also obtained from the Bahir Dar Zuriya in which 97.6% of the respondents indicated diseases as not the limiting factor in the production year. The percentage of farmers (10.32%) who indicated diseases as problems in maize production in the Mecha district was higher than in the other districts. It was expected that, with no disease problems, the application of pesticides would be very limited. Based on this, 88.1%

of the farmers from Jabi Tehnan, 95.23% of the farmers from Bahir Dar Zuriya, and 89.68% of farmers from Mecha reported no use of pesticides for maize production (Table 3.7).

Table 3.7: Disease and weed control of maize fields by districts

		Jabi Tehnan (n=84)		Bahir Dar Zuriya (n=42)		Mecha (n=126)	
		Freq.	%	Freq.	%	Freq.	%
Did this field suffer from plant disease during the last cropping season?	No	81	96.43	41	97.6	113	89.68
	Yes	3	3.57	1	2.4	13	10.32
Did you apply pesticide?	No	74	88.1	40	95.23	113	89.68
	Yes	10	11.9	2	4.77	13	10.32
Did this field suffer from witchweed (Striga)?	No	82	97.61	0	0	119	94.4
	Yes	2	2.39	0	0	7	5.6
Did you Apply herbicide?	No	59	70.24	0	83.3	91	72.2
	Yes	25	29.76	0	16.7	35	27.8
The number of weeding in the current season?	Not weeding at all	0	0	0	0	3	2.4
	One time	24	28.98	9	21.44	22	17.5
	Two times	50	59.59	26	61.9	86	68.25
	Three times	10	11.089	0	16.66	14	11.1
	Four times	0	0	0	0	1	0.79

3.4. Conclusion

This study aimed to assess the constraints on maize production in three districts in West Gojjam: Jabi Tehnan, Bahir Dar Zuriya, and Mecha. The findings of this study provided proof of evidence that demographic characteristics including age, gender, household size, marital status, and farmers' age have an impact on maize production. In the research area, a large portion of the household respondents was male (96.2%) and married (95.6%). The quite low female engagement in the region could be one of the productions limiting factors as the involvement of females can play a significant role in production and productivity. Household size (4-6) with active working age, young and productive age (45-54) in the study area might contribute significant benefits to maize production in the future as they increase their production via physical activity. The land-holding size of farmers in the study areas is very small and fragmented. Because of the long-distance walking from home to production land, the efficiency of working power has been reduced. Even though the farmers are very experienced in maize farming, they still use the old production systems, which are oxen plowing, continuing to use local varieties, and using common types of fertilizers repeatedly (Urea, DAP, and NPS) which are primarily constrained by the time and quantity desired. The good news is that insect pest attacks are limited across the study areas, and weed damage is also limited. Therefore, based on this research, it can be concluded that for farmers across the three districts, the maize production system is affected by socioeconomic, fertilizer, seed, and land preparation factors.

CHAPTER 4. *EFFECTS OF INTEGRATED APPLICATION OF INORGANIC AND ORGANIC FERTILIZERS ON SOIL CHEMICAL PROPERTIES IN NORTHWEST ETHIOPIA

ABSTRACT

For many nations, maintaining agricultural productivity and production is hampered by the degradation of soil fertility. The use of either organic or inorganic fertilizer alone may change the soil in ways that are both advantageous and disadvantageouson plantdevelopment, and availability of nutrients. To improve the soil's condition, farmyard manure and NPSBZn blended fertilizer can be used together.In this context, a study was conducted in 2017–2018 to determine the effect of the combined use of farmyard manure (FYM) and NPSBZn blended fertilizer on soil physicochemical properties and the yield of maize in the Jabi Tehnan and Mecha districts. The experiment was designed using a randomized complete block design with three replications. There was a total of nine treatment combinations which include five levels of NPSBZn blended fertilizer (100, 150, 200, 250, and 300 kg ha^{-1}), four levels of farmyard manure (0, 12, 16, and 20 t ha^{-1}) and one blanket recommendation of (150 kg ha^{-1} and 200 kg ha^{-1} DAP).Results showed that combined use of farmyard manure and NPSBZn blended fertilizer significantly ($p<0.05$) increased soil total nitrogen, available sulfur (AS), available boron (AB), and available zinc (A Zn) but the significant increment of soil P^H, cation exchange capacity and organic matter was observed by only the effect of farmyard manure. While significant improvement in available phosphorus (AP) was recorded due to the main effect of both farmyard manure and blended fertilizer. Therefore, solving the soil fertility problems of the study areas through the integrated application of farmyard manure and NPSBZn blended fertilizer could be one of the options to improve the soil physico-chemical properties.

Keywords: Soil property, Blended fertilizer, farmyard manure, Available sulfur, Available P; Available zinc.

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4.1. Introduction

The vast African continent, and Ethiopia in particular, are characterized by severe soil degradation, rain-fed and fragmented land holdings, extremely low external inputs like fertilizer and agrochemicals, and the use of traditional agricultural methods that result in the depletion of soil nutrients and organic matter contents, which cause unsustainable agricultural productivity and food insecurity (Bezabih Emana*et al.,* 2010, FAO and ITPS, 2015). Excessive soil exploitation and improperand unscientific use of soil without consideration for long-term sustainability have led to a decline in soil health and endangered the security of food production (Puig, 2015). Multi-nutrient deficiencies have emerged in Ethiopian soils as a result of nutrient mining brought on by inadequate fertilizer usage on the one hand and uneven fertilizer use on the other, which may in part be responsible for drop in fertilizer factor productivity (Wassie Haile and Shiferaw Boke, 2011).

Evidence showed that the average soil loss in Ethiopia is about 42 tons/ha/year (Zemenfes Tsighe,1995). The decrease in organic matter content is 3 tones/ha/year(Lal,2015; Tekalign Mamo and Tegbaru Bellete,2015). This loss of soil fertility is further aggravated by continuous cultivation, which leads to nutrient mining of the soils.

Commercial fertilizer is one of the most critical inputs that can bring about a rapid increase in agriculture. The total fertilizer use has generally increased for long years ago, but the amount and kind of fertilizer used in the country are low and only Urea and DAP were applied as sources of N and P fertilizers to crops by smallholder farmers in the highland of Ethiopia (Gete Zelleke *et al.*,2010), including the study area. A recently acquired soil inventory data revealed that the deficiencies of most nutrients such as N, P, and S are widespread in Ethiopian soils and similarly in the study area (EthioSIS, 2016). To overcome this problem, the Ethiopian Ministry of Agriculture has recently introduced a new NPSBZn blended fertilizer containing N, P, S, Zn, and P with a ratio of 16.9 N – 33.8 P_2O_5 + 7.3S + 2.23Zn + 0.67B (MoARD,2013). However, chemical fertilizers alone are unable to maintain and sustain long-term soil health and crop productivity because they are unable to improve soil physicochemical properties and supply trace elements (Mitiku Woldesembet *et al.*, 2014).

Some farmers' overuse of mineral nutrients can have unfavourable outcomes, including leaching, water resource pollution, and the annihilation of beneficial insects and microorganisms. Only 30–40 percent of Ethiopian smallholders use fertilizer and those who do apply on average only 37–40 kilogram per hectare (ha), significantly below recommended rates this because of the expensive cost of chemical fertilizers and lack of soil and crop-specific and fertilizer recommendations. (Spielman, *et al.,* 2013; Yadav *et al.,* 2019; Eyasu Elias*et al.,*2020). Over-reliance on mineral fertilizer without due diligence to the organics may lead to depletion of SOM, exacerbated soil acidity, depletion of and secondary nutrients such as S, Mg, Ca, and micronutrients not supplied by chemical fertilizers that caused declined soil productivity (Singh *et al.*,2007).

As an alternative to chemical fertilizers, organic fertilizers can be used as nutrientsources in production systems involving a partial reduction in the use of chemicals fertilizer (Usman, *et al.*,2015).They play important role in soil fertility, soil structure improvement, erosion control, and supply of a wide range of nutrients (Jahiruddin *et al.,* 2012; Haliru *et al.,* 2015) and help plants in combating pests and diseases (Khadem *et al.,* 2010). There is unending literature reporting the efficiency and effectiveness of organic nutrient sources in maintaining soil quality (physical, biological, and chemical properties), improving crop yields, and sustaining productivity (Wakene Negassa *et al.*2001; Suge*et al.,* 2011). Organic fertilizers supply all essential crop nutrients (N, P, K, S, Ca, Mg, B, Cl, Cu, Fe, Mn, Mo, Ni, Zn, Ni and Pb) in balanced forms, including micronutrients. This is often not the case for anyone inorganic fertilizer. Since all these nutrients make up the biomass of organic residues, they are released during the decomposition process into the soil. The downside to applying organic fertilizers alone is that they contain very minimal amounts of these nutrients and as such must be applied in bulky quantities to meet crop nutrient demands (Timsina, 2018). However, the addition of organic amendments alone is insufficient to maintain soil fertility and increase crop yields due to limited access to organic inputs, low nutrient contents, and high labor demand for preparation and transporting (Getachew Agegnehu, van Beek, and Bird, 2014; Girma Chala and Gebreyes Gurmu, 2017). In Ethiopia, farmyard manure and crop residues are becoming the main source of fuel and livestock feed instead of incorporating into the soil (Yihenew Gebre Selassie, 2015).

Balanced and integrated use of organic and inorganic fertilizers may enhance the accumulation of soil organic matter and improves the soil's physical properties. Application of inorganic fertilizers results in higher soil organic matter (SOM) accumulation and biological activity due to increased plant biomass production and organic matter return to soil in the form of decaying roots, litter, and crop residues (Babbu *et al.,* 2015).

The sole application of organic fertilizers has proved to be a slow means of nutrient supply to the soil. Hence the combined use of organic and inorganic nutrient sources has been proposed (Brempong *et al.,* 2017). Such applications harness the benefits of synergistic interaction between organic and inorganic nutrient sources. Therefore, the objective of this study was to evaluate the effects of organic and inorganic fertilizers on soil properties and to quantify the synergistic benefits of their combinedapplications on physio-chemical propertiesin the study area.

4.2. Materials and Methods

4.2.1. Experimental site

Jabi Tehnan and Mecha, two promising maize-producing districts, were chosen for this study during 2017/18. In chapter 2, sub-section 2.1, the locations of the study sites are given in detail.

4.2.2. Experimental design and treatments

The study employed a four-by-four factorial experiment with three replications in a randomized complete block design. Plots and replications were spaced apart by 0.5 and 1 meter, respectively. Gross plot dimensions were 4 m by 4 m and net plot dimensions were 3.2 m by 2.5 m, respectively. The entire experimental area measured 94 by 14 meters. Farmyard manure and chemical fertilizer (NPSBZn blended fertilizer) were the treatments used in this study. Half dose of urea fertilizer of blanket recommended (150 kg ha^{-1} urea and for the N adjusted and all DAPfertilizerwere applied as a basal application at sowing, and the remaining N was top-dressed 35 days after sowing. Inorganic and organic fertilizers were applied at rates of 100, 150, 200, 250, and 300 kg ha^{-1} and 0, 12, 16, and 20 t ha^{-1} for NPSBZn blended fertilizer and farmyard manure, respectively. Farmyard manure was acquired from farmers in the research region, chemical fertilizers were bought.

4.2.3. Experimentalprocedures

Three repeated plowed passes were used to split large soil clods into smaller ones after the experimental field was prepared by oxen plowing. Levelling was applied to the field, and blocks and plots were created. We received well-decayed farmyard manure from nearby farmers (from cattle). All inactive and non-degradable components were separated and eliminated. The manure was spread out on a plastic sheet in the shade to dry, maintaining the moisture content below 22%. The varying levels of collected farmyard manure were put at random one month before planting by considering its slow nutrient-releasing and properly mixed with the soil(Oueriemmi *et al.*,2015). As per their treatment level, all rate of NPSBZn blended fertilizer were randomlyappliedby drilling once during plantingand thorough mixing with the soil in the plots.For the N adjusted and half dose of urea fertilizer of blanket recommended and also all DAP fertilizer were applied as a basal application at sowing, and the remaining N was top-dressed 35 days after sowing.

4.2.4. Soil samples collection and laboratory analysis

Composite and undisturbed soil samples (to a depth of 0–20 cm) were taken from each replication of the test field before chemical and organic fertilizer applications to determine the physicochemical parameters of the soil. The auger-collected composite samples were properly mixed after being taken diagonally from five points on each block to create composite representative samples.

Following harvest, soil samples were also taken at a comparable depth from each experimental plot. Except for total nitrogen and organic carbon, which are determined using a 0.5 mm sieve, the composite sample was air-dried, crushed, and subjected to a 2 mm sieve for analysis. After sample preparation, measurements of soil texture, soil pH, organic carbon (OC), cation exchange capacity (CEC), total nitrogen (N), available phosphorus (P), available sulfur (S), available boron (B), available and zinc (Zn) were made in the soil analytical laboratories of Debre Berhan University and Debre Berhan Agricultural Research Centre.

The soil textural analysis was performed using the hydrometer method, and the total nitrogen (N) found in the soil samples was evaluated using the Kjeldahl method (Bremner and Mulvaney, 1982). To calculate the soil's organic matter, the percentage of organic carbon (% OC) was multiplied by a value of 1,724 (Brady & Weil, 2008). Available phosphorus was determined using the Olsen method (Olsen *et al.,* 1954). A soil-to-water ratio of 1:2.5 was used to measure the pH of the soil suspended in water. The soil's cation exchange capacity was measured using the Black-described method (CEC) (Black, 1965). Sulfur concentrations were calculated using turbid metric analysis (Hoeft *et al.,* 1973). Borax was found using a hot water extraction technique (Havlin *et al.,* 2016). According to Lindsay and Novell (1978), DTPA was used to extract the available Zn. The same analytical methods employed for soil analysis were also utilized to examine the farmyard's chemical composition.

4.2.5. Statistical analysis

The analysis of variance (ANOVA) was performed on all soil data collected using statistical analysis software (SAS) version 9.0 (SAS, 2004). While the difference amongst treatments was separated by using the least significant difference (LSD) test at $p \leq 0.05$. Using simple linear correlation coefficients, an investigation of the relationship between soil and maize grain yield was conducted.

4.3. Results and Discussion

4.3.1. Selected soil physico-chemical properties of the experimental site before planting

The laboratory findings of the selected soils' physicochemical characteristics that were examined before sowing are reported in (Table 4.1). The texture indicates the soil's nutrient content, water-holding capacity, and degree of weathering. The soils of both research areas were classified as clay loam using the International Soil Science Society (ISSS) system's soil textural categorization triangle (Rowell, 1994). This type of soil retains water and nutrients well, promoting improved crop growth and development.

According to the pH range suggested by Cooke *et al.*(1993), the soil pH at Jabi Tehnan (6.01) and (6.08) Mecha, ranged from mildly acidic to almost neutral. Most crops do best in soils that are neutral to mildly acidic in pH. Hence, a soil pH in the range of 5.5-7.0 is ideal for most grain crops, and the pH range of 5.5-7.0 can offer the most sufficient plant nutrient levels overall (Brady & Weil, 2008). This measure determined that the pH at both experimental locations was within acceptable bounds.

Mecha had a medium amount of cation exchange (CEC). But at Jabi Tehnan, it was high (Landon, 1991). Landon categorizes soils as extremely high, high, medium, moderate, or very low if their CEC is greater than 40, 25, 15, 5, or 5 Cmol $(_{+})$/kg. Due in large part to the high clay composition of the soils, high CEC suggests that the soils can effectively hold nutrients. The soil's high buffering capacity against induced chemical changes is another benefit of the soil's high CEC value (Hazelton and Murphy, 2007).

At Jabi Tehnan and Mecha, the levels of organic carbon were 1.7% and 1.4%, respectively. These organic carbons at both sites had values classified as the medium at Jabi Tehnan and the lowest at Mecha (Mamo,1991). The medium and low levels of organic carbon could be linked to continuous monoculture, the less and continuous use of inorganic fertilizes, and the total clearance of crop residue since crop stalks are used for cattle feed and fuel rather than being incorporated into the soil (Abamagal,2019).

According to Landon's (1991) rating, the soil total N was in the medium at JabiTehnan (0.14%). while a low level of total N was recorded at Mecha (0. 13%). The poor total nitrogen content in the study area may be due to sustained mono-cropping, high temperatures during the summer season, and the leaching of nitrate by heavy rainfall rampant in winter (Kumar, 2019). According to Tekalign Mamo*et al.* (1991), the experimental soil exhibited lower rangeof available phosphorous concentrations in both study locations. The non-fallow system of production and the reduced levels of organic matter as a result of all agricultural wastes being used for cattle feeding and fuel instead of recycling may also be responsible for the low phosphorus content (Otto,2002). Both experimental locations' soil available S contents were in the low range (20 low, 20-80 optimal, 80-100 high, and > 100 very high), according to EthioSIS (2014). This could be primarily brought on by the lack of parent material in the soil that contains sulfur, soil degradation, crop residue clearance, crop uptake, low soil organic matter (OM), use of non-S fertilizers (only N and P-containing fertilizers are employed), and inadequate management techniques. Most grain crops absorb sulfur in levels ranging from 10 to 30 kg ha^{-1}, which are comparable to those of phosphorus (Weil and Mughogho, 2002), but there has never been a practice in the research locations of adding this nutrient externally. This study's findings are consistent with those of Asrat Hailu *et al.* (2016), who found that S deficiency was present in soil samples taken from several parts of Ethiopia. Shehu *et al.* (2018), observed that soil samples from the Jabi Tehnan and Mecha sites, respectively, had nearly low(0.016 kg ha^{-1}) and moderately high (0.042 kg ha^{-1}) accessible boron values. The change in soil pH in the area is the most likely reason for the difference in boron content. According to Landon (1991), available zinc (Zn) for weathered tropical soils was in the inadequate zone at both sites. Reduced Zn value can be linked to the removal of topsoil sheet erosion and ongoing crop yield harvesting (Markos Mathewos, 2020).

Table 4.1: Soil Physico-chemical properties of the experimental locations before treatment application

Parameters	Jabi Tehnan	Mecha
Textural class	Clay loam	clay loam
pH	6.01	6.08
CEC ($cmol_{(+)}$ kg^{-1})	20.842	16.9
OC (%)	1.7	1.4
TN (%)	0.14	0.13
Av. P (ppm)	8.77	6.106
Av.S (mg kg^{-1})	10	16
Av. B (mg kg^{-1})	0.016	0.042
Av. Zn (mg kg^{-1})	0.251	0.249

EC = Cation exchange capacity; OM = Organic matter; TN = Total nitrogen; Av. P = Available phosphorous, Av. S = Available Sulfur; Av. B = Available boron; Av. Zn = Available Zinc

4.3.2. Chemicalcomposition of farmyard manure

The farmyard manure utilized in this experiment had a pH of 7.3 at Mecha and 7.1 at Jabi Tehnan, and the reaction had a slightly alkaline pH. At Jabi Tehnan and Mecha, the farmyard manure's organic carbon and total nitrogen concentrations were 32.13 and 31.10, and 0.441 and 0.453, respectively. This suggests that the farmyard manure spread on the experimental field has thoroughly decomposed. At Jabi Tehnan and Mecha, the concentrations of sulfur and phosphorus that were readily available were 8.43 and 10.2 and 15.92, and 16.72, respectively. (Table 2). At Jabi Tehnan and Mecha, the farmyard manure's available boron and zinc concentrations were (0.013 and 0.020) and (0.23 and 0.09), respectively. In both cases, the CEC was 29.4 and 31.3 (cmol $_{(+)}$ kg^{-1}) (Table 4.2).

Table 4.2: Chemical characteristics of farmyard manure used in the experiment

Parameters	Jabi Tehnan	Mecha
pH	7.1	7.3
CEC(cmol$_{(+)}$ kg^{-1})	29.4	31.3
OC (%)	32.13	31.10
TN (%)	0.44	0.45
Av. P (ppm)	15.92	16.72
Av.S (mg kg^{-1})	8.43	10.2
Av.B (mg kg^{-1})	0.013	0.02
Av. Zn (mg kg^{-1})	0.23	0.09

CEC = Cation exchange capacity; OM = Organic matter; TN=Total nitrogen; Av. P = Available phosphorous, Av. S = Available Sulfur; Av. B = Available boron; Av. Zn = Available Zinc

4.3.3. Effects of farmyard manure and NPSBZn blended fertilizers on selected soilChemicalproperties after harvesting of maize

4.3.3.1. Soil pH

Following the harvest of maize, soil analysis results showed that farmyard manure highly affected the pH of the soil in a significant ($p > 0.05$) manner. The major effect of NPSBZn blended fertilizer and their interaction, however, had no significant effect on soil pH ($p > 0.05$) (Table 4.3).

The greatest pH values (6.295) at Jabi Tehnan and (6.1491)at Mecha were found in the plots treated with 20 t ha^{-1} farmyard manure, which were statistically comparable with 16 t ha^{-1} farmyard manure at both experimental locations. While the lowest soil pH value (5.2110) at

Jabi Tehnan and (5.3958) Mecha was measured in the non-treated plot which was statistically on par with 12 t ha^{-1} farmyard manure at both experimental locations.

The results showed that increasing the amounts of farmyard manure from 0 to 20 t ha^{-1}improved soil pH by 4.74 and 1.14 % over the results of the P^H analysis before planting and by 21.25% at Jabi Tehnan and 14.75percent at Mecha over the blanket recommendation. The increase in soil pH of plots treated with farmyard manure when compared to the analytical results of satellite control plots might be due to the high pH value of the farmyard manure. This could be evident from the positive correlation (r= 0.56398 **) at Jabi Tehnan and (r= 0.60786) Mecha discovered between pH and organic matter (Tables4.8 &4.9). This is supported by the findings of Wong *et al.* (1998), who noted that an increase in soil pH was seen as a result of a higher farmyard manure application rate.

4.3.3.2. Soilorganic matter (%)

The main effect of farmyard manure was significantly ($p<0.05$) influenced soil organic matter However, the sole NPSBZn blended fertilizer and their interaction were not significantly ($p< 0.05$) affected soil Organic matter (Table 4.3).

The highest percentage of organic matter (4.63039%) at Jabi Tehnan and (4.87746 %) Mecha was recorded in plots treated with 20 t. ha^{-1} farmyard manure which was statistically on par with 16 t ha^{-1} farmyard manure at both experimental locations while the lowest value of organic matter (3.38562 %) at Jabi Tehnan and (3.63271 %) Mecha was measured in the non-treated-plot-which-was-statistically par with 12 t ha^{-1} farmyard manure at both experimental locations.

Organic matter content increased by 44.56% in Jabi Tehnan and 48.52% in Mecha when compared to the blanket recommendation, and by 56.36% in Jabi Tehnan and 105.55%in Mecha when compared to the pH analysis result before planting. The enrichment of farmyard manure with the organic matter may be responsible for the increase in organic matter over satellite control. These outcomes are in line with those of Lima *et al.* (2009), who claimed that the application of mature farmyard manure improved soil organic matter because of its higher content of stable carbon.

Table 4.3: Maine effect of farmyard manure on soil reaction (pH) and organic matter, combined over years 2016/17 and 2017/18 by districs

	pH		OM	
	Jabi Tehnan	Mecha	Jabi Tehnan	Mecha
Treatments				
BR	5.02	5.23	3.29	3.29
FYM tha^{-1}				
0	5.21b	5.39b	3.39b	3.64b
12	5.56b	5.41b	3.89b	4.14b
16	6.24a	6.095a	4.51a	4.77a
20	6.294a	6.15a	4.64a	4.88a
LSD (0.05)	0.66	0.48	0.14	0.15
CV (%)	15.34	11.08	4.56	4.66

Means followed by the same letter within the same column of the respective treatment are not significant; BR=blanket recommendation (150 kg ha^{-1}urea &200 kg ha^{-1}DAP); FYM=farmyard manure; BF= blended fertilizer; CV = Coefficient of variation;LSD= Least Significant Difference at 5% level

4.3.3.3. Totalnitrogen (%)

Total nitrogen was significantly ($P<0.05$) affected by the main effects of farmyard manure and NPSBZn blended fertilizer. Likewise, the interaction effect of farmyard manure and NPSBZn blended fertilizer also significantly ($P<0.05$) affected total nitrogen (Table 4.4).

When all treatment combinations were considered, the total nitrogen concentration at Jabi Tehnan varied from 0.09 to 0.2% and 0.18 to 0.24 at Mecha.The application of 100 kg ha^{-1} of NPSBZn blended fertilizer and no farmyard manure resulted in the lowest value (0.09%) at Jabi Tehnan and (0.18%) at Mecha, while the highest value (0.2%) at Jabi Tehnan and (0.24%) Mecha was attained from the application of 300 kg ha^{-1} of NPSBZn blended fertilizer and 20 t ha^{-1} of farmyard manure.

The amount of total nitrogen increased significantly above the blanket recommendation by 14.29% at Jabi Tehnan and 30.44% in Mecha, as well as 42.86% and 84.62% above the total nitrogen analysis result before planting. The relatively high total nitrogen contents of the plots treated with 20 t ha^{-1} farmyard manure and 300 kg ha^{-1}NPSBZn blended fertilizer could be attributed to the release of mineralized nitrogen from the farmyard manure and the N supplied to the soil by the NPSBZn blended fertilizer. This can be confirmed by the positive correlation (r = 0.67 **) at Jabi Tehnan and (r= 0.60**) Mecha between total nitrogen and organic matter (Tables 4.8 &4.9). This conclusion was consistent with the findings of Abreha Kidanemariam*et al.* (2012), who showed that total N content rose with increasing doses of both organic and inorganic fertilizers.

Table 4.4: Interaction effects of NPSBZn blended fertilizer and farmyard manure on total nitrogen (%) content, combined over years 2016/17 and 2017/18 by districs

Treatments		Jabi Tehnan	Mecha
BR		0.18	0.184
BF Kg ha^{-1}	FYM t ha^{-1}		
100	0	0.09h	0.18d
	12	0.11g	0.20c
	16	0.13e	0.22b
	20	0.15c	0.23b
150	0	0.11g	0.19c
	12	0.12f	0.22b
	16	0.14d	0.22 b
	20	0.15c	0.23b
200	0	0.12f	0.22b
	12	0.13e	0.22 b
	16	0.14d	0.22 b
	20	0.15c	0.23b
250	0	0.13e	0.22b
	12	0.14d	0.22 b
	16	0.15c	0.23b
	20	0.17b	0.23b
300	0	0.13e	0.22 b
	12	0.14d	0.22b
	16	0.17b	0.23b
	20	0.2a	0.24a
LSD (0.05)		$3.9*10^{-11}$	0.01
CV (%)		1.72	3.02

Where means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation (150kg ha^{-1} Urea &200kg ha^{-1} DAP); BF: Blended fertilizer (NPSBZn); FYM: Farmyard manure; CV = Coefficient of variation;LSD= Least Significant Difference at 5% level

4.3.3.4. Cation exchange capacity (CEC)

Cation exchange capacity is one of the most important parameters used in assessing soil fertility and its capacity to retain nutrients against leaching. The main effect of farmyard manure was significantly (p<0.05) influenced soil cation exchange capacity. However, the single NPSBZn blended fertilizer and its interaction had no significant ($p < 0.05$) effect on soil cation exchange capacity (Table 4.5).

The plots treated with 20 t ha^{-1} farmyard manure, which was statistically similar to 16 t ha^{-1} farmyard manure at both experimental locations, had the highest CEC (22.0468 (cmol $_{(+)}$ kg^{-1}) at Jabi Tehnan and (21.8111(cmol $_{(+)}$ kg^{-1}) Mecha. In contrast, the lowest value of CEC (20.9628(cmol $_{(+)}$ kg-1) was observed at Jabi Tehnan and (21.0806(cmol $_{(+)}$ kg^{-1}) Mecha in the untreated plot, which was statistically on par with 12 t ha^{-1} farmyard manure in both experimental locations.At Jabi Tehnan and Mecha, the value of CEC increased significantly beyond the blanket recommendation by 5.78% and 29.05%, respectively, as well as by 1.68% and 2.64% above the CEC analysis result before planting. The increase in CEC of treated plots over control plots could be attributed to an increase in soil CEC as a result of increasing doses of farmyard manure application (Deepa, 1998).

4.3.3.5. Availablephosphorus

The results of the analysis of variance demonstrated that the main effects of the NPSBZn blended fertilizer and farmyard manure significantly ($P< 0.05$) affected the amount of phosphorus that was readily available. However, in both experimental locations, the interaction effect of NPSBZn blended fertilizer and farmyard manure did not significantly ($p > 0.05$) affect the amount of accessible phosphorus (Table 5).

The lowest available phosphorus levels (5.5767 ppm) at Jabi Tehnan and (4.0860 ppm) in Mecha were obtained from the least amount of NPSBZn blended fertilizer (100 kg ha^{-1}). The highest available phosphorus levels (9.3084 ppm) at Jabi Tehnan and (6.8034 ppm) at Mecha were obtained from 300 kg ha^{-1}NPSBZn blended fertilizer, but it was significantly on par with 250, 200 kg ha^{-1}.The increase in NPSBZn blended fertilizer from 100 to 300 kg ha^{-1} increased the amount of available phosphorus by 7.72% over the blanket recommendation and by 6.14% over the amount of available phosphorus analysis result before planting at Jabi Tehnan and by 11.78% over the blanket recommendation and by 11.42% before to planting at Mecha.The relatively high phosphorus released from the blended NPSBZn fertilizer may be the cause of the greater accessible phosphorus gained from the higher inorganic fertilizer (Tunebo *et al.,* 2020).

Regarding farmyard manure, the lowest available phosphorus (6.5797 ppm) at Jabi Tehnan and (4.8090 ppm) at Mecha were found in a non-treated plot at both locations, while the highest levels (9.7357 ppm) at Jabi Tehnan and (7.1157 ppm) at Mecha were obtained from the application of 16 tha^{-1} farmyard manure at both locations.The increase from 0 to 16 tha^{-1} increased the amount of available phosphorus at Jabi Tehnan by 11.68% over the blanket recommendation and by 11.01% above the available phosphorus analysis result before planting, and at Mecha by 16.89% over the blanket recommendation and by 16.54% above the pH analysis result before planting. The higher available phosphorus obtained from the higher farmyard manure might be due to the relatively higher phosphorus released from supplied farmyard manure for this plot's soils (Ayaga *et al.*,2006). This can be confirmed by the positive correlation between the available P and OM at Jabi Tehnan and the available P and OM (r = 0.32387) (Tables 8 & 9). In every instance, when the rate of farmyard manure increased, the amount of available P in the soil also increased.

Table 4.5: Effect of farmyard manure and NPSBZn blended fertilizer on available phosphorus and cation exchange capacity

	Av P(ppm)		CEC(cmol $_{(+)}$ kg^{-1})	
Treatments	Jabi Tehnan	Mecha	Jabi Tehnan	Mecha
BR	8.64	6.09	21.689	21.25
FYM tha^{-1}				
0	6.58c	4.81c	20.98b	21.08b
12	8.64b	6.32b	21.29b	21.09b
16	9.74a	7.12a	21.99a	21.76a
20	8.11b	5.93b	22.05a	21.81a
LSD (0.05)	0.78	0.57	0.67	0.61
BF Kg ha^{-1}				
100	5.58b	4.08b	21.3	21.53
150	8.59a	6.28a	21.7	21.51
200	8.63a	6.31a	21.7	21.1
250	9.23a	6.7a	21.7	21.51
300	9.31a	6.8a	21.7	21.50
LSD (0.05)	0.87	0.63	ns	ns
CV (%)	12.7	12.7	4.2	3.88

Where means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation (150kg ha^{-1} Urea &200kg ha^{-1} DAP); BF: Blended fertilizer(NPSBZn); FYM: Farmyard manure; CV = Coefficient of variation;LSD= Least Significant Difference at 5% level.

4.3.3.6. Availablesulfur (mg kg^{-1})

The interaction effect of farmyard manure and NPSBZn blended fertilizer at both experimental locations significantly ($P<0.05$) affected the amount of available sulfur (Table 4.6).

The combination of 300 kg ha^{-1} of NPSBZn blended fertilizer and 20 t ha^{-1} farmyard manure resulted in the highest mean available sulfur of 24.98 and 19.36 mg kg^{-1} at Jabi Tehnan and Mecha, respectively, while the plot that received 100 kg ha^{-1} of NPSBZn blended fertilizer with no farmyard manure application resulted in the lowest available sulfur of 22.34 at Jabi Tehnan and 17.31 mg kg^{-1} at Mecha.The results showed that increasing the amounts of farmyard manure from 0 to 20 t ha^{-1}andNPSBZn blended fertilizer from 100 to 300 kg ha^{-1}increased the amount of available sulfur in the soil by 75.05% at Jabi Tehnan and 57.01% at Mecha above the blanket recommendation as well as by 42.86% and 84.62% at Jabi Tehnan and Mecha, respectively, over the available sulfur analysis result beforeplanting. Such an increase in available S might be due to the sulfur released from farmyard manure and supplied by NPSBZn blended fertilizer(Eleni Getachew,2022).These findings are supported by Lemanowicz *et al.* (2014) who reported who said that applying farmyard manure boosted the soil's sulfur concentration.

Table 4.6: Interaction effects of farmyard manure and NPSBZn blended fertilizer on available sulfur (mg kg^{-1})

Treatments		Jabi Tehnan	Mecha
BR kg ha^{-1}		14.27	12.33
BF Kg ha^{-1}	FYM t ha^{-1}		
100	0	22.34s	17.31s
	12	22.65r	17.55r
	16	22.76o	17.64o
	20	22.91k	17.76k
150	0	22.66q	17.56q
	12	22.73p	17.62p
	16	23.08i	17.89i
	20	23.42g	18.15g
200	0	22.77n	17.65n
	12	22.85l	17.71l
	16	23.66f	18.34f
	20	23.84e	18.48e
250	0	22.8m	17.67m
	12	22.92j	17.76j
	16	24.57d	19.04d
	20	24.67b	19.12b
300	0	23.38h	18.12h
	12	23.42g	18.15g
	16	24.66c	19.11c
	20	24.98a	19.36a
LSD (0.05)		13E-9	0.03
CV (%)		3.4948	3.78

Where means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation (150kg ha^{-1} Urea &200kg ha^{-1} DAP); BF: Blended fertilizer (NPSBZn); FYM: Farmyard manure; CV = Coefficient of variation;LSD= Least Significant Difference at 5% level

4.3.3.7. Available boron (mg kg^{-1})

The main effect of farmyard manure and NPSBZn blended fertilizer on the available boron was significant (P <0.05). Similarly, there was a significant interaction effect of farmyard manure and NPSBZn blended fertilizer on the available boron (Table 4.7).

The highest mean available boron 1.4 and 2.58 mg kg^{-1} was produced by combining 300 kg ha^{-1} of NPSBZn blended fertilizer with 20 t ha^{-1} farmyard manure at Jabi Tehnan and Mecha, respectively. In contrast, the plot that received 100 kg ha^{-1} of NPSBZn blended fertilizer with no farmyard manure application produced the lowest available boron, which was 0.088 mg kg^{-1} at Jabi Tehnan and 0.00125 mg kg^{-1} at Mecha.The available boron increased by 98.89% atJabi Tehnan and 98.83% at Mecha when compared to the conventional recommendations of

150 kg ha^{-1} and 200 kg ha^{-1} DAP, and by 94.32% and 99.61%, respectively, above the available boronanalysis result before planting in Jabi Tehnanand Mecha respectively. The increase in available boron in treated plots compared to blanket recommendation plots could be attributed to increased doses of farmyard manure and NPSBZn blended fertilizer application. Such a considerable increase in available boron was caused by the interrelationship with other elements in farmyard manure and NPSBZn blended fertilizer (improved pH and organic matter content) (Moraghan and Mascagni, 1991).

4.3.3.8. Availablezinc (mg kg^{-1})

Farmyard manure and NPSBZn fertilizer had a significant main effect on the quantity of zinc that was readily available ($P < 0.05$). Farmyard manure and NPSBZn blended fertilizer also exhibited a significant interaction effect on the amount of zinc that was readily available. (Table 4.7).

The highest mean available zinc, 0.2890 and 2.58 mg kg^{-1} were obtained at Jabi Tehnan and Mecha, respectively, by combining 300 kg ha^{-1} of NPSBZn blended fertilizer with 20 t ha^{-1} of farmyard manure. While, the plot that received 100 kg ha^{-1} of NPSBZn blended fertilizer but did not get any farmyard manure treatment produced the lowest available zinc, which was 0.2651 mg kg^{-1} at Jabi Tehnan and 0.2985 mg kg^{-1} at Mecha.

The findings demonstrated that increasing the amounts of farmyard manure from 0 to 20 t ha^{-1} and NPSBZn blended fertilizer from 100 to 300 kg ha^{-1} caused a significant increase in the amount of zinc that was available, increasing it by 10.31% at Jabi Tehnan and 12.98% at Mecha above the general recommendation as well as by 18.09% and 24.75% at Jabi Tehnan and Mecha, respectively, over the available zinc analysis result before planting.

which could be attributed to improvements in soil P^H and the factors responsible for zinc deficiency, such as soil organic carbon (SOC), readily available phosphorus (P), exchangeable cations, and cation exchange capacity (CEC) (Alloway 2009, Bereket Haileselassie,2018). The results of Rutkowska (1999), who investigated zinc concentration levels in solutions of more than 100 agricultural soils are comparable to the zinc concentration values discovered in the current study, which ranged from 0.20 to 0.46 mgL^{-1}.

Table 4.7: Interaction effects of farmyard manure and NPSBZn blended fertilizer on available zinc and available boron

		Available Zn(mg kg^{-1})		Available Boron (mg kg^{-1})	
Treatments		Jabi Tehnan	Mecha	Jabi Tehnan	Mecha
BR kg ha^{-1}		0.26	0.26	0.08	0.06
BF Kg ha^{-1}	FYM t ha^{-1}				
100	0	0.26s	0.278s	0.09s	0.001l
	12	0.267r	0.278r	0.15r	0.01k
	16	0.27o	0.2768o	0.27p	0.14jik
	20	0.27k	0.2k	0.72l	0.25i
150	0	0.268q	0.27 q	0.15r	0.052jlk
	12	0.27p	0.27p	0.19q	0.07jlk
	16	0.27i	0.27i	0.80j	0.n66g
	20	0.27g	0.28g	0.84h	1.03f
200	0	0.26n	0.27n	0.49o	0.16ji
	12	0.269l	0.28l	0.66m	0.23i
	16	0.277f	0.28f	0.92f	1.41e
	20	0.278e	0.29e	0.99e	1.69d
250	0	0.26m	0.28m	0.65n	0.18ji
	12	0.27j	0.28j	0.77 k	0.5h
	16	0.285d	0.29d	1.09d	1.88cc
	20	0.286b	0.29b	1.23b	2.14b
300	0	0.28h	0.28h	0.81i	0.97f
	12	0.27g	0.28g	0.91g	1.03f
	16	0.29c	0.29c	1.1c	1.98c
	20	0.29a	0.3a	1.41a	2.59a
LSD (0.05)		0.0001	0.0001	0.001	0.132
CV (%)		4.3.	3.02	9.45	5.31

Where means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation (150kg ha^{-1} Urea &200kg ha^{-1} DAP); BF: Blended fertilizer (NPSBZn); FYM: Farmyard manure; CV = Coefficient of variation;LSD= Least Significant Difference at 5% level

Table 4.8: Correlation among soil chemical properties affected by organic and inorganic nutrient sources at Jabi Tehnan experimental site

	P^{H}	CEC	OM	AvP	Av S	AV B	AV Zn	TN
PH	1							
CEC	1	1						
OM	0.56**	0.56**	1					
Av P	0.20*	0.20*	0.32**	1				
Av S	0.36*	0.35*	0.60**	0.55**	1			
AV B	0.36*	0.35*	0.60**	0.55**	0.47*	1		
AV Zn	0.36*	0.35*	0.60**	0.55**	0.38*	0.54**	1	
TN	0.42*	0.42*	0.67*	0.50*	0.88**	0.88**	0.88**	1

Table 4.9: Correlation among soil chemical properties affected by organic and inorganic nutrient sources at Mecha experimental site.

	P^H	CEC	OM	AvP	Av S	AV B	AV Zn	TN
P^H	1							
CEC	0.84**	1						
OM	0.61**	0.57**	1					
Av P	0.10*	0.04*	0.32*	1				
Av S	0.34*	0.28*	0.54**	0.55**	1			
AV B	0.34*	0.28*	0.60**	0.55**	0.46*	1		
AV Zn	0.34*	0.28*	0.60**	0.55**	0.59**	0.56**	1	
TN	0.24*	0.20*	0.60**	0.49*	0.59**	0.59**	0.59**	1

CEC= Cation exchange capacity; OM= organic matter; AvP = Available phosphorous; Av S= available sulfur; AV B= Available boron; AV Zn= Available zinc; TN= total nitrogen; *= correlatated; ** = highily correlatated

4.4. Conclusion

Continuous cultivation, inadequate fertilizer treatment, and complete removal of crop residue which is used for cattle feed and fuel rather than being incorporated into the soil are the key contributors to the reduction in soil fertility in Ethiopia.The best option to address Ethiopia's soil nutrient depletion is integrated soil fertility management. The soil in the study area required improvement, so NPSBZn blended fertilizer and farmyard manure were applied to the soil. According to the findings of a single application of farmyard manure, soil characteristics (pH, cation exchange capacity, and organic matter) rose as the amount of applied farmyard manure was increased. Farmyard manure and blended fertilizer applied to the experimental plots had a positive effect on the amount of available phosphorus as well. In the same way, a considerable increase in soil chemical parameters was caused by the synergistic nutrient interaction effect caused by farmyard manure and NPSBZn blended fertilizer (soil total nitrogen, available sulfur, available boron, and available zinc).Therefore, the combined application of organic and inorganic fertilizers increased the soil's chemical properties such as soil organic carbon, available nitrogen, and available phosphorus, while significantly while significantly lowering its pH.

CHAPTER 5. *RESPONSE OF GROWTH PARAMETERS, YIELD, AND YIELD COMPONENTS OF MAIZE (Zea mays L.) TO THE INTEGRATED USE OF NPSBZn BLENDED FERTILIZER AND FARMYARD MANURE IN JABI TEHNAN AND MECHA DISTRICTS, NORTHWESTERN ETHIOPIA

ABSTRACT

A two-year field study was conducted to investigate the effect of integrated use of NPSBZn blended fertilizer and farmyard manure (FYM) on maize growth, yield, and yield components at Koga and Bachima villages in Mecha district, and at Geray and Jiga villages in Jabi Tehnan district. The treatments consisted of factorial combinations of five levels of NPSBZn (100, 150, 200, 250, and 300 kg ha^{-1}) and four levels of FYM (0, 12, 16, and 20 t ha^{-1}) plus one blanket recommendation (200 DAP and 150 kg ha^{-1} Urea). The experiments were laid out in a randomized complete block design with three replications. Except for days to silking and leaf area index at both locations, and days to physiological maturity, ear number per plant, ear length, and diameter at Mecha, main and interaction effects on all parameters were significant at both locations. The only main effect of NPSBZn was detected on the harvest index at Jabi Tehnan. Generally, the results obtained 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. The combined application of 250 kg ha^{-1}NPSBZn with 20 t ha^{-1} FYM resulted in grain yields of 5618.5 and 5421 kg ha^{-1}, at Jabi Tehnan and Mecha, respectively. The same combination shortened days to 50% tasselling by 3.46 days and delayed 90% physiological maturity by 2.95 days compared with the blanket recommended fertilizer at Jabi Tehnan. As the main effect, compared to the blanket recommendation, 250 kg ha^{-1} at Jabi Tehnan and 300 kg ha^{-1}NPSBZn at Mecha reduced the days to 50% silking by 0.23 and 0.29 days, respectively. At Mecha, the application of 300 kg ha^{-1}NPSBZn reduces days to 90% physiological maturity by 0.89 when compared to the blanket recommendation. The increase in FYM rate from 0 to 20 t ha^{-1} caused 0.83 and 0.28 extra days to reach 50% silking at Jabi Tehnan and Mecha, respectively. Grain yield had a highly significant and positive correlation with growth and yield components. Thus, the application of 250 kg ha^{-1}NPSBZn with 20 t ha^{-1} FYM was the most acceptable rate for increasing maize output at both locations

Keywords: Blended fertilizer, combined application,farmyard manure, grain yield,maize

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5.1. 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 (Matou, Todo, & Mojo, 2013). So, it is not unexpected that a major focus of Ethiopian policy is on enhancing the dynamism of the agricultural area.

Ethiopia is the second-most populous country in Africa after Nigeria, with a current population of 102.4 million (Alemayhu Bekel& Yihunie Lakew, 2014). With a fertility rate of 4.2 children born per woman, the country is projected to be among the top eight countries in the world with the greatest population increase between 2017 and 2050, with the total population estimated to rise to 190.9 million (Tassew Woldehan& Mesele Araya, 2019). Because agriculture plays such a large role in the economy and the livelihoods of the rural population, due to the 2015–20166 ElNioo-related drought and repeated poor rainy seasons, an estimated 8.5 million people in Ethiopia are facing food insecurity (Funk*et al.,* 2018). The country needs to increase production as well as the nutritional quality of food grains to feed and meet the nutritional requirements of such a huge population. Since the horizontal expansion of the area under cultivation is not possible, production per unit area has to be increased with the least amount of harm to natural resources, especially the soil. Proper nutrient management is one of the key factors for maintaining soil health and ultimately obtaining high yields (Selim, 2020).

In large parts of sub-Saharan Africa, maize is the principal staple crop. From 2007 to 2017, the area in which maize is grown in sub-Saharan Africa has increased by almost 60% (FAOSTAT, 2019). At present, as a sub-Saharan country, Ethiopia has the fifth largest area devoted to maize but is second only to South Africa in yield and third, after South Africa and Nigeria, in production (Abate Tsedeke *et al.,* 2015).

In Ethiopia, maize grows in almost all regions of the country at altitudes of less than 2000 meters above sea level (Adefris Teklewold *et al.,* 2015). In Ethiopia, maize ranks first in its productivity per hectare and second next to teff in the production area (CSA, 2016). More than 9 million smallholder farmers cultivate maize on around 2 million hectares (14 percent of Ethiopia's total land area), with around 88 percent of its output going toward food consumption (Bachewe *et al.,* 2019). It is cultivated on over 2.5 hectares of land, accounting for 19.46% of the total cereal crop area, and with an annual production of 105,570,935.92 quintals, it contributes to about 30.88% of the cereal production in Ethiopia; it is the highest-yielding cereal crop in the country (CSA, 2016). In the west Gojam highlands, maize constitutes 5.9% and 7.71% of the cultivated land and grain production, respectively, with an average yield of 506.13 kg ha^{-1}. In the 2020 *Meher* planting season, 8837186 and 335474 smallholder farmers reportedly grew maize in the country in general and in the west Gojam zone in particular (CSA, 2019). At the farm level, the national (Ethiopia), regional (Amhara), and local (East Gojam) yields of 4.179 and 4.272, or 2.5 kg ton ha^{-1}, respectively (CSA, 2019), are significantly lower than the global average yield (5.021ton ha^{-1}) (Gustavsson *et al., 2011*), due to several constraints: biotic (inadequate improved varieties, pests, and diseases), abiotic (low soil fertility, land and water degradation, and drought), and socioeconomic (input unavailability).

These high yield gaps are most probably caused by many abiotic factors, including technical efficiency gaps (i.e., inefficiencies in production caused by crop management constraints), economic constraints (i.e., economic constraints to increase input use), technology gaps (i.e., lack of access to advanced technologies), and biotic factors (disease and weed). Among these, maize-based mono-cropping and poor soil fertility are the major problems limiting the productivity of the crops (Abate Tsedeke *et al.,* 2015).

Declining soil fertility is a fundamental impediment to agricultural growth and a major reason for the slow growth in food production in sub-Saharan Africa in general and particularly in Ethiopia. In addition to macronutrients (NPK), the role of micronutrients like brown and zinc for maize productivity was not regarded by producers due to other nutrients being ignored and only using inorganic fertilizers like DAP and urea being common (Tully *et al., 2015*). A balanced fertilization program with macro- and micronutrients in plant nutrition is very important in the production of high yields and high-quality products (Sawan *et al.,* 2001). Macro- and micronutrient deficiencies have been reported for different soils and crops (Ilyas *et al.,* 2015).

Mineral nutrition alone has contributed significantly to increasing crop yields during the 20th century. Dowswell *et al.* (1996), reported that 50% of the increase in crop yields worldwide during the 20th century was due to the application of chemical fertilizers. They also stated that during the 21st century, essential plant nutrients will be the single most important factor limiting crop yields, especially in developing countries. He also reported that the continued application of chemical fertilizer can change the soil pH, upset beneficial microbial ecosystems, increase pests, and even contribute to the release of greenhouse gases (Potla *et al.,* 2013).

Organic fertilizer application enhances crop yield per unit of applied nutrients by providing a better physical, chemical, and microbial environment (Potla *et al.,* 2013). However, the use of organic fertilizer alone may not fully satisfy crop nutrient demand due to low availability, relatively low nutrient content, high application rates, and high labor requirements unless it is integrated with inorganic fertilizers (Sanginga & Woomer, 2009). Improved fertility management through the combination of organic and mineral fertilizers can enable efficient use of the inputs applied and increase overall system productivity (Mucheru-Muna *et al.,* 2014).

The use of organic manure in conjunction with balanced fertilizers has been shown to improve crop growth, nutrient uptake, and yield of maize (Tetarwal *et al.,* 2011; Geng *et al.,* 2019; Sharma *et al.,* 2014). In addition to increasing production, it is equally important to raise food crops of superior nutritional quality to counter the widespread nutritional deficiencies among people. The application of farmyard manure combined with mineral fertilizers improved the chemical, biological, and physical properties of soil and maintained a balanced supply of nutrients (Macholdt *et al.,* 2019), which resulted in better growth and higher crop yield. Other researchers reported a higher yield of maize under integrated nutrient management (NPK+FYM) as compared to chemical fertilizers alone (Sharma *et al.,* 2014; Singh *et al*., 2019; Rajneesh *et al.,* 2018). Therefore, maximizing the usage of organic sources of fertilizer and combining it with chemical fertilizers in integrated form appears to be the best alternative for sustainable crop production while maintaining soil fertility status in maize and other cereal-based cropping systems (Sanginga & Woomer, 2009).

In Ethiopia, commercial fertilizer, mainly in the form of urea and DAP, was introduced in the 1960s by higher education institutions through limited laboratory and research activities (Murphy, 1968). As a result of this work, a blanket rate of 100 kg ha^{-1} Urea plus 100 kg DAP ha^{-1} was recommended, regardless of crop or soil type (Wassie Haile and Tekalign Mamo, 2013), as the country's soils have suffered from nutrient depletion and decreased productivity.

The blanket fertilizer application of 100 kg urea and 100 kg DAP causes a steady decline in nutrient levels in the soil and fails to address the nutrient requirements of specific crops, including maize (Diriba Shiferaw *et al.,* 2013). The country has started using fertilizers that can supply deficient nutrients in the form of blended or compound fertilizers. Among these, NPSBZn blended fertilizer is one of them.

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 an option is the combined application of inorganic fertilizer and farmyard manure. Not only for the above reason but also due to long-term unbalanced fertilization practice, deficiency of other nutrients, mainly potassium (K), sulfur (S), zinc (Zn), and boron (B), has started to become apparent (Getachew Agegnehu *et al.,* 2014; Wassie Haile and Tekalign Mamo, 2013; Abiye Astatkie *et al.,* 2004).

Soil fertility management research outputs using farmyard manure and inorganic fertilizer are currently unavailable and have not been conducted in the selected district (Jabi Tehnan and Mecha District Agriculture Office report), and the soil in the experimental area is deficient in nitrogen, phosphorus, sulfur, zinc, and boron nutrients, as indicated by the Ethio-SIS map (Tadele Amare *et al*., 2018).

Hence, this experiment was conducted in the Jabi Tehnan and Mecha district, which is one of the major maize preproduction belt areas in the country, to investigate the best combination rate of NPSBZn blended fertilizer and farmyard manure that improved growth and yield of maize.

5.2. Materials and Methods

5.2.1. Site description

Jabi Tehnan and Mecha, two promising maize-producing districts, were chosen for this study. In chapter 2, sub-section 2.1, the locations of the study sites are given in detail.

5.2.2.Experimental Design, Treatments, and Procedures

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 $kg{\cdot}ha^{-1}$) and four levels of well decayed, from cattle source, aged three to six months of manure (0, 12, 16, and 20 $t{\cdot}ha^{-1}$) and one blanket recommended 150 $kg{\cdot}ha^{-1}$ urea (69 kg·N) and 200 $kg{\cdot}ha^{-1}$ 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 $kg{\cdot}N{\cdot}ha^{-1}$ of conventional fertilizer, excluding DAP and Urea, was administered to all treatments (Abate Tsedeke *et al.*, 2015). 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 m by 4 m (16 m2) 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 m × 2.4 m (7.68 m2), and the gross area for the experiment was 14 m × 94 m = 1316 m2. 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 culturally practiced methods for hybrid maize cultivation. From all collected farmyard manure, non-decomposable 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.

5.2.3. Land preparation, sowing, and crop management

The land was plowed three times and all recommended agronomic practices of the extension package for the crop were done throughout the cropping seasons, Maize variety called BHQPY-545, was used as the test crop described in Chapter 2, sub-subsections 2.2. and 2.3.

5.2.4. Sampling and analysis of soil and farmyard manure

The detailed soil analysis of the study area is described in chapter 2, Subsection2.4.1.

5.2.5. Data collection and measurement

At maturity, five plants were randomly tagged from each net plot area to record data on growth parameters (plant height and number of green leaves per plant) and yield component parameters (number of ears per plant, ear length, ear diameter, number of kernels per ear, and cob weight). Yield (grain and biomass) was recorded by harvesting the net plot area. Crop data collection and measurement procedures were described in detail in Chapter 2, Subsection 2.4.2.

5.2.6. Data analysis

The Statistical Analysis System (SAS) (version 9.3) was used to perform an analysis of variance (ANOVA) on all crop data collected. A detailed description is indicated in Chapter 2, Section 2.5.

5.3. Results and Discussion

5.3.1. Phenological parameters

5.3.1.1. Days to 50% tasselling

The combined analysis of variance on days to 50% tasselling over years showed that days to 50% tasselling were significantly ($P < 0.001$) affected by the application of NPSBZnblended fertilizer**,** farmyard manure, and their interactions at Jabi Tehnan (Table 5.4). While at Mecha, the impact ofNPSBZn blended fertilizer and farmyard manure on the days to 50% tasselling was significant ($P <0.001$), but their interaction results were not significant ($P >0.05$) (Table 5.4).

At the Jabi Tehnan site, the combined application of 250 kg ha^{-1}NPSBZn and 20 t ha^{-1} farmyard manure shortened days to 50% tasselling by 3.46 days as compared to the blanket recommended fertilizer application (200 kg ha^{-1} DAP and 150 kg ha^{-1} Urea) (Table 5.1). When compared to the blanket recommendation, the application of 100 kg ha^{-1}NPSBZn without the application of farmyard manure increased days to 50% tasselling by 2.92 days, and it was statistically equivalent to the combination of 100 kg ha^{-1}NPSBZn blended fertilizer and 12 t ha^{-1} farmyard manure.The result was similar to Yohannes Melaku *et al*. (2021), who reported that the shortest period for 50%tasseling (61 days) was recorded from the combined application of 150 kg ha^{-1} NPS fertilizer and12 tha^{-1} FYM whereas, the largest number of days to 50% tasselling (80) was registered for the control treatment.Similarly, these findings are consistent with those of Alooya *et al.* (2008) and Tetarwal *et al.* (2011), who found that adding more fertilizer reduced the number of days needed for maize to tassel by 50%. This could also be attributed to their synergistic effect: applying farmyard manure in conjunction with NP fertilizers provides balanced micro- and macronutrients, which would have aided in enhancing metabolic activity in the early growth phase, which in turn encouraged overall growth and extended through the vegetative growth stage, resulting in a prolonged period for tasselling (Biruk Masrie *et al.,* 2015).

Mean comparisons for blended fertilizer, (NPSBZn), treatments at Mecha, on the other hand, revealed the application of 300 kg ha^{-1} blended fertilizer shortened days to 50% tasselling (51.1413) by 1.0587 days than the blanket fertilizer DAP and Urea (52.2 days). Whereas the longest 55.2626 days to50% of tasselling were recorded from 100 kg ha^{-1} of blended fertilizer (NPSBZn) (Table 5.2.).

The early tasselling in response to the increasing amount of NPSBZn blended fertilizer could be attributed to the nutrients N, P, and S B and Zn in NPSBZn blended fertilizer, which leads to vigorous and enhanced vegetative growth and ultimately causes the crop to tassel early instead of prolonging vegetative growth. Similarly, Kinfe Tekulu et al., 2019 reported that the control plot had the highest (77.46) tasselling days compared to plots that received the highest NPSBZn blended fertilizer (300 kg ha^{-1}), which had the shortest (75.38) tasselling days. According to the research findings of Cock & Ellis (1992), sufficient nutrient application results in rapid growth and hastened tasselling, while too little or no nutrient application results in slow growth and delayed tasselling and silking. These results are in line with those of Ayoola & Makinde (2008) and Uwah *et al.* (2014), who observed a reduction in the number of days to 50% tasselling and silking in maize with increased rates of fertilizers.

Concerning the effect of farmyard manure, the shortest period for 50%tasseling (52.27 days) was recorded from the application of 20 t ha^{-1} but it was significantly on par with the 16 tha^{-1} (Table 5.2.). Whereas the longest 52.9 days to50% of tasselling were recorded from untreated plot. Similar observations were reported by Amin (2011), who reported that cow dung application gave plants that achieved 50% tasselling significantly earlier than the control. According to this researcher,the control plots achieved 50% tasselling in about 60 days, while the treated plots achieved 50% tasselling in fewer days, and with the application of 15 t ha^{-1} of cow dung, 50% tasselling was achieved in about 57 days.

Table 5.1: Interaction effects of NPSBZn blended fertilizer and farmyard manure on days to 50% Tasselling and Days to Physiological Maturity, combined over years 2016/17 and 2017/18 in Jabi Tehnan district of Ethiopia.

Treatment		D*50%* T	DPM
BR kg ha^{-1}.		53.2	142
BF kg ha^{-1}.	FYM t ha^{-1}		
100	0	56.1a	131.7l
	12	55.9a	135.3k
	16	55.5b	135.5jk
	20	55.3b	136.5i-k
150	0	54.8c	136.5i-k
	12	54.6cd	136.9h-k
	16	54.4de	137.8g-i
	20	54.2ef	137.7g-i
200	0	54.0fg	138.3gh
	12	53.8g	139.1fg
	16	53.5h	142.2cd
	20	52.8i	142.8bc
250	0	52.6i	137.1h-j
	12	52.3 j	140.7d-f
	16	51.3l	142.9bc
	20	49.7o	144.9a
300	0	52.1jk	140.2ef
	12	51.9k	140.9de
	16	50.9m	143.9a-c
	20	50.4n	144.3ab
LSD		0.30	1.7
CV%		7.32	5.4

Wheremeans within a column followed by the same letter(s) are not significantly different; D50%T = the number of days to 50% tasselling; DPM: Days to physiological maturity; BR: Blanket recommendation (200 kg ha^{-1}. DAP and 150 kg ha^{-1}. Urea); BF: NPSBZn blended fertilizer; FYM: Farmyard manure; CV: Coefficient of variation; LSD: Least Significant Difference.

5.3.1.2. Days to 50% silking

The combined analysis of variance over years for the days to 75% Silkingshowed that at both experimental locations, there was a significant ($P<0.001$) differenceon days to 50% silking of maize due to the main effects of NPSBZn blended fertilizer and farmyard manure. However, there was no significant ($P>0.05$) effect from the interaction of NPSBZn blended fertilizer and farmyard manure application (Table 5.4).

The shortest days to 50% silking (60.5 and 60.7) were obtained from plots treated with 250 and 300 kg ha^{-1}NPSBZn blended fertilizer at Jabi Tehnan and Mecha, respectively, and were delayed by (0.2 and 0.3) days compared to the blanket recommendation. However, it was also on par with 300 kg ha^{-1}NPSBZn at Jabi Tehnan and 250 kg ha^{-1}NPSBZn at Mecha. The maximum days to 50% silking 63.4 and 64.3 were recorded from the minimum rate of blended fertilizer (100 kg ha^{-1}NPSBZn) at Jabi Tehnan and Mecha, respectively (Table 5.2).

It was known that blended fertilizers (NPSBZn) with different rates of N, P, S Zn, and B might have encouraged early establishment, rapid growth, and development of crops. It, therefore, is shortening the days to silking. Similarly, Asrat Hailu *et al.*(2016), also found that days to silking were significantly affected by the application of blended fertilizers(NPSBZn). In line with this, Kinfe Tekulu *et al.*(2019), found that 50% of silking was significantly affected by the application of blended fertilizer rates (NPSBZn). Ayoola & Makinde(2008) and Uwah *et al.* (2014),also observed a reduction in the number of days to 50% silking in maize with increased rates of fertilizers. In contrast to the results of this experiment, the outcomes of other researchers verified that the silking of the maize crop was not significantly affected by NPSBZn blended fertilizer with different rates of N, P, S Zn, and B doses (Kinfe Tekulu *et al.*, 2019).

The increase in the rate of farmyard application from 0 to 20 t ha^{-1} caused a reduction in days to 50% silking (60.8 and 61.2) which Cause for 0.8and 0.3 extra days to reach 50 % days of silking at Jabi Tehnan and Mecha, respectively but statistically similar with 16 t ha^{-1} at both locations. Whereas maximum numbers of days to 50% silking (62.7) at Jabi Tehnan and (62.9) at Mecha were obtained from no farmyard manure application which is statistically at par with the rate of 12 t ha^{-1} of farmyard manure at both locations (Table 5.2.).

Increasing levels of cattle manure make the soil nutrients balanced, creates 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 optimum potential resulting in shortening the days to silking**.** These improvements in days to 50% silking with an increase in rates of cattle manure applied agreed with the findings of Sisay Gurmu and Adugnaw Mintesnot (2017), 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.

Table 5.2: Main effects of NPSBZn blended fertilizer and farmyard manure on days to 50% Silking, days to 50% tasselling, and days to physiological maturity, combined over years 2016/17 and 2017/18 in Jabi Tehnan and Mecha districts of Ethiopia.

Treatments	Experimental Locations			
	JabiTehnan	Mecha		
	D*50%* S	D*50%* T	D*50%* S	DPM
BR	60.3	52.2	61	142
BF kg ha^{-1}				
100	63.4a	55.3 a	64.3 a	137.3b
150	62.1b	52.5b	62.5105b	137.7b
200	62.0b	53.1b	61.9 b	138.4b
250	60.5c	51.2c	60.81 c	140.6a
300	60.5c	51.1c	60.71 c	141.1a
LSD	1.1	1.2	0.9	1.5
FYM (t ha^{-1})				
0	62.7a	52.9a	62.9a	137.9b
12	61.8ab	52.6b	62.4ab	138.9ab
16	61.5bc	52.3c	61.7bc	139.7a
20	60.8c	52.27c	61.2 c	139.5ab
LSD	0.95	1.1	0.8	1.3
CV %	6.96	4.1	8.64	6.5

Where means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation (200 kg ha^{-1}DAP and 150 kg ha^{-1}Urea); BF: NPSBZn blended fertilizer; FYM: Farmyard manure; CV: Coefficient of variation; LSD: Least Significant Difference; DS: Days to 50% silking; DT: Days to50% tasselling; DPM: Days to; Physiological maturity.

5.3.1.3. Days to 90% physiological maturity

The pooled analysis of variance over years revealed that days to 90% maturity of maize were significantly ($P<0.001$) influenced by the application of NPSBZn blended fertilizer,farmyard manure, and their interactions at Jabi Tehnan, while at Mecha, the impact of NPSBZn blended fertilizer and farmyard manure on days to 90% maturity was significant ($P<0.001$), However, their interaction results werenot significant ($P>0.05$) (Table 5.4).

At Jabi Tehnan, maize on the plot that received 250 kg ha^{-1}NPSBZn blended fertilizer and 20 t ha^{-1} took the maximum number of days to 90% physiological maturity (145.0 days). Hence, 2.95 extra days were required to reach the maturity of maize as compared to the conventional fertilizer applications of DAP and urea. It was, however, statistically comparable tothe application of 300 kg ha^{-1}NPSBZn blended fertilizer integrated with 20 and 16 t ha^{-1} farmyard manure.Conversely, the shortest day to reach 90% physiological maturity (131.7) was recorded from the applicationof 100 kg ha^{-1} NPSBZn (Table 5.1.).

The maximum days to reach 90% physiological maturity due to increasing NPSBZn blended fertilizer and farmyard manure might be attributed to the increased rate of nitrogen from both sources (blended inorganic fertilizer and farmyard manure), especially the gradual release of nutrients from farmyard manure, which delays physiological maturity by promoting or encouraging vigorous vegetative growth and development of the plants. Other probable reasons could be associated with the supply of additional nutrients, positive interactions of nutrients in both fertilizer and manure, and additional benefits from farmyard manure (increases soil moisture-holding capacity and decreases leaching of nutrients, in addition to releasing nutrients like nitrogen and phosphorus), which may promote the vegetative growth of the plants and, in turn, prolong the maturity of maize plants (Bargaz, *et al.,*2018).Similarly, the result was in line with Yohannes Melaku *et al*. (2021), who reported that the combined application of 150 kg ha^{-1}NPS fertilizer and 12 tha^{-1}FYMtook minimum days to physiological maturity (107days) whereas the maximum (129 days) was recorded for the control treatment.

At Mecha, the maximum number of days to 90% physiological maturity was 141.1, at the rate of 300 kg ha^{-1}NPSBZn 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}NPSBZn 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 withthe application of150 and 200 kg ha^{-1}NPSBZn (Table 5.2).

It could be due to the increased rate of nutrients, especially nitrogen stimulation, which encouraged vegetative growth, prolonged the growing period, and delayed crop maturity. It could also be due to the nutritional integrity. Phosphorus, sulfur, and boron increase the uptake of nitrogen since they are used for chlorophyll synthesis and initial root development (Rahman & Giessen, 2017). Positive relations between B, K, and N fertilizers for improving crop yields and maturity (Fageria, 2002).

This result is in line with the report by Asrat Hailu*et al.* (2016) and Kinfe Tekul *et al.* (2019), who reported that maturity is significantly affected by the application of NPSBZnblended fertilizer rates and early maturity days were recorded with the application of NPSBZn blended fertilizer whereas the longest days to maturity were recorded for the control.

The application of 20 t ha^{-1} of farmyard manure resulted in the maximum number of days to reach the maturity of 139.7, which was delayed by 1.8 days compared to plots that did not receive farmyard manure (137.9) (Table 5.2). However, it was significantly on par with all rates of farmyard manure except for nil application. However, no farmyard manure application caused the shortest days to reach physiological maturity.

The increase in days to maturity of maize in response to an increase in FYM could be because it increases soil moisture-holding capacity and decreases leaching of nutrients, in addition to releasing nutrients like nitrogen and phosphorusthatencourage vegetative growth,prolonging the growing period and hence the maturity date. The result of this study agrees with the finding of Alem Redda and Fetien Abay (2015), who reported that a greater number of days (122.5) to physiological maturity were, recorded when a higher dose (9 t ha^{-1}) of FYM was used.

5.3.2. Growth parameters

5.3.2.1. Plant height

Based on the combined analysis of variance of two years' data, NPSBZn blended fertilizer, farmyard manure, and their interaction, significant differences ($p < 0.05$) in plant height of the maize crop at both experimental locations (Table 5.4).

The tallest plant heights (218.91 cm) at Jabi Tehnan and 217.797 cm at Mecha were recorded from the combined application of 250 kg ha^{-1}NPSBZnblended fertilizer and 20 t ha^{-1} farmyard manure; which showed an increment in length of 1.3 cm at Jabi Tehnan and 1.8 cm at Mecha compared to the conventional DAP and urea fertilizers. However, at Mecha, the treatment combination level that resulted in the greatest plant height was significantly comparable to 250 and 300 kg ha^{-1}NPSBZnblended fertilizer combined with 16 t ha^{-1} farmyards, as well as 300 kg ha^{-1}NPSBZnblended fertilizer combined with 20 t ha^{-1} farmyard manure application. Whereas the shortest plant heights of 169.1 cm at Jabi Tehnan and 168.8cm at Mecha were obtained with 100 kg ha^{-1}NPSBZnblended fertilizer and no farmyard manure application (Table 5.3).

The significant increase in plant height observed by plants treated with the highest NPSBZnblended fertilizer and cattle manure could be due to the significant role of nutrients individually and also their synergy with the fact that nitrogen is one of the major yield-limiting nutrients and the adequate supply of it promotes the formation of chlorophyll, which in turn results in higher photosynthetic activity, vigorous vegetative growth, and taller plants

(Potarzycki, 2009). Phosphorus is required in large quantities in shoot and root tips where metabolism is high and cell division is rapid (Uchida,2000). Similarly, sulfur promotes the formation of chlorophyll, higher photosynthetic activity, vigorous vegetative growth, and taller plantsBewket Getachew (2019). The presence of boron in the NPSBZn blended fertilizer also significantly increased plant height due to its important role in cell division and nitrogen absorption from the soil, enhancing plant growth and ultimately increasing plant height. Zinc enhances nitrogen uptake and metabolism, photosynthesis, and chlorophyll synthesis (Potarzycki, 2009).

5.3.2.2. Number of green leaves per plant

Based on the results of a combined analysis of variance over years, the number of green leaves per plant of maize was significantly ($P < 0.01$) affected by the different rates of applied NPSBZn blended fertilizer and farmyard manure ($p < 0.01$) and by their interaction (Table 5.4.).

At both locations, the same level of treatment combination of 250 kg ha^{-1}NPSBZn blended fertilizer and 20 t ha-1 farmyard manure gave a higher number of green leaves (12.1 and 11. 8 plants at Jabi Tehnan and Mecha, respectively). Hence a 10. 3% and 17.6 % increments in green leaf number per plant were observed in the Urea and DAP-treated plots. However, at Mecha, this treatment combination resulted in a statistically similar result with plots with 300 kg ha^{-1}NPSBZn blended fertilizer combined with 20 t ha^{-1} farmyard manure. While 100 kg ha^{-1}NPSBZn blended fertilizer with no farmyard manure application gave the lowest number of green leaves per plant 8.9 and 9.0 at Jabi Tehnan and Mecha, respectively. However, it had no statistical difference between the combined application of 100 kg ha^{-1}NPSBZn blended fertilizer and 12 t ha^{-1} farmyard manure at Jabi Tehnan (Table 3.5).

The synergistic effects of fertilizers, the availability of nutrients, the improvement in the physicochemical properties of the soil, and increased microbial activity may all be responsible for the increase in the number of green leaves per plant that results from an increase in combined fertilizer. It's possible that the release of nitrogen and phosphorus from the farmyard and inorganic fertilizers increased cell growth and multiplication (Bargaz, 2018).The application of farmyard manure to the soil at varying levels may have improved soil fertility (Ahmad *et al.,* 2013), improved soil structure, increased soil organic matter, and enhanced microbial activity (Das *et al.*, 2017), and the nutrients released from manure thus supported and enhanced rapid root development (Abou *et al.,* 2005), which might have enhanced leaf number. Organic fertilizers such as farmyard manure influence plant growth and production by improving the chemical, physical, and biological properties of soils (Wubshet Mekonnen*et al.,* 2017; Samuel*et al.,* 2018and Singh*et al.,*2020).

Generally, significantly increased and optimum growth, yield, and yield components were obtained in response to the application of 193 kg ha^{-1}NPSBZn, which was statistically in parity with the standard fertilizer practice of applying 100 kg ha^{-1} DAP (Ewnetu Teshale and Afework Legesse, 2020). Several authors (Dewal & Pareek, 2004; Mekonnen Kebebew, 2020), reported that macro and micronutrients (nitrogen, phosphorous with sulfur, and born) fertilizer applications can increase plant height, spike length, number of tillers, and number of kernels with increasing doses and combinations.

Table 5.3: Interaction effects of NPSBZn blended fertilizer and farmyard manure on Plant Height and Number of green leaves Per plant, combined over years 2016/17 and 2017/18 in Jabi Tehnan and Mecha districts of Ethiopia.

Treatments		Experimental Locations			
		Jabi Tehnan		Mecha	
		PH(cm)	NGLPP	PH(cm)	NGLPP
BR kg ha^{-1}		217.6	11	216	10
BF kg ha^{-1}	FYM t ha^{-1}				
100	0	169.1p	8.9l	168.8l	9.0l
	12	181.0o	9.0l	180.7k	9.5k
	16	181.6o	9.5k	181.3kj	9.7j
	20	188.8n	9.9j	185.3ij	10.0i
150	0	188.9m	9.9ij	188.6ih	10.3hi
	12	190.2l	10.1h-j	193.5g	10.3h
	16	192.7k	10.3g-i	192.4gh	10.4gh
	20	195.9j	10.4f-h	195.7gf	10.6fg
200	0	199.0i	10.5fg	198.8f	10.7f
	12	209.6g	10.7ef	209.3dc	10.7f
	16	212.5de	11.1cd	211.7b-d	11.2cd
	20	213.3d	11.2c	212.3b-d	11.2cd
250	0	200.5h	10.5fg	203.3e	10.71f
	12	211.9e	10.9de	211.5b-d	10.8ef
	16	214.2c	11.3c	213.6a-c	11.3cd
	20	218.9a	12.1a	217.7a	11.8a
300	0	211.0f	10.7ef	208.9d	10.8f
	12	212.0e	11.1cd	211.9b-d	11.0de
	16	216.4b	11.6b	213.9ba	11.3bc
	20	217.0b	11.7b	216.7a	11.6ab
CV		8.5	10.7	12.1	12.8
LSD		0.8	0.3	4.3	0.3

Where means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation (200 kg ha^{-1}DAP and 150 kg ha^{-1}Urea); BF: NPSBZn blended fertilizer; FYM: Farmyard manure; CV: Coefficient of variation; LSD: Least Significant Difference; PH: Plant height; NGLPP; Number of green leaves per plant.

Table 5.4: Mean square values of the effects of Year, Block, NPSBZn blended fertilizer, farmyard manure, and their interactions on the Phenology and Growth variables were measured at the Jabi Tehnan and Mecha districts of Ethiopia.

Two years combined result								
Sources of variation	DF	DT	DS	PH	AGBM	DPM	NGLPP	LAI
Jabi Tehnan								
Y	1	0.013NS	4.7NS	0.0NS	19.1NS	7.6NS	0.0NS	0.014NS
BL	2	0.2NS	16.4*	4.0NS**	2824277.7**	7.8*	0.1NS	0.8NS
BF	4	87.1**	35.8**	5340.3**	74515425.8**	242.2**	15.8**	3.9**
FYM	3	12.8**	18.8**	860.4**	20905000.5**	120.9**	5.7**	1.4*
FYM X BL	12	1.2**	2.1NS	46.1**	679417.1**	7.8**	0.3**	0.4
Error		0.1	3.2	0.5	195533.6	2.1	0.1	0.4
Total	97	97	97	97	97	97	97	97
Mecha								
Y	1	0.03NS	2.69NS	0.5637NS	16.90NS	8.07NS	0.01NS	0.66NS
BL	2	73.8NS	3.80NS	4.1849NS	242405.70NS	185.3**	1.43**	0.01*
BF	4	21.7**	52.6**	5081.9585**	62287000.1**	72.47**	11.11**	1.94**
FYM	3	2.26**	17.1**	820.82173**	18242164**	19.38*	3.30**	1.5**
BF XFYM	12	3.5NS	1.23NS	44.8347**	986592.40**	4.19NS	0.14**	0.1**
Error		3.37	2.50	12.77	122797.70	6.73	0.02	0.2
Total		97	97	97	97	97	97	97

Where * significantly different at 5; NS, non-significant, Y: Year; BL: Block; BF: NPSBZn blended fertilizer; FYM: Farmyard manure; DF: Degree of freedom; DT: Days to 50%Tasselling, DS: Days to 50% silking; PH: Plant height; AGBM: above-ground biomass; DPM: days to physiological maturity; NGLPP: Number of green leaves per plant; LAI: leaf area index; HI: Harvest index.

5.3.2.3. Leaf area index

The combined analysis of variance over years showed that the effect ofNPSBZnfertilizer and farmyard manure on the leaf area index was significant ($P < 0.01$) (Table 5.4.),However, their interaction resultswere not significant at both locations.

The leaf area index (LAI) is a crucial growth index determining the capacity of a plant to trap solar energy for photosynthesis and has a marked effect on the growth and yield of the plant(Lawlor,1995) Application of 300 kg ha^{-1}NPSBZn fertilizer resulted in the highest leaf area index (3.9) and (3.4 at Jabi Tehnan and Mecha, respectively, which showed a relative reduction of leaf area index by 8.2percent at Jabi Tehnan and 17.1 percent at Mecha than the conventional DAP and Urea. However, the least amount of NPSBZnblended fertilizer (100 kg ha^{-1}) resulted in the lowest leaf area index (2.9) at Jabi Tehnan and (2.6) at Mecha. At both locations, the NPSBZnblended fertilizer rate resulted in the lowest leaf area index and was statistically similar to the application of 150 and 200 kg ha^{-1} NPSBZn (Table 5.5).

The reason for the increased leaf area index with an increased NPSBZn blended fertilizer rate could be attributed to the vigorous growth and leaf expansion in length and width in response to the significant role of individual nutrients and their synergy as well. More above-ground biomass from the expanded leaves is produced in response to nitrogen (Ziska,1996). Phosphorus also promotes rapid canopy development, contributing to root cell division. Phosphorus, boron, sulfur, and zinc; increase nitrogen uptake that is used for chlorophyll synthesis, activate enzymes, increase resistance to abiotic and biotic stresses, and protect against oxidative damage(Dash,2015).

The application of 20 t ha^{-1} farmyard manure gave a higher leaf area index(3.5 and 3.1,at Jabi Tehnan and Mecha, respectively) compared to the blanket application of conventionally recommended DAP and urea fertilizers. However, the farmyard manure rate that resulted in the maximum leaf area index was statistically comparable to 16 t ha^{-1} at both experimental locations and also to 12 t ha^{-1} at JabiTehnan.

Increased leaf area index with increasing farmyard manure could be attributed to increased leaf area during vegetative development, as well as aiding in the maintenance of functional leaf area during the growth period in response to N availability.This result is consistent with Eleduma *et al.* (2020), observations 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. In addition, it might have boosted the material's bulk density, porosity, and moisture-holding capacity, which would have encouraged root development and improved the plant's ability to absorb nutrients (Preisser *et al.,* 2014).

Table 5.5: Main effects of NPSBZn blended fertilizer and farmyard manure on leaf area index and harvest index, combined over years 2016/17 and 2017/18 in Jabi Tehnan and Mecha districts of Ethiopia.

	Experimental location		
	Jabi Tehnan		Mecha
Treatments	LAI	HI%	LAI
BR	3.9	50.5	3.8
BF kg ha^{-1}			
100	2.9c	44.9c	2.6c
150	3.0bc	49.5b	2.8bc
200	3.1bc	53.1a	2.8bc
250	3.3b	52.8a	3.0b
300	3.9a	52.6a	3.4a
LSD	0.37	2.17	0.2
FYM (t ha^{-1})			
0	3.0b	50.0	2.6b
12	3.2ab	50.4	2.8b
16	3.3ab	51.6	3.1a
20	3.5a	50.3	3.2a
CV %	19.79081	7.483956	13.71
LSD	0.3	NS	0.2

Means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation (200 kg ha^{-1}DAP and 150 kg ha^{-1}Urea); BF: Blende fertilizer (NPSBZn); FYM: Farmyard manure; CV: Coefficient of variation; LSD: Least Significant Difference; LAI: Leaf area index; HI: Harvest index.

5.3.3. Yield-related parameters

5.3.3.1. Number of ears per plant

A combined analysis of variance on the number of ears per plant over years showed that, at Jabi Tehnan, the mean number of ears per plant was significantly ($P < 0.001$) affected by the applications of NPSBZn blended fertilizer, farmyard manure, and their interaction (Table 3.8). On the other hand, at Mecha, NPSBZnblended fertilizer and farmyard manure application significantly ($P < 0.001$) affected the number of ears per plant. However, their interaction did not influence the number of ears per plant (Table 5.11).

At Jabi Tehnan, the highest number of ears per plant (1.7), which was higher in number by 3.45 % as compared to the conventional fertilizers DAP and urea was observed from the combined application of 250 kg ha^{-1}NPSBZn blended fertilizer with 20 t ha^{-1} farmyard manure. While the application of 100 kg ha^{-1}NPSBZn blended fertilizer with all rates of combined farmyard manure application resulted in fewer ears per plant (1.4) (Table 5.6).

This might be a reduction in relative competition between plants for nutrients in response to the synergetic effect of fertilizer (blended and farmyard manure) as a fertilizer or nutrients within the fertilizer. Sulfur facilitates N and P absorption, cell division, chlorophyll synthesis, and photosynthesis (Rahman & Rao, 2001), which can increase the number of ears per plant in maize. These findings are consistent with those of Zada *et al.* (2000), who discovered that the number of cobs increased as the level of organic and inorganic fertilizers increased.

At Mecha, the maximum number of ears per plant was 1.6, which was lower in number by 1.03 % compared with the conventional fertilizers DAP and urea recorded by the application of 300 kg ha^{-1} blended NPSBZn fertilizer. Statistically, the lowest number of ears per plant (1.0) was obtained from the application of 100 NPSBZn kg ha^{-1} but which was statistically similar to the application of 150 kg ha^{-1}NPSBZn (Table 5.7).

The current finding is in line with that of Dagne Chimdessa (2016) and Asrat Hailu *et al.* (2016), who reported that NPSBZn blended fertilizer containing N, B, and Zn significantly, influenced the number of ears per plant. The application of blended fertilizer increased the number of cobs by 68 to 75% over the control (without fertilizer). Mozafar (1989), also reported that the application of B fertilizer to maize production encourages good maize development.

The maximum number of ears per plant (1.4) was attained from the plot treated with 20 t ha^{-1} farmyard manure but statistically similar to the application of 16 t ha^{-1} farmyard manure. (Table 5.7).

The availability of both micro- and macronutrients, which encourage the formation of chlorophyll, higher photosynthetic activity, vigorous vegetative growth, and enhanced growth of the plant, which results in a taller plant with a greater number of ears, was primarily responsible for the increased in the number of ears per plant caused by the increase in farmyard manure. Getachew, Bewket (2019). These findings were in agreement with the studies of Devi*et al.* (2002), Ogar and Asiegbu (2005), and Aujla *et al*. (2007), who reported the yield attributes obtained from the application of higher rates of cattle manure. Achieng *et al*. (2010), also reported that farmyard manure is very effective in the production of corn cobs.

5.3.3.2. Ear length

Based on data from a multi-year combined data analysis of variance, at Jabi Tehnan, ear length was significantly ($P < 0.001$) affected due to the applications of NPSBZn blended fertilizer, farmyard manure, and their interaction effect. At Mecha, the main factors blended (NPSBZn) fertilizer and farmyard manure application ($P < 0.001$) affected ear length; however, their interaction did not affect ear length (Table 5.11).

Cob length is a very important yield-contributive parameter of maize. It considerably contributes to the grain yield of maize by influencing the number of grains and grain size. A combined application of 250 kg ha^{-1}NPSBZn blended fertilizer and 20 t ha^{-1} farmyard manure resulted in the longest ear length (17.5 cm) at Jabi Tehnan, which is exceeded by 5.6% over the conventional Urea and DAP application. Whereas 100 kg ha^{-1} with no farmyard manure application recorded the shortest ear length (9.1 cm) (Table 5.6).

The probable reason for the increment of ear length due to the increasing combined application of NPSBZn blended fertilizer with farmyard manure may be that their integration creates the availability of both macro- and micronutrients, which promote the growth and development of plant parts (Sarwar *et al.,* 2010). The results are also consistent with those of GeremewBiramo (2017), who stated that the use of NPSBZn blended fertilizer in conjunction with farmyard manure may have supplied 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, anNPSBZn blended fertilizer rate of 300 kg ha^{-1} gave the longest ear length (16.2 cm) compared to the conventional fertilizers DAP and urea. Which was statistically comparable to 200 and 250 kg ha^{-1} blended fertilizers (NPSBZn). However, there was no significant statistical variation with 150 kg^{-1}. The application of 100 kg ha^{-1}NPSBZn blended fertilizer gave the shortest ear length (13.4 cm) (Table 5.7).

These results agree with the finding of Bakala Anbessa, Girma Abera, and Soya Kasa. (2021), who reported that the application of NPSBZn blended fertilizer rates had highly significant ($P < 0.01$) effects on the ear length of maize. According to his result, the largest ear length (16.10 cm) was obtained under the application of 200 kg NPSBZn, while the shortest ear length of maize (11.57 cm) was recorded under control. These results agree with the finding of Mozafar (1989), who reported that the application of B fertilizer to maize production encourages good corn development.

The application of 20 t ha^{-1} farmyard manure resulted in the longest ear length (15.7 cm), which is lower in length by 4.35 percent as compared with conventional fertilizers DAP and urea. However, there was no statistical difference in the rest rate of farmyard manure except for the plot treated with no farmyard manure, which gave the shortest ear length of 13.9 cm (Table 5.7).

Increased ear length with an increase in the cattle manure application rates might be attributed to the stimulating effect of the manure, which supplies the plant with nutrients required for a better length of the ear in response to a favorable soil environment (Yohannes Melaku,2021). These results were in agreement with those of Eleduma *et al.* (2020), who found that maize plants amended with the maximum farmyard manure rate (20 t ha^{-1}) had superior ear length (17.4 cm) than the control (15.1 cm), which decreased with each decrease in the level of cattle manure applied.

Table 5.6: Interaction effects of NPSBZn blended fertilizer and farmyard manure on the Number of ears per plant, ear length, and ear diameter, combined over years 2016/17 and 2017/18 in Jabi Tehnan districts of Ethiopia.

Treatments		EL(cm)	ED(cm)	NEPP
BR kg ha^{-1}		16.54	4.46	1.66
BF kg ha^{-1}	FYM t ha^{-1}			
100	0	9.1n	2.61n	1.4f
	12	10.1m	2.8mn	1.4f
	16	10.4m	3.0lm	1.4f
	20	10.7m	3.1k-m	1.4f
150	0	11.0kl	3.2j-l	1.4f
	12	11.3jk	3.3i-l	1.4f
	16	11.4jk	3.31h-l	1.4f
	20	11.7j	3.4h-k	1.4ef
200	0	11.8j	3.5g-j	1.4f
	12	12.8hi	3.6f-h	1.4ef
	16	14.2de	4.3cd	1.5de
	20	14.5d	4.4bc	1.5de
250	0	12.4i	3.5g-i	1.4f
	12	13.5fg	3.9d-f	1.5de
	16	15.1c	4.5a-c	1.5d
	20	17.5a	4.8a	1.7a
300	0	13.1gh	3.8e-g	1.4f
	12	13.7ef	4.0de	1.55067c
	16	15.3c	4.6a-c	1.6c
	20	16.1b	4.7ab	1.7b
CV		3.6	7.9	2.6
LSD		0.5	0.3	0.044

Where means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation (150 kg ha^{-1}urea &200 kg ha^{-1}DAP); BF: Blended fertilizer (NPSBZn); FYM: Farmyard manure; CV: Coefficient of variation; LSD: Least Significant Difference; EL: Ear length; ED: Ear diameter; NEPP: Number of ears per plant.

5.3.3.3. Ear diameter

The combined analysis of variance over years for the ear diameter showed that the ear diameter was significantly ($P < 0.001$) affected by the application of blended fertilizer (NPSBZn), farmyard manure, and their interactions at Jabi Tehnan (Table 5.11). While at Mecha, the impact of blended fertilizer (NPSBZn) and farmyard manure on the ear diameter was significant ($P <0.001$), but their interaction results were not significant ($P >0.05$).

The combined application of 250 kg ha^{-1}NPSBZn blended fertilizer and 20 t ha^{-1} farmyard manure resulted in the thickest ear diameter (4.7767 cm) atJabi Tehnan which exceeded the conventional Urea and DAP application by 6.63%. But it was statistically similar to the combined application of 300 and 250 kg ha^{-1}NPSBZn blended fertilizer and 16 t ha^{-1} farmyard manure and also 300 kg ha^{-1}NPSBZn blended fertilizer and 20 t ha^{-1} farmyard manure. While the integration of 100 kg ha^{-1} with no farmyard manure application resulted in the thinnest ear diameter of 2.6 cm, it was statistically on par with the 100 kg ha^{-1}NPSBZn blended fertilizer and 12 t ha^{-1} farmyard manure combination (Table 5.6).

The increment of ear diameter at higher rates of NPS fertilizer and FYM might be due to the higher availability of nutrients resulting in a maximum number of grain rows and ovules filled enough with starch after fertilization and the continuous filling of kernels with sufficient photosynthesis (Yohannes Melaku,2021).These findings were in agreement with Verma *et al.* (2006), who reported that ear diameter increased on account of chemical fertilizer and organic manure application.

At Mecha, the thickest ear diameter (4.2 cm), which was reduced in thickness by 5.5 percent compared with the conventional fertilizers DAP and urea, was recorded from NPSBZn blended fertilizer supplemented with 300 kg ha^{-1}. However, there were no significant differences in the plots treated with NPSBZn blended fertilizer at 250 kg ha^{-1}. With no significant statistical difference with 150 kg ha^{-1} of NPSBZn blended fertilizer, the thinnest 3.7 cm values of ear diameter were obtained with the application of 100 kg ha^{-1}NPSBZn(Table 5.7). This might be nutrient availability in response to the positive synergy effect of nutrients(Rashid *et al.*, 2022). Since they are used for chlorophyll synthesis, activate enzymes, increase resistance to abiotic and biotic stresses, and protect against oxidative damage (Potarzycki & Grzebisz, 2009).

The comparison of treatment means revealed that the thickest ear diameter was 4.1 cm, which was 6.9% thinner than the conventional fertilizer DAP and Urea was obtained from the plot treated with 20 t ha^{-1} farmyard manure (Table 5.7). This was statistically equivalent to 16 t ha^{-1}. In the meantime, with no significant statistical difference with 12 t ha^{-1} of farmyard manure, no farmyard manure application resulted in the thinnest ear diameter (3.7 cm). The increase in ear diameter observed from plots treated with a high level of farmyard manure might be a result of improvements in the physical status of soil plants receiving sufficient amounts of nutrients throughout their growth period and being nourished properly, which resulted in maximum ear diameter. This result is unlike the work ofEleduma *et al.* (2020), who found that ears diameter was significantly affected by theapplication of farmyard manure rates.

Table 5.7: Main effects of NPSBZn blended fertilizer and farmyard manure on the number of ears per plant, ear length, and ear diameter, combined over years 2016/17 and 2017/18 in Mecha districts of Ethiopia.

Treatments	NEPP	EL (cm)	ED (cm)
BRkg ha^{-1}	1.6	16.42	4.42
BF kg ha^{-1}			
100	1.0d	13.4 b	3.7c
150	1.2cd	13.8b	3.9bc
200	1.3bc	15.2a	3.9b
250	1.4b	16.1a	3.9ab
300	1.6a	16.2a	4.2a
LSD	0.2	0.9	0.2
FYM (t ha^{-1})			
0	1.1c	13.9 b	3.8b
12	1.2bc	14.9 a	3.8b
16	1.34525ab	15.2a	4.1a
20	1.40659a	15.71a	4.1a
CV %	22.6	11.5	9.2
LSD	0.14	0.8836	0.2

Means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation (150 kg ha^{-1}Urea &200 kg ha^{-1} DAP); BF: NPSBZn blended fertilizer; FYM: Farmyard manure; CV: Coefficient of variation; LSD: Least Significant Difference; NEPP: Number of ears per plant; EL: Ear length; ED: Ear diameter

5.3.3.4. Number of kernels per ear

The two factors influenced the number of kernels per ear exclusively and interacted significantly ($P < 0.001$) in both research sites, according to the combined analysis of variance results (Table 5.11).

Crops on a plot treated with 250 kg ha^{-1}NPSBZn blended fertilizer and 20 t ha^{-1} farmyard manure produced the highest number of kernels per ear (555.9 and 525.625 at Jabi Tehnan and Mecha, respectively), exceeding DAP and Urea treated crops by 0.5 and 0.5%.This treatment was also statistically similar to the application of 300 kg ha^{-1}NPSBZn blended fertilizer combined with 16 or 20 t ha^{-1} farmyard manure at both experimental locations (Table 5.8). However, applying 100 kg ha^{-1}NPSBZn blended fertilizer with no farmyard manure resulted in the lowest (330.9) at Jabi Tehnan and Mecha (290.6). However, at Jabi Tehnan, the treatment combination level (250 kg ha^{-1}NPSBZn blended fertilizer and 20 t ha^{-1} farmyard manure) that gave the minimum result was not significantly different from 100 kg

ha^{-1}NPSBZn blended fertilizer combined with 16 t ha^{-1} farmyard manure application (Table 5.8).

An increase in the number of kernels per ear with increased application of NPSBZn blended fertilizer and farmyard manure could be attributed to the different nutrient content of blended NPSBZnfertilizer. This might have increased the utilization of applied nutrients by the crop, increasing cell elongation, and it exerted a significant influence on basic plant life processes, such as nitrogen metabolism (Roy, 2006). Moreover, improved crop growth and development and the combined effect of macro- and micronutrients throughout the growing period did not put the plants under nutrient stress at any stage, resulting in an enhanced number of kernels per ear (Kogbe & Adediran, 2003).

Table 5.8: Interaction effects of NPSBZn blended fertilizer and farmyard manure on the Number of kernels per ear, combined over years 2016/17 and 2017/18 in Jabi Tehnan and Mecha districts of Ethiopia.

Treatments		Jabi Tehnan	Mecha
BR kg ha^{-1}		552.604	523.240
BF kg ha^{-1}	FYM t ha^{-1}		
100	0	330.9j	290.6l
	12	337.9j	297.6kl
	16	338.9j	302.6k
	20	387.9i	349.6j
150	0	395.9i	355.6j
	12	395.9i	357.6j
	16	418.9h	389.6i
	20	446.2g	407.6h
200	0	444.9g	410.6h
	12	458.6f	425.9fg
	16	457.6f	436.9f
	20	544.9bc	510.6c
250	0	452.9fg	418.6gh
	12	520.6d	485.9d
	16	544.9bc	511.6bc
	20	555.9a	525.6a
300	0	510.2e	460.292e
	12	537.6c	506.3c
	16	553.6ab	522.6ab
	20	554.2ab	523.6a
CV (%)		8.79	2.420769
LSD		9.9751	11.771

Means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation (150 kg ha^{-1}Urea &200 kg ha^{-1}DAP); BF: NPSBZn blended fertilizer; FYM: Farmyard manure; NKPE: Number of kernels per ear; CV: Coefficient of variation; LSD: Least Significant Difference.

5.3.3.5.Thousand Kernels weight

Thousand kernel weight was significantly ($P < 0.001$) influenced by NPSBZn blended fertilizer, farmyard manure application, and their interaction at both experimental locations (Table 5.11).

The combined application of 250 kg ha^{-1}NPSBZn blended fertilizer and 20 t ha^{-1} farmyard manure at Jabi Tehnan and 300 kg ha^{-1}NPSBZn blended fertilizer with 20 t ha^{-1} at Mecha had the higher thousand-grainweight of292.6 and 290.8g at Jabi Tehnan and Mecha, respectively, which were higher than the conventional fertilizers DAP and Urea by 3.26 % and 4.954 %. But it was statistically at par with the combined application of 300 kg ha^{-1}NPSBZn blended fertilizer at Jabi Tehnan and 250 kg ha^{-1}NPSBZn 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}NPSBZn blended fertilizer with no farmyard manure application at Jabi Tehnan and Mecha, respectively (Table 5.9).

A significant increase in the weight of thousands of kernels could also be attributed to the synergistic effects of combined fertilizers on maize growth-promoting photosynthesis and grain filling (Salim & Raza, 2020). The result of this study is supported by the finding of Tariku Beyene *et al.* (2018), who reported that integrated nutrient management significantly improves thousands of kernel weights.

Table 5.9: Interaction effects of NPSBZn 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		Jabi Tehnan	Mecha_
BR kg ha^{-1}		281.6	278.85
BF kg ha^{-1}	FYMt ha^{-1}		
100	0	253.8j	252.6k
	12	266.5i	264.6j
	16	267.9i	266.005ij
	20	271.18h	269.261hi
150	0	271.28h	269.4h
	12	272.48gh	270.6gh
	16	275.68fg	273.8fg
	20	276.48f	274.6f
200	0	278.8ef	276.9ef
	12	281.7e	280.0e
	16	288.08cd	286.2cd
	20	288.48cd	286.6b-d
250	0	276.08f	274.2f
	12	286.8cd	284.9cd
	16	289.5a-c	286.6b-d
	20	292.7a	289.9ab
300	0	285.8d	283.5d
	12	287.48cd	285.6cd
	16	288.8bc	287.9a-c
	20	291.8ab	290.8a
CV		5.6	9.4
LSD		3.3	3.3

Means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation (150 kg ha^{-1}urea &200 kg ha^{-1} DAP); BF: NPSBZn blended fertilizer; FYM: Farmyard manure; TKW: thousands kernel weight; CV: Coefficient of variation; LSD: Least Significant Difference.

5.3.3.6.Grain yield

Combined analysis of variance over yearsindicates that,NPSBZn blended fertilizer, farmyard manure and their interaction had a significant ($p < 0.001$) effect on maize grain yields at both locations (Table 5.11).

At both experimental locations, the combination of 250 kg ha^{-1} of blended fertilizers (NPSBZn) and 20 t ha^{-1} of farmyard manure resulted in the highest mean grain yields of 5618.5 t ha^{-1} and 5421.00 kg ha^{-1} at Jabi Tehnan and Mecha, respectively, which were significantly higher than the conventional fertilizers DAP and Urea by 16.5 % at Jabi Tehnan and 15.9 % at Mecha. But the treatment combination level that gave the maximum result was statistically at par with 250 and 300 kg ha^{-1}NPSBZn blended fertilizer combined with 16 t ha^{-1} farmyard manure at both locations and also 200 and 300 kg ha^{-1}NPSBZn blended fertilizer combined with 20 t ha^{-1} farmyard manure at Mecha (Table 5.10).

The lowest yield, on the other hand, was obtained at Jabi Tehnan (2218.6kg) and Mecha(2091.29) from plots that received 100 kg ha^{-1} of NPSBZn blended fertilizer but no farmyard manure application. At Mecha, however, there was no statistically significant difference between 100 kg ha^{-1}NPSBZn blended fertilizer and 12 t ha^{-1} farmyard manure combination at the treatment combination level that produced the lowest result (Table 5.10).

This increase in grain yield with increased NPSBZn blended fertilizer and farmyard manure could be attributed to the positive nutrient interactions in the NPSBZn blended fertilizer and farmyard manure. This is confirmed by the work of Han *et al*. (2016), who stated that:The possible synergistic effect of organic (FYM) and inorganic NPSBZn blended fertilizer increased crop yield: organic manure has a balanced supply of nutrients, including micronutrients, increased soil nutrient availability due to increased soil microbial activity, the decomposition of harmful elements, soil structure improvements and root development, and increased soil water availability and inorganic fertilizer characterized by high nutrient contents, and are rapidly taken up by plants.

However, increasing the supply of NPSBZn blended fertilizer beyond the rate of 250 kg ha^{-1} with 20 t ha^{-1} farmyard manure combinations tended to decrease mean grain yield (Table5.10). The reduction in grain yield at the higher rate of blended fertilizer (NPSBZn and farmyard manure) might be due to more assimilated products going to the vegetative components than the grain or excessive application of nutrients, especially N, causing high tissue N concentrations, which might have a toxic effect on maze growth and result in stunted growth and reduced grain yield (Smith & Hamel, 1999).

In accordance with this finding of Wu *et al.* (2010), combining organic manures with inorganic fertilizer could have improved nitrogen usage quality, micro- and macronutrient recovery, P solubilization, and uptake by plants, and K supply, resulting in better maize growth and yield. A combination of organic and inorganic fertilizers is thought to be a good choice for improving nutrient recovery, plant growth, and ultimate yield; otherwise, higher N and P application rates are expected to achieve a higher yield in maize (Mubeen *et al.,* 2013).

Ma *et al.* (2011), found that combining organic and inorganic nutrient sources increased synergism and coordination between nutrient release and plant regeneration, resulting in improved crop growth and yield. In addition, Moe *et al.* (2017) and Wakene Negassa *et al.* (2001), discovered that combining organic and inorganic fertilizers efficiently improved nitrogen use efficiency, and integrating inorganic and organic nutrients improved maize yield by 35%.

5.3.3.7. Above-ground biomass

NPSBZn blended fertilizer and farmyard manure interacted and, in the interim, stood alone to have a significant impact on above-ground dry biomass at both experimental locations, according to information from a combined data analysis of variance over years (Table 5.11).

Above-ground biomass yield advantages of 17.4% and 19.4% were obtained in comparison to the conventional DAP and urea by increasing NPSBZn 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. The application of 250 kg ha^{-1}NPSBZn blended fertilizer and 20 t ha^{-1} farmyard manure resulted in the highest above-ground dry biomass of 10895.0 kg ha^{-1} and 10787.9 kg ha^{-1} at Jabi Tehnan and Mecha, respectively (Table 5.10). However, no statistical variations were observed with the combined application of 300 kg ha^{-1}NPSBZn blended fertilizer and 20 t ha^{-1} farmyard manure at Jabi Tehnan.

On the other hand, the lowest above-ground biomass of 4609.4 kg ha^{-1} and 4896.9 kg ha^{-1} were recorded from the application of 100 kg ha^{-1}NPSBZn blended fertilizer at Tehnan and Mecha, respectively. But it was significantly on par with 100 kg ha^{-1}NPSBZn blended fertilizer integrated with 12 t ha^{-1} farmyard manure at Mecha (Table 5.10).

The combined application of NPS fertilizer and FYM boosted the yield of maize's above-ground biomass, which can be attributed to the accelerated vegetative growth caused by the higher availability of N, which increased the ground's photosynthetic area. High nutrient applications also encourage the accumulation and transfer of dry matter, which boosts economic yield (Yohannes Melaku,2021). According to Tetarwal *et al.* (2011), the improved physicochemical properties of the soil and the beneficial impact of organic manure (FYM) on the steady supply of additional nutrients through mineralization may be responsible for the increase in dry biomass yield brought about by the integrated nutrient management approach.

The present results are supported by Habtamu Yigermal*et al.* (2019), who found that 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 obtained the significantly highest biomass yields of maize (8579 and 8475 kg ha^{-1}) from the combined application of NPK (60-45-30 kg ha^{-1}) with FYM (10 t ha^{-1}).

5.3.3.8. Harvest index

The pooled analysis of variance over years revealed that either the main effect of farmyard manure or its interaction with NPSBZn blended fertilizer did not exert a significant effect on the harvest index (HI) at Jabi Tehnan. However, only NPSBZn blended fertilizer caused a highly significant ($p <0.001$)effect on this parameter.At Mecha, both significant ($p <0.001$) interactions and the main effect of treatment on the harvest index were observed (Table 5.11).

At Mecha, NPSBZn 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}NPSBZn blended fertilizer combined with 12 and 16 t ha^{-1} farmyard manure and without farmyard manure application, 200 kg ha^{-1}NPSBZn blended fertilizer combined with 12, 16, and 20 t ha^{-1} farmyard manure, and 250 kg ha^{-1}NPSBZn blended fertilizer combined with 16 t ha^{-1} farmyard manure. Whereas crops on a plot treated with the least rate of NPSBZn blended fertilizer (100 kg ha^{-1}) along with no farmyard manure application recorded the lowest harvest index of 43.8, but it was statistically on par with 100 kg ha^{-1}NPSBZn blended fertilizer with 12 and 20 t ha^{-1} farmyard manure application and also 150 kg ha^{-1}NPSBZn blended fertilizer with 12 t ha^{-1} and without farmyard manure application (Table 5.10).

The higher maize harvest index with increased NPSBZn blended fertilizer and farmyard manure application could be attributed to higher grain yield per plant as a result of efficient uptake of plant nutrients in response to the balance of macro- and micronutrients and their synergy within and between the fertilizer (blended and farmyard manure), as well as the increasing harvest index with increasing rates of both NPSBZn blended fertilizer and farmyard manure up to a certain level.

The finding of this study is supported by Amanullah *et al.*(2009), who reported thateffective 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.* (2019), boron increases crop yield even in phosphorus-deficient soils due to synergy in phosphorus absorption through B. On the contrary, according to Dong *et al.* (2012), improved nutrient availability may have slowed senescence and extended the life cycle of the maize plant, resulting in a higher economic yield and harvest index.

Fantaye Belay and Hintsa Meresa (2017), reported that the maximum harvest index of maize was obtained from the application of 50–150 kg ha^{-1} of NPSBZn blended fertilizer, as opposed to conventional DAP, but further increasing the blended fertilizer rate (NPSBZn) above 150 kg ha^{-1} became the cause for the reduction of the harvest index.

The maximum harvest index of 53.108 was obtained at Jabi Tehnan from 200 kg ha^{-1} of NPSBZn blended fertilizer, which was 14.91% higher than the blanket rationally, recommended fertilizers DAP and urea treatment application. However, statistically, it was comparable to 250 and 300 kg ha^{-1}. However, statistically, the minimum harvest index (44.974) was recorded from the least level of NPSBZn blended fertilizer (100 kg^{-1}) (Table 5.5.). However, increasing the supply of NPSBZn blended fertilizer beyond the rate of 200 kg ha^{-1}, tended to decrease mean HI.

Increasing the HI with increased NPSBZn blended fertilizer could be related to the availability of nutrients, especially N, attributed to the positive effect on assimilating partitioning to the GI. The reduction in HI at the higher rate of NPSBZn blended fertilizer might be attributed to greater vegetative biomass production compared to grain yield. This result agrees with the findings of Kinfe Tekulu*et al.* (2019), who reported that the harvest index of maize was found to be highest at the rate of 150 kg ha^{-1}NPSBZn as compared to the control treatment. Desta Ekero *et al.* (2020), also reported that the harvest index of teff was found to be highest in blended fertilizer treatments as compared to the control. In line with this result, Marschner (1995) stated that excess nutrient application resulted in a reduction of HI in cereal crops.

Table 5.10: Interaction effects of NPSBZn blended fertilizer and farmyard manure on above-ground biomass, grain yield, and harvest index, combined over years 2016/17 and 2017/18 in Jabi Tehnan and Mecha districts of Ethiopia

Treatments		Jabi Tehnan		Mecha		
		AGBM(kg ha^{-1})	GY(kg ha^{-1})	AGBM(kg ha^{-1})	GY(kg ha^{-1})	HI%
BR kg ha^{-1}		9282.9	4688.4	9037.9	4554.6	50.4
BF kg ha^{-1}	FYM t ha^{-1}					
100	0	4609.4o	2218.6n	4896.9m	2091.29m	43.85 h
	12	5612.7n	2441.2m	5099.6m	2223.56m	44.285 h
	16	6080.4mn	2664.0l	5562.6l	2734.83l	49.16 e-g
	20	6474.4lm	2708.4l	6301.2k	2996.12k	47.75f-h
150	0	6745.7kl	3107.3k	6741.9j	3248.50j	48.504f-h
	12	6966.1kl	3410.6j	7296.7i	3377.42j	46.391gh
	16	7245.9jk	3741.1i	7462.0hi	3715.42i	49.8e-g
	20	7598.3ij	3904.0hi	7628.5g-i	3847.47hi	50.48e-g
200	0	7815.4hi	3953.0h	7816.4f-h	3909.81gh	50.05e-g
	12	8518.1fg	4493.1f	8095.0ef	4553.25f	56.23a-d
	16	9713.9de	5269.2c	9099.0cd	5211.69bc	57.297ab
	20	9890.4c-e	5394.2bc	9204.4cd	5321.05ab	57.815ab
250	0	8182.1gh	4275.5g	7894.5fg	4087.97g	51.834d-f
	12	8913.9f	4782.9de	8355.1e	4949.95de	59.263 a
	16	10135.5b-d	5417.5a-c	9393.7c	5356.17ab	57.017ab
	20	10895.0a	5618.5a	10787.9a	5421.00a	50.27e-g
300	0	8 813.1f	4638.5ef	8192.8ef	4786.97e	58.419a
	12	9492.4e	4977.2d	8913.1d	5044.05cd	56.64a-c
	16	10297.1bc	5490.5ab	10063.0b	5391.99ab	53.68a-e
	20	10686.6ab	5518.5b	10366.4b	5401.03ab	52.215c-f
CV		6.025247	4.314493	4.423964	4.021951	7.818230
LSD		568.3	207.62	403.29	192.73	4.6609

Where means within a column followed by the same letter(s) are not significantly different, BR: Blanket Recommendation; FYM: Farmyard manure; CV: Coefficient of variation; LSD: Least Significant Difference; BR: blanket recommendation (150kgha^{-1}Urea &200 kg ha^{-1}. DAP); BF: Blended fertilizer; (NPSBZn) AGBM: Above ground biomass; GY: Grain yield; HI: Harvest index

Table 5.11: Mean square values of the effects of Year, Block, blended fertilizer, (NPSBZn)farmyard manure, and their interactions on Yield Components and yield variables measured at Jabi Tehnan and Mecha districtscombined over years 2016/17 and 2017/18

Source of Variation	DF	NEPP	NKPE	EL	ED	TKW	GY	HI
Jabi Tehnan								
Y	1	0.0NS	1.0NS	0.5NS	0.0NS	8.7NS	23.8NS	8.3NS
BL	2	0.0**	1.7NS	1.4**	0.1NS	22.3NS	748811.1**	46.6NS
BF	4	0.1**	146178.4**	98.0**	8.8**	2356.8**	31340119.3**	594.2**
FYM	3	0.1**	26268.7**	39.1**	3.7**	691.0**	6311967.4**	257.5NS
BF XFYM	12	0.0**	2342.0**	3.7**	0.2*	45.8**	213103.9**	25.3NS
Error		0.0	78.1	0.2	0.1	7.8	18431.6	9.1
Total	97	97	97	97	97	97	97	97
Mecha								
Y	1	0.21NS	16.88NS	1.88NS	0.01NS	11.04NS	403.70NS	30.97NS
BL	2	1.13**	1028.63**	10.14**	0.51*	23.02NS	445399.8**	86.82**
BF	4	0.39*	153923.2**	38.6**	0.7**	2327.5**	30356792**	140.3**
FYM	3	0.04NS	30728.6**	17.6 **	1.1**	673.78**	5960696.3**	65.7*
BF XFYM	12	0.08	2019.04**	3.83NS	0.1NS	42.92**	239281.4**	36.2**
Error		97	87.48	2.97	0.1	7.96	19998.50	15.4
Total	97	NEPP	97	97	97	97	97	97

Were, * significantly different at 5 % respectively; NS, non-significant. Y: Year; BL: Block; BF: blended fertilizer (NPSBZn); FYM: Farmyard manure; DF: Degree of freedom; NEPP: Number of ears per plant; CW: cob weight; TKW: Thousand Kernels Weighty: Grain yield; NKPE and NKPR: Number of kernels per ear and row; EL&ED: Ear length and diameter; HI: Harvest index

5.3.4. Correlation of selected maize growth, yield, and yield components

A comparison of the correlation coefficients at Jabi Tehnan revealed that grain yield had a higher correlation coefficient (r = 0.966**)with plant hight (r = 0.951**) above-ground biomass ,number of kernels per ear (r = 0.945**), ear length (r = 0.932**), thousand kernel weight (r = 0.921**) and the number of green leaves per plant(r = 0.915**), and ear diameter (r = 0.885**) .The number of ears per plant had a relationship with grain yield, but at a lower magnitude than the other yield components. The number of kernels per ear (r = 0.954**) had the highest correlation coefficient at Mecha, followed by above-ground biomass (r = 0.935**), thousand kernel weight (r = 0.934**), number of green leaves per plant (r = 0.922**), plant height (r = 0.685**), and ear length (r = 0.541**) of ear per plant and ear, diameter exhibited relationships with grain yield, with correlation coefficients of lower magnitudes when compared to the previous yield components.

Table 5.12: Correlation coefficient matrix of the relationship between selected growth parameters and maize yield components at Jabi Tehnan

	AGBM	ED	NEPP	NGLPP	NKPE	EL	TKW	PH	GY
AGBM	1.00								
ED	0.872**	1.00							
NEPP	0.677*	0.721*	1.00						
NGLPP	0.922**	0.869**	0.726*	1.00					
NKPR	0.926**	0.853**	0.693*	0.923**					
NKPE	0.926**	0.862**	0.687**	0.907**	1.00				
CW	0.790*	0.781*	0.714*	0.845**	0.787*				
EL	0.925**	0.902**	0.823**	0.927**	0.906**	1.00			
TKW	0.915**	0.837**	0.627**	0.892**	0.908**	0.892**	1.00		
PH	0.947**	0.874**	0.644**	0.923**	0.950**	0.919**	0.955**	1.00	
GY	0.951**	0.885**	0.673*	0.915**	0.945**	0.932**	0.921**	0.966**	1.00

NB: AGBM = above-ground biomass; ED= ear diameter; NEPP= number of ears per plant; NGLPP= number of green leaves per plant; NKPE=number of kernels per ear; EL= ear length; TKW= thousand kernels weight; PH= plant height; GY=grain yield and ** = significantly different at 5%.

Table 5.13: Correlation coefficient matrix of the relationship between selected growth parameters and maize yield components at Mecha

	AGBM	ED	NEPP	NGLPP	NKPE	EL	TKW	PH	GY
AGBM	1.00								
ED	0.420*	1.00							
NEPP	0.558*	0.622*	1.00						
NGLPP	0.953**	0.427*	0.536*	1.00					
NKPR	0.932**	0.411*	0.469*	0.902**					
NKPE	0.930**	0.441*	0.549*	0.899**	1.00				
CW	0.865**	0.450*	0.512*	0.848**	0.864**				
EL	0.550*	0.258*	0.519*	0.551*	0.580*	1.00			
TKW	0.905**	0.442*	0.531*	0.910**	0.918**	0.579*	1.00		
PH	0.656*	0.539*	0.542*	0.615*	0.677*	0.411*	0.683*	1.00	
GY	0.935**	0.430*	0.529*	0.922**	0.954**	0.541*	0.934**	0.685*	1.00

Where, AGBM = above-ground biomass; ED= ear diameter; NEPP= number of ears per plant; NGLPP= number of green leaves per plant; NKPE=number of kernels per ear; EL= ear length; TKW= thousand kernels weight; PH= plant height; GY=grain yield and ** = significantly different at 5%.

5.4. Conclusion and Recommendations

Hence, a factorial experiment consisting of different levels ofNPSBZn blended fertilizer and farmyard manure was conducted inJabi Tehnan and Mecha districtsduringthe2017 and 2018 main croppingseasons. Accordingly, at both sites of the experiment and in consecutive years of experiment results, NPSBZn blended fertilizer along with farmyard manure was efficiently used by maize crops for their growth and development and was found to significantly (P<0.001) increase the growth and yield attributes of maize.

At both locations, except for days to silking and leaf area index and days to physiological maturity, the number of ears per plant, ear length, and ear diameter at Mecha, almost all parameters were significantly hastened and improved or increased by the individual as well as the combined application of blended NPSBZn fertilizer and farmyard manure. Exceptionally, the only main effect of NPSBZn 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 availability of nutrients from both sources for plant development and vegetative performance was a major factor in the improvement.

The results of phenology, growth, and yield parameters indicated the fertility of the soil in the experimental area was not satisfactory because all fertilized treatments, especially the combined application of NPSBZn blended fertilizer and farmyard manure, gave a better result than either of them alone or the blanket recommendation, which gave relatively low results. This indicates that integrated nutrient management is the best approach for the growth and yield performance of the crop. Additionally, the integrated approach has a long-term benefit in that it also improves the physicochemical properties of the soil for sustainable crop production.

In general, this research contradicts prior findings that using farmyard manure reduced recommended inorganic fertilizer rates by half. Instead, a high rate of NPSBZn (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 it can be a viable alternative to integrated soil fertility management.

CHAPTER 6. GENERALCONCLUSION AND RECOMMENDATIONS

6.1. General Conclusion

Based on the survey results, the farmers across the three districts are dominated by males and are of active working age. The highest proportions were also married to people with a lot of farming experience. The three main types of fertilizers are urea, DAP, and NPS, with urea being used by the majority of farmers. Local seeds are the dominant seed types used across the study areas. Weed and pest infestations in maize fields are extremely low. Furthermore, most farmers have very small plots of land that they plough regularly.Therefore, it can be inferred from this research that socioeconomic, fertilizer, seed, and land preparation factors have an impact on farmers in all three maize production systems. As a result, it is possible to draw the conclusion that factors such as household demographics (particularly those related to gender and particularly those headed by women), size status (non-married and small family size), age > 55 (less productive) compared to 35–44 (highly productive), land distribution (molest but fragmented production plot), land distance from home (high walking distance from the production site), and experience (16–30 years) all played a role in reaching this conclusion. Weed management methods, accessibility (inability to obtain fertilizer from the normal source), and fertilizer type (repeatedly one kind (urea and DAP and now NPS with little or no application of organic source fertilizer) are all crucial in lowering yield.

The results of the soil tests before sowing indicated that most of the chemical properties of the experimental site were indicative of low fertility status. Thus, the chemical properties of the soil, such as its organic carbon content, total nitrogen, and available phosphorus, were found to be low. Soil analysis results after crop harvest revealed that the use of FYM in conjunction with various levels yielded fruitful outcomes. The results demonstrated a significant increase in soil total nitrogen (TN), available sulphur (AS), available boron (AB), and available zinc (A Zn) when farmyard manure and NPSBZn blended fertilizer were used together. However, only farmyard manure had a significant impact on soil pH, cation exchange capacity, and organic matter. Despite the fact that farmyard manure and mixed fertilizer both had considerable positive effects on the amount of accessible phosphorus (AP).Therefore, the combined application of organic and inorganic fertilizers increased the soil's chemical properties such as soil organic carbon, available nitrogen, and available phosphorus, while significantly lowering its pH.

The integrated strategy also has a long-term advantage in that it enhances the soil's physicochemical characteristics for sustained crop production. Generally, the results obtained 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. According to the study's findings, integrated use of organic and inorganic fertilizer can provide an iprovement of soil characteristics and crop yield. Therefore, farmers can use organic and inorganic fertilizer combindelly to reduce the danger of soil fertility loss,to bring crop yield increament and agricultural sustainability. The combined application of NPSBZn blended fertilizer and farmyard manure, produced better results than the use of either of them alone.

6.2. General Recommendations

Therefore, the most acceptable rates at both experimental locations for increasing maize output was 250 kg ha^{-1}NPSBZn with 20 t ha^{-1} FYM application.

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APPENDIXES

Appendix 1: Survey questionnaire

Diagnosis Survey of Maize Production Constraints and Opportunity in North Western Ethiopia

1.Zone____

2.Woreda/District ____

3.Peasant Associationname(PA) ________________________________

4.Selection Number of theHousehold_____________________________

5.NameoftheHousehold (respondent)___________________________

6. Respondent Cell phone____________________________________

7. GPS coordinates:

- *latitude*__________
- *longitude*__________

8. Altitude (meters)

9.Enumerator'sname______________________________________

10. Supervisor's name____

11.Dateof data collection _______________________________

12.Signature of Enumerator_______________________________

13.Signature supervisor ____

Section One: - Household Demographic Characteristics

Q.1.Fill The FollowingTable.

Age of household	Sex	Education level	Head of the household

Codes

Educational level		Marital statuses		Head of the household	
Illiterate	=1	Married	=1	Husband	
1st grad completed	=2	Never married	=2	House wife	=1
2nd grad completed	=3	Divorced	=3	Son /Daughter	=2
3rd grad completed	=4	Widower/Widowed	=4	Grand child	=3
12th grad completed	=5			Other Relatives	=4
Collage completed	=6			Hired workers	=5
University finish	=7				
Others(Read and write)	=8				

Section Two:Land Resource

Q.1.Doyou haveyourown land?

☐ Yes= 1 No=2

Q.2.Ifyes to question no.1,whatisthetotal sizeofyourland holding? (ha /'Gasha'/ 'Kert'/ other local unit (specify)

- ✓ For Barely Production_______unit
- ✓ For potato production______(unit)
- ✓ Grazing_____________(unit)
- ✓ Fallow ________________(unit)
- ✓ Rent-out _______________(unit)
- ✓ Teff______________(unit)
- ✓ Non cropped _________________
- ✓ Nigger seed _____________(unit)
- ✓ For finger millet____________________(Unite)
- ✓ For field bean production____________(unit)
- ✓ For Maize (wild oat) production___________(unit)
- ✓ Faba bean farm _____________(unit)
- ✓ Lupine _________________
- ✓ Wheat______________________
- ✓ Sun Flower______________(unit)

Other (specify) ______________(unit)

Q.3.How didyouacquireyourownland? (Encircle)

1. Inherited/gift from family
2. Landredistribution
3. Purchase
4. Other(specify)-------------------------------
5. Share cropped out --------------

Q5. What is the distance from your homestead to the maize production farm land? _____________km

Section Three: AgriculturalInputs inthe reference Period

Q1.Haveyou been using inputs (chemical fertilizer, improved seed, chemical, compost, manure…) everyear?

Yes ☐ No☐

Q.2. Ifnoto question no1, why?

Impute type	Reasons
Improve seed	
Chemical fertilizer	
Compost	
Manure	
Pest sides	
Herbicide	

Reason Codes

Notnecessary for maize cultivated	=1	Notavailable	=2
Harmfultothe soil	=3	Tooexpensive	=4
Landisfertile	=5	Notknow its importance	=6
couldn't obtain credit		Others(specify)------------------------	

Q3. Ifyes to question no.1, Inputs for maize production in your farm land? (Specify, quantity)

Q3.1. Seed

- Local yes ☐ No☐
- Improved yes ☐ No☐
- Amount______________ (kg/ha)
- Methods of sowing ____

Q3.2. DAP (qt/ha)

- yes ☐ No☐
- amount _________________kg/ha
- time of application ____
- Methods of application ____

Q3.3. Urea (qt)/ha

- yes ☐ No☐
- amount _________________kg/ha
- time of application ____
- methods of application ____

Q3.4. NPS (qt)/ha

- yes ☐ No☐
- amount ________________kg/ha
- time of application ____

Q3.5. NPSBZn (qt)/ha

- yes ☐ No☐
- amount ________________kg/ha
- time of application ____

Q3.6. Compost

- yes ☐ No☐
- amount ________________kg/ha
- time of application ____
- methods of application ____

Q3.7. Manure

- yes ☐ No☐
- amount ________________kg/ha
- time of application ____
- methods of application ____
-

Q3.8. Compost + Manure

- yes ☐ No☐
- amount ________________kg/ha
- time of application ____
- methods of application ____

Q3.9. Compost + Chemical fertilizer

- yes ☐ No☐
- amount ________________kg/ha
- time of application ____
- methods of application ____

Q3.10. Manure + Chemical fertilizer

- yes ☐ No☐
- amount ________________kg/ha
- time of application ____
- methods of application ____

Q3.11. Compost+ Manure + Chemical fertilizer

- yes ☐ No☐
- amount ________________kg/ha
- time of application ____
- methods of application ____

Q3.12. Manure

- yes ☐ No☐
- amount _________________kg/ha
- time of application ____
- methods of application ____

SECTION Four: Cropping System

Q1. What type of production system do you adopt on your maize production?

a. Sole cropping ☐ b. mixing cropping ☐ c. Mono cropping ☐ d. Others (Specified)

Q2. If you adopt cropping system (rotation and mixed cropping)

2.1. if you were used crop rotation what was the sequence/ pattern of the crop?____

____

____

____

2.2.If you were used intercropping on your farmlands, What were the crops intercropped on your maize farmlands ?____

____

____

____

SECTION Five: Production Constraints

Q1. What are the major maize production constraints on your farm? Rank horizontally*

Crop type	Insects	Soil erosion	Diseases	Weeds	Flood	termite	Frost	Seed shortage	Lack Qualified seed	Fertilizer shortage	Lack of pesticide	Lack of production knowledge	Others (specify
Maize													

* 1 =most severe, 2= second severe, 3=third severe etc.

Q2. Elaborate your agricultural activity and measure towards minimization of maize production constraints.

a) For Insect____

_____________________________________,_______________________________

_

b) For disease____

___________________________________,________________________________

_

c) For drought___________________________,______________________________

____________________________________,_______________________________

_

d) For weeds_________________________,_________________________________

____________________________________,_______________________________

_

e) For flood__________________________,_________________________________

___________________________________,________________________________

_

f) For Frost_________________________,__________________________________

____________________________________,_______________________________

__

g) For Seed shortage__________________,_________________________________

___________________________________,________________________________

_

h) For Fertilizer shortage____________________,___________________________

_______________________________________,____________________________

_

i) For Lack of pest side___________________,______________________________

____________________________________,______________________________

j) Others (specify)______________________,_________________________________

______________________________________,_____________________________

Section Six: Yield and Production Opportunity

Q1.How much yield do you produce per gasha /kert/ ha

____

Q2. How is the trend of volume of maize yield during the past 5 years? (Tick)

Crop type	Trend		
	Increasing	Decreasing	Same
Maize			

Q3.What are the opportunities you have to improve maize productivity?

____

____

____

Section Seven: Crop and Soil Management

Q1. Do you carried out Soil fertility maintenance and agronomic practices on yours maize production land?

Yes ☐ 2. No ☐

Q2. If your answer is no for question number 1, what are the reasons for not exercising soil fertility management and agronomic practices?

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Q3. If yes what are soil and agronomy management that you commonly used?

Q3.1. soil management practices

- Commercial fertilizer used (none, v. low, low, medium)__________________
- Compost or other organic fertilizer used (none, v. low, low, medium)__________
- Following and crops rotation practices(NO , yes)__________________
- Soil water conservation practice (NO, yes)________________________

Q3.2.Agronomic practices (under line)

- Tillage frequency(one time , two time three time)_____________________

- What was the main tillage method used?(Conventional hand hoe , Planting basins (potholes) ,Zero tillage , Ploughing)
- Hoeing type and frequency { (Inter cultivation, earthling up,) one times , two times, three times)} ____
- What type of weed management do you used?(cultural, chemical)
- Do practice weeding? Yes no
- If yes Weeding frequency(one times, two times,three times)_____________

Number of weeding in the main season	First weeding			Second weeding			Third weeding		
	Month After sowing	Week After sowing	Type	Month After sowing	Week After sowing	Type	Month After sowing	Week After sowing	Type
			1=man. 2=chem.			1=man. 2=chem.			1=man. 2=chem.

Q4. Regarding to Soil and water conservation practice, fill the followingtable.

Soil and water conservation practice	Have you implemented this practice 1= yes , 2= no	If yes, what time /year was this practice implemented?	If No Or Stopped Practicing, What Is The Reason
Mulching			
Farm yard manure			
Compost manure			
Slash and burn			
Green manure			
Terracing			
Grass strips			
Crop residues /household refuse			
Minimum/ zero tillage			
Drainage (water logging)			
Other (specify)			

Q5.Do you applying plant residues or other suitable materials (compose, FYM and cattle manure) to the soil surface to compensate for loss of nutrients due to continuous cropping and complete removal of crop residues?

Yes ☐ 2. No ☐

Q6.Ifnoto question no 5, why?____

____

____

____

Q7. What is the importance's of crop-residues? (Rank 1, 2, 3…in order of importance's)

1) Feed_____________
2) Fuel______________
3) Construction _________
4) Selling___________
5) Compost preparing _________
6) Others___________

Q8. What type of Soil amendments do you use?

1) Ash
2) Gypsum
3) Lime
4) FYM

Q9. Did you incorporate any of the following crop residues in maize production land?

	1=yes, 2=no	amount	Unit	Source	If no, why not?
Common bean					
Barely					
Wheat					
Weeds					
Maize					
None					
Other					

_______________________,____

____

ThankyouforyourKindness cooperation!

Appendix Table 1: Nutrients levels applied in the form of farmyard manure applied at Jabi Thanan

	Nutrient (kg ha^{-1})									
Treatments	N		P		S		B		Zn	
FYM (tha^{-1})	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
0			0	0	0	0	0	0	0	0
12			172.08	191.04	110.4	70.88	0.144	0.156	2.16	2.76
16			229.44	254.72	147.2	70.88	0.192	0.208	2.88	3.68
20			286.8	318.4	184	88.6	0.24	0.26	3.6	4.6

Appendix Table 2: Nutrients levels applied in the form of farmyard manure applied at Mecha

	Nutrient (kg ha^{-1})									
Treatments	N		P		S		B		Zn	
FYM(tha^{-1})	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
0			0	0	0	0	0	0	0	0
12			201.72	200.64	173.16	122.4	0.276	0.24	2.52	1.08
16			268.96	267.52	230.88	163.2	0.368	0.32	3.36	1.44
20			336.2	334.4	288.6	204	0.46	0.4	4.2	1.8

Appendix Table 3: Nutrients levels applied in the form of Blended fertilizer(NPSBZn), Di-ammonium phosphate (DAP), and Urea

Treatments	Nutrient (kg ha^{-1})				
Blended fertilizer (NPSBZn) (kg ha^{-1})	N(kg ha^{-1})	P_2O_5(kg ha^{-1})	S(kg ha^{-1})	Zn(kg ha^{-1})	B(kg ha^{-1})
100	16.9	7.3	33.8	2.23	0.67
150	25.35	10.95	50.7	3.345	1.005
200	33.8	14.6	67.6	4.46	1.34
250	42.25	18.25	84.5	5.575	1.675
300	50.7	21.9	101.4	6.69	2.01
DAP 200(Kgha^{-1})	18	46	0	0	0
Urea (Kgha^{-1})	46	0	0	0	0

Appendix Figure 1: Farmyard manure measuring before application

Appendix Table4: Weather conditions of the study area in 2016/17 and 2017/18

	Jabi Thanan						Mecha					
			Daily temperature (℃)						Daily temperature (℃)			
Months	Average monthly		Max		Min		Average monthly		Max		Min	
	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
OCT	79.340	106.360	22.135	21.790	10.864	10.390	59.86	120.84	24.167	23.929	14.029	13.696
NOV	36.130	114.830	22.010	21.989	8.767	9.382	14.62	51.97	24.266	24.257	12.009	12.557
DEC	0.780	9.390	22.358	23.102	7.152	8.938	0.61	5.22	25.323	25.279	10.012	11.919
JAN	0.210	6.890	25.105	23.610	6.587	8.994	0.09	0.08	28.630	27.082	9.514	10.281
FEB	48.190	67.400	25.293	25.930	11.935	11.300	44.21	19.76	28.699	29.906	13.734	13.832
MAR	56.630	13.650	27.665	27.578	13.121	11.765	36.82	7.03	30.296	30.966	14.812	14.666
APR	110.670	79.730	28.142	27.032	13.817	13.265	92.31	43.79	30.450	30.300	16.952	16.009
MAY	210.360	86.850	24.541	27.326	13.844	14.306	272.3	92.83	26.324	29.991	16.496	16.773
JUN	139.030	267.510	25.114	22.183	13.703	13.191	190.31	246.95	25.836	24.735	15.715	15.246
JUL	502.440	429.140	20.401	19.173	13.224	12.482	525.04	454.45	22.389	21.536	15.038	14.640
AUG	459.900	380.190	19.648	19.235	12.559	12.178	517.32	411.75	21.343	21.133	14.656	14.146
SEP	259.280	164.270	21.081	21.518	12.329	11.385	335.61	169.76	22.937	23.876	14.949	14.677

BIOGRAPHY OF THE AUTHOR

Mitiku Ashrenafi Ejigu was born on December 12, 1985, G.C in Shebel BerentaDistrict, East Gojjam, and Ethiopia. Merti Jeju Elementary School, Adama Secondary High School, and Adama Atse Gelawudiwos Preparatory School were his primary, secondary, and preparatory schools, respectively. He earned a BSc. and MSc. in Crop Production and Protection and Agronomy from Jimma and Haramaya Universities, respectively, in 2007 and 2013. Up until 2009, he worked as a fruit and vegetable expert at the North Showa Zone's Ankober Woreda Agricultural Office. He then worked at the Gambella Agricultural Technical and Vocational Educational Training College (GATVTC) as an instructor until 2011. Since September 2013, he has been working as a lecturer, researcher, and community service worker at Debre Brehan University.He is now pursuing a Doctor of Philosophy (Ph.D.) in Agronomy at Bahir Dar University's College of Agriculture and Environmental Sciences.