Determining Appropriate Fertilizer Scheme for Maize and Sorghum Cultivation in the Sahel Agroecological Zone of Cameroon

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ABSTRACT

The objective of this study was to investigate appropriate fertilization schemes to improve the production of maize and sorghum in the Sahel agroecological zone of Cameroon. The experiment was carried out in 2018 at IRAD (Institute of Agricultural Research for Development) Kismatari experimental field. The experimental setup was a complete randomized block design in four replicates and four treatments for each crop. For maize, treatments were: T1 (No input), T2 (100 kg NPK + 100 kg Urea.ha⁻¹), T3 (150 kg NPK + 150 kg Urea.ha⁻¹), and T4 (200 kg NPK + 200 kg Urea.ha⁻¹). For sorghum, treatments were: T1 (No input), T2 (50 kg NPK + 50 kg Urea.ha⁻¹), T3 (100 kg NPK + 100 kg Urea.ha⁻¹), and T4 (150 kg NPK + 150 kg Urea.ha⁻¹). All fertilizer treatments NPK and urea were applied to both crops respectively at 3 and 5 weeks after sowing. Nine weeks after sowing, the plant height was highest at T3, following by T2 and T4 for the two crops. The treatment
T1 exhibited the lowest grain yield while T2 and T3 showed intermediate grain yield. The treatment T4 produced the highest biomass, number of ears.plant$^{-1}$, and grain yield (maize: 3.3 t. ha$^{-1}$, sorghum: 2.9 t.ha$^{-1}$) for the two crops and thus appears to be the most appropriate fertilizer recommendation for maize and sorghum production in the Sahel zone. However, costs-benefits studies for the use of fertilizer NPK and urea are warranted to facilitate adoption by farmers in the agroecological zone.

Keywords: Fertilizer recommendation; grain yield; NPK; sorghum bicolor; urea; Zea mays.

1. INTRODUCTION

The primary sources of food energy in Cameroon are starchy roots and cereals, in particular maize (also known as corn), sorghum and rice [1]. Cameroon provides 0.20% of the total world production of maize. It is the most cultivated culture in the country. Besides being an outstanding staple food in most parts of the country, it is also used to produce livestock feed all over the country. Total production of this crop has increased significantly, from 360,000 metric tons in 1961 to 2,344,665 in 2018 [2]. Despite the importance of this crop, most farmers grow it in relatively small areas (0.4 to 0.6 ha), and the country is not self-sufficient [1]. Until the late 1980s, maize was widely regarded as a crop for domestic consumption only and was not considered a potential cash crop. However, with strong demand from breweries and the livestock sector, its production is gaining importance as a cash crop. The harvest provides about 12% of the country’s caloric and protein needs [1].

Sorghum is the 5th most cultivated cereal in the world. It contains a large number of nutrients including proteins, carbohydrates, various minerals, as well as vitamins B, C and F. Cameroon produces 2.39% of the world’s sorghum. This production increased from 255,000 tons in 1961 to 1,416,116 tons in 2018 [2].

Most of the soils on which these cereals are grown are degraded. Land degradation remains a primary global concern, due to its detrimental effects on biodiversity, agricultural production and food security. The broad zones of sub-Saharan lands, including Cameroon, are impacted by diverse types of degradation, such as declining fertility of the land [3]. The nutrient-balances are highly negative, and the signs of nutritional deficiencies are widespread. This situation is accentuated by intense farming [4], mismanagement of residues [5] and mediocre access to mineral dressings because of the high cost and uneven provisions [6]. Besides, there is restricted use of organic fertilizer because of the enormous areas of cultivable space and the ploughing requirements. The low level of soil fertility in cultivated land is also responsible for the increase in weed infestation in most fields, in this case, striga. It has therefore been hypothesized that a rise in soil fertility could reduce weed infestation and increase crop productivity in Cameroon.

Manure appliance has excellent potential to improve the nutrient content of deteriorated lands and raise the nutrient level of the plant [4,7]. The production data sheets currently recommend 100 kg of NPK + 150 kg of urea ha$^{-1}$ for the cultivation of maize and sorghum [8,9]. However, because of the complexity and heterogeneity of cropping systems in Cameroon, the recommendations for fertilizers must consider the agricultural environments and therefore, the inherent characteristics of the soil. Thus, an appropriate fertilization scheme is necessary for specific products under specific site-system conditions to obtain the best results which will be quickly adopted by users. The objective of this trial was to develop an appropriate fertilizer scheme to improve soil fertility and boost agricultural production of maize and sorghum.

2. METHODOLOGY

2.1 Study Site

Experiments were carried out in 2018 at an IRAD experimental field station of Garoua, particularly at Kismatari (Fig. 1). It belongs to the Sahel agro-ecological zone of Cameroon. The area is characterized by a monomodal rainfall pattern of varying duration and intensity. Temperatures vary with averages up to 28 °C in Garoua. The maxima are around 40 to 45 °C in April, and 400 to 1,200 mm.year$^{-1}$ is an interval rainfall recorded in the area [10,11]. Soil samples were randomly collected with an auger (0-15 cm) and thoroughly mixed to form a composite sample. The soil samples were air-dried and sieved through 2 mm...
screen to remove stones and plant debris and then sent to the laboratory for analysis.

2.2 Soil Analysis

Soil analytical data are usually derived from standard methods. Here the soil testing methods were based on those used by the Brookside Laboratories INC, New Bremen, USA. Soil pH was determined in the ratio of 1:1 soil–water suspensions using a digital pH meter [12]. Organic matter was determined by loss on ignition method at 360°C [13] and Estimated Nitrogen (N) Release which is a computed estimate of the N that may be released annually through organic matter decomposition was calculated based on the loss on ignition method. Sulphur (S), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), boron (B), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), aluminium (Al), and phosphorus (P) were determined after extraction with Mehlich III solution [14] and Total Exchangeable Cations (TEC) was obtained by summation of the cations [15]. The per cent of a given element found on the soils total exchange capacity was calculated, and these values add to 100 for any given sample. Phosphorus was also determined by the Bray II method [16]. Ammonium (NH₄⁺), and nitrate (NO₃⁻) which are the predominate forms of inorganic N in soils were determined by the 1 N KCl cadmium reduction method [17].

The soil of the study site (Table 1) is of clay type. Based on the United State Department of Agriculture Natural Resources Conservation classification of soil pH, the soil of Kismatari was slightly acidic (pH 6.1 – 6.5). According to guidelines elaborated for acid soils analyzed by Bray method, available P was medium in Kismatari soil [18]. According to Mehlich III method [19], available K (mg.kg⁻¹) was high (>60); Mg (mg.kg⁻¹) was high (>40); Ca (mg.kg⁻¹) was high (>1050 for silt loam soils); S (mg.kg⁻¹) was low (<20); Boron, Zn, and OM were low; Cu, Fe, and Mn were medium in the Kismatari soil. However, for cereal crops Cu < 2.0 mg.kg⁻¹ is recommended.

Fig. 1. Study site
Table 1. Physical and chemical characteristics of the study site soil (0-15 cm)

<table>
<thead>
<tr>
<th>Macronutrients</th>
<th>Value</th>
<th>Micronutrients and Physics features</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P^+</td>
<td>35.25 mg.kg⁻¹</td>
<td>B^+</td>
<td>&lt;0.20 mg.kg⁻¹</td>
</tr>
<tr>
<td>P Bray II</td>
<td>40.20 mg.kg⁻¹</td>
<td>Fe⁺</td>
<td>103.25 mg.kg⁻¹</td>
</tr>
<tr>
<td>Estimated N Release( N/acre)</td>
<td>30.00 mg.kg⁻¹</td>
<td>Mn⁺</td>
<td>89.8 mg.kg⁻¹</td>
</tr>
<tr>
<td>Total Exchange Capacity (TEC)</td>
<td>9.66 meq.100 g⁻¹</td>
<td>Cu⁺</td>
<td>1.88 mg.kg⁻¹</td>
</tr>
<tr>
<td>S⁺</td>
<td>2.80 ppm</td>
<td>Al⁺</td>
<td>326 mg.kg⁻¹</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>1292.50 mg.kg⁻¹/63.02%</td>
<td>Zn⁺</td>
<td>2.09 mg.kg⁻¹</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>194.40 mg.kg⁻¹/17.91%</td>
<td>OM (%)</td>
<td>0.78%</td>
</tr>
<tr>
<td>K⁺</td>
<td>93.00 mg.kg⁻¹/2.94%</td>
<td>pH</td>
<td>6.46</td>
</tr>
<tr>
<td>Na⁺</td>
<td>29.00 mg.kg⁻¹/1.48%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other bases</td>
<td>5.04%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H⁺</td>
<td>9.00%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.3 Plant Materials

The plant material consisted of the RVDT variety of maize and the Zouaye variety of sorghum produced by IRAD of Garoua.

2.4 Experimental Procedure

After ploughing and staking, each speculation was sown on 26th June at the rate of three grains per hole following an 80 cm × 25 cm and 80 cm × 40 cm pattern respectively for maize and sorghum. Complete Randomized Block Design in 4 replicates with 4 m × 4 m (16 m²) plot size was used for each crop. Thinning was done at 2 WAS to have two plants per stand. For maize experiment, treatments were:

- T1= No input control;
- T2= 100 kg NPK + 100 kg Urea per ha;
- T3= 150 kg NPK + 150 kg Urea per ha and
- T4= 200 kg NPK + 200 kg Urea per ha.

For sorghum experiment, treatments were:

- T1= No input control;
- T2= 50 kg NPK + 50 kg Urea per ha;
- T3= 100 kg NPK + 100 kg Urea per ha and
- T4= 150 kg NPK + 150 kg Urea per ha.

These doses of fertilizers were defined on the basis of that currently recommended for the culture of each crop [8,9]. The application of NPK was done 3 WAS (Week After Sowing) and urea 5 WAS. Manual weeding was done as required. Plant height was measured at 5, 7 and 9 WAS for maize and 4, 5, 6 and 9 WAS for sorghum. At harvest (15th October), the biomass, the number of ears and the grain yield were evaluated.

2.5 Data Analysis

The collected data were processed by an analysis of variance (ANOVA) using IBM SPSS Statistics 25 software. This analysis was preceded by the Kolmogorov-Smirnov and Shapiro-Wilk tests for normality on the one hand and the Levene test for the homogeneity of variances on the other hand. The Student-Newman-Keuls test at the 5% threshold was used to classify the means. The relationships between the parameters studied were highlighted by the Pearson correlation test.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Plant height

The doses of fertilizers provided significantly improved the plant height of maize (P = .000) and sorghum (4WAS: P = .001, 9 WAS: P = .000) as a function of time (Fig. 2).

Thus five weeks after sowing (WAS), the T2, T3 and T4 treatments significantly increased (P = .000) the height of the maize plants by 21.8, 41.1, and 50.9% respectively compared to T1 (control). The increase in plant height was 83.8, 115.3, and 58.9% for T2, T3, and T4 respectively compared to T1 (control) 7 WAS. From 7 WAS, the highest height was observed at T3. Thus, 9 WAS, there was no significant difference between the plant height of T2 and T4; however, the plant’s heights of these treatments were significantly (P = .000) lower than that of T3 (Fig. 2).

The plant height of sorghum was significantly (P = .001) higher at T3 compared to the other
However, at 5 and 6 WAS, there was no significant difference between the treatments tested for plant height. 9 WAS, the applied fertilizer doses (T2, T3, and T4) significantly improved \( (P = .000) \) the height of the sorghum plants by 17.8, 21.5, and 12.6% respectively compared to the control (T1). As in maize, the highest sorghum height was observed at T3 (Fig. 2).

### 3.1.2 Biomass and yield

The fertilizers tested significantly improved the biomass, the number of ears produced and the yield of both crops per hectare (Fig. 3).

In maize, T2, T3, and T4 significantly boosted \( (P = .008) \) the biomass by 50.0, 44.4 and 96.7% respectively compared to T1 (Fig. 3). The number of ears of maize produced by T2 and T3 was not significantly different from that of T1; however, that of T4 was significantly \( (P = .001) \) higher than that of other treatments. The treatments T2 (77.4%), T3 (62.1%), and T4 (156.0%) significantly \( (P = .000) \) increased the grain yield of maize compared to T1; the yield of T4 was more than twice as high as that of T1.

In sorghum, there was no significant difference between the biomass and the number of ears of control T1 and those of T2 and T3 (Fig. 3).

However, the biomass of T4 significantly exceeded \( (P = .007) \) those of T1, T2 and T3 by 48.9, 39.3, and 37.3% respectively. The number of ears of T4 significantly exceeded \( (P = .000) \) those of T1, T2 and T3 by 83.3, 64.6, and 65.5% respectively. Treatments T2 (57.1%), T3 (11.4%), and T4 (164.8%) significantly increased \( (P = .000) \) the grain yield of sorghum compared to T1; the yield of T4 was more than twice as high as that of T1 (Fig. 3).

### 3.1.3 Correlation between measured parameters

The maize yield (Table 2) was significantly and positively correlated with plant height \( (r_{\text{WAS}}: 0.74, P = .001; r_{\text{WAS}}: 0.56, P = .024) \), biomass \( (r: 0.76, P = .001) \) and the number of ears \( (r: 0.74, P = .001) \). The number of maize ears was significantly and positively correlated with biomass \( (r: 0.54, P = .033) \). The maize biomass was significantly and positively correlated with plant height \( (r_{\text{WAS}}: 0.56, P = .026) \).

The sorghum yield (Table 3) was significantly and positively correlated with the biomass \( (r: 0.73, P = .001) \) and the number of ears \( (r: 0.89, P = .000) \). The number of sorghum ears was significantly and positively correlated with biomass \( (r: 0.76, P = .001) \).
Fig. 3. Effect of fertilizers on biomass, number of ears and yield of maize and sorghum

Maize: T1=No input, T2=100 kg NPK + 100 kg urea ha\(^{-1}\), T3=150 kg NPK + 150 kg urea ha\(^{-1}\) and T4=200 kg NPK + 200 kg urea ha\(^{-1}\); sorghum: T1=No input, T2=50 kg NPK + 50 kg urea ha\(^{-1}\), T3=100 kg NPK + 100 kg urea ha\(^{-1}\) and T4=150 kg NPK + 150 kg urea ha\(^{-1}\). Mean ± Standard error (n = 4) with the same letter for each specie and for each parameter are not significantly different at the 0.05 probability level.

Table 2. Pearson correlation for maize

<table>
<thead>
<tr>
<th></th>
<th>PH_5WAS</th>
<th>PH_7WAS</th>
<th>PH_9WAS</th>
<th>Biomass</th>
<th>N*_ears</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH_5WAS</td>
<td>1</td>
<td>.581*</td>
<td>.706**</td>
<td>1</td>
<td>0.421</td>
<td>.740*</td>
</tr>
<tr>
<td>PH_7WAS</td>
<td>.581*</td>
<td>1</td>
<td>.835***</td>
<td>.555*</td>
<td>0.013</td>
<td>.385</td>
</tr>
<tr>
<td>PH_9WAS</td>
<td>.706**</td>
<td>.835***</td>
<td>1</td>
<td>.555*</td>
<td>0.013</td>
<td>.385</td>
</tr>
<tr>
<td>Biomass</td>
<td>.555*</td>
<td>.444</td>
<td>.497</td>
<td>1</td>
<td>0.217</td>
<td>.561</td>
</tr>
<tr>
<td>N*_ears</td>
<td>.421</td>
<td>.013</td>
<td>.217</td>
<td>.555*</td>
<td>1</td>
<td>.561</td>
</tr>
<tr>
<td>Yield</td>
<td>.740*</td>
<td>.338</td>
<td>.611</td>
<td>.764**</td>
<td>.739**</td>
<td>1</td>
</tr>
</tbody>
</table>

*PH: plant height; WAS: Week After Sowing; *, **, ***: respectively significant at the 0.05, 0.01 level, and 0.001 level.
Table 3. Pearson correlation for sorghum

<table>
<thead>
<tr>
<th></th>
<th>PH_4WAS</th>
<th>PH_5WAS</th>
<th>PH_6WAS</th>
<th>PH_9WAS</th>
<th>Biomass</th>
<th>N°_ears</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH_4WAS</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PH_5WAS</td>
<td>.755**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PH_6WAS</td>
<td>0.413</td>
<td>.806***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PH_9WAS</td>
<td>0.143</td>
<td>0.057</td>
<td>0.100</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomass</td>
<td>-0.079</td>
<td>-0.148</td>
<td>0.069</td>
<td>0.054</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N°_ears</td>
<td>-0.036</td>
<td>-0.102</td>
<td>0.037</td>
<td>0.219</td>
<td>.756**</td>
<td>1</td>
<td></td>
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<tr>
<td>Yield</td>
<td>-0.112</td>
<td>-0.188</td>
<td>-0.085</td>
<td>0.119</td>
<td>.729**</td>
<td>.890***</td>
<td>1</td>
</tr>
</tbody>
</table>

PH: plant height; WAS: Week after Sowing; **, ***: respectively significant at the 0.01 level, and 0.001 level

3.2 Discussion

The contribution of increasing doses of fertilizer significantly raises the growth (Plant height) and the yield (Biomass, number of ears, and grain yield) of maize and sorghum. This result is similar to those of Onasanya et al. [20] in Nigeria; Saidou et al. [21] in Benin; Achiri et al. [22], and Ngosong et al. [23] in Cameroon on maize. It also corroborates those of Kammoum et al. [24] on sorghum in Cameroon. This result could be explained by the role of N, P and K in the mineral nutrition of plants. K has an essential role in photosynthesis, it improves the circulation of the ascending sap in the xylem and descends in the phloem and allows the transfer of assimilates to reserve organs (grains, fruits, etc.). Phosphorus (P) favours root growth and raises the volume of roots, promoting plant nutrition [25-29]. The significant yield difference observed with augmented fertilizer doses could be the consequence of soil nutrient dynamics initiated by optimal soil N-P balance and essential plant metabolic pathways [23,30].

The treatment T3 (maize: 150 kg NPK + 150 kg Urea.ha⁻¹, sorghum: 100 kg NPK + 100 kg Urea.ha⁻¹) showed the greatest height growth in the two speculations. However, its yield was lower than that of T2 (maize: 100 kg NPK + 100 kg Urea.ha⁻¹, sorghum: 50 kg NPK + 50 kg Urea.ha⁻¹) in maize (arithmetically) and sorghum (statistically). This result would be explained by the fact that at T3, the plants would have allocated the majority of their resources for vegetative growth at the expense of yield.

4. CONCLUSION

N, P and K fertilizers enhance the growth, biomass accumulation and the grain yield of maize and sorghum in the Sahel agroecological zone of Cameroon. The highest rate of fertilizer applied (maize: T4 = 200 kg NPK + 200 kg Urea.ha⁻¹, sorghum: T4 = 150 kg NPK + 150 kg Urea.ha⁻¹) emerges suitable for the cultivation of maize and sorghum in the Sahel area. But, it would be necessary in future to assess the effect of higher doses of fertilizer on the growth and yield of these two crops and the economic benefits of the treatments.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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