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Effect of Nutrient Omitting on Phonological Parameters and Growth Performance of Maize (*Zea mays* L.) at Omo Nada District, Jimma Zone, Southwestern Ethiopia

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Abstract: A plant nutrient is a chemical element that is essential for direct effect on plant growth and yield when it is applied based on soil nutrient level and crop requirement. Thus, a field experiment was conducted during 2019/20 cropping season to identify the most influential nutrient on the phonological and vegetative performance of maize on Nitisols of Omo Nada District, Southwestern Ethiopia. Nine combination of mineral fertilizers including one control plot with a total of ten treatments (NP, PKS (-N), NKS (-P), NPS (-K), NPK (-S), NPKS, NPKSZn (-B), NPKSB (-Zn) and NPKSZnB) were used. The experiment was laid out in Randomized Complete Block Design (RCBD) each replicated four times. The collected data was subjected to ANOVA using SAS 9.3 version software. LSD test was used to separate means at 5% level of significant ($P<0.05$). Accordingly, most of phonological and growth parameters were significantly affected due to combined application of major macronutrients (NPKS) with micronutrients (Zn), where non-fertilized and N omitted plots were inferior in all parameters. The results revealed that combined application of NPKS and Zn fertilizer significantly affected days to 50% tasseling, days to 50% silking, stem diameter, NDVI value, leaf area index and plant height. Therefore, we can recommend that appropriate fertilizer usage will address problems of limiting nutrients in most smallholder maize fields once the nutrients are established.

Keywords: Limiting Nutrients, Phonological Parameters, Growth Performance

1. Introduction

Continuous depletion of soil fertility status is a major constraint for the reduction of crop yields recorded in farming systems of sub Saharan Africa (SSA). Identifying and application of exact nutrient sources based on crop requirement has become a major target to overcome food security problem [10]. Maize is one of the most important cereal crop cultivated in Ethiopia and ranks first in terms of production and productivity which accounts 3.67 t ha^{-1} but is much lower than its yield potential due to poor soil nutrients status [5]. Recent study conducted by [21] also confirmed that the productivity level of maize was lower than that of national productivity in Southern part of Ethiopia. Therefore, to increase the productivity and subsequently minimize shortage of food, it is imperative to identify soil nutrients limiting maize growth and production because maize is the most important food crop cultivated by smallholder farmers in Southwestern part of Ethiopia.

Regarding on nutrient demand, maize is an exhaustive crop having higher potential than other cereals and absorbs large quantities of nutrients from the soil during different growth stages. However, most soils cannot supply all essential plant nutrients in sufficient amounts to support good crop growth and yield and hence supplying nutrients based on plant need is one of the most effective means to increase nutrient uptake in crop plants as well as to improve quality [15]. Among essential plant nutrients Nitrogen (N), phosphorus (P), Sulfur (S) and potassium (K) are macronutrients that play a major role in plant growth and crop yields [17]. According to EthioSIS [6] in addition to macronutrients (NPKS), zinc (Zn) and boron (B) deficiencies are widespread in Ethiopian soil, while some soils are also deficient in copper, manganese and iron, which all potentially are bottlenecks to increase crop productivity.

In Ethiopia the existing fertilizer application is based on blanket recommendation which assumes the need of a crop for nutrients is similar over time and large areas. Research that aims to improve soil fertility management and productivity of small-scale farmers has to reckon with soil variation by identifying the most limiting nutrients and come up with flexible recommendations rather than blanket recommendations [13]. Therefore, there is a need to investigate crop response due to nutrient application to identify the most limiting nutrients in smallholder fields of Ethiopia. Insufficient application of nutrients and poor soil management practices along with harsh climatic conditions have contributed to the degradation of soils including soil fertility in developing countries [8]. Amongst of them, poor soil fertility is the principal factors that limit maize productivity in maize growing areas of Ethiopia [1].

Deficiency of essential nutrients in the soil system has been implicated to limit uptake of the nutrients, growth and yields of crops. However, soil fertility status varies spatially and temporally from place to place due to variation in land use, crop management practices, method of fertilizer applications, cropping system and indigenous soil nutrient status [16]. Understanding soil variability in relation to its application, distribution and causes is an important means for improving sustainable land use strategies and yield improvement. Majority of the soil fertility variation within farming systems is caused by spatial soil heterogeneity [22]. Smallholder farmers largely tackle soil variation by location-specific field management based on crop performance and crop responses they observed in their fields over past years. Research that aims to improve soil fertility management and productivity of small-scale farmers has to reckon with soil variation by identifying the most limiting nutrient elements and come up with flexible recommendations rather than blanket recommendations. Therefore this experiment was conducted to identify the most limiting nutrient for phonological parameters and growth performance of maize.

2. Materials and Methods

2.1. Description of Study Area

A field experiment was conducted in Nitisols of Omo Nada District South-western Ethiopia during 2019/20 rainy cropping season. The experimental sites was selected relatively to cover a broad range of major maize growing areas in the district, representing high rainfall agro-ecologies having gentle slopes, minimum soil heterogeneity and were enough to accommodate the proposed treatments. The temperature was ranged from a minimum of 12.64°C in April to the maximum of 28.36°C in December. The mean annual rainfall was 1198mm. The predominant soil type in Southwestern part of Ethiopia in general and the study area in particular is Nitisols which have reddish colour with moderately acidic in reaction. On the average, the soil is deep and relatively highly weathered well-drained, sandy clay in texture, highly weathered and strongly to moderately acidic in reaction.

2.2. Nutrient Set Up and Experimental Procedures

The experiment was conducted on farmers' fields during main rainy cropping season where farmers' fields were used as replication. The experimental treatments were; full nutrient [120 kg nitrogen (N)/ha as urea, 40 kg phosphorus (P)/ha as triple super phosphate (TSP), 40 kg potassium (K)/ha as muriate of potash (KCl), 20 kg sulfur (S)/ha as magnesium sulfate, 5 kg zinc (Zn)/ha as zinc sulfate and 2.5 kg (B) as Borax]; a full nutrient without N, full nutrient without P, full nutrient without K, full nutrient without S, full nutrient without Zn, full nutrient without B and plots without nutrient amendment were included for comparison. The experiment was laid out in a completely randomized block design (RCBD) with four replications. The net plot area of the site was 3.75m x 2.4m=9m^2. There was 0.3 m and 0.75m spacing between plants and each row respectively. BH-661 maize variety (with 160 average days to maturity) was used as a test crop and all nutrients (P, K, S, Zn, B) were applied at planting except N, which was applied in two equal splits, half at planting and the remaining half amount 21 days after planting. Urea, Triple super phosphate (TSP), Murate of Potash (KCl), Zinc Sulphate and Borax were used as sources of nutrient for supplying N, P, K, Zn and B, respectively. Agronomic management practices were done by researcher using appropriate control measures uniformly for all the trial.

3. Results and Discussion

3.1. Effect of Nutrient Omission on Phonological Parameters

3.1.1. Normalized Difference Vegetative Index (NDVI)

The mean value indicated that omitting nutrients highly significantly affected ($P<0.01$) NDVI value of maize. The maximum NDVI value (0.80) was recorded from application of NPKSZnB, which was similar with plots treated with NPKS and NPKSZn while, the minimum value (0.55) was recorded from control and N - omitted plots. The result shows a higher and balanced fertilization produced maize plants with a higher chlorophyll reflectance. Hence, canopy spectral reflectance might use as an indicator of N status of plants, thereby used as an indicator for avoiding yield losses by detecting N deficiency through remote sensing. It is important to save N when it is sufficient in the soil and plants at vegetative stage. Moreover, it is widely used to estimate crop growth in relation with maize leaf N content and grain yield. The current result was in agreement with the finding of [11, 20].

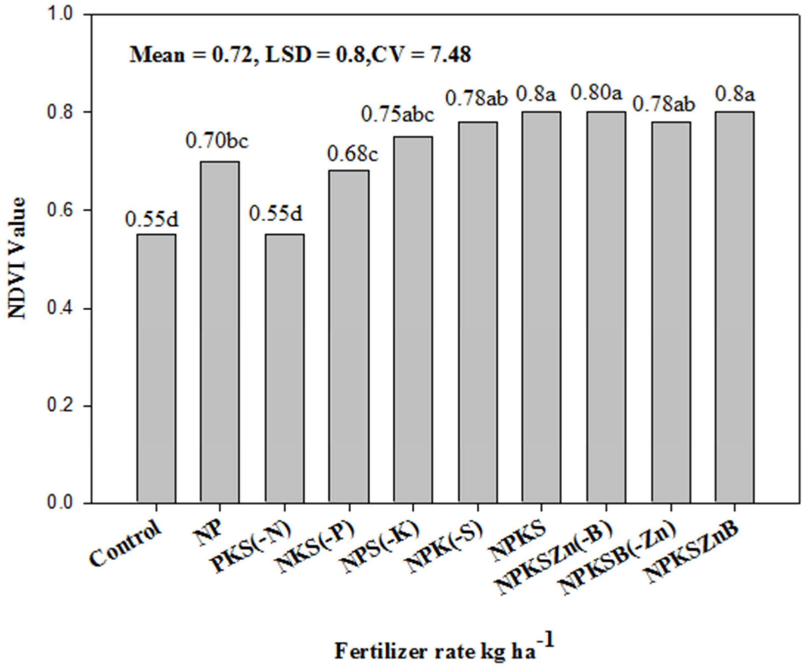

Figure 1. *Effect of nutrient omission on maize NDVI value.*

3.1.2. Days to 50% Tasseling

Application of mineral fertilizer had significant effect ($P<0.05$) on maize 50% tasseling and reduced the number of days required for tasseling compared with the control. Accordingly, the shortest days to 50% tasseling was recorded from application of 120 kg ha^{-1} N and 40 kg ha^{-1} P whereas the longest days to 50% tasseling was recorded from the control and N-omitted plots. Days to 50% tasseling hastened by 7.7% due to application of NP fertilizer over unfertilized plots. Optimum fertilization and increase N rate might have increased the rate of photosynthesis in the plant because maize crop accumulates more heat units (thermal time) to tasseling with increasing the rate of N and vice versa [4]. Sufficient amount of N applied in soil results in rapid growth, hastened tasseling, while too little or no N, resulted in slow growth, and delayed tasseling [12]. The current result was in agreement with the finding of [23] who observed a reduction in number of days to 50% tasseling in maize with increased rates of fertilizers. However, it contradicts with the finding of [2] who reported that control plot where no fertilizer was applied took significantly minimum number of days to tassel.

3.1.3. Days to 50% Silking

The shortest time needed to reach days to 50% silking was recorded from plots treated with 120kg ha^{-1} N and 40kg ha^{-1} P while, the longest days required to reach 50% silking was recorded from unfertilized plots (Table 1). Days to 50% silking was hastened by 8.6% due to application of NP compared to control plots. Application of N and P hastened days to silking because maize take up N and P from the soil which encouraged early establishment, rapid growth and development, thereby shortened days to silking whereas, under control plots plants haven't take up sufficient nutrients that caused the longest days to silking. Moreover, the decrease in days to 50% silking with NP fertilization might attribute due to P, which is known to enhance silking of maize. According to [3], the early phonological development in maize with P application probably might due to the increased root development and thus helped the plants to obtain more P to complete its life cycle quickly which is in conformity with the result of the current study.

3.2. Effect of Nutrient Omission on Growth Parameters

3.2.1. Plant Height

The ANOVA showed that there was a highly significant effect ($P<0.01$) on maize plant height via application of mineral fertilizers. The result ranged from 206.0cm to 294.0cm, recording the shortest plant height from the control and N-omitted treatment while the tallest plants from NPKSZn fertilized plots. The extent of plant height reduction due to nutrient omission was in the order of omitting N>P>NP>K>Zn>NPKSZnB>S and NPKS having 28.1%, 14.1%, 5.3%, 4.4%, 4.3%, 2.4% and 0.8% compared with NPKSZn fertilized plots, respectively indicating as the combination of nutrients increases, plant height was increased consistently up to a certain level. Similarly, the recommended NP fertilizer rate also significantly increased plant height by 26.04% over unfertilized plots. The result was in conformity with the finding of [9, 18] who reported that as the combination of macro and micronutrients are balanced up to optimum levels plant height can increase due to their effects on cell division and protein synthesis and it's partitioning to stems that might have favorable impacts on maize plant height.

3.2.2. Leaf Area Index (LAI)

Leaf area index values ranged from 2.3 to 4.6, recording the lowest value from non-fertilized crops while the maximum from combined application of major macronutrients (NPKS) and (Zn). The reason for an increase in LAI might be due to development of more expanded leaves produced in response to balanced application of nutrients thereby attributed to enhanced vegetative growth. This suggest that balanced application of mineral nutrients on maize increased leaf size in an attempt to maximize light interception and maximize the overall plant economy for acquisition of resources needed for growth and development thereby it has a primary importance in increasing the yield. According to [19], balanced fertilization of crops up to optimum level helps efficient utilization of nutrients that leads to high photosynthetic productivity and accumulation of high dry matter. This ultimately increases plant growth and development, which may result in improved yield attributes like leaf length and leaf size, thereby increased production [19]. This result was in conformity with finding of [14] who reported that growth and yield of maize in terms of leaf area index varied significantly due to various fertility levels.

3.2.3. Stem Girth (Diameter)

The maximum stem diameter (2.5cm) was obtained from application of NPKS, while the smaller stem diameters (1.7cm and 1.9cm) were recorded from control and N omitted plots, respectively. The significant difference among treatments might be attributed due to supplying of essential nutrients from both NPKS fertilizer which enhanced vegetative growth of crop and have a positive effect on maize stem girth. Stem girth is an important growth parameter, which influences carbon storage and its subsequent utilization for grain filling in maize. It contributes significantly to grain yield of maize because it controls both number of grains per cob and grain size. The higher nutrient uptake right at early stage of crop growth might be one of the reasons for improved vegetative growth. The increase in stem girth of maize under balanced fertilization might due to cell expansion, which induces sturdiness and healthiness of plants, including better root development. These findings were in line with findings of [7] who reported that highest stem girth was recorded from application of NPK (15-15-15 $kgha^{-1}$).

Table 1. *Effects of NOT on maize tasseling, silking, plant height, LAI and stem diameter.*

Treatments	Day to 50% Tasseling	Day to 50% Silking	Plant height (cm)	LAI	Stem girth (cm)
Control	84.00^{a}	88.30^{a}	206.00^{c}	2.28^{f}	1.70^{d}
NP	78.30^{c}	81.30^{c}	278.50^{a}	3.83^{cd}	2.30^{ab}
-N	84.30^{a}	87.30^{ab}	211.50^{c}	2.70^{e}	1.90^{c}
-P	83.50^{ab}	88.00^{a}	252.50^{b}	3.73^{d}	2.20^{b}
-K	79.30^{c}	82.00^{c}	281.10^{a}	4.13^{bc}	2.40^{ab}
-S	80.00^{bc}	83.00^{c}	291.00^{a}	4.48^{ab}	2.40^{ab}
NPKS	80.00^{bc}	83.00^{c}	291.70^{a}	4.38^{ab}	2.50^{a}
-B	79.00^{c}	82.00^{c}	294.00^{a}	4.63^{a}	2.30^{ab}
-Zn	81.50^{abc}	84.80^{abc}	281.50^{a}	4.35^{ab}	2.40^{ab}
All	81.50^{abc}	84.00^{bc}	287.00^{a}	4.35^{ab}	2.30^{ab}
Mean	81.10	84.40	267.50	3.90	2.20
SE (±)	0.53	0.48	60.40	0.07	0.02
F-value	36.22	57.23	72.81	35.77	13.19
P-value	<.0001	<.0001	<.0001	<.0001	<.0001
Sign	***	***	***	***	***

Means within a column followed by the same letter are not significantly different from each other at p<0.05. NS=not significant at P>0.05, *, ** and *** significant at P<0.05, p<0.01 and p<0.001, respectively.

4. Conclusion

Based on the results we can conclude that nutrient limitation in soils has led to a drastic decline in maize growth performance in most smallholder farms. The observation in this study that the full nutrient treatment out performed treatments where nutrient elements was omitted or the control without any amendment in almost all the parameters measured irrespective of the soil types, is indicative that poor soil fertility is a major determinant of crop performance in all the soils. In addition, maize growth and nutrient uptake is a function of soil types and the most limiting nutrient element also varied with soil types. However, nitrogen and phosphorus generally are the major limiting nutrient elements in the studied area. Therefore, appropriate fertilizer usage will address problems of limiting nutrients in most smallholder maize fields once the nutrients are established.

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