Original Research Article

Influence of seasonal changes on growth performance and leaf biomass production of two *Moringa oleifera* varieties grown under Sahelian condition in Burkina Faso

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ABSTRACT

Aims: An experiment was conducted to compare the growth performance of two varieties of *Moringa oleifera* (wilt variety and PKM-1) under different seasonal period at two locations in northern Burkina Faso, to be used for improving household nutrition.

Study design, Place and Duration of Study: Two separates trials corresponding to sowing period (cold and warm) were laid out at each site (Bani and Tougou) in a completely randomized design with three blocks between December 2017 and September 2018.

Methodology: Each block was subdivided into two plots of 8 m² (separated from each other by 3 m break) intended to receive each variety *Moringa* at each sowing period. The seeds were sown with 2 seeds by pit at 2 cm depth with spacing of 0.5 m x 0.5 m in each plot ploughed up to 30 cm. Watering was done daily during the dry season and consisted of bringing 24 liters of water in each plot at two times. Vegetative growth measures (plant height, number of leaves) were done weekly while leaf biomass production was assessed monthly from the 40th day after sowing.

Results: The results indicate that seedlings growth parameters and foliar biomass differed significantly among the two *Moringa oleifera* varieties and were influenced by the sowing period and sites. Although these varieties grew well, *Moringa oleifera* var PKM-1 grew faster and produce much leaves compared to the wild or local variety of *Moringa oleifera*. Greater growth attributes (height and number of leaves) and foliar biomass were noted for PKM-1.

Conclusion: The warm period (March / April) appear to be the most recommendable set up period for the growth and biomass accumulation of the two varieties of *Moringa oleifera*.

Keywords: Moringa; morphological growth; leaf biomass; sowing period.

1. INTRODUCTION

The current food crisis is a result of rapid growth in food demand due to rapid population growth in conjunction with a decline in the growth of food supply in the Sub-Saharan Africa. In the Sahelian countries, food tree species are important in the feeding regimes of the population [1] and provide them income through the small business from their various non timber forest products. Among the most used species by the populations of the North and the Sahel regions, drumstick (Moringa oleifera, Moringaceae) is being considered as a potential source of dietary calcium intake in developing countries [2] as well as combating under-nutrition in general [3]. Indeed, drumstick represents an important food source especially for its high content of proteins, nutrients and vitamins of the vegetative parts as well as two amino acids (arginine and histidine) which are particularly important for children [4], It is a fast growing, perennial tree which can reach a maximum height of 7-12 m and a diameter of 20-40 cm at breast height. The young leaves are edible and are commonly cooked and eaten or used to make soups, porridges and salads [1]. Although native to India, drumstick has been planted around the world and is naturalized in many tropical countries as it grows well in all types of soil, from acid to alkaline [5]. *M. oleifera* is considered as “The Miracle Tree” because it is a multipurpose and exceptionally nutritious vegetable tree with numerous potential uses [6]. Identified as the most widely cultivated species among the 13 known species of Moringaceae family [7], *M. oleifera* is friendly with tropical, subtropical and semi-arid climate, where it primarily grows [8].

The plant is becoming increasingly more appreciated around the world, as almost every part of the tree can be used [9] due to their pharmacological, nutritional, water purifying properties (seeds) and also as an alley crop in the agro-forestry industry, livestock feed, vegetable dyes, foliar spray, cosmetics and oil production [10]. Many ecotypes are present in India [11] where new varieties have been recently developed. Among them, hybrid drumstick (PKM-1 or Periyakulam-1) is the superior variety of *M. oleifera* which was made from pure breading in order to obtain high productivity plants [12]. The pure breed seeds have all the beneficial traits as in the wild variety but with a better production quantity, providing quality fruits as well as oil production [13]. PKM-1 is high yielding edible variety and has high demand due to its medicinal value [14]. Despite all these various uses and the importance of this variety of the species in the wellbeing of local African people, the production systems are still not yet been improved [1] and their cultivation is very sparse. Although *Moringa oleifera* shows diversification in many characters and high morphological variability, which may become a resource for its improvement, the major factors that limit productivity are the absence of elite varieties adapted to local conditions [15]. Furthermore, information about the production in other countries than India is scarce, so the production has to be estimated through experimentations [16]. There is a need to increase the level of cultivation of the species especially in the sahelian countries [1] where it is rarely mentioned in farmers' preferences. Previous studies indicate that *Moringa oleifera* varities could be cultivated in plot in the form of nutrition garden [17]. Production of fresh Moringa leaves in nutrition garden set up in the Sahel may be an alternative way of increasing the supply of *Moringa* leaves as a vegetable crop. Considering the cultivation challenges, cultivation systems need to be explored [16]. This could be firstly made through identification of the factors influencing the species cultivation. In the present study, an attempt was made to observe the growth performance of two varieties of *Moringa oleifera* (wilt variety and PKM-1) under different seasonal period in the sahelian condition of Burkina Faso. Therefore, this study aimed to determine the appropriate growing period of *Moringa oleifera* and *Moringa oleifera* var PKM-1, grown in northern Burkina Faso to be used for improving household nutrition during the lean season. The specific objective of this research is to compare the field growth performances of the two varieties of *Moringa oleifera* (wild and PKM-1 varieties) in terms of height, number of leaves and leaf biomass production. This study investigated the following null hypotheses:

(i) There is no significant difference in the level of establishment between *Moringa oleifera* and *Moringa oleifera* var PKM-1

(ii) There is no variation in the growth attributes of *Moringa* varieties (shoot height, number of leaves, leaf fresh weight and leaf dry weight) whatever the sowing period;

(iii) There is no significant relationship between the seedlings growth variables of these varieties and their sites of establishment.

2. MATERIAL AND METHODS

2.1 Study area

The study was conducted in the Sahelian zone of Burkina Faso at two locations: Tougou, in the Northern administrative region at about 25 km east of Ouahigouya and Bani in the Sahel region at about 30 km south of Dori (Figure 1). Phytogeographically, the experimental sites are part of the Sub-Sahelian sector [18]. The climate is of Sahelian type with two contrasting seasons: a long dry season from October to May and a short rainy season from June to September. The study area has an annual rainfall ranging between 300 and 600 mm per year with most of the rains falling between June and September. Daily temperatures are subject to high fluctuations ranging from 18°C in December–January to more than 40°C in April–May.

The studied regions have experienced a significant and continuous degradation of its natural resources, especially soils, due to the climate variability and the rapid increase of the population. The average population density thus exceeds 212 inhabitants per km². The mayor ethnic groups at Tougou are Mossis and fulanis while Remaibe, Fulbe, Bella and Mallebe are the main ethnic groups at Bani. Mojority of them practice agro-pastoralism [19].

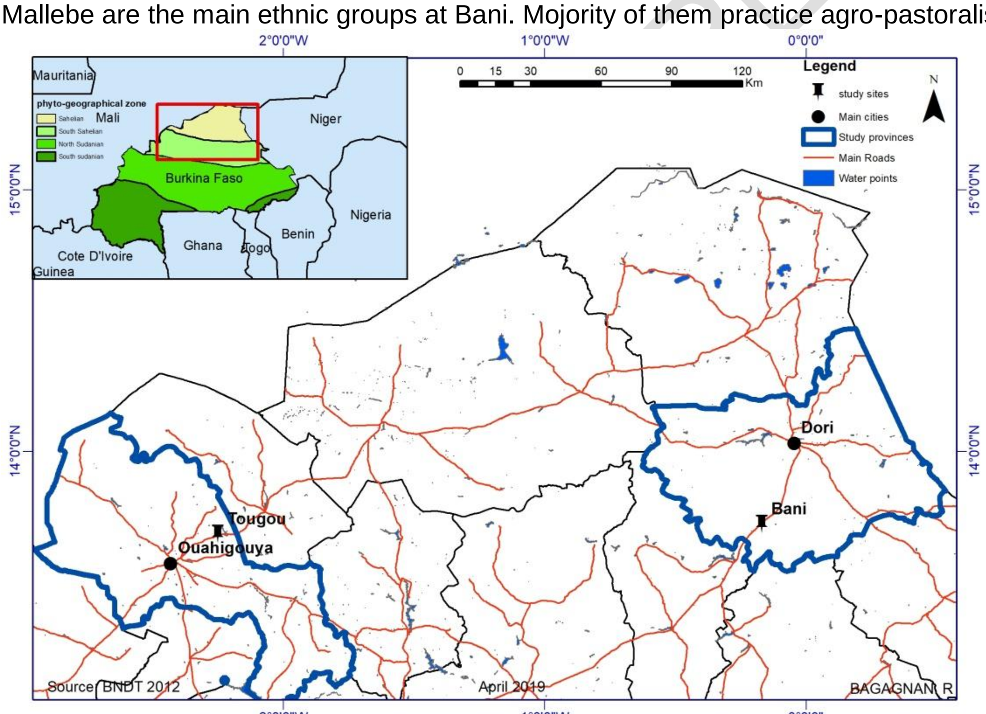

Fig. 1. Phytogeographic map and situation of the experimental site in Northern Burkina Faso

2.2 Experimental design and agronomics operations

Two separates trials corresponding to sowing period were carried out after the rainy season at two periods: cold period (started on 15th December 2017) and warm period (started on 15th March 2018). A completely randomized design with three replications was used for each trial at each site by combining these two varieties (wild variety and PKM-1) with two factors depending on sowing period and site of establishment. Then, each trial has three blocks each subdivided into two plots of 8 m² (separated from each other by 3 m break) intended to receive each variety of Morienga oleifera. The plots were demarcated and ploughed as the soil inside each plot was stirred up 30 cm deep to create conditions for good root development of seeds. Manure is well known to have strong influence on Moringa growth and leaves production [5, 20]. Then, two wheel barrow of animal manure were applied in each plot or plank when preparing the soil followed by a preliminary watering during two days before sowing.

At each sowing period, the seeds were sown with 2 seeds by pit at 2 cm depth for the two varieties with a spacing of 0.5 m × 0.5 m. The indicated germination rate for the seeds of the different varieties was around 80%. After seedling emergence, shoots are trimmed to maintain only one per pits. The seedlings obtained from the skinning are used to transplant any empty pits. The plots were weeded once a month to eliminate the herbaceous competition and amended by 4 kg of manure per plot. Watering was done daily during the dry season and consisted of bringing 24 liters of water in each plot at two times (morning and the afternoon) because shoots were younger with shadow roots and needed water at closer intervals. During the rainy season, watering regime was the same as in the dry season except the day it rains when it is provided by rainwater.

2.3 Data collection and analysis

Prior to the experiments, soils were sampled at random locations for the determination of the amount of nutrients and their properties. Data on vegetative growth (plant height, number of leaves) and leaf biomass production were collected during the experimental period (24 weeks) for each trial. For both varieties of *Moringa*, ten randomly selected plants were tagged to take measure on height at first branch emergence (cm) and number of leaves per plant; measurements were done weekly since the emergence of shoots. Height growth was determined by using measuring tapes and number of leaves by count. For each species, fresh leave biomass was assessed monthly per plot from the 40th days after the sowing date. Fresh leaves were systematically collected by hand per plant and weighed immediately. Dry leaves biomass was determined using a digital weighing balance while the leaves were dried in the oven at 60°C to constant weights.

All collected data were analyzed using R Statistical Software in order to check differences among treatments. The normality of data was tested using the Shapiro-Wilk test, and homogeneity of variances using Leven's test. Separation of means for statistical significance was done using the test of Tukey HSD (Honestly Significant Difference).

3. RESULTS AND DISCUSSION

3.1 Soil composition of the field

Soils of the two sites are dominated by tropical ferruginous soils leached with stains and concretions; they are locally associated with indurate tropical ferruginous soils at Tougou. The results revealed soils to be acidic with sandy loam surface soil texture and silt loam texture from 20 cm deep to 50cm, even though the site of Tougou had higher clay content than Bani (Table 1). Bulk density is almost the same in the two considered horizon in the two sites. Globally, the soil nutrient content on the two site were low and inadequate for optimum plant vegetative development. Otherwise, the 0 to 20 cm soil depth range had higher nutrient contents than the 20 to 50 cm soil depth range, with slightly higher values in Bani except for potassium and phosphorus. However, the application of manure to soil during the trial will provide potentials benefits including improving of fertility, structure, increasing soil organic matter and water holding of soil.

Plant growth and survival is adversely affected by a deficit of essential nutrients. Soil factors affect seedling growth via their influence on root growth and root activities by which the plant is supplied with the water, nutrients, and oxygen it requires for its development [21]. In this study soil quality in Bani and Tougou were as limiting factors of plant growth due to the low mineral nutrients and organic matter in the soil. Low levels of nutrient contents (nitrogen, phosphorus, potassium, carbon, CEC) were observed at the two research locations (Table 1); thus corroborating the results of previous works [22, 23] that soils of northern Burkina Faso are deficient in nitrogen, phosphorus, potassium and carbon. However, this can be alleviated and improved by the application of manure. Indeed, organic materials are known to modify soil properties and boost the soil nutrient content [24, 25]. Organic amendments contributed to important growth and yield of *Moringa oleifera* [26, 27], indicating the effectiveness of animal manure in this study. The best condition for plants is when the soil pH was neutral where almost all nutrients were available to support plants optimal production [28]. Then, the application of manure during the trial must provide potentials benefits for seedlings including improving of soil nutrient content, structure, increasing soil organic matter and water holding of soil.

Table 1. Soil properties in the two sites before the trial set up at Bani and Tougou

Soil parameters (units)	Horizon depth (cm)	Bani (Mean ± SD)	Tougou (Mean ± SD)
Clay (%)	0–20	9.8 ± 0.5	25.7 ± 6.6
	20–50	26.8 ± 1.6	34.4 ± 3.5
Silt (%)	0–20	29.7 ± 1.7	31.8 ± 2.6
	20–50	37.5 ± 2.1	36.1 ± 1.4
Sand (%)	0–20	60.3 ± 2.2	41.2 ± 3.1
	20–50	35.4 ± 1.5	29.1 ± 2.4
Bulk density (g / cm3)	0–20	0.55 ± 0.02	0.66 ± 0.02
	20–50	0.54 ± 0.06	0.65 ± 0.05
Soil pH (H_2O)	0–20	6.6 ± 0.1	6.4 ± 0.1
	20–50	6.5 ± 0.1	6.0 ± 0.3
Total organic Matter (%)	0–20	3.65 ± 0.22	1.78 ± 0.23
	20–50	2.43 ± 0.19	1.12 ± 0.30
Total nitrogen (%)	0–20	0.39 ± 0.08	0.17 ± 0.03
	20–50	0.29 ± 0.05	0.13 ± 0.02
Phosphorus (mg / kg)	0–20	1.11 ± 0.20	2.50 ± 0.62
	20–50	0.80 ± 0.18	0.74 ± 0.25
Potassium (mg / kg)	0–20	130.1 ± 30.4	187.9 ± 37.5
	20–50	80.2 ± 19.1	119.2 ± 42.4
Exchangeable bases (cmol / kg)	0–20	12.14 ± 2.8	3.96 ± 0.85
	20–50	13.25 ± 1.33	3.96 ±0.82
Cationic exchange capacity (cmol / kg)	0–20	16.92 ± 2.58	6.01 ± 1.07
	20–50	17.72 ± 2.28	5.95 ± 0.39

Note. SD = standard deviation

3.2 Variation in growth parameters and leaf biomass production

The emergence delay of shoots differed between the periods of set up on the sites (10 and 7 days respectively for the cold and warm periods). During early stage (until the 40th days), average increase in plants height and number of leaves differed significantly among the two moringa varieties and were influenced by the period of set up and the location of the sites (Table 2; Figure 2). The analysis of variance revealed that there was a marked difference in the growth variables among the two varieties of Moringa where period of set up and sites location had significant effect on all growth variables. Interactions of site location and period of set up with varieties were significant for shoot height except for (Period x Sites x Varieties). These results reveal that at the early stage, Moringa oleifera var PKM1 grew faster and produces more leaves than the wild variety (Local) in the two sites although there are no significant differences in trial set up during the warm period at Bani (Figure 2 A2). It also appears that mean values of height growth were significantly greater for shoots sowed during the warm period. The effect of the site location reveals that all the growth variables were the highest at Bani.

Table 2. Analysis of variance of early growth variables (leaves number and height at the 40th day) at the study sites (Bani and Tougou) as influenced by the different factors and their combination

Source of variation	Shoots number of leaves			Shoots heights		
	Df	F value	P value	Df	F value	P value
Period	1	47.6471	**< 0.0001**	1	271.3038	**< 0.0001**
Sites	1	34.4250	**< 0.0001**	1	58.3236	**< 0.0001**
Varieties	1	37.1779	**< 0.0001**	1	53.3674	**< 0.0001**
Period x Sites	1	0.2118	0.6468	1	25.4841	**< 0.0001**
Period x Varieties	1	1.9059	0.1717	1	9.6006	**0.0028**
Sites x Varieties	1	2.9779	0.0887	1	12.4987	**0.0007**
Period x Sites x Varieties	1	0.0529	0.8187	1	3.0819	0.0834
Residuals	72			72		

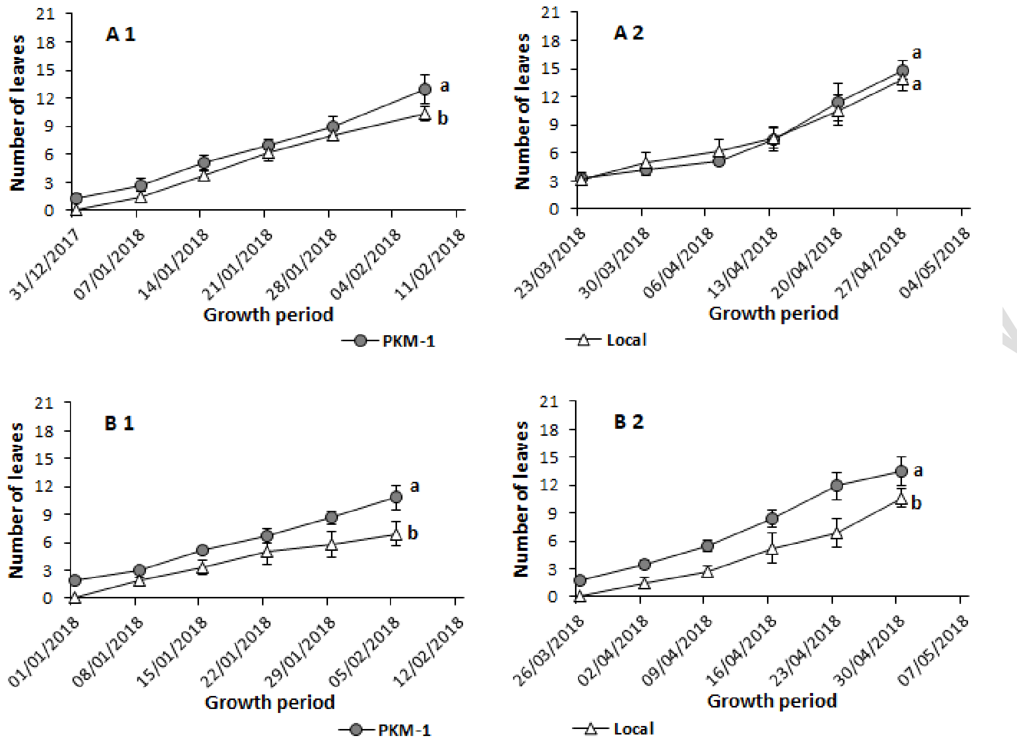

Fig. 2. Weekly average increase in mean number of leaves per plant of the different varieties of Moringa (PKM1 and Local) during the first month of the trials at Bani (A1, A2) and Tougou (B1, B2).

A1 : First trial setup during the cold period at Bani; A2: Second trial setup during the warm period at Bani; B1: First trial setup during the cold period at Tougou; B2: Second trial setup during the warm period at Tougou

Different letters across curves denote significant differences ($p < 0.05$) according to Tukey's HSD test. Error bars represent standard deviation

The temporal variation in seedling growth of the two varieties of Moringa oleifera according to the two growing period is shown in Figure 3. Analysis of the growth curves' shapes reveals a noticeable difference between the two periods of production. It appears that after their emergence, seedlings grew slowly over two months during the cold period against one month for the warm period. It is only after this phase of slow growth that the development of seedlings becomes more important whatever the variety or the site. The analysis of variance at the end of each trial revealed that there was a significant difference in plant growth among the two varieties where period of set up and sites location had significant effects (Table 3). Factors as period of setup, sites and varieties had significant effects on shoot height. Period by sites interactions as the interactions of period and sites with varieties had also significant effects. The result indicates that mean values in plant height were significantly greater on the site of Bani. Seedlings sowed during the warm period showed higher growth attribute compared to those sowed during the cold period on the two sites of their establishment. Otherwise, mean heights values of PKM1 were significantly greater than those of the wild variety of Moringa oleifera (Local) in the two sites although there are no significant differences in the second trial at Bani (Figure 3 A2).

Table 3. Analysis of variance of seedlings height at the end of the trials as influenced by the different factors and their combination

Source of variation	Final plants heights		
	Df	F value	P value
Period	1	271.6208	**0.0000**
Sites	1	41.2588	**< 0.0001**
Varieties	1	16.7356	**< 0.0001**
Period x Sites	1	8.2323	**0.0054**
Period x Varieties	1	0.8912	0.3483
Sites x Varieties	1	2.1748	0.1446
Period x Sites x Varieties	1	6.0612	**0.0162**
Residuals	72		

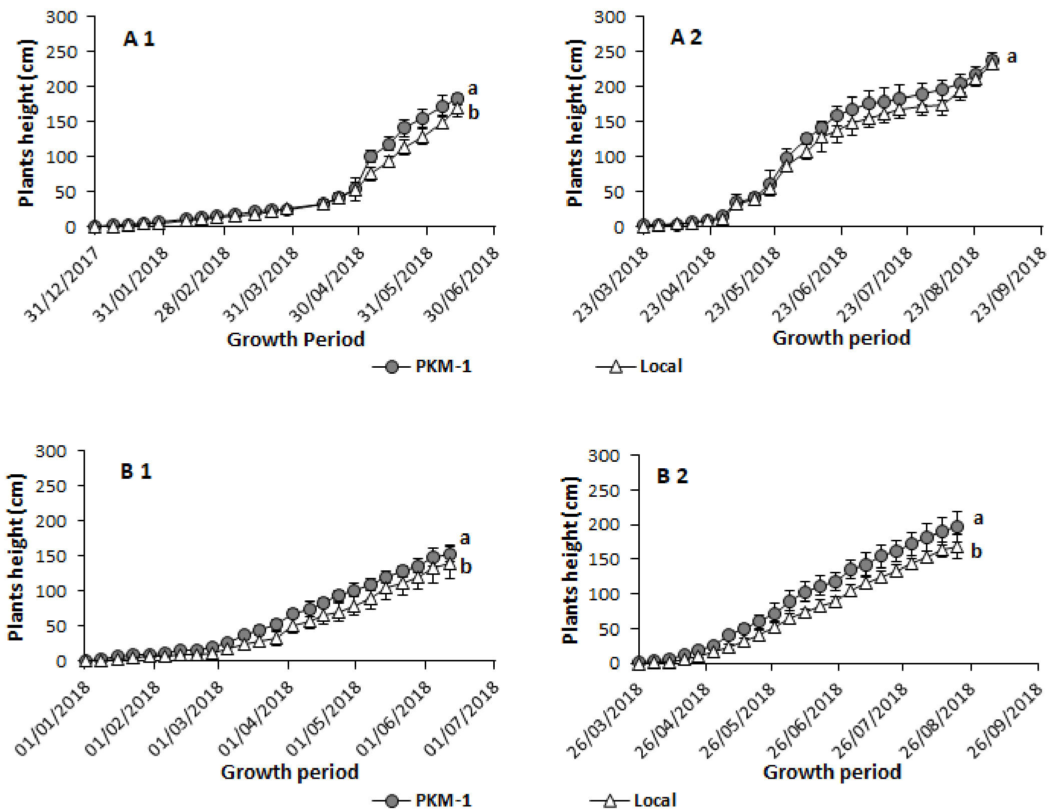

Fig. 3. Monthly average increase in mean seedlings' heights (cm) of the different varieties of Moringa (PKM-1 and Local) at the sites of Bani (A1, A2) and Tougou (B1, B2).

A1: First trial setup during the cold period at Bani; A2: Second trial setup during the warm period at Bani; B1: First trial setup during the cold period at Tougou; B2: Second trial setup during the warm period at Tougou

Different letters across curves denote significant differences ($p < 0.05$) according to Tukey's HSD test. Error bars represent standard deviation

Results on foliar biomass from *Moringa oleifera* varieties established at Bani and Tougou are presented in Figure 4. The analysis of variance at each assessment period revealed that there was a significant effect of the period and site on foliar biomass while difference among varieties was significant only at the earlier stage (Table 4). This result indicates that leaf biomass production was significantly greater on the site of Bani compared to Tougou and for seedlings sowed during the warm period. Otherwise mean values of leaf biomass were significantly greater for PKM-1 variety at the first month whatever the period of setting up and sites; in the following months (2nd and 5th), the same trend is observed on the site of Tougou except on the fifth month for the first trial where differences were not significant between varieties (Figure 4 B1). However on the site of Bani, even if the same trend is observed, varieties did not differ significantly in foliar biomass production on the 2nd and 5th months (Figure 4 A1 and A2).

The results show that seedlings growth (height increment and number of leaves) and foliar biomass differed significantly among the two *Moringa oleifera* varieties and were influenced by the sowing period and sites. Similar results were reported by [29] who noted that morphological characteristics of *Moringa oleifera* vary widely, depending on season, variety, fertilization, and irrigation regime. According the observation of this experiment, seedlings of the two varieties grow more rapidly when there are sown during the warm seasons (March to June) as compared to those sown during the cold period (December to February). This corroborating the conclusions of [1] and [30] that Moringa yields best under warm and dry conditions. However, our results disagree with those of [15] that the largest yield of Moringa occurs in wet or cold season. Sowing location also give a significant difference in the yield of Moringa plants in height and in form of leaves. Indeed, seedlings grown at Bani showed good performance in height development and produced more leaves than those grown at Tougou. Furthermore, these differences in seedlings growth parameter were followed by difference in total dry weight of leaves. There are any differences in climatic conditions (air temperature, relative air humidity, etc.) between the two sites as they are all located in the same phytogeographical and climatic zones. The most likely explanation for these differences in yield between sites of location is that of soil nutrient content which was better at Bani than Tougou. Then, in the current study as well as previous studies on Moringa varieties that are being cultivated in different geographical locations of the world [31, 12, 32], it is observed that morphological parameters (growth attribute and biomass) and other basic characteristics differ greatly based on the environment in which these plants are grown. As expected, growth parameters and foliar biomass production varied significantly within varieties at the early stage as throughout the trial. [32] reported that considerable variations for various morphological characteristics in drumstick exist. The results of the present study have shown superior growth attributes (height and number of leaves) and greater foliar biomass for *Moringa oleifera* PKM-1 compared to the wild or local variety at any site for the two sowing period. These differences within varieties may be explained by the fact that PKM-1 is the superior variety of *Moringa oleifera* which was made from pure breading hybrid seeds for cultivation purpose of high productivity plants. As reported by previous studies [12, 14], PKM-1 variety has all the beneficial traits as in the wild variety (Local) but with a better production quantity and fast growing. This poor performance of the wild variety of Moringa oleifera could probably be due to poor genetic adaptations [31] influenced by climatic conditions in these areas.

Table 4. Statistical significance of the different factors and their combination on monthly leaf dry biomass production

Source of variation	First month			Third month			Fifth month		
	Df	F value	P value	Df	F value	P value	Df	F value	P value
Period	1	1482.75	**0.0000**	1	390.237	**0.0000**	1	688.375	**0.0000**
Sites	1	622.67	**< 0.0001**	1	133.436	**< 0.0001**	1	475.605	**< 0.0001**
Varieties	1	489.73	**< 0.0001**	1	23.206	**< 0.0001**	1	1.303	0.2709
Period x Sites	1	1027.05	**0.0000**	1	265.598	**0.0000**	1	529.579	**< 0.0001**
Period x Varieties	1	339.44	**< 0.0001**	1	17.882	**0.0006**	1	1.0756	0.3151
Sites x Varieties	1	130.77	**< 0.0001**	1	20.626	**0.0003**	1	1.6081	0.2229
Period x Sites x Varieties	1	167.78	**< 0.0001**	1	14.475	**0.0015**	1	2.4584	0.1365
Residuals	16			16			16		

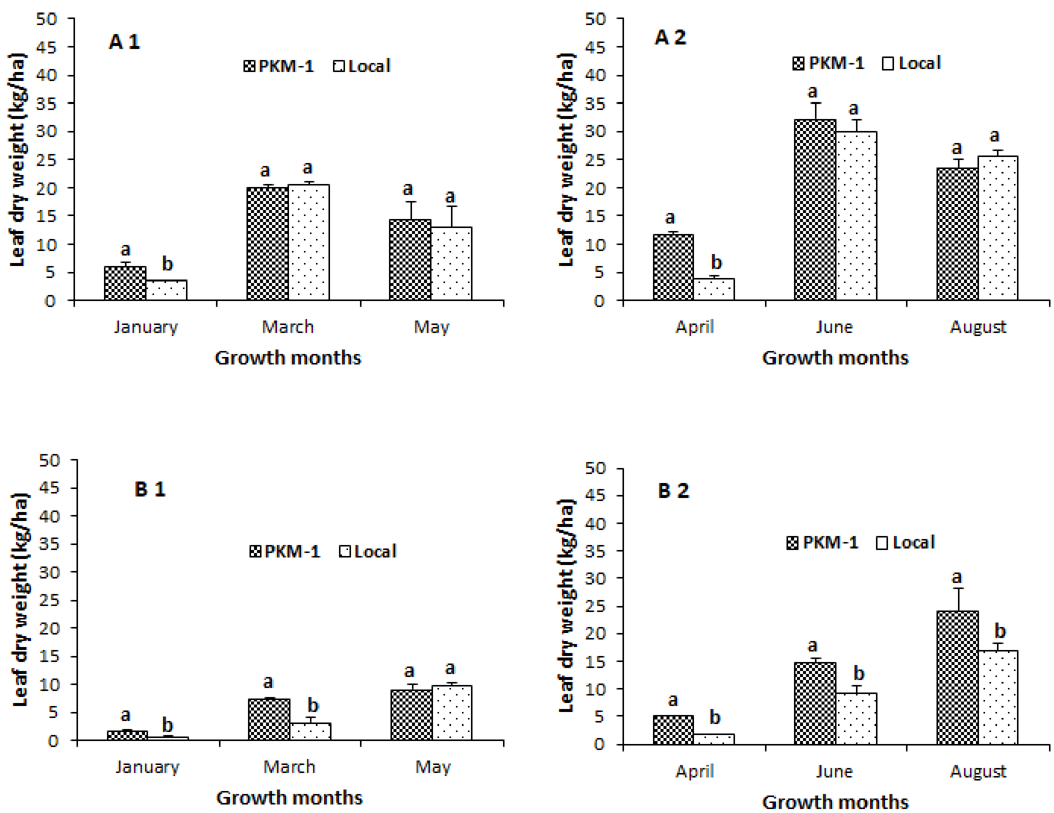

Fig. 4. Leaf dry biomass production of the different varieties of Moringa (PKM-1 and Local) at the sites of Bani (A1, A2) and Tougou (B1, B2).

A1: First trial setup during the cold period at Bani; A2: Second trial setup during the warm period at Bani; B1: First trial setup during the cold period at Tougou; B2: Second trial setup during the warm period at Tougou

Error bars represent standard deviation and letters on the bars indicate significant difference ($p < 0.05$) between the varieties at each month

4. CONCLUSION

Based on the observation of this experiment, the two varieties had different growth attributes over the two sowing periods even if the warm period is the best season for optimum growth and leaves production. The null hypothesis is therefore totally rejected for H2 and H3. However, the hypothesis that Moringa oleifera does not differ in growth performance with Moringa oleifera var PKM-1 (H1) was partially rejected because they differ significantly on the two sites only for the cold period trial but only on the site the site of Tougou Bani during the warm period.

From the above results, it may be concluded that:

(i) Difference of location, soil type and cultivation period affected the morphophysiological character and leaf yield of Moringa oleifera plants;

(ii) Although both varieties grew well, Moringa oleifera var PKM-1 grew faster and produce much leaves compared to the wild or local variety of Moringa oleifera;

(iii) The warm period (March / April) appear to be the most recommendable set up moment for the growth and biomass accumulation of the two varieties of Moringa oleifera.

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