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Research Article

Photoperiod Sensitivity and Variability of Agromorphological Traits and Brix Content of Sweet Sorghum Cultivated in Burkina Faso under Two Sowing Dates

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Sweet sorghum is mainly cultivated for the sweetness of its stems and the quality of its fodder. Unfortunately, its cultivation is gradually being abandoned in Burkina Faso due to climatic hazards. In a general context of strong variations in the rainfall regime, it is, therefore, important to determine the effect of the sowing period on the expression of agromorphological traits and Brix content. Thus, 29 sweet sorghum accessions were evaluated using 15 quantitative variables in a three-replicate Fisher block design with two sowing dates spaced 25 days apart. The results of the study showed that only stalk length (pr. = 0.519) and internode length (pr. = 0.367) were not significantly influenced by sowing date. Indeed, delayed sowing resulted in an increase in the number of vegetative (+2.44) and useful (+1.3) tillers, as well as Brix (+1.16%). However, a reduction in leaf area (−4.35 cm × 1.43 cm), plant height (−85.69 cm), panicle length (−2.63 cm), and panicle weight (−6.19 g), as well as a reduction in the sowing-to-flowering cycle from 3 to 21 days, was obtained at the second sowing date. Thus, all accessions are sensitive to photoperiod with photoperiodic coefficients varying from 0.19 (GB02) to 0.93 (BSA5). These results could be exploited in the sweet sorghum improvement program.

1. Introduction

Agricultural activity in Africa takes place in a context of permanent risks [1]. In recent decades, climate change has been marked by an increase in temperature and a variation in rainfall, one of the consequences of which is its current and future impact on agriculture and food security [2]. The Sahel is one of the regions of the world that has experienced the most severe droughts since the 1970s [3]. This has resulted in an overall rainfall deficit of about 30% over the entire Sahel region [4]. This decrease in average annual rainfall and the reduction in the duration of the rainy season resulted in a mismatch between the varietal cycles and the duration of the rainy season [5].

Thus, the choice of cultivars according to agroclimatic conditions is a key element in the strategy of securing production, with regard to the low soil fertility and spatial and interannual variability in season length [6]. Understanding the complex biological traits that determine the adaptation of a crop to climate is an interesting perspective, which could contribute not only to managing the impact of climate change, but also to preserving genetic resources. The adaptation of cereal production to current climate conditions, therefore, remains a priority for farmers.

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the most important cereals in terms of food and feed at the global level [7]. In Burkina Faso, it is cultivated in almost the entire territory on more than 1,907,651 hectares, for a production of about 1,849,595 tons during the 2019-2020 agricultural season [8]. Several types of sorghum with varying potential are grown and maintained by the farmers. The dynamic management of this diversity by farmers allows an evolutionary adjustment to a heterogeneous environment, but also to meet diversified use needs [9]. Among these types of sorghum is sweet sorghum, which has been little studied in the country's breeding programs. One of the main characteristics of sweet sorghum is the accumulation of large amounts of carbohydrates such as sucrose, glucose, and fructose in their juicy stems [10–13]. Despite production under a variety of agroecological conditions, sweet sorghum remains a marginal crop. It is very little exploited by the population, and its cultivation is still practiced in small areas, especially in the hut fields [14]. Its stalks are generally eaten as sweets, and its grains are used in human and animal food [15]. Most previous studies on sorghum have focused on grain sorghum [9, 16, 17]. The few studies that have been devoted to it have focused mainly on its genetic diversity and its sugar production potential, especially Brix [14]. These studies, which have highlighted the existence of significant genetic diversity that can be exploited in sweet sorghum improvement programs, have not, however, highlighted its response to photoperiod variation. However, several previous studies have shown very high sensitivity of most West African sorghum to photoperiod variation [18–21]. This characteristic gives them an important evolutionary advantage due to the continental climate of the zone, characterized by strong interannual variations in rainfall [22]. [15] reported a gradual abandonment of sweet sorghum cultivation due to climatic hazards such as irregular rainfall, progressive reduction of cultivable land, and low labor force. This is accentuated by the recurrence of droughts in West Africa, which has led to the adoption by farmers of varieties with shorter cycles than traditional cultivars [23]. Nowadays, very early varieties are still favored by agricultural extension programs, which believe that they are more resilient during bad seasons [19].

However, most farmers remain attached to their traditional varieties with longer cycles than modern varieties [24]. Indeed, traditional varieties, despite their limited productivity, have high yield stability [25]. The photoperiod sensitivity of these cultivars ensures that flowering is synchronized with the end of the rainy season regardless of the sowing date [26–28]. Moreover, the great diversity of their cycles constitutes an essential tool for adapting to the major climatic risks observed in the Sahelian zone and contributes to the resilience of cropping systems in these zones [20]. In the Sudano-Sahelian climate, production potential is determined very early by the first rains and the farmers' sowing date [29]. The length of the growing season decreases linearly with the date of rainfall. By integrating both the interannual climatic uncertainty and the staggered sowing practices of African farmers, it can be seen that photoperiod-sensitive varieties have a wider adaptation zone than early maturing varieties [19]. African sorghum improvement programs are beginning to incorporate photoperiodism in modern material, even though this work goes against one of the paradigms of the Green Revolution, which associates earliness with productivity [30]. The general objective of this study is to know the effect of two sowing dates on the expression of agromorphological traits and the Brix content of sweet sorghum accessions in Burkina Faso. In particular, the aim is (i) to determine the effect of the delayed sowing on the expression of agromorphological traits and the Brix content of local sweet sorghum genotypes and (ii) to determine their level of sensitivity to photoperiod.

2. Materials and Methods

2.1. Plant Material. The plant material consists of 29 sweet sorghum accessions belonging to four agromorphological groups and six genetic groups identified by [14]. These sorghum accessions come from six provinces of the country (Table 1). They were selected from the germplasm of the "Laboratoire Biosciences" of the "Université Joseph KI-ZERBO" based on the importance of their production in the areas of collection and the germination rate of their seeds.

2.2. Experimental Site. The field experiments were conducted at the "Institut du Développement Rural (IDR)" in Gampèla, located 18 km from Ouagadougou, at 12°5′ North latitude and 1°12′ West longitude. Rainfall and temperature records during the trial year are shown in Figure 1. Thus, during the trial period (2019), cumulative rainfalls were 777.1 mm from June to October 201 and 715.4 mm from July to October. The extreme temperatures were 30.9°C (June) and 27.4°C (August) [31].

2.3. Variation of the Photoperiod Duration during Experiment Year. Figure 2 shows the variation of the monthly average duration of the daily photoperiod. The duration increases gradually from January (11 h 28 mins 48 s) to June, where a peak is obtained (12 h 50 mins 24 s). It starts to decrease from July onwards. Its minimum value is obtained in December (11 h 25 mins 36 s). The days are indeed longer than the nights from May to August (>12 h 30 mins).

2.4. Experimental Design. Two trials were set up on 18 June and 12 July 2019, respectively. These dates were chosen to coincide with the usual sorghum sowing period in Burkina Faso and with the summer solstice (20 June) in order to study the cycle (maturing period) of accessions sown on long days (sowing on 18 June) and on short and decreasing days (sowing on 12 July).

A three-replicate Fisher block design was used for each trial. Each replicate consisted of 29 lines with one accession per line. Two border lines were made on either side of each replicate. Each line consisted of 14 pockets. The distances between lines, patches, and replications were 80 cm, 40 cm, and 2 m, respectively. The area of each trial was approximately 502 m^2 (25.6 m × 19.6 m).

2.5. Cultivation Techniques. Prior to planting the trial, both plots were first plowed with a tractor and leveled. During the course of the trial, a thinning with one plant per stake was carried out 15 days after sowing, followed by two wedding carried out, respectively, three and seven weeks after sowing. Ridging was carried out towards the end of the vegetative development of the plants in order to counteract the lodging caused by the high winds. The amendments consisted of

Table 1: List of the 29 accessions of sweet sorghum.

Accession code	Collection area	Agromorphological group	Genetic group
BBO5	Bam	III	E
BKB5	Bam	V	F
BKO2	Bam	II	E
BSA5	Bam	I	B
BZI3	Bam	I	B
GBI1	Gnagna	III	E
GBI3	Gnagna	III	E
GBO2	Gnagna	I	C
GBO4	Gnagna	I	D
GBO6	Gnagna	V	F
GBO8	Gnagna	II	A
GBO9	Gnagna	II	A
KBA10	Komondjairi	I	—
KBA14	Komondjairi	I	A
KBA2	Komondjairi	I	D
KBA5	Komondjairi	I	C
KBA9	Komondjairi	I	—
KGA1	Komondjairi	—	F
KGA2	Komondjairi	I	D
KGA6	Komondjairi	I	B
KGA7	Komondjairi	I	A
KGA8	Komondjairi	I	C
LTI5	Lorum	I	B
NBO1	Namentenga	I	F
NBO4	Namentenga	II	A
SAR7	Soum	I	A
SDJ2	Soum	I	C
SPO1	Soum	I	C
SPO3	Soum	I	C

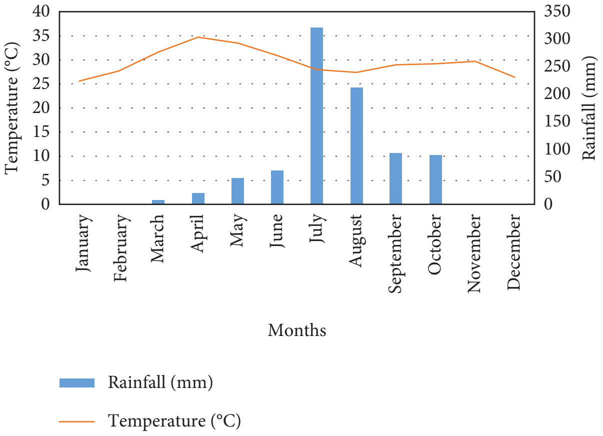

Figure 1: Variation of rainfall and temperature in the experiment site of "Gampèla" station [31].

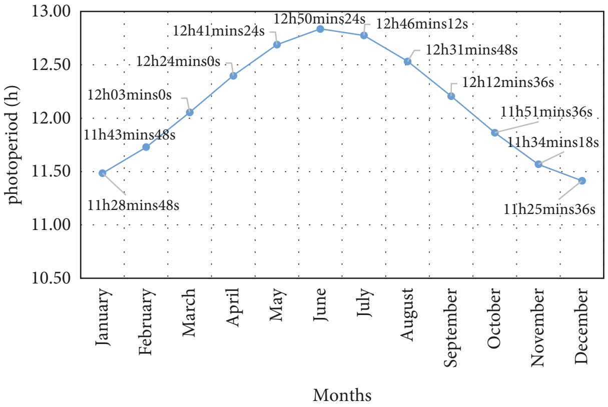

Figure 2: Variation of the monthly average duration of the daily photoperiod [31].

NPK fertilizer (14-23-14) at a rate of 100 kg/ha one week after the first weeding and urea at the same rate during the weeding. The plot was also treated with furadan at the juvenile and floral morphogenesis stages to control attacks by *Atherigona soccata.*

2.6. Data Collection. Fifteen quantitative variables were measured directly, and data collection was carried out from emergence to full grain maturity and included descriptive variables of phenology, plant architecture, yield, and soluble dry matter content of the stem (Brix). The Brix, which represents the fraction of sucrose in a liquid, was measured at the grain maturity stage on internodes 2, 4, and 6 using an ATAGO PAL-α portable digital refractometer with an accuracy of ±0.2%. According to [32, 33], sugar is unevenly distributed at the internodes of a single stem. The Brix measurement of each individual was determined by averaging the values obtained for each of the three internodes. Phenology parameters such as days to swelling (NDS), days to heading (NDH), and days to flowering (NDF), as well as the number of vegetative tillers (NVT) and the number of productive tillers (NPT), were recorded on the whole row. Other parameters were measured on three randomly selected plants in each row. These were the length (LEL) and the width (LEW) of the third subpanicular leaf, the length of the internode (LIN), the length of the peduncle (LPE), the height of the plant (HPL), the number of the internodes (NIN), the diameter of the main stem (DIS), the weight of the main panicle (PAW), and the length of the main panicle (PAL).

The photoperiodism coefficient (Kp) of each genotype was then determined by taking the ratio of the difference in sowing time–the appearance of the ligule of the flag leaf of the main stem between the first (NDS1) and the second (NDS2) sowing dates over the time difference between the two sowing dates ($|D1-D2|$), expressed in the Julian calendar [28, 34].

Kp = (NDS1 − NDS2/|D1 − D2|): Kp varies from 0 (for photoperiod insensitive varieties) to 1 for strictly photoperiodic varieties because the shortening of the vegetative period totally compensates for the sowing delay).

2.7. Statistical Analysis. The Excel 2016 spreadsheet and the Statistica version 6 software were used to analyze the collected data. Excel 2016 spreadsheet was used to make the figures and to calculate the photoperiodism coefficient of the accessions. The analysis of variance (ANOVA) was performed to assess the variability of the plant material and to determine the effect of sowing date on the expression of the traits using Statistica software.

3. Results

3.1. Effect of Sowing Date on the Vegetative Morphological Traits. The results of the analysis of variance recorded in Table 2 revealed high variability in the current plant material. Indeed, all vegetative traits discriminated significantly among the accessions evaluated (pr. <0.001).

In addition, the sowing date had a very significant influence on the expression of most vegetative traits (pr. <0.001) except for internode length (pr. $=0.367$). A significant increase in the number of vegetative tillers (+2.44 tillers) and productive tillers (+1.30 tillers) was observed at the second sowing date. However, delayed sowing resulted in a significant reduction of 6.19% and 20.92% in leaf size, 25.58% in the number of internodes (−3.46 cm), and 26.43% in plant height (−85.69 cm). With regard to the F values, the effect of the sowing date was the most preponderant on the expression of vegetative morphological traits.

As for the sowing date × genotype interaction, its effect was not significant on tillering and stem diameter (pr. $=0.279$). However, it had a significant effect on other vegetative traits such as leaf size and plant architecture, such as the number and length of internodes (pr. <0.042) and plant height (pr. $=0.028$).

3.2. Effect of Sowing Date on the Agronomic Traits. The results of the analysis of variance recorded in Table 3 revealed a variability within 29 accessions for all agronomical traits. Indeed, these traits significantly discriminated the accessions.

Sowing date significantly influenced the expression of most agronomic traits, except peduncle length (pr $=0.569$). Phenological traits were the most affected by the sowing date (very high F value). Indeed, the extreme values of the sowing-flowering time were 71 and 94 days at the first sowing date and 62–81 days at the second sowing date. As for the weight of the main panicle, the maximum values for the two sowing dates were 205.97 g and 189.16 g, respectively. The delayed sowing resulted in a significant decrease in the number of days from sowing to swelling (−11.89 days), the number of days from sowing to heading (−11.05 days), the number of days from sowing to flowering (−11.06 days), the panicle length (−2.63 cm), and the panicle weight (−6.19 g). The rate of reduction of the sowing-flowering time, panicle length, and main panicle weight was 12.79%, 8.27%, and 4.22%, respectively.

The sowing date × genotype interaction also had a very significant effect on the expression of all agronomic traits. The effect was more significant on phenological traits.

3.3. Effect of Sowing Date on Soluble Dry Matter Content (Brix). The results of the analysis of variance were recorded in Table 4. The Brix was discriminated very significantly among the accessions (pr. <0.001). Moreover, the Brix was also significantly influenced by sowing date (pr. <0.001), and genotype x sowing date interaction (pr $=0.001$). Indeed, a significant increase of about 6.48% in the mean Brix value was recorded during the second sowing date (Table 4).

Twenty-one accessions improved their Brix during delayed sowing (Figure 3), of which 15 showed a variation of more than 1%. Five accessions, GBO9 (5.43%), KBA10 (5.41%), SPO1 (4.86%), BKB5 (4.05%), and KBA2 (3.47%), increased their Brix by more than 3%. Five other genotypes (GBO4, GBO8, KBA5, NBO1, and SPO3) experienced very small Brix variation between the two sowing dates and expressed Brix contents of more than 20% regardless of the sowing date. However, a reduction of the Brix at the second sowing date was observed in eight accessions. Among these accessions, four (SAR7, KGA1, GBI3, and KBA14) showed a reduction of more than 1%.

3.4. Photoperiod Sensitivity of Sweet Sorghum Accessions. The results in Figure 4 showed that all accessions responded with a reduction of the sowing-heading time from 04.67 to about 23.33 days for a 25-day gap between the two sowing dates. Heading started on August 24 and ended on September 16 at the first sowing date. On the second sowing date, the heading started on September 9 and ended on September 25. There was a 16-day gap between the start of heading on the two dates and a 09-day gap between the end of heading, which coincided with the end of the rainy season starting in October. Most accessions started heading in September, during which time the photoperiod duration declined considerably.

All sweet sorghum accessions were indeed sensitive to photoperiod variation (Table 5). Thus, four classes of

Table 2: Results of the analysis of variance of vegetative morphological traits.

	Traits	NVT	NPT	LEL (cm)	LEW (cm)	NIN	LIN (cm)	DIS (cm)	HPL (cm)
Min.	D1	0	0	55.67	5.17	9	10.34	1.43	188.33
	D2	0	0	52.67	3.3	6.67	9.67	1.05	129
Max.	D1	8	5	88.5	10.73	16.67	31.5	2.97	464.33
	D2	11	6	80.83	10.17	13.67	31.07	2.2	347.67
Mean	D1	2.39	1.93	70.27	7.79	13.09	23.48	2.11	334.94
	D2	4.83	3.23	65.92	6.16	9.63	23.24	1.64	249.25
ΔD	(D2–D1)	2.44	1.3	−4.35	−1.63	−3.46	−0.24	−0,47	−85.69
Variation rate (%)	(ΔD/D1) ∗ 100	102.09	67.36	−6.19	−20.92	−26.43	−1.02	−22.27	−25.58
Sowing date	F	79.69	40.54	43.73	235.48	529.8	0.82	39.51	683.34
	Pr.	<0.001	<0.001	<0.001	<0.001	<0.001	0.367	<0.001	<0.001
Genotype	F	3.18	2.65	5.81	16.69	13.53	30.72	0.93	24.51
	Pr.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.569	<0.001
Sowing date × genotype	F	1.08	1.07	2.83	1.69	1.61	1.61	1.17	1.69
	Pr.	0.37	0.381	<0.001	0.028	0.042	0.042	0.279	0.028

NVT: number of vegetative tillers, NPT: number of productive tillers, LEL: leaf length, LEW: leaf width; NIN: number of internodes; LIN: internode length; HPL: plant height; DIS: stem diameter, D1: 1^{st} sowing date, D2: 2^{nd} sowing date, CV: coefficient of variation, ΔD: difference between the values of the two sowing dates, SD: standard deviation.

Table 3: Results of the analysis of variance of agronomic traits.

	Traits	NDS (days)	NDH (days)	NDF (days)	LPE (cm)	PAL (cm)	PAW (g)
Min.	D1	64	71	75	29.67	13.27	107
	D2	58	62	66	25.83	11.67	101.21
Max.	D1	90	94	97	80.83	45.67	205.97
	D2	74	81	82	79.5	41.67	189.16
Mean	D1	78.37	82.36	86.49	52.94	31.82	146.82
	D2	66.48	71.31	75.43	52.53	29.19	140.63
ΔD	(D2–D1)	−11.89	−11.05	−11.06	−0.41	−2.63	−6.19
Variation rate (%)	(ΔD/D1) ∗ 100	−15.17	−13.42	−12.79	−0.77	−8.27	−4.22
Sowing date	F	2299.3	1732.7	2011.6	0.42	35.22	5.94
	Pr.	<0.001	<0.001	<0.001	0.519	<0.001	0.016
Genotype	F	40.1	48.0	57.6	44.14	24.98	2.21
	Pr.	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Sowing date × genotype	F	11.3	8.6	10.2	1.77	2.94	1.61
	Pr.	<0.001	<0.001	<0.001	0.019	<0.001	0.041

Min.: minimum; Max.: maximum; NDS: number of days sowing–panicle swelling; NDH: number of days sowing–panicle heading; NDF: number of days sowing–flowering; LPE: Peduncle length; PAL: panicle length; PAW: main panicle weight; D1: 1^{st} sowing date; D2: 2^{nd} sowing date; ΔD: difference between the values of the two sowing dates; Pr.: probability; F: fisher value.

accessions were identified. Class 1 consisted of six accessions with low photoperiod sensitivity ($Kp < 0.3$), class 2 of 11 accessions with moderate photoperiod sensitivity ($0.3 \leq Kp < 0.5$), class 3 of 11 accessions with high photoperiod sensitivity ($0.5 \leq Kp < 0.8$), and class 4 of a single genotype with higher photoperiod sensitivity ($Kp > 0.8$). The GBO2 and GBI1 accessions were the least sensitive to photoperiod variation ($Kp = 0.19$), while the BSA5 accession was the most sensitive to photoperiod variation with coefficients (Kp) of 0.19 and 0.93, respectively.

4. Discussion

The variability observed within the germplasm for most quantitative traits is similar to the results reported by [14]. Indeed, these accessions come from different morphological and genetic groups already defined by [14].

The variability of the accessions was also reflected in the differential response to photoperiod variation. The significant effect of sowing date on most of the quantitative traits, except for internode length and peduncle length, would testify to the importance of the effect of environmental factors such as rainfall regime, temperature, humidity, and insolation on the behavior of cultivated annual species. These factors are characterized by high variability and spatiotemporal unpredictability in Sahelian regions [35, 36]. Indeed, phenological, vegetative, agronomic, and Brix content traits were strongly affected by sowing date. Phenology was the main parameter of sowing date that strongly influenced the expression of other morphological traits and Brix content. However, several authors have reported that the phenology of photoperiod-sensitive sorghum is even influenced by variation in photoperiod duration [22, 37]. *Sorghum* phenology, in fact, is influenced by the variability

Table 4: Results of the analysis of variance of brix.

		Brix (%)
Min.	D1	13.2
	D2	12.8
Max.	D1	23.83
	D2	24.17
Mean	D1	17.6
	D2	19.12
ΔD	(D2–D1)	1.6
Variation rate (%)	(ΔD/D1) ∗ 100	6.46
Sowing date	F	20.23
	Pr.	<0.001
Genotype	F	6.0
	Pr.	<0.001
Sowing date × genotype	F	2.25
	Pr.	0.001

Min.: minimum; Max.: maximum; D1: 1st sowing date; D2: 2nd sowing date; ΔD: difference between the values of the two sowing dates; Pr.: probability; F: fisher value.

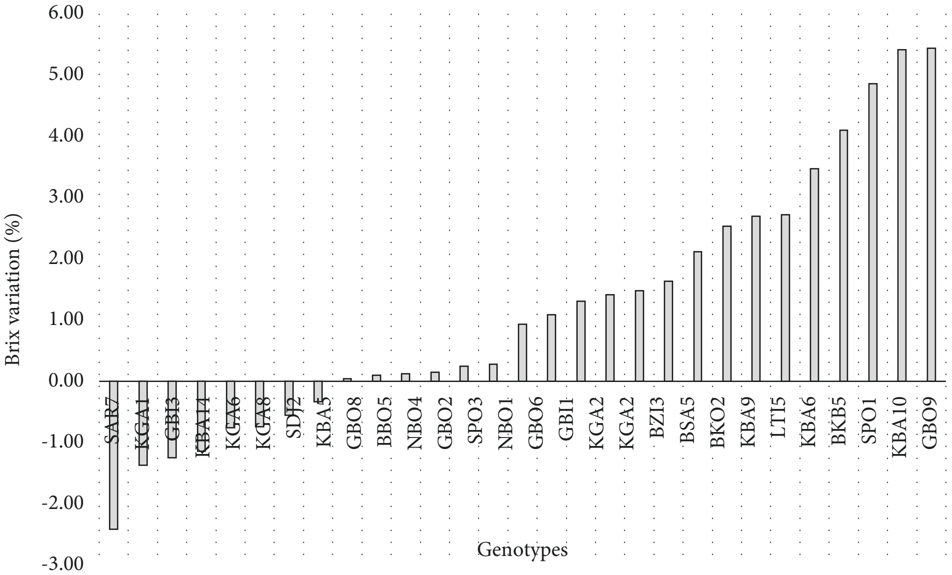

Figure 3: Variation of brix of the stem of the sweet sorghum accessions between the second and the first sowing dates.

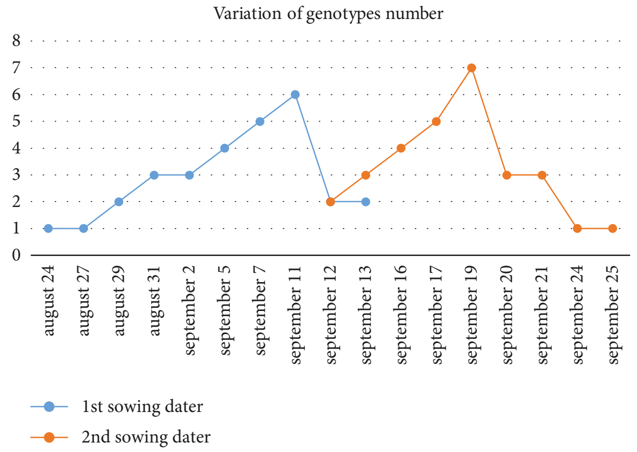

Figure 4: Variation of genotypes number according to the heading date of the accessions during the two sowing dates.

of the sowing-flowering cycle, which is strongly affected by day length in photoperiod-sensitive sorghum genotypes [22, 37, 38] and by the variability of the development rate of vegetative organs. Leaf and phytomer production is influenced by temperature [39, 40] and sowing date, possibly by photoperiod effects according to [41]. Indeed, the photoperiodic character of local sorghum varieties allows it to naturally adjust its cycle length to the likely duration of the rainy season [19, 42]. This leads to a reduction in cycle length when sowing is delayed and a lengthening of the cycle when sowing is early.

The 25-day sowing offset resulted in a reduction of the sowing-flowering time from 03 to about 21 days at the second sowing date and a 15-day gap between the start of flowering and 10 days between the end of flowering of the two sowing dates. All genotypes studied would be photoperiodic because the reduction of the sowing-flowering cycle

Table 5: Photoperiod coefficient values of sweet sorghum accessions.

Accessions	Photoperiod coefficient (Kp)	Photoperiod sensitivity
GBO2	0.19	WS
GBI1	0.19	WS
BKB5	0.24	WS
BKO2	0.28	WS
KGA6	0.28	WS
SPO3	0.29	WS
GBI3	0.31	MS
KBA10	0.35	MS
KGA2	0.39	MS
GBO6	0.42	MS
KGA1	0.43	MS
NBO4	0.44	MS
GBO4	0.44	MS
BBO5	0.45	MS
KGA7	0.45	MS
NBO1	0.48	MS
KBA14	0.49	MS
GBO9	0.51	HS
GBO8	0.52	HS
SDJ2	0.52	HS
KBA2	0.55	HS
KBA5	0.57	HS
SAR7	0.61	HS
SPO1	0.61	HS
KBA9	0.64	HS
KGA8	0.72	HS
LTI5	0.72	HS
BZI3	0.77	HS
BSA5	0.93	VHS

Kp: photoperiod coefficient; WS: weakly sensitive ($Kp < 0.3$); MS: moderately sensitive ($0.3 \le Kp < 0.5$); HS: highly sensitive ($0.5 \le Kp < 0.8$); VHS: very highly sensitive ($0.8 \le Kp < 1$).

at the second sowing date is characteristic of photoperiodic plants. This immediately resulted in a clustered flowering towards the end of the rainy season. Several previous studies [26–28] have reported a very high sensitivity of West African sorghum to photoperiodicity. This sensitivity of sorghum to photoperiod causes a shortening of the cycle when sowing is delayed, thus favoring flowering at the end of the rainy season. Thus, this characteristic would give them an important evolutionary advantage due to the continental climate of the zone, characterized by strong interannual variations in the rainfall regime. This characteristic specific to photoperiodic plants allows them to interrupt vegetative development in favor of grain production [18, 36], hence a drop in performance for most of the late-sown traits. Moreover, this interruption is made without taking into account the complete development of the plant but acts as a distress signal that intervenes to allow the transition from the vegetative phase to the reproductive phase in order to ensure the sustainability of the species [36]. Similar observations on photoperiodism have been made on Burkina Faso's sorghum [16, 43, 44]. Indeed, [39] on sweet grain sorghum reported cycle reductions of 03 to 10 days at three- and two-week sowing shifts, respectively. However, according to [28], a 15-day delay in sowing, for example, in the off-season (cool and hot dry season), can delay the cycle length by several months. Thus, depending on the sowing date, the cycle length of sorghum in Sudano-Sahelian Africa can vary from 90 to 190 days for the same variety [28]. The differential sensitivity of accessions to photoperiod variation observed in this study, which resulted in several photoperiodicity classes, could reflect the control of the cycle by more than one gene. Similar results are reported by [28], who revealed that the vegetative cycle is under the control of at least two major and several minor genes.

Delayed sowing thus led to a reduction in the size of the vegetative organs of sweet sorghum genotypes cultivated in Burkina Faso. Previous studies [41, 45, 46] revealed a reduction in growth during late sowing independently of water availability or other resources. The reduction in growth observed in this study would be much more related to the number of internodes and stem thickness than to internode length, which was not significantly affected by sowing date as reported by [38, 47]. The shortening of the vegetative cycle could also explain these results. Thus, the reduction in plant size observed at the second sowing date would be linked to a decrease in the number of phytomers (growth units) [41, 47].

The increase in the number of vegetative and productive tillers during delayed sowing could be explained by a kind of vegetative compensation by the production of numerous vegetative tillers by the plant due to the rapid interruption of the vegetative phase by the reproductive phase. Indeed, tillering ability depends both on the variety and on environmental conditions, including temperature and photoperiod [48]. Previous studies have reported an effect of temperature on heading in some sorghum genotypes. Indeed, [49, 50] revealed that a low night temperature (15°C) induces panicle initiation and reduces the number of final leaves, while a high night temperature (30°C) limits panicle initiation and increases the number of final leaves in all varieties. Thus, the concentration of heading of accessions of both sowing dates in the first half of September would be linked to a decrease in night temperature observed at this period. This could explain the shortening of the vegetative cycle of the accessions during the delayed sowing.

However, sweet sorghum genotypes (GBO9, KBA2, and SPO1), which are very sensitive to photoperiod by shortening their sowing-flowering cycle, increased their Brix content at the delayed sowing. On the other hand, genotypes (GBO4, NBO1, and SPO3) with low sensitivity to photoperiod expressed high and stable Brix contents (more than 20%) independently of sowing date. This difference in the expression of Brix content of the evaluated accessions would be related to the high genetic variability of the study material. [38] also reported variable Brix levels between genotypes and an effect of sowing date on Brix content of local sweet sorghum genotypes in Mali. However, contrary to the results obtained by [38], the high Brix levels recorded at the second sowing date in this study would be more related to the concentration than to the size of the storage compartment.

The study has certainly highlighted accessions with a high Brix irrespective of the sowing date, but the quantity of juice produced by the stalk and its biochemical composition, which is very decisive in the valorization of sweet sorghum, has not been evaluated. Thus, in the current context of climatic variability marked by recurrent pockets of drought and the constant reduction in rainfall, the characterization of accessions for drought tolerance combined with the quantification of the juice produced by each genotype and the analysis of the nutritional composition of the juice could make it possible to identify genotypes of interest that are tolerant to drought stress and have a high juice production potential with a high Brix. These genotypes could then be integrated into the sweet sorghum breeding program. Varieties developed from these genotypes of interest could then be more easily adopted by farmers and contribute to improving sweet sorghum production in Burkina Faso and the tropics.

5. Conclusion

The study showed that the expression of most agro-morphological traits and Brix is significantly influenced by sowing date variation. Indeed, delayed sowing resulted in a significant reduction in phenological, agronomical, and vegetative traits values on the one hand, and an increase in stem Brix content and vegetative and productive tillers production, on the other hand, in most of the sweet sorghum genotypes evaluated. Phenology was most affected by the sowing date. All the sweet sorghum accessions tested are sensitive to photoperiod with a coefficient of photoperiodism varying from one genotype to another. The accessions thus reduced their sowing-flowering time by 3 to 21 days for a sowing offset of 25 days. GBO2 and GBI1 accessions were the least photoperiodic ($Kp = 0.19$), while the BSA5 accession was the most photoperiodic ($Kp = 0.93$). However, the Brix content of some accessions was slightly affected by the variation in sowing date. Thus, the genotypes GBO4, GBO8, KBA5 NBO1, and SPO3, which obtained Brix contents above 20% regardless of sowing date, could be selected for the sweet sorghum breeding program.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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