Original Research Article

Comparative effect of biological fixation of nitrogen and chemical fertilizer on yield optimization of two Sorghum varieties in the Western Highlands

ABSTRACT

Sorghum (*Sorghum bicolor* (L) Moench) is a staple in Africa, South Asia and Central America. In Cameroon, it is the main food of the population of the Sudano-Sahelian zone. Its production could decline by up to 20% by the middle of the century, due to climatic disturbances. This climatic disturbance in Cameroon has led to several consequences among which, low crop yields. The comparative effect of the biological fixation of nitrogen and chemical fertilizer on the optimization of yield of two varieties of Sorghum, was conducted during the month of July to October at IRAD (Institute of Agricultural Research for Development) station of Foumbot. The experimental design was a complete randomized block with two factors: varieties of sorghum (V_1: S35 and V_2: BIOGLOR) and treatments (T_0: control, T_1: 20-10-10 and T_2: sorghum / NITU beans). The collar diameter, the number of leaves and plant height were evaluated each week and yield in the end of the cropping season. As a result, treatment T1 induced very significantly (P < .01) growth (shoot length, leaf and collar diameter). T1 (V1: 1.30 ± 0.11 $t.ha^{-1}$, V2: 2.01 ± 0.07 $t.ha^{-1}$) and T2 (V1: 1.12 ± 0.02 $t.ha^{-1}$, V2: 2.15 ± 0.03 $t.ha^{-1}$) showed statistically equal yields, and significantly different from T0 (V1: 0.50 ± 0.06 $t.ha^{-1}$, V2: 0.55 ± 0.05 $t.ha^{-1}$). The BIOGLOR variety has the highest yield (1.57 ± 0.57 $t.ha^{-1}$) compared to the S35 variety (0.97 ± 0.19 $t.ha^{-1}$). The treatment T2 is the recommended fertilizer system because of the higher grain yield of sorghum and its ability to protect the environment.

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Keywords: growth, NPK (20-10-10) fertilizer, productivity, legume-Rhizobium symbiosis, sorghum, varieties

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1. INTRODUCTION (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

Sorghum (*Sorghum bicolor* (L) Moench) is one of the most important cereals grown in the world. With 57.6 million tonnes harvested worldwide in 2017, sorghum grain is the fifth largest cereal crop after maize, wheat, rice and barley [1]. It is well suited to dry and hot conditions. About 90% of sorghum and 70% of world production is in developing countries. African and Asian countries alone account for over 95% of the total food use of sorghum [2]. It has a C4 metabolism giving it good photosynthetic efficiency [3]. Overall, sorghum is richer in protein than maize and rice [4]. Sorghum is a staple in Africa, South Asia and Central America. According to FAO, Africa is the largest producer of sorghum, with 27.2 million tonnes of annual production, equivalent to 47.25% of world production [1]. In Cameroon, it is the main food of the population of the Sudano-Sahelian zone. But, the production is still very inferior in view of the very strong demand with brewing companies such as Guinness. It is estimated that, in the face of current global warming trends, production of major grain could decline by up to 20% by the middle of the century [5]. This climatic disturbance coupled with soil degradation in Cameroon has resulted in several consequences including low crop yields.

Indeed, the management of soil fertility remains a major problem in Cameroon in general and in the western highlands in particular. The acidity of tropical soils and their nutrient starvation, including phosphorus and particularly nitrogen, are the most common factors [6-10]. These poor soils become ineffectual after one, two or three crops to give a good yield. Africa loses 8 million metric tons of soil nutrients each year and more than 95 million hectares of land are degraded to the point

of reducing significantly productivity according to the International Center for Soil Fertility and Agricultural Development (IFDC) [11].
Many solutions have been propounded to solve this problem. Chemical fertilizers are used to supply the plants with one or more mineral elements that are not in the soil or that are present in insufficient amount, or in non-assimilable forms [6, 12]. For many poor farmers, biological nitrogen fixation is a lasting and complementary solution to industrial nitrogen fertilizer [6]. Although several studies are still being done on the options for soil fertilization for the expansion of sorghum production in the western highlands of Cameroon; to our knowledge, no studies have been conducted on the impact of biological nitrogen fixation on sorghum yield in this region. Hence, the objective of this study wais to evaluate the effect of biological nitrogen fixation and chemical fertilizer on the optimization of yield of two varieties of sorghum in the western highlands of Cameroon.

2. MATERIAL AND METHODS

2.1 Materials

2.1.1 Study site

The experiment was carried out in the polyvalent station of the Institute of Agricultural Research for Development (IRAD) of Foumbot, located in the Foumban Sub-division, Noun Division, West Region of Cameroon (Fig. 1). This station is located at an altitude of 1010.5 m at 5 ° 28 North latitude and 10 ° 33 East longitude. The soils are volcanic, annual rainfall is 1,538.8 mm and the wettest periods of the year are between July and September. The temperature oscillates between 20 and 24 ° C.

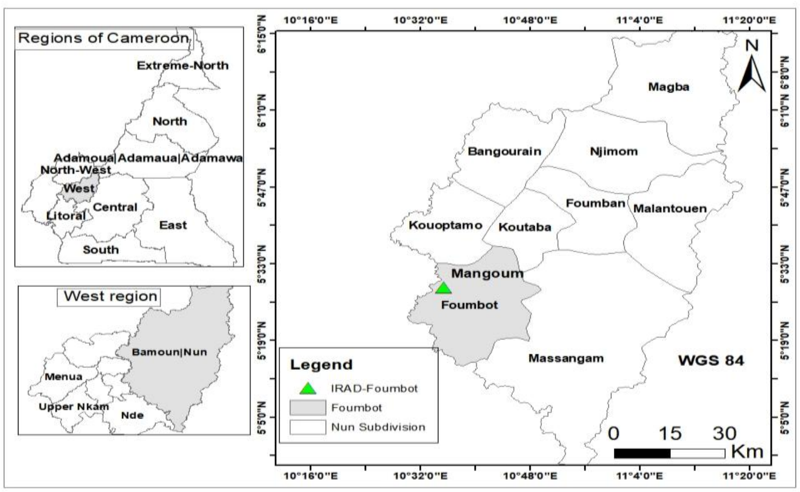


Fig. 1. Experimental site [13]

The physical and chemical analysis of the soil was done at Brookside Laboratories, Inc. New Bremen, OH 45869, University of Illinois, United States (Table 1).

Table 1. Physical and chemical properties of experimental soil (0-20 cm)

	Particulars	Unit	Value	References
	pH	-	6.2	[14]
Extractable minors	Aluminum		1373	
	Boron		0.45	
	Copper		7.77	
	Iron		121	
	Magnesium	$mg.kg^{-1}$	380	
	Manganese		21	
	Potassium		238	
	Phosphorus		14	[15]
	Sodium		30	

	Zinc		2.91	
Base Saturation percent	Calcium	%	61	
	Hydrogen		12	
	Magnesium		17.14	
	Potassium		3.3	
	Sodium		0.71	
	Ammonium (NH_4-N)	ppm	30.9	[16]
	Nitrate (NO_3-N)		19.9	

2.1.2 Plant material

The plant material consisted of two sorghum varieties, S35 and BIOGLOR both from International Institute of Tropical Agriculture (IITA) and a variety of beans, NITU which is an improved variety, from IRAD. It has a dwarf habit, a short cycle (65-70 days), a yield of 2 - 2.5 $t.ha^{-1}$ and is adapted to agro-ecological zones III, IV and V [17, 18].

2.2 Experimental design

The experimental setup was a complete randomized block design with two factors. Soil management practices (T0: Control, T1: chemical fertilizer, T2: NITU Beans + Sorghum) was the primary factor and varieties (V1: S35 and V2: BIOGLOR), the secondary factor. In total, 18 experimental units of 2.4 m² (1 m x 2.4 m) were organized in three blocks spaced 1 m each.

2.3 Sowing and amendment

Sorghum was sown on July 04, 2018, with 80 cm spacing between the holes and 75 cm spacing between the rows [19]. In the T2 treatment (Sorghum + bean), the beans were sown the same day as the sorghum according to the scheme: a line of beans interposed with a line of millet. The spacing between the bean pockets was 30 cm and the spacing between the lines was 50 cm. Thus, each T2 treatment contained three (03) rows of Sorghum and four (04) rows of beans. Two weeks after sowing, 48 g of 20-10-10 were applied in T1 treatment at the rate of 200 kg per hectare [20]. Four (04) seeds of Sorghum were sown in each hole, followed by a post-emergent thinning.

2.4 Agronomic parameters

Agronomic growth parameters (shoot length, number of leaves and collar diameter) were collected weekly from the fourth week after sowing up to the end of the heading stage on five (5) selected and labeled plants of sorghum.

Five sorghum plants were harvested in each experimental unit (plot). Using a pruner, the panicles were separated from their stems and introduced into the previously labeled envelopes. The stems were also marked. In the laboratory, data were collected on the fresh weight of panicles and stems using a sensitive scale (0.01). Dry biomass was obtained by weighing the samples after drying in an oven at 60 ° C until a constant weight (72 h) was obtained [21].

The dry matter content (DM) was obtained using the following formula:

$$DM (\%) = (DW / FW) \times 100.$$

Where, DM: Dry Weight; FW: Fresh Weight; DM: Dry matter content.

Dry grain weight of sorghum was obtained at harvest by weighing the dry grain using a precision electronic scale. Grain yield of Sorghum was calculated according to the formula of [22]:

$$\text{Sorghum Yield } (t.ha^{-1}) = \frac{WG \times 12}{2.4} \times 10{,}000 \text{ m}^2$$

Where, WG = Weight of dry sorghum Grain (kernel) per head weighed using a 0.001 g precision scale; 12 = number of sorghum per elementary unit (plot); 2.4 m^2 = area of elementary unit; 10,000 m^2 = 1 hectare.

2.5 Data analysis

The collected data were processed by an analysis of variance (ANOVA) using JMP8 software. The means were compared with each other using the Student Newman Keuls test at a 5% threshold. The correlation between measured parameters was done using Pearson correlation coefficients. The graphical representations of the data were carried out with the Excel 2010 software of the Microsoft program.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Effect of treatments on growth of sorghum

Growth in shoot length increased significantly (P < .05) over time (Fig. 2). The chemical fertilizer treatment (T1) resulted in a highly significant growth (P < .001) in the shoot length of the sorghum, in the two varieties (S35 and BIOGLOR) from fourth to sixth week after sowing, with respect to the T2 and T0 treatments. This growth became constant from the sixth to the eighth week, for all the treatments (T0, T1 and T2).

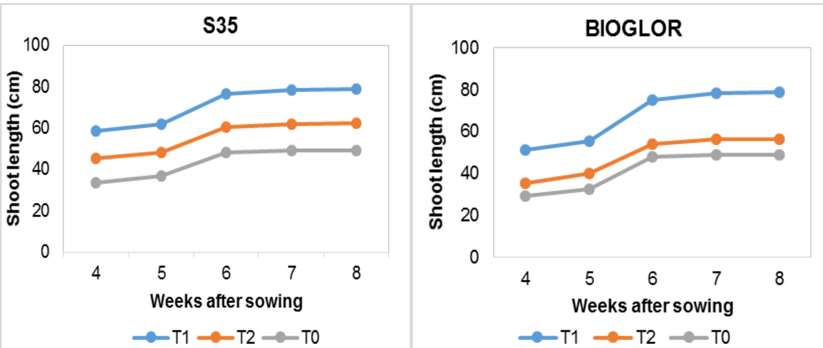


Fig. 2. Effect of fertilization on shoot length of sorghum
T0: control; T1: NPK (20-10-10); T2: Sorghum-NITU bean

The collar diameter was significantly influenced by the treatments over time (Fig. 3). Significant increase (P < .01) in the collar diameter was observed from the fourth to the seventh week for the treatments T1 and T2 in the S35 variety compared to treatment T0. In the BIOGLOR variety, the chemical fertilizer treatment (T1) significantly (P < .01) improved the growth of the collar diameter from the fourth to the eighth week. It was followed by the treatment T2 (sorghum-bean).

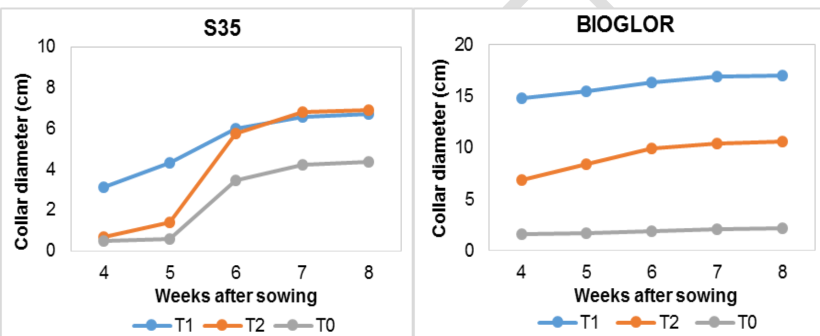


Fig. 3. Effect of fertilization on collar diameter of sorghum
T0: control; T1: NPK (20-10-10); T2: sorghum-NITU bean

The different treatments significantly influenced the number of leaves (Fig. 4). In the V1 variety (S35), the treatments T1 and T2 increased significantly (P < .01) the number of leaves compared to the treatment T0 (control). In the V2 variety (BIOGLOR), the treatment T1 gave a higher number of leaves compared to the treatment T0, it was followed by the treatment T2.

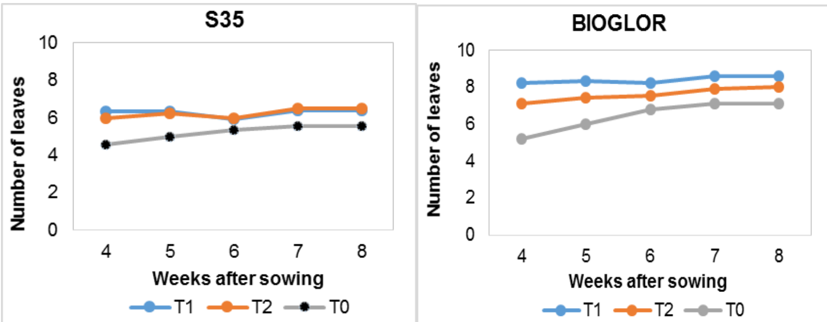


Fig. 4. Effect of fertilization on number of leaves of sorghum
T0: control; T1: NPK (20-10-10); T2: sorghum-NITU bean

3.1.2 Effect of treatments on the yield components of sorghum

The dry matter contents obtained differed significantly ($P < .01$) depending on the type of fertilization (Table 2). The treatment T2 (sorghum-NITU bean) significantly increased the dry matter content of the plant (V1: 36.60 ± 2.23%, V2: 38.88 ± 4.10%) compared to treatments T1 (NPK) (V1: 33.70 ± 0.30%, V2: 34.85 ± 1.98 %) and T0 (Control) (V1: 34.50 ± 0.31%, V2: 34.8 ± 0.32%).
The treatments significantly ($P < .01$) influenced grain yield of sorghum (Table 2). Thus, the treatments T1 (V2: 2.01 ± 0.07 $t.ha^{-1}$) and T2 (V2: 2.15 ± 0.03 $t.ha^{-1}$) had significantly higher grain yields than the treatment T0 (V2: 0.55 ± 0.05 $t.ha^{-1}$).

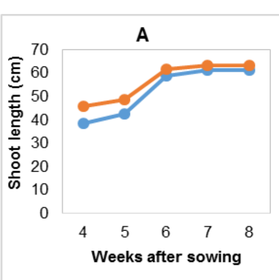
Table 2. Influence of fertilization on dry matter content (%) and yield of sorghum

Varieties	Treatments	Dry matter content of plant (%)	Yield ($t.ha^{-1}$)
	T0	34.50 ± 0.31 ^{b}	0.50 ± 0.06 ^{b}
S35	T1	33.70 ± 0.30 ^{b}	1.30 ± 0.11 ^{ab}
	T2	36.60 ± 2.23 ^{ab}	1.12 ± 0.02 ^{ab}
Means S35		**34.93 ± 0.94 A**	**0.97 ± 0.19 B**
	T0	34.80 ± 0.32 ^{b}	0.55 ± 0.05 ^{b}
BIOGLOR	T1	34.85 ± 1.98 ^{b}	2.01 ± 0.07 ^{a}
	T2	38.88 ± 4.10 ^{a}	2.15 ± 0.03 ^{a}
Means BIOGLOR		**36.18 ± 2.13 A**	**1.57 ± 0.57 A**
Varieties (V)		ns	**
Treatment (T)		*	**
V * T		**	**

*T0: control; T1: NPK (20-10-10); T2: sorghum-NITU bean. Values (means) followed by the same letter are not significantly different (ns). *: $P < .05$, **: $P < .01$*

3.1.3 Effect of the variety on growth and yield of sorghum

A significant difference was observed between the varieties for the shoot length (Fig. 5A), the collar diameter (Fig. 5B), and the number of leaves (Fig. 5C). From the seventh to the ninth week, the variety V1 (S35) had a greater shoot growth than the variety V2 (BIOGLOR). From the seventh to the eleventh week, the variety V1 (S35) had the largest collar diameter (Fig. 5B). The BIOGLOR variety produced a larger number of leaves than the S35 variety (Fig. 5C).
The variety did not significantly influence the dry matter content of plant (Table 2). However, the variety V2 (BIOGLOR) produced a higher grain yield (1.57 ± 0.57%) than that of the variety V1 (S35: 0.97 ± 0.19%) (Table 2).



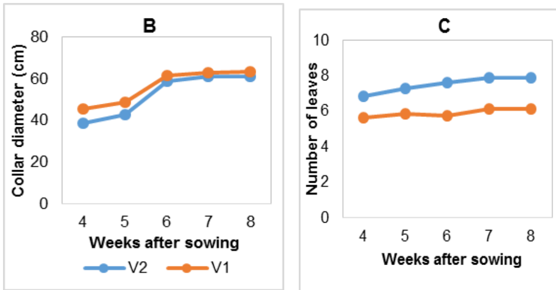


Fig. 5. Effect of the variety on growth of Sorghum
A: Shoot length; B: Collar diameter; C: number of leaves

3.1.4 Correlation

Analysis of the correlation table between measured and evaluated parameters related to sorghum productivity showed that most were not significantly correlated (Table 3). Only four (4) of these correlation coefficients showed that some of these variables were significantly, correlated. Thus, the number of leaves per plant (NL) was significantly ($P < .001$) and positively correlated to the yield (r = + 0.767 ***) and the collar diameter (r = + 0.783 ***). There was also a positive and significant ($P < .001$) correlation between the collar diameter and the yield (r = + 0.782 ***). The collar diameter was also significantly ($P < .01$) and positively correlated to shoot length (r = + 0.658 **).

Table 3. Correlation matrix of the measured variables on Sorghum varieties

	DM	Yield ($t.ha^{-1}$)	SL	CD	NL
DM	1				
Yield ($t.ha^{-1}$)	-0.003 ns	1			
SL	-0.019 ns	0.467 ns	1		
CD	0.120 ns	0.782 ***	0.658 **	1	
NL	0.025 ns	0.767 ***	0.369 ns	0.783 ***	1

***, *** Significant at .01 and .001 probability levels, respectively; ns: indicates no significant difference was observed at .05 probability level. SL: Shoot Length, NL: Number of Leaves, CD: Collar Diameter, DM: Dry Matter content of sorghum,*

3.2 Discussion

The different soil management practices had significant influence on the growth kinetics of sorghum during the vegetative phase. In general, chemical fertilizer treatment (T1) showed the higher shoot length, number of leaves and collar diameter in both varieties compared to treatment T2 (sorghum-NITU bean). This would be due not only to the competitiveness of the bean for water, soil nutrients, sunlight, but also choking caused by the density of the canopy [23-25]. For good growth, a plant needs enough water, mineral salts, and light to efficiently achieve photosynthesis. This result highlights the importance of the shift in sowing date between sorghum and NITU beans. Our result is similar to that of [26] who showed that simultaneous sowing of millet (*Pennisetum glaucum* (L.) R. Br.) and cowpea (*Vigna unguiculata* (L.) Walp.) reduced the size of millet by 5.05% and 20.65% compared to a shift in the date of sowing of cowpeas preceding that of millet for 20 to 30 days. The collar diameter and the number of leaves were also significantly improved by T1 treatment relative to T2 and T0.
In general, the poor performance of the plants observed on the control soils (T0) can be attributed to the characteristics of the acid soils (acid pH of about 6.2 according to the soil test results), the toxicity and the nutrient deficiencies (Ca, Mg, P, K, B and Zn) [27-32].

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The grain yield of sorghum evaluated showed that there was statistically significant difference between different treatments. The treatments T1 (chemical fertilizer) and T2 (sorghum- NITU bean) showed statistically equal yields which were significantly different from the treatment T0 (control). The positive effect of cereal-leguminous crop combination on sorghum grain yield in this study can be explained by symbiotic nitrogen fixation by leguminous crop [19]. The atmospheric nitrogen fixed by the bean was immediately beneficial to sorghum. This result can be explained by the strong competitiveness for the use of soil nitrogen and sorghum light on the one hand, and the precocity of the bean variety used on the other hand. This result did not corroborate with those found by [33-35] who showed at the end of their investigation that the growth of two or more crops in association often results in a decrease in yields of two crops due to competition for limited essential resources. But, it corroborated those of [36] who found that 50%/50% intercrop of cowpeas and sorghum, and intercrop of 75%/25% sorghum and cowpeas gave better sorghum yield than 100% sorghum.

The BIOGLOR variety had the higher yield (1.57 ± 0.57 $t.ha^{-1}$) than the S35 variety (0.97 ± 0.19 $t.ha^{-1}$), a difference of half a ton. The influence of the variety on the yield has been reported by several authors on different types of crop plants such as cowpea, soybean, Bambara groundnut or corn and even beans [7, 9, 29, 37, 38]. In most cases, it is the varieties improved to have specific characteristics such as resistance to disease, salt tolerance, drought, improved ability to acquire major nutrients, which are the most effective [9].

The study of the correlations revealed that the number of leaves per plant was significantly and positively correlated to the yield and the collar diameter; the collar diameter was significantly and positively correlated to the yield and the shoot length. This result suggests that grain yield is related to leaf number and collar diameter. Indeed, the number of leaves and the collar diameter are excellent indicators of the rate of growth in the plant. The number of leaves influences the yield, thanks to the role played by the leaves in photosynthesis and consequently in the accumulation of reserves [12].

4. CONCLUSION

It comes out of this work with purpose to compare the effect of the biological fixation of nitrogen and the chemical fertilizer on the optimization of the yield of two varieties of sorghum, that chemical fertilizer (T1) improved significantly the growth (shoot length, number of leaves and collar diameter). The treatments T1 (V1: 1.30 ± 0.11 $t.ha^{-1}$, V2: 2.01 ± 0.07 $t.ha^{-1}$) and T2 (intercrop of sorghum and NITU bean: V1: 1.12 ± 0.02 $t.ha^{-1}$, V2: 2.15 ± 0.03 $t.ha^{-1}$) showed statistically equal yields which were significantly different from the control treatment T0 (V1: 0.50 ± 0.06 $t.ha^{-1}$, V2: 0.55 ± 0.05 $t.ha^{-1}$). The BIOGLOR variety had the higher yield (1.57 ± 0.57 $t.ha^{-1}$) than the S35 variety (0.97 ± 0.19 $t.ha^{-1}$). Treatment T2 is the fertilizer system to recommend not only because of the highest sorghum grain yield, but also its ability to protect the environment.

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