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Effects of Blended NPSB Fertilizer Rates on Maize (*Zea mays* L) Yield and Yield Components of at Banshure Kebele in Bedele District, South Western Ethiopia

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Abstract

Soil test based fertilizer recommendation concurrent to the actual limiting nutrients for a given crop helps to supply adequate and balanced plant nutrients for sustainable crop production without affecting soil health negatively. Blended NPSB fertilizer is a newly introduced fertilizer for crop production in the study area. However their optimum rate for maize crop production is not yet determined in the study area. Therefore, a study was conducted to investigate the effects of blended NPSB fertilizer rates on maize yield and yield components in Bedele district at Banshure Kebele during the 2021main cropping season. The experiment was laid out in randomized complete block design (RCBD) with three replication of the treatments (0, 25, 50, 75, 100, 150, 200, 250 and 300 kg ha^{-1}) of blended NPSB fertilizer rates supplemented with the recommended nitrogen rate for maize production in Bedele District. Selected soil properties before trial were analyzed following standard laboratory procedure at soil laboratory of Bedele Agricultural Research Center. Soil analytical results before planting indicated that, the soils of the research sites had clay textural class, are moderately acidic (5.48 and 5.47), medium in OC content (2.04 and 2.12%), had low TN (0.17 and 0.18%), medium available P (1.67 and 1.77 mg kg^{-1}), low available S (9.26 mg kg^{-1}), low available B (0.3 and 0.36 mg kg^{-1}), medium CEC (20.94 and 22.64 cmol (+) kg^{-1}) and very low PBS (16.85 and 16.29%), for Alle and Abu respectively. The analysis of variance indicated that, the blended NPSB fertilizer rate highly significantly affected maize growth, yield and yield components. Moreover, the result showed that economically feasible grain yield (7173.6 kg ha^{-1}) and net benefit (74897.58 ETB ha^{-1}) with highest marginal rate of return of 2957% were obtained from the plot treated with 150 kg ha^{-1} of blended NPSB fertilizer rate. Therefore, based on the result obtained from this study, application of 150 kg ha^{-1} of blended NPSB fertilizer rate and recommended N can be tentatively suggested as economically profitable for the production of maize at the study area.

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Blended fertilizer, Soil fertility, grain yield, Economical feasibility.

Introduction

The soils of Ethiopian highlands are deficient in most macro- and micro-nutrients as well as in organic matter (Elias, 2016). One of the major problems negatively affecting crop productivity in Africa including Ethiopia is rapid depletion of nutrients in smallholder farms (Achieng *et al.,* 2010). According to Tekalign *et al.,* (2001), low availability of nitrogen (N) and phosphorus (P) has been demonstrated to be a major constraint to cereal production, whereby N is deficient in almost all soils and (P) is deficient in about 70% of the Ethiopian soils. Soil degradation and nutrient depletion further aggravated due to the use of unbalanced fertilizer forms and rates based on site specific and crop nutrient demand (Hussain *et al.,* 2006). Nutrient mining due to sub-optimal fertilizer uses coupled with unbalanced nutrients, favored the emergence of multi nutrient deficiency in Ethiopian soils and resulted in stagnant crop productivity (Wassie and Shiferaw, 2011).

Maize is one of the world's leading cereals, ranking second in production after wheat (FAOSTAT, 2019). It is the major staple food crop and source of cash in Ethiopia (Abera *et al.,* 2013). Maize is used in Ethiopia directly for human consumption as food or for the preparation of local drinks; In addition, maize leaves are used for animals feed and dry stalks are used as fuel and for the construction of fences (Akalu, 2015). Ethiopia is the third largest maize producer in Africa next to Nigeria and Egypt (FAOSTAT, 2017). In Ethiopia maize is the second in area coverage next to teff, with total land area of 10,478,217 hectare being under cereals, of which maize covered about 17.68% (2,274,305.93 hectares) (CSA, 2020); and it is the major cereal crop of the study area covering about 40 % of the total area under production in Bedele district (BDAO, 2021). Despite the large area under maize production, the current national productivity is about 4200 kg ha^{-1} (CSA, 2020), which is far below the worlds average productivity of 5800 kg ha^{-1} (FAOSTAT, 2019).

In Ethiopia, di-ammonium phosphate (DAP) and urea have been the only chemical fertilizers used for crop production with initial understanding that nitrogen and phosphorus are the major limiting nutrients of Ethiopian soils (Bekabil and Hassan, 2006). However, plant growth and crop production require ample supply and balanced amounts of essential plant nutrients, but the use of only urea and DAP have totally ommited the use of micronutrients (Mengel and Kirkby, 1996). Since deficiency of macro and micronutrients are reported in tropical soils thereby necessitating the application of nutrient sources that reduce such deficiencies (Hassan *et al.,* 2010) this can only be achieved if fertilizers are suitable to the soil condition and the nutrient contents fits to the needs of the crops.

It is so important to increase the productivity of crops along with desirable attributes through improved management practices and application of other sources of nutrients beyond the blanket recommendation of urea and DAP, especially those that contain potassium, sulfur and other micro nutrients (Ethio-SIS, 2016). Moreover, according to soil fertility survey report maps (Soil fertility Atlas), the depletion of nitrogen, phosphorous, sulfur, and boron is widely spread in Bedele district (Ethio-SIS, 2016). To overcome this problem of nutrient deficiency, Ethio-SIS recommended fertilizers such as NPS, NPSB, NPSZn, NPSZnB, NPSFeZn, and NPSFeZnB for Oromia region in general and NPSB for the study area in particular (Ethio- SIS, 2016).

Based on such evidence, DAP is gradually being substituted by blended NPSB fertilizer for crop production in the study area (BDAO, 2021). Even though new blended fertilizers such as NPSB (18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B) are currently being used by the farmers in the study area, there is no any study conducted on the effects of newly introduced blended NPSB fertilizer in relation maize yield and yield components. Therefore, there is a need to evaluate their effect on maize in particular as it is the major cereal crop of the study area and its surroundings. Therefore, this study was initiated with the general objective to determine the optimum rate of blended NPSB fertilizer that increases maize yields with amending soil fertility at Banshure Kebele of Bedele District, South Western Ethiopia.

Accordingly, the specific objectives of the study were:

To evaluate the response of maize yield and yield components to different rates of blended NPSB fertilizer.

To identify economically feasible NPSB fertilizer rate for the study area.

Materials and Methods

Description of the Study Area

Location

Field experiments were conducted at two sites of Banshure Kebele, in Bedele district of Buno Bedele Zone, South Western Ethiopia in 2021 main cropping season. Bedele district is located between 8°14'30" and 8°37'53"N, and 36°13'17" and 36°35'05"E (Figure 1). The district is located at 483 km away from Addis Ababa on the road to Mettu.

Climate

According to the sixteen-year (2005-2021) climate data recorded at Bedele Meteorological Station, the mean annual rainfall of the study area is 1942 mm and the mean monthly minimum and maximum temperature are 13 and 26^{0}C, respectively. The rainy season extends from April to October with the maximum rains in the months of May, June, July, August and September (Figure 2), whereby the mean monthly rainfall exceeds 301mm (BMES, 2021).

Soil type and topography

According to Alemayehu (2015), the soil type of the study area belongs to the reference soil group of Nitisols. The soils are generally deep, well-drained and red tropical soils with diffuse horizon boundaries and a clay-rich nitic subsurface horizon (Driessen *et al.*, 2001). Nitosols are predominantly derived from basic parent rocks through strong weathering, which are more fertile than most other red tropical soils (FAO-WRB, 2006). The area is characterized by undulating topographically. In general, Bedele district is characterized by lowland and midland, having an altitude ranging from 1013 to 2390 meters above sea level with humid climatic condition (BDAO, 2021).

Vegetation and Farming systems

Subsistence farming is the main livelihood of the community. Mixed crop-livestock farming system is predominant in the agricultural production of Bedele district. Most of the residents in the area are dependent on agriculture (LDMA, 2010), and crop and livestock are the important sources of income for all relatively wealthy community members (CSA, 2018).

The concentrated common vegetation in the district is Bamboo, Gravilia robista, Cordia Africana and acacia species. The crops grown by smallholder farmers of the area include maize (*Zea mays*), teff (*Eragrostis tef*), sorghum (*Sorghum bicolor*), barley (*Hordeum vulgare*), wheat (*Triticum spp*), rice (*Oryza sativa*) and different pulse crops, finger millet (*Eleusine coracana*), fruits, different types of vegetables and spices.

Farmers in the district are using traditional plough drawn by oxen and maize is rotated with legume crops such as bean for maintaining soil fertility of cultivated lands and chemical fertilizers such as DAP and urea at the rates of 46 kg P_2O_5 ha^{-1} and 46 kg N ha^{-1} are applied for all types of crops grown in the district annually since 1995 when extension package program was launched around Bedele (BDAO, 2021). However, the yields are still low due to declining soil fertility and limited information on the right fertilizers with the right rates for the major crops grown in the district.

Experimental Site Selection

Bedele district was selected purposively for the experiment, because maize is the major crop grown widely in the district. Two specific experimental sites Alle and Abu were selected from model farmers in maize production based on the willingness of the farmers to provide their farmland for experimental purpose.

Soil Sampling and Analysis

After the experimental sites were identified, soil samples were collected from the experimental fields following zigzag pattern to increase precision (ICARDA, 2013). From each experimental field 15 disturbed soil samples were collected at depth of 0-20cm by using auger. For each site, one composite sample was prepared from the bulk samples for the determination of soil physicochemical properties of the soil before planting. Two undisturbed soil samples from both experimental sites for bulk density determination were taken by using core sampler following Jamison *et al.*, (1950) method. Soil bulk density (ρb) was measured and determined by measuring the volume of undisturbed soil sample collected using a core sampler and the sample was weighed after oven-dried at a temperature of 105^{o}C. Then, the result was calculated by the formula as described by Jamison *et al.*, (1950).

$$\rho b = \frac{\text{Mass of soil in gram}}{\text{Volume of soil in cm}^3} \quad \ldots(1)$$

The composite soil samples were air dried, ground using a pestle and mortar and allowed to pass through a 2 mm sieve for all parameters except organic carbon and total nitrogen and through a 0.5 mm sieve for organic carbon and total nitrogen. The collected samples were analyzed for selected physicochemical properties mainly for soil texture, soil pH, exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+), cation exchange capacity (CEC), organic carbon (OC), total N, available P, available S, and available B at Bedele Agricultural Research Center Laboratory. Soil texture was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). Soil pH was determined in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter (Rhoades, 1982). Organic carbon was determined as described by Walkely and Black (1934). Exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with 1M ammonium acetate at pH 7, then exchangeable Ca^{2+} and Mg^{2+} were determined from the extracted solution with atomic absorption spectroscopy (AAS) method, whereas exchangeable K^+ and Na^+ were determined with flame photometer (Rowell, 1994).

To determine the cation exchange capacity (cmol(+) kg^{-1} soil), the soil sample first was leached using 1 M ammonium acetate, washed with ethanol and the adsorbed ammonium was replaced by sodium (Na).

Then, the CEC was determined titrimetrically by distillation of ammonia that was displaced by Na (Sahlemedhin and Taye, 2000). Percent base saturation was calculated by dividing the sum of the base forming cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+)) by CEC of the soil and multiplying by 100.

$$\text{PBS}(\%) = \frac{\text{Sum of exchangeable bases (Ca, Mg, Na and K)}}{CEC} * 100 \quad \ldots(2)$$

Available phosphorus in soil was determined by the Bray-II (Bray and Kurtz, 1945) extraction method. Total nitrogen was analyzed by Kjedahl method as described by Bremner and Mulvaney (1982). Available S was determined by KH_2PO_4 extractant (Johnson and Fixen, 1990). Available B was estimated by hot water extraction method (Havlin *et al.*, 1999).

Description of Experimental Materials

Maize variety

Maize variety BH-661, which was released by Bako Agricultural Research in 2011 was used as a test crop. It performs well in altitudinal range of 1600-2200 masl with annual rainfall amount ranging from 1000-1500 mm. It can give grain yield of 95-120 and 65-85 q ha^{-1} under research station and farmers field, respectively (BARC, 2011).

Types of fertilizers

Blended NPSB fertilizer was used as a source of N, P, S and B. This Blended fertilizer contains 18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B. Urea was used as a supplementary source of nitrogen (46%).

Experimental Design and Treatments

The experiment was arranged in randomized complete block design (RCBD) with three replications. Treatments were nine levels of blended NPSB fertilizer rates, (0, 25, 50, 75, 100, 150, 200, 250 and 300 kg ha^{-1}) with 92 kg ha^{-1} of nitrogen which was recommended for maize production in Bedele district (Dagne, 2015). The treatment was decided standing from blanket recommendation 100 kg ha^{-1} which is commonly used by the farmers in the district for all types of crops. Urea was used as a supplementary source of nitrogen for all treatments.

The nine levels of blended NPSB fertilizer rates were compared to each other to determine the optimal rate. Since, nitrogen is the most limiting factor for plant growth and is found in low amount in blended fertilizer, urea was applied in split applications to all plots.

The plot size was 3 m x 4 m ($12m^2$). The test crop was also planted in rows with 1m x 0.5 m x 0.8 m x 0.5 m spacing between blocks, plots, rows and plants respectively (BARC, 2011). The Maize variety of BH-661 was planted in 2021 cropping season at seed rate of 50,000 seeds/ha (BARC, 2011).

Management of the Experiment

The experimental fields were ploughed using local plough (Maresha) according to farmer's conventional farming practices. The fields were ploughed three times, before planting. The land was plowed and made suitable for crop planting.

All cultural practices were applied in accordance to the farmer's practices for maize production. Full rate of blended NPSB fertilizer was applied at planting as per the rates of the treatments and urea was applied in split applications to all plots 30 days after planting and at tasseling stage. Other necessary agronomic management practices such as weeding and pest control were carried out uniformly for all treatments.

Crop Data Collection

Phenological and growth parameters of maize

Days to 50% tasseling

Days to tasseling was recorded based on number of days from planting up to when 50% of plants shed pollen.

Days to 50% silking

Days to 50% silking was recorded as the number of days require from planting to when 50% of the maize plant showed extrusion of silks in each plot. Both days to 50% tasseling and silking were determined based on visual observation.

Plant height (m)

Plant height (m) was measured from ground level to tassel of three (3) randomly selected plants from three central rows. A carpenter's (measuring) tape was used for measuring the height.

Cob length (cm)

Cob length (cm) was measured from the point where the cob is attached to the stem to the tip of the cob from three (3) randomly selected plants in central net plot at crop harvest.

Yield and yield components of maize

Number of rows per cob

Number of row per cob was counted from three cobs and the average was used for analysis.

Number of grain per cob

Number of grain per cob was calculated by counting the number of grains in three cobs of the three central rows of each sub-plot and their average was calculated.

Grain yield (kg ha^{-1})

Grain yield (kg ha^{-1}) was measured by husking and cleaning the grain from three central row plants (net plot area) and converted to kg ha^{-1}

Thousand grains weight (gm)

Thousand grains weight (gm) was determined based on the weight of 1000 grains sampled from the sample used to determine grain yield of each treatment.

Aboveground dry biomass yield (kg ha^{-1})

Aboveground dry biomass yield (kg ha^{-1}) of plants from the net plot area was harvested at physiological maturity and weighed after sun-dried to determine aboveground biomass yield

Stalk yield (kg ha^{-1})

Stalk yield (kg ha^{-1}) was calculated by subtracting grain yield from the above ground dry biomass yield. Harvest index (%) was calculated as the ratio of grain yield to the above ground dry biomass yield expressed as percentage.

$$\text{HI (\%)} = \frac{\text{Grain yield (kg/ha)}}{\text{Above ground dry biomass (kg/ha)}} * 100 \quad \ldots(3)$$

Statistical Data Analysis

After harvesting the data collected from both sites were pulled together and subjected to statistical analysis of variance (ANOVA) using SAS version of 9.3 (SAS, 2004). Significant difference between and among treatment means were assessed using Duncan's multiple range taste (DMRT) at 0.05 level of probability (Gomez and Gomez, 1984).

Partial Budget Analysis

Economic analysis was made using the prevailing inputs at planting and for outputs at the time of crop was harvest. Partial budget was calculated for average yield of the different treatment combinations. At the time of harvest the market price of maize grain was 12 ETB kg^{-1}. The variable cost was calculated by multiplying the price of blended NPSB fertilizer (17.182 ETB ha^{-1}) with the amount of blended NPSB fertilizer rate applied to each treatment. The cost of other production practices like ploughing, planting and weeding were assumed to remain the same or insignificant among the treatments. Analysis of the marginal rate of return (MRR %) was carried out for non-dominated treatments, and the MRRs were compared to a minimum acceptable rate of return (MARR) of 100% to select the optimum treatment (CIMMYT, 1988).

Results and Discussion

Maize Phenological Growth, Yield and Yield Components

The major agronomic parameters and yield components measured for this study include days 50% to tasseling, days 50% to silking, number of cobs per plot, cob length, number of rows per cob, plant height, total above ground biomass yield, number of grains per cop, thousand grains weight, grain yield, harvest index and stalks yield. All the data on these parameters were recorded and analyzed statistically.

50% Days to tasseling and silking

Regarding days to 50% tasseling and silking, there was significance difference ($p<0.05$) among blended fertilizer rates. The shortest length of time to tasseling and silking (76.66 and 83.66 respectively) were recorded from the treatment treated with 300 kg ha^{-1} of NPSB fertilizer (T9), followed by the treatment treated with 250 kg ha^{-1} of fertilizer (T8). On the other hands, the longest days to tasselling and silking (90 and 97, respectively) was recorded for maize grown on the control plot (Table 5). The higher fertilizer use leads the crop to enhanced growth and ultimately the crop tassel early instead of lengthy vegetative growth. In line with this result, Uwah *et al.*, (2011) reported a reduction in number of days to 50% tasselling in maize with increased rates of blended fertilizers. Dagne (2016) also reported similar results with this finding.

Number of cobs per plot, cob length, rows per cob, grains per cob and thousand grains weight

The results of the study revealed that there was highly significant ($p<0.01$) difference among number of cobs per plot due to levels of blended NPSB fertilizer. The highest cob number (39) was counted from the plot that received 300 kg ha^{-1} of NPSB fertilizer rate, followed by cob numbers of 38, 37 and 37 from the plots that received 250, 200 and 150 kg ha^{-1} of blended NPSB fertilize rates respectively, whereas the lowest (25) cob number was recorded on the control plot followed by (27) cobs from the plot that received 25 kg ha^{-1} of blended NPSB fertilizer rate (Table 6). This might be due to the fact that plants that received optimum blended fertilizer were in a position to hold two or more cobs per plant. Number of cobs per plant is determined by prolific ability of the Maize variety (Adefris *et al.*, 2015) and the growth behavior of the crop which is dependent upon management practices and climatic factor. In line with this study Fufa *et al.*, (2019) reported the highest cob number from the plot that received the highest blended NPSB fertilizer rate. Accordingly, Besufikad and Tesfaye (2019) also reported the interaction of optimum plant population and fertilizer rate improve the number of cobs. Likewise, Mehta *et al.*, (2005) reported that application of 60kg P_2O_5 gave more number of maize cobs as compared to 40kg P_2O_5 and control.

Regarding cob length, the result obtained from the study showed that there was highly significant ($p<0.01$) difference in cob length due to application of different rates of blended NPSB fertilizer. Accordingly, the longest (18.83 cm) cob was recorded from the treatment that received 300 kg ha^{-1} of blended NPSB fertilizer rate followed by (18.52 cm) from the plot that received 250 kg ha^{-1} of blended NPSB fertilizer; whereas the shortest (15.8 cm) cob length was recorded on the control plot followed by (16.61cm) from the plot that received 25 kg ha^{-1} fertilizer rate (Table 6). The increment in cob length might be due to an increase in cell elongation and more vegetative growth attributed to different nutrient content.

The result obtained from this study is in line with that of Raouf and Ali (2016), who reported that increased amount of fertilizer, increased the length of cobs when compared to the control plot. Fufa *et al.*, (2019) also reported the longest cob length record from fertilized plot than the control plot.

Regarding number of rows per cob, the results showed that ($p>0.05$) there was no significance difference among rows per cobs due to blended NPSB fertilizer rates (Table 6). This might be due to the fact that rows per cob in maize are formed at the early growth stage of maize, when there is less competition among plants for nutrients. This result agrees with the findings of Raouf and Ali (2016) who reported that the application of additional fertilizer did not significantly alter number of rows per cob.

Number of grains per cob is the prominent factor that influences yield in maize. The results from this study indicated that application of different rates of blended NPSB fertilizer highly significantly ($p<0.01$) affected the number of grains per cob. Accordingly, the highest number of grains (553) per cob was recorded on the plot that received 300 kg ha^{-1} of blended NPSB fertilizer followed by (539) grains recorded on the plot treated with 250 kg ha^{-1} of NPSB fertilizer; and the lowest number of grains (426) per cob was obtained from the control plot followed by (467) grains from the plot that received 25 kg ha^{-1} of blended NPSB fertilizer rate (Table 6). This might be due to the fact that plants provided with sufficient blended NPSB fertilizer rate may have higher capacity to efficiently utilize other nutrients from the growing media and produce bigger cobs that produce higher number of grains per cob. (Fufa *et al.*, 2019) also reported the highest number of grains from the plot treated with the highest rate of blended NPSB fertilizer rate and the lowest from the control plot.

Regarding thousand grain weight, the result from this study showed that thousand grain weight was highly significantly ($p<0.01$) affected by application of different rates of blended NPSB fertilizer. Accordingly, the highest thousand grain weight 402.25 gm was obtained from the plot treated with 300 kg ha^{-1} of blended NPSB fertilizer rate followed by 386.35 gm from the plot that received 250 kg ha^{-1} of NPSB fertilizer rate. The lowest thousand grain weight, 295.32 gm, was recorded on the control plot, followed by 314.32 gm from the plot that received 25 kg ha^{-1} of blended NPSB rate (Table 6). The increment in thousand grain weight with increased rate of blended NPSB may be due to the fact that phosphorous fertilizer plays great role in root and shoot development and in grain filling of the crops. Similarly, Dagne (2016) found that application of blended fertilizer significantly increased thousand grain weights as compared to recommended NP and control plot.

Plant height

Plant height of maize was significantly ($p<0.01$) increased by the application of different rates of blended NPSB fertilizer. Accordingly, the longest plant (3.14 m) plant height was measured on the plot that received 300 kg ha^{-1} of blended NPSB fertilizer rate (T9) followed by (3.08 m) on the plot that received 250 kg ha^{-1} of NPSB fertilizer rate; whereas the shortest (2.49 m) plant height was recorded on the control plot followed by the (2.61 m) height recorded on the plot that received 25 kg ha^{-1} of blended NPSB fertilizer rate (Table 7). In general, this study indicated an increase in plant height with increased blended fertilizer rates from 0 to 300 kg ha^{-1}.

The increment in plant height might be due to an increase in cell elongation and more vegetative growth attributed to different nutrient content. The result gained from this study agrees with that of Knife *et al.*, (2019), who reported that, plant growth and development declines if any of the essential elements are less than their threshold values in the growing media or not adequately balanced with other essential plant nutrients.

Grain yield, harvest index, stalk yield and total aboveground dry biomass yield

Mean grain yield of maize was significantly ($p<0.01$) increased by application of different rates of blended NPSB fertilizer. Accordingly, the highest grain yield 7272.5 kg ha^{-1} was obtained from the treatment treated with 300 kg ha^{-1} of blended NPSB fertilizer rate, followed by 7261.6 kg ha^{-1} from the plot that received 250 kg ha^{-1} of NPSB, whereas the lowest mean grain yield 1836.8 kg ha^{-1} was recorded on the control plot (T1) followed by 2496.5 kg ha^{-1} from the plot that received 25 kg ha^{-1} of NPSB fertilizer (Table 8).

The mean grain yield of maize 7272.5 kg ha^{-1} of the study area surpassed the national average yield 5800 kg ha^{-1} (FAOSTAT, 2019) and 4200 kg ha^{-1} (CSA, 2020). This might be due to combined effect of nutrients like nitrogen, phosphorus, sulfur and boron in blended fertilizer, which might have enhanced growth and development of the crop. Optimum fertilizer application nourishes and supplies nutrients required for good productivity. The optimum nitrogen, phosphorous, sulfur and boron levels might have helped in the efficiency of absorption and utilization of other required plant nutrients that ultimately increase the grain yield of maize.

Fayera *et al.*, (2014) reported that, the increase in grain yield might be due to the effect of balanced nutrients in improving crops agronomic performance, thereby enhancing nutrient use efficiency. Smilarly, Jafar (2018) found better grain yield from application of blended fertilizer compared to recommended NP fertilizer and control plot. Moreover, Fufa *et al.*, (2019) also reported the highest grain yield of maize from application of 150 kg ha^{-1} of NPSB fertilizer with 92 kg ha^{-1} of nitrogen in split application. Similar grain result was also reported by Onasanya (2009) in maize research, whereby up to certain levels of fertilizer rate, the yield of maize increased proportionally.

Result obtained from this study indicated also that the **%** HI was significantly ($p<0.01$) affected by application of different rates of blended NPSB fertilizer. The highest value of 53.25% HI was obtained due to the application of 150 kg ha^{-1} of blended NPSB fertilizer with recommended nitrogen. The second highest 46.55% HI was obtained from the plot treated with 200 kg ha^{-1} of NPSB fertilizer. The lowest value 25.9% HI was recorded on the control plot followed by 28.97% from the treatment that received 25 kg ha^{-1} of NPSB fertilizer (Table 8). High harvest index indicates the presence of good partitioning of biological yield to economic yield. Generally, harvest index (%HI) indicates the balance between the productive parts of the plant and the reserves, which form the economic yield. This result is in agreement with the finding of Awoke and Muhaba (2021), who reported that application of different rates of inorganic fertilizer levels had a significant effect on the maize harvest index.

Table.1 Effects of blended NPSB fertilizer rates on days to 50% tasseling and silking

NPSB fertilizer rates (kg ha^{-1})	50% DT	50% DS
0	90^{a}	97^{a}
25	86.66^{ab}	93.66^{ab}
50	85^{abc}	92^{abc}
75	84.16^{abc}	91.16^{abc}
100	81.66^{abc}	88.66^{abc}
150	80b^{c}	87b^{c}
200	80b^{c}	87b^{c}
250	78b^{c}	85.33^{bc}
300	76.66^{c}	83.66^{c}
LSD(0.05)	8.9	8.9
CV (%)	9.28	8.55

DT=Days to tasselling, DS=Days to silking, CV=Coefficient of variance; LSD= Least significant difference at 5% level

Table.2 Effects of blended NPSB fertilizer rates on number of cobs per plot, cob length, number of rows per cob, number of grains per cob and thousand grains weight.

NPSB fertilizer rates (kg ha^{-1})	NCPP	CL(cm)	NRPC	NGPC	TGW (gm)
0	25^{e}	15.86^{g}	12.33^{a}	426.33^{f}	295.32^{g}
25	27de	16.61^{fg}	12.66^{a}	467.17^{e}	314.32^{fg}
50	29^{cd}	16.94^{ef}	13^{a}	473.00^{de}	331.75^{ef}
75	31^{bc}	17.33^{def}	13^{a}	490.33^{cd}	341.87^{de}
100	33^{b}	17.50^{cde}	13^{a}	496.33^{c}	348.03de
150	37^{a}	17.91^{bcd}	13^{a}	522.83^{b}	357.03^{cd}
200	37^{a}	18.19^{abc}	13.16^{a}	529.17^{b}	376.47^{bc}
250	38^{a}	18.52^{ab}	13.16^{a}	539.00^{ab}	386.35^{ab}
300	39^{a}	18.33^{a}	13.16^{a}	553.17^{a}	402.25^{a}
LSD(0.05)	2.85	0.83	0.97	20.71	20.36
CV (%)	7.38	4.07	6.49	3.56	4.99

NCPP=Number of cobs per plot; CL=Cob length; NRPC= Number of rows per cob; NGPC=Number of grains per cob; TGW=Thousand grains weight; CV=Coefficient of variance; LSD= Least significant difference at 5% level

Table.3 Effects of blended NPSB fertilizer rates on plant heights

NPSB fertilizer rates (kg ha^{-1})	PH (m)
0	2.49^{e}
25	2.61^{d}
50	2.68^{cd}
75	2.75^{bc}
100	2.85^{b}
150	3.02^{a}
200	3.03^{a}
250	3.08^{a}
300	3.14^{a}
LSD(0.05)	0.119
CV (%)	3.58

PH=Plant height; CV=Coefficient of variance; LSD= Least significant difference at 5% level

Table.4 Effects of blended NPSB fertilizer rates on grain yield, harvest index, stalk yield and above ground dry biomass yield

NPSB fertilizer rates (kg ha^{-1})	GY (kg ha^{-1})	(HI %)	SY (kg ha^{-1})	AGDBY (kg ha^{-1})
0	1836.8^{d}	25.91^{e}	5424^{d}	7261^{f}
25	2496.5^{cd}	30.52^{de}	6156^{cd}	8328^{ef}
50	2597.2^{cd}	28.97^{de}	6502^{cd}	9099^{ef}
75	3596.9^{c}	33.44^{cde}	6988^{cd}	10381de
100	4740.7^{b}	40.79^{bc}	7185^{cd}	11926^{cd}
150	7173.6^{a}	53.25^{a}	6208^{cd}	13215^{c}
200	7183.1^{a}	46.55^{ab}	8367^{cb}	15500^{b}
250	7211.6^{a}	42.79^{bc}	9908^{b}	17170^{b}
300	7272.5^{a}	37.16^{bcd}	12578^{a}	19851^{a}
LSD(0.05)	1126.1	9.78	2290.3	2212.6
CV (%)	19.14	22	25.5	15.17

GY=Grain yield; HI=Harvest index; SY=Stalk yield; AGDBY= Above ground dry biomass yield, CV=Coefficient of variance; LSD= Least significant difference at 5% level

Table.5 Correlation coefficients among maize grain yield, yield components and available soil nutrients

	AGDB	NCPP	CL	NRPC	NGPC	TKW	DT	DS	GY	HI	pH	OC	TN	P	B	S
AGDB	1.00															
NCPP	0.725***	1.00														
CL	0.584***	0.749***	1.00													
NRPC	0.332**	0.081ns	0.266ns	1.00												
NGPC	0.737***	0.857***	0.869***	0.198**	1.00											
TKW	0.754**	0.829***	0.759***	0.289**	0.803**	1.00										
DT	-0.296**	-0.421***	-0.702***	-0.159ns	-0.521***	-0.491***	1.00									
DS	-0.296**	-0.421***	-0.703***	-0.159ns	-0.521***	-0.491***	1.000***	1.00								
GY	0.813***	0.813***	0.626***	0.289**	0.743***	0.838***	-0.398***	-0.398***	1.00							
HI	0.264ns	0.579***	0.490***	0.120***	0.489***	0.609***	-0.428***	-0.4278***	0.758***	1.00						
OC	0.290*	0.188ns	0.043ns	0.191ns	0.031ns	0.242ns	0.258ns	0.258ns	0.323*	0.188NS	-0.312*	1.00				
TN	0.297*	0.194ns	0.055ns	0.199ns	0.021ns	0.245ns	0.273*	0.273*	0.329*	0.191ns	-0.323*	0.992***	1.00			
P	0.626***	0.68***	0.681***	0.121ns	0.669***	0.689***	-0.616***	-0.616***	0.601***	0.390***	-0.397***	0.029ns	0.036ns	1.00		
B	0.879***	0.840***	0.760***	0.294*	0.841***	0.787***	-0.444***	-0.444***	0.794***	0.404***	-0.471***	0.165ns	0.177ns	0.660***	1.00	
S	0.807***	0.663***	0.588***	0.448***	0.659***	0.732*	-0.227ns	-0.228ns	0.658***	0.247*	-0.447***	0.313*	0.325*	0.506***	0.762***	1.00

AGDB=Above ground dyr biomass, NCPP=Number of cobs per plot, CL=Cob length, NGPC=Number of grains per cob, TKW=Thousand kernels weight, DT=Days to tassiling, DS=Days to silking, GY=Grain yield, HI=Harvest index, pH=Soil pH, OC=Organic carbon, TN=Total nitrogen, P=Available phosphorus, B=Available boron, S=Available sulfur, NS, *, ** and ***, Non-significant, Significantly different at 0.05, 0.01, 0.001 probability levels respectively

Table.6 Partial budget analysis of blended NPSB fertilizer rate for maize production

NPSB (kg ha^{-1})	Av.yld (kg ha^{-1})	Adj.yld (kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
0	1836.8	1653.12	19837.44	0	19837.44	0
25	2496.5	2246.85	26962.2	429.55	26532.65	1558
50	2597.2	2337.48	28049.76	859.1	27190.66	153
75	3596.9	3237.21	38846.52	1288.65	37557.87	2413
100	4740.7	4266.63	51199.56	1718.2	49481.36	2775
150	7173.6	6456.24	77474.88	2577.3	74897.58	2957
200	7183.1	6464.79	77577.48	3436.4	74141.08	D
250	7211.6	6490.44	77885.28	4295.5	73589.78	D
300	7272.5	6545.25	78543	5154.6	73388.4	D

Av.yld= Average yield, Adj.yld=Adjusted yield, GFB=Gross field benefit, TVC=Total variable cost, NB=Net benefit, MRR=Marginal rate of return

Fig.1 Location map of the study area and experimental sites (Alle and Abu)

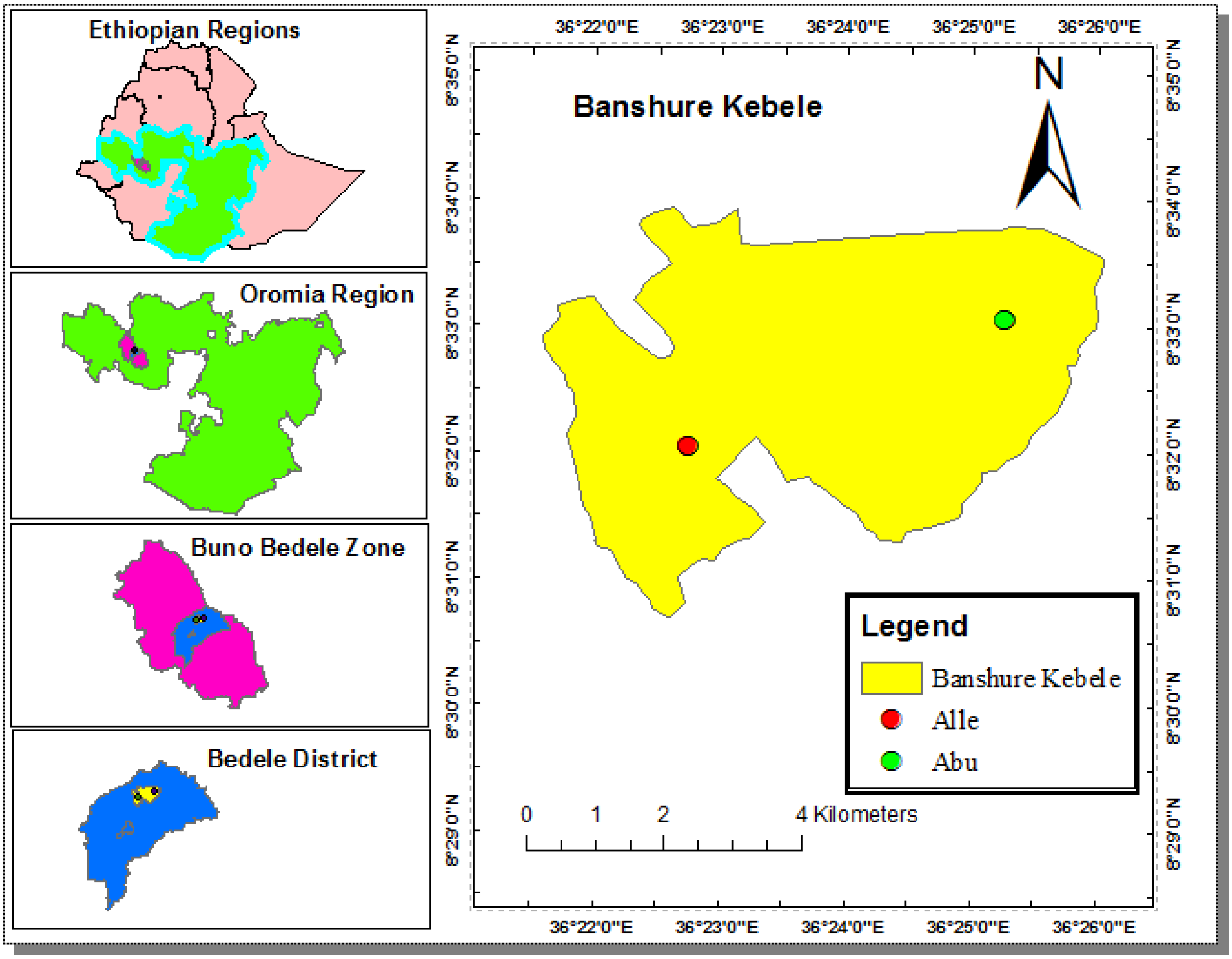
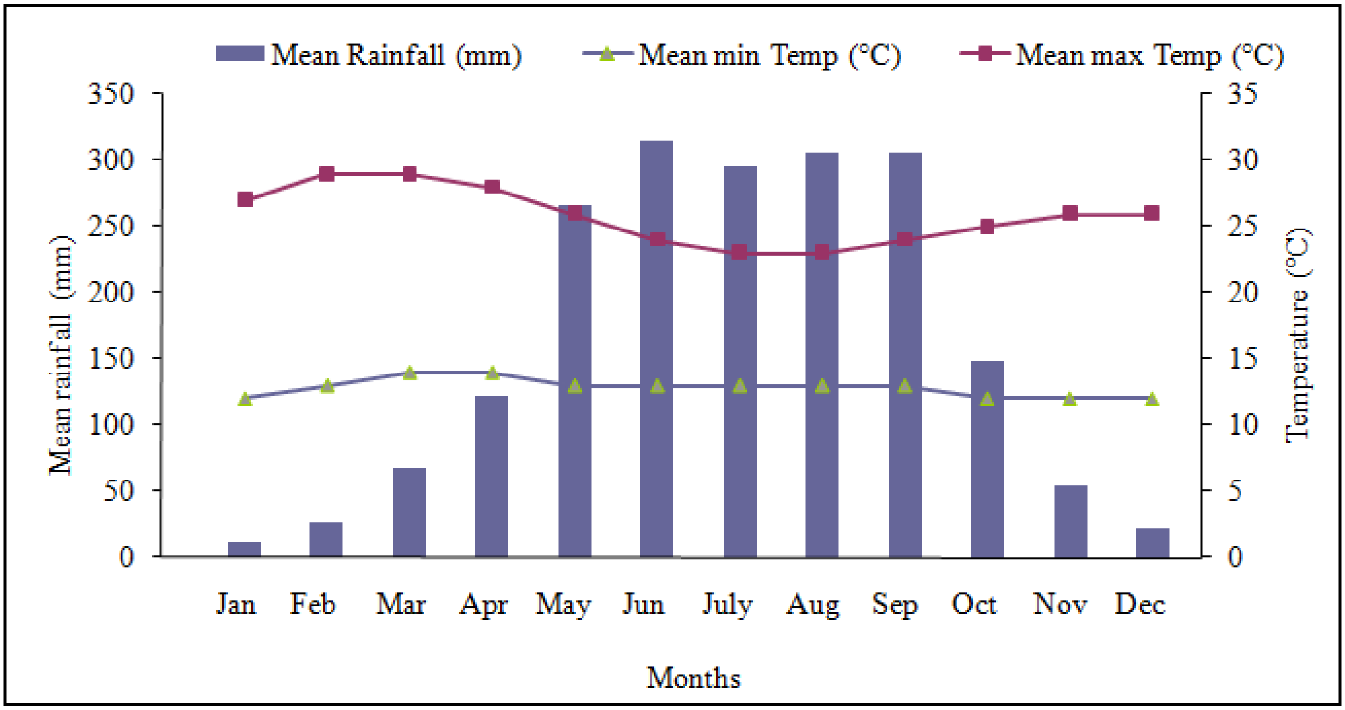


Fig.2 Mean monthly rainfall and maximum and minimum temperature of Bedele district (2021)



Regarding stalk yield, analysis of variance showed that stalk yield was significantly ($p<0.01$) increased by application of different rates of blended NPSB fertilizer. The highest stalk yield 12578 kg ha^{-1} was obtained from the treatment treated with the highest blended fertilizer rate, whereas the lowest stalk yield 5424 kg ha^{-1} was recorded from the control plot (Table 8).

Increasing blended fertilizer rates from 0 to 300 kg ha^{-1} significantly increased maize stalk yield. Plants grown on plots treated with higher rate of balanced nutrients might have been more initiated for vegetative growth, good photosynthesis and higher cell division that can in turn influence the stalk yield. Fagera *et al.*, (2011) also reported the highest stalk yield of maize from the plot received highest fertilizer rate and the lowest from the control plot.

Regarding total aboveground dry biomass yield, application of different rates of blended NPSB fertilizer showed a significant ($p<0.01$) variation. Accordingly, the highest total aboveground dry biomass yield (19851 kg ha^{-1}) was obtained from the treatment supplied with 300 kg ha^{-1} of NPSB fertilizer rate (T9) followed by (17170 kg ha^{-1}) from (T8), which received 250 kg ha^{-1} of NPSB fertilizer rate. The lowest aboveground dry biomass yield (7261 kg ha^{-1}) was obtained from the control plot followed by 8328 kg ha^{-1} from the plot that received 25 kg ha^{-1} of NPSB fertilizer rate (Table 8). This may be due to sulfur that increases the formation of chlorophyll and encourage vegetative growth and boron that helps in nitrogen absorption.

These results are similar with those of Mekuanent and Kiya (2020), who observed a significant disparity in biomass yield of maize due to different blended fertilizer rates, whereby the highest blended fertilizer rate produced the highest above ground biomass yield; and the lowest biomass yield was gained from the treatment with the lowest fertilizer rate. The result of this study is in line also with the findings of Wubshet *et al.*, (2017), which revealed that the application of 150 kg ha^{-1} of blended NPSB fertilizer rate increased the biomass yield over the control.

Association between Maize Grain Yield, Yield Components and Soil Nutrients

A simple correlation analysis was done to consider the association of different agronomic parameters of the maize crop and soil nutrients. Both positive and negative associations between the parameters have been observed (Table 9). Grain yield exhibited positive and significant correlation with agronomic and yield components and negative correlation with 50% days to tasseling and silking. Grain yield was directly and significantly (p<0.01) positively correlated with number of rows per cob (0.289**) and significantly (p<0.001) positively correlated with above ground dry biomass yield (0.813***), number of cobs per plot (0.813***), cob length (0.626***), number of grains per cob (0.743***), thousand grains weight (0.838***) and harvest index (0.758***), whereas, it was significantly (P<0.001) negatively correlated with 50% days to tasseling (-0.398***) and silking (-0.398***).

This result indicated that, increased days to 50% tasseling and silking result in reduction of grain yield, while total above ground dry biomass yield, number of cobs per plot, cob length, number of grains per cob, thousand grains weight and harvest index have resulted in increasing maize grain yield. The results on the association of grain yield in this study agree with the findings of Gebreyesus (2008) who reported that, grain yield was positively and highly significantly associated with total above ground dry biomass and yield components of the crop.

Similar to above ground biomass and yield components, grain yield was significantly (p<0.05) positively correlated with soil organic carbon (0.323*) and total nitrogen (0.329*) as well as significantly (p<0.001) positively correlated with available phosphorus (0.601***), available boron (0.794***) and available sulphur (0.658***). The positive correlation between soil total nitrogen, available phosphorus, available sulphur and available boron indicates the soil nutrient status may affect grain yield and yield components directly. These findings were also in line with finding of Mahmood *et al.*, (2017) who reported a significant positive correlation was found among grain yield, soil total nitrogen and available phosphorus. Furthermore maize grain yield has a positive and significant correlation with biological yield and yield components as well as with nutrient contents of the soil and it has negative correlation with 50% days to tasseling and silking (Table 9).

Economic Feasibility of NPSB Fertilizer Rates for Maize Production

Economic analysis for each treatment was performed and income computed based on the current local market price of maize in study area. Net benefit was calculated by subtracting the total variable cost (TVC) from the gross field benefit (GFB) for each treatment. All variable costs were calculated excluding the price of other agronomic practices such as cost of seed, land preparation, sowing, weeding and harvesting since all those practices are uniform to all plots. The grain yield was adjusted downward by 10% to reflect the difference between the experimental field and the expected yield at farmer's field with farmer's practices from the same treatments (Agegnehu and Rezene, 2006).

Dominance analysis led to the selection of treatments ranked in increasing order of total variable costs (Table 10). For each pair of ranked treatments, the percent marginal rate of return (MRR) was calculated. The MRR (%) between any pair of un-dominated treatments was the return per unit of investment in fertilizer. Analysis of marginal rate of return (MRR) was carried out for non-dominated treatments and the MRRs were compared to a minimum acceptable rate of return (MARR) of 100% to select the optimum blended NPSB fertilizer rate (CIMMYT, 1988). The highest net benefit of 74897.58 ETB ha^{-1} with the highest marginal rate of 2957% was obtained from the plot treated with 150 kg ha^{-1} of blended NPSB fertilizer rate (T6). On the other hand, the lowest net benefits 19837.44 ETB ha^{-1} was obtained from the control plot.

Soil test based fertilizer recommendation that is based on actual limiting nutrients for a given crop will help to supply adequate plant nutrients. To avoid the deficiency of nutrient caused by blanket recommendation of DAP and Urea, Ethio-SIS tested the soils of Ethiopia and gave recommendation based on the actual limiting nutrients at Regional, Zonal, district and Kebele levels. Based on the limiting nutrients, blended NPSB fertilizer is recommended for Bedele district, even though the optimum rate of this fertilizer for major crops grown in the district was not known. Field experiment was conducted during the 2021 main cropping season (June to November months) in Bedele district on two farmer's fields with the objectives of assessing the effect of blended NPSB fertilizer rates on maize yield and yield components, and to identify the economically feasible rate of blended NPSB fertilizer for optimal yield of maize. The treatments consisted of nine levels of blended NPSB (0, 25, 50, 75, 100, 150, 200, 250, 300 kg ha^{-1}) fertilizer rates. The experiment was arranged as a randomized complete block design with three replications. Maize variety named 'BH-661' was used as a test crop. The fertilizer materials used were urea (46%N) and blended NPSB (18.9%N, 37.7%P_2O_5, 6.95% S and 0.1%B).

All necessary maize yield and yield components were recorded and analyzed using SAS software. Accordingly, economically feasible grain yield (7173.6 kg ha^{-1}) and the highest harvest index (53.25%) were recorded from the plot treated with 150 kg ha^{-1} of blended NPSB fertilizer rate with the recommended nitrogen 92 kg ha^{-1}N for maize production in the district. The longest plant height (3.14 m), the highest above ground dry biomass (19851 kg ha^{-1}), number of cobs per net plot (39), cob length (18.83 cm), number of row per cob (13.16), number of grains per cob (553), thousand grains weight (402.25 gm) and stalk yield (12578 kg ha^{-1}) were recorded at NPSB rate of 300 kg ha^{-1}; which were statistically significant. Number of rows per cob was not significantly influenced by application of blended NPSB fertilizer rates.

The partial budget analysis revealed that application of 150 kg ha^{-1} of blended NPSB fertilizer rate gave the best economic net benefit of (74897.58 ETB ha^{-1}) with the marginal rate of return of 2957%. Therefore, it can be concluded that application of 150 kg ha^{-1} of NPSB fertilizer with the recommended nitrogen (92 kg ha^{-1}N) can be tentatively recommended for production of maize in the study area and other areas with similar agro-ecological conditions without affecting the soil properties negatively. However, since the experiment was conducted for one cropping season on two locations, repeating the experiment over seasons and locations using BH-661 maize and other improved varieties seems inevitable to make conclusive recommendation.

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