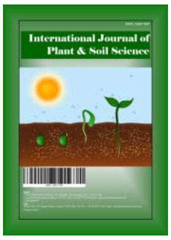

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Growth of Millet [*Pennisetum glaucum* (L.) R. Br.] and Sorghum (*Sorghum bicolor* (L.) Moench) Plants under Water Stress Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. Author KKJ designed the study, wrote the protocol and the first draft of the manuscript performed the statistical analysis. Authors YKB and AOYA managed the data collection of the study. Authors BMM and KFH managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Water stress effect on millet and sorghum plants growth was investigated in this work. Grains were germinated for 7 days in Petri dishes. Plants obtained were transplanted into pots, with 60 repetitions per species. For 6 days, they received 100 ml of water before being divided into four batches corresponding to four treatments (100, 50, 25 and 10 ml). An increase in water stress led to a reduction in size of both plant species and leaves number produced, while root system growth was recorded. Millet plants suffered more from depressive effect of water stress than those of sorghum. Therefore, millet is more predisposed to respond to drought than sorghum.

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1. INTRODUCTION

Agriculture is a key sector for creating jobs, creating wealth and reducing food insecurity. The food crops include traditional cereals, such as millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*). In developed countries, these cereals are mainly intended for animal feed or industrial use [1]. While in developing countries such as Côte d'Ivoire, production is largely for own consumption (manufacture of traditional food and beer) by people. In Côte d'Ivoire, millet and sorghum are of economic and food importance limited to northern zone, occupied by savanna vegetation [2]. Millet and sorghum are, respectively, third and fourth cereal in terms of production and consumption [3]. Ivorian productions of these two cereals are growing steadily [2]. Indeed, local varieties of sorghum have yields of 910 kg/ha compared to improved variety Framida which gives 1270 kg/ha. Average millet yields vary between 600 and 800 kg/ha, but can drop to 300 kg/ha or exceed 1,500 kg/ha. Some improved varieties of millet give yields that vary between 1,870 and 1,930 kg/ha. National production of millet and sorghum domestic production is not sufficient for domestic demand. Consequently, Côte d'Ivoire imports 12,000 tons of grains per year from Sahelian countries to make up deficit [3]. A valuation program for these two cereals is necessary in order to reduce their import.

Côte d'Ivoire, like many countries, has suffered negative impacts of climate change in recent years. These impacts are manifested by an irregularity and poor distribution of precipitation which can accentuate water deficit which is an important factor limiting plant production [4,5]. This is why National Institute of Agronomic Research [6] recommends that research programs, which aim to improve plant production in arid and semi-arid regions, pay great attention to agronomic evaluation performance of cultivated plants that can experience water stress. In cereals, several studies [7,8,9] have revealed that water stress is cause of a drop in productivity. In Côte d'Ivoire, millet and sorghum productions, from 1990 to 2010, were weakly negatively correlated with rainfall. The minimum productions, expected in 2060 and 2110, are, respectively, 88,683 and 65,578 tons [2].Therefore, the aim of the present study is to evaluate the water stress effect on growth of millet and sorghum.

2. MATERIALS AND METHODS

2.1 Study Site

Study was conducted at University Nangui Abrogoua, Côte d'Ivoire. Its geographic coordinates are 5°17'and 5°31' north latitude and 3°45 'and 4°22' west longitude [10]. Site of this University is subjected to a subequatorial type climate comprising four seasons: A large and a small rainy season, respectively, from March to July and October to November, then, a large and a small dry season, respectively, of December to February and August to September. Site has a tropical climate and average temperature is 26.6 °C, 1784 mm of precipitation falls per year and soil is sandy clay [11].

2.2 Plant Material

Plant material consists of two traditional cereals grains, varieties of which are unknown (Fig. 1). These are millet and sorghum. Dry grains were purchased at local market in Abidjan city, Côte d'Ivoire.

(a) (b)

Fig. 1. Millet (a) and sorghum (b) grains

2.3 Methods

2.3.1 Plant production

Seeds for sowing were selected by means of germination test which consists of putting grains in water and removing those floating on surface. After test, retained grains were germinated on filter paper soaked in water for 7 days in Petri dishes. Plants obtained were transplanted into pots, with 60 seedlings per species. Growth media substrate consists of 700 g of top soil layer which has a field capacity of 100 ml.

2.3.2 Application of water stress

The transplanted plants, at the cotyledonous leaves stage, were watered for 6 days at 100 % water volume at field capacity (fc), i.e. 100 ml of water. Plants of each species were divided into four batches of 15 plants, to be subjected to different water regimes. Plants were watered every 5 days. Different treatments are:

- Treatment T0: plants receive 100 % of field capacity, ie 100 ml of water;
- Treatment T1: plants receive 50 % of field capacity, ie 50 ml of water;
- Treatment T2: plants receive 25 % of field capacity, ie 25 ml of water;
- Treatment T3: plants receive 10 % of field capacity, ie 10 ml of water.

2.3.3 Morphological parameters measured

Morphological parameters studied were plant height, leaves number, leaf surface, leaf specific weight, number and length of roots. Measurements were taken on 15th day after treatment.

2.3.4 Analysis of collected data

Data collected was analyzed with Statistica 7.1 software. Their treatment initially focused on variance analysis. Then, a comparison of means was carried out according to Newman-Keuls test at 5% threshold, when a significant difference is observed between them.

3. RESULTS

3.1 Evolution of Morphological Parameters of Millet According to Treatments

Our results (Table 1) reveal that plant height and leaves number decreased when water lack became severe. Leaf surface decreases with increasing water stress, while leaf specific weight changes in opposite direction. There is an increase in number and length of roots when water stress is more pronounced.

3.2 Evolution of Morphological Parameters of Sorghum According to Treatment

Plant sizes, at T0 (100 % fc) and T1 (50% fc) are of same order of magnitude and greater than those recorded at T2 (25% fc) and T3 (10% fc) (Table 2). Difference between leaf surface is not significant. Specific leaf weights evolve in a real roller-coaster way. Overall trends show that leaf specific weight decreases with increasing intensity of water stress. As for leaves number and roots length, they increased slightly from T0 to T2, before falling. As with millet, we also observe root growth when water stress becomes severe.

3.3 Comparison of Morphological Parameters of Millet and Sorghum According to Treatment

General trends show that highest values of leaf specific weight were obtained in millet (Table 3). Contrary trends were observed for other parameters.

Table 1. Morphological parameters of millet according to treatment

Treatments / Parameters	T0	T1	T2	T3
Ph (cm)	3.4± 0.6a	3.2±0.6a	1.7±0.3b	2.0±0.3b
Ln	4.8±0.2a	2.8±0.3b	2.0±0.7b	2.0±1.5b
La (cm^2)	0.9±0.02a	0.05±0.0b	0.08±0.0b	0.05±0.0b
Slw (mg/cm^2)	90.9 ±17c	108.3±8.3b	66.8±8.1d	136.7±18.5a
Rn	5.0±1.0d	7.7±0.6b	6.3±0.3c	8.3±1.2a
Rl	2.9±0.3c	3.9±0.6b	4.0±0.3a	4.9±0.3a

Numbers with different letters on same line are statistically different. Ph: Plant height; Ln: leaves number; La: Leaf area; Slw: Specific leaf weight; Rn: Roots number; Rl: Roots length

Table 2. Morphological parameters of sorghum according to treatment

Parameters \ Treatments	T0	T1	T2	T3
Ph (cm)	6.3±0.0a	6.±0.6a	5.2±0.1b	5.1±0.4b
Ln	4.3 ±0.2a	4.3±0.3a	4.8±0.2a	4.3±0.2a
La (cm^2)	0.2±0.04a	0.2±0.01a	0.3±0.01a	0.2±0.01a
Slw (mg/cm^2)	80.3±23.1a	69.03±5.5b	80.7±26a	70.2±13.7b
Rn	12.0±0.6ab	11.7±1.2b	13.0±2.1a	10.7 ±2.3b
Rl	4.3±0.3a	5.3±0.2a	5.6±0.7a	5.9±0.6a

Numbers with different letters on same line are statistically different. Ph: Plant height; Ln: leaves number; La: Leaf area; Slw: Specific leaf weight; Rn: Roots number; Rl: Roots length

Table 3. Morphological parameters of millet and sorghum according to treatment

Treatments	T0		T1		T2		T3	
Parameters \ Species	Millet	Sorghum	Millet	Sorghum	Millet	Sorghum	Millet	Sorghum
Ph (cm)	3.4 ± 0.6b	6.0 ±0.03c	3.2 ±0.6b	6.8 ±0.6c	1.7 ±0.3a	5.2 ±0.1b	2.0 ±0.3a	5.1 ±0.4b
Ln	4.8 ±0.2c	4.3 ±0.2b	2.8 ±0.3b	4.3 ±0.3b	2.0 ±0.7a	4.8 ±0.2b	2.0 ±1.5a	4.3 ±0.2b
La (cm^2)	0.9 ±0.02a	0.2 ±0.04b	0.05 ±0.0c	0.2 ±0.01b	0.08 ±0.0c	0.3 ±0.01b	0.05 ±0.0c	0.2 ±0.01b
Slw (mg/cm^2)	90.9 ±17c	80.3 ±23.1d	108.3 ±8.3b	69.03 ±5.5e	66.8 ±8.1f	80.7 ±26d	136.7 ±18.5a	70.2 ±13.7e
Rn	5.0 ±1.0b	12.0 ±0.6b	7.7 ±0.6d	11.7 ±1.2b	6.3 ±0.3c	13.0 ±2.1b	8.3 ±1.2d	10.7 ±2.3b
Rl	2.9 ±0.3b	4.3 ±0.3	3.9 ±0.6c	5.3 ±0.2c	4.0 ±0.3c	5.6± 0.7c	4.9± 0.3d	5.9± 0.6c

Numbers with different letters on same line are statistically different. Ph: Plant height; Ln: leaves number; La: Leaf area; Slw: Specific leaf weight; Rn: Roots number; Rl: Roots length.

4. DISCUSSION

We noted that sizes and leaves number of millet and sorghum plants decreased when water shortage approached 50 % of soil field capacity. These results are consistent with those obtained by El-Zohiri and AbdElal [12] on taro (*Colocassia esculenta*). They observed a reduction in plants height subjected a watering dose of 25% compared to plants subjected to 100% of field capacity of substrate. According to Shao et al. [13], lack of water slows down plant growth because it greatly affects cell expansion and cell growth due to low turgor pressure. The same authors report that maintaining cell turgor, through osmotic regulation, allows other plants, such as millet (*Panicum miliaceum*), to support water deficit. As water nutrition and mineral nutrition are two inseparable phenomena, decrease in sizes and leaves number of two species studied may also be linked to reduction in flow of mineral elements to roots. Sorghum plants leaf surface seem to behave better compared to those of millet in face of different water regimes. According to Lebon et al. [14], one of first reactions of plants to water deficit is to reduce leaf surface, which is a determinant of transpiration. This behavior of millet constitutes a strategy for reducing water loss [15]. Amount of water stored will be used to ensure plant survival during drought period. From T1 to T3 treatment, highest value of leaf specific weight recorded in millet, which has a small leaf surface, indicates that this plant concentrates a significant amount of water within it compared to sorghum. Our results confirm those of Scofield et al. [16] who state that decrease in relative moisture content is faster in susceptible varieties than in varieties tolerant to water stress. We infer that millet is more drought tolerant than sorghum. Number and roots length in millet and sorghum increased as plants were increasingly affected by water stress. Results corroborate those of Tshiabukole [17] who also observed, in maize, a significant increase in root system from male flowering, following reduction in quantity of water. This sustained growth of roots is explained by fact that in conditions of water deficit, plants obtain their water supply through root exploration [18]; roots burrow into deep layers of soil in search of water [17]. This type of root system would be a trait for adaptation to drought. Our results also showed that majority of morphological parameters studied were more depressed by water stress in millet plants than in sorghum plants. Therefore, millet is more predisposed to respond to water stress than sorghum.

5. CONCLUSION

We learned from this study that water scarcity reduces leaves production and leaves size of millet and sorghum. Conversely, the two species significantly increase the number and the size of their roots, under same conditions, to be able to absorb water from deep layers of soil. Most interesting result of this work is that millet has emerged as plant most predisposed to respond to lack of water.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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