INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 25, No. 6, p. 108-121, 2024

RESEARCH PAPER OPEN ACCESS

Effect of sowing dates on the growth and seed production of okra [*Abelmoschus esculentus* (L.) Moench] during the off-season in Burkina Faso

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Key words: Sowing dates, Okra genotypes, Seed production, Burkina Faso

http://dx.doi.org/10.12692/ijb/25.6.108-121 Article published on December 05, 2024

Abstract

Okra is a widely cultivated traditional vegetable in Burkina Faso. Its fruits are rich in micronutrients, vitamins, fiber, and mucilage, making it an essential dietary supplement. Despite its potential, okra cultivation faces challenges due to the limited availability of quality seeds. This study aimed to identify optimal sowing dates for producing high-quality okra seeds in Burkina Faso. Nine okra genotypes were evaluated under field conditions in Gampela during the 2022-2023 dry season. Sowing was conducted on three different dates (January 16, February 6, and February 27). Parameters related to germination, growth, and seed production were measured. Results revealed that sowing date significantly influenced plant growth and germination rates. Plants sown on February 6 (DS2) exhibited the best balance of growth, seed production, and germination rates (75.67%). Although January 16 (DS1) achieved the second-highest germination rate (67%) after DS2, growth parameters such as plant height and stem diameter were lower. February 27 (DS3) promoted maximum plant height but resulted in lower germination rates (55.74%) and fewer capsules. Genotypes Pusa Sawani, O2, and TOT2786 demonstrated adaptability to varying sowing dates, providing reliable options for farmers. The findings recommend prioritizing February sowing for optimal seed quality and yield under dry season conditions in Burkina Faso.

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Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is an economically significant vegetable crop widely cultivated in tropical and subtropical regions worldwide, particularly in West Africa (Abdulraheem *et al.*, 2019). Renowned for its adaptability to hot climates, drought, and low soil fertility, okra is suitable for both small gardens and large commercial farms (Abdulraheem *et al.*, 2017). Okra fruits, which can be consumed fresh, cooked, dried, or processed, provide a rich source of calcium, iron, magnesium, protein, vitamins A and C, and are often used as a dietary supplement in okra-growing regions (Doumbia, 2010).

Globally, India is the leading producer of okra, with an annual production of 6.466 million tons on approximately 0.531 million hectares, while Nigeria ranks first in Africa, producing 1.917 million tons on 0.149 million hectares (FAOSTAT, 2023).

Despite its importance, okra production in Burkina Faso remains relatively low (Sawadogo *et al.*, 2009). This situation contrasts with the plant's agronomic potential and the population's food needs. In 2021, okra production in Burkina Faso was estimated at only 23,021.85 tons (FAOSTAT, 2023), largely due to various constraints such as water stress, pests and diseases, and limited fruit preservation methods (Nana *et al.*, 2009). Additionally, the limited availability of quality seeds, combined with suboptimal agricultural practices, is a significant challenge (Ouedraogo, 2016). Like many other crops, okra faces numerous diseases and pests that hinder the production of sufficient quantities of high-quality seeds. However, seed quality is crucial for successful crop production (Moniruzzaman, 2007).

The timely availability of seeds in adequate quantity and quality is a prerequisite for optimal production (Ouedraogo, 2016). According to the Alliance for a Green Revolution in Africa (AGRA) in 2011, most African farmers only manage to produce a quarter of their average yield potential due to poor seed quality coupled with poor agricultural practices.

Sowing time has a significant impact on seed production and okra quality (Hossain *et al.*, 1999; Yadav *et al.*, 2001). Access to quality seeds is crucial for increasing agricultural production and combating food insecurity (Ripama, 2009). Several studies conducted in West Africa have demonstrated the significant impact of sowing dates on seed production. For example, research on sesame production in Nigeria revealed that sowing in June resulted in significantly higher yields compared to those planted in July and August (Adebayo *et al.*, 2020). Similarly, a study on maize showed that optimal sowing dates vary by region, with yield gains of up to 43% when planting is well-timed (Ogunlela *et al.*, 2021). Regarding cowpea, it is recommended to plant photoperiod-sensitive varieties between mid-July and mid-August to avoid excessive vegetative growth (IITA, 2019). However, research on the effects of sowing dates and cultivars on okra seed production in West Africa, particularly in Burkina Faso, is limited or non-existent (Fondio *et al.*, 2011). This study aims to determine the effects of sowing dates on okra seed production and germination in Burkina Faso.

Materials and methods

Study Site

The experiment was conducted at the experimental station of the Institute of Rural Development (IDR) located in Gampela, approximately 20 kilometers east of Ouagadougou, Burkina Faso. Geographically, the Gampela station is located at 12°22' west longitude and 12°25' north latitude. The climate is characterized by two distinct seasons: a dry season from October to May (8 months) and a rainy season from June to September (4 months). During the 2022 rainy season, preceding the experiment, the IDR Gampela meteorological station recorded a total rainfall of 913 mm. The average daily minimum and maximum temperatures during the experimental period (2023) were 12°C and 34°C in January (the coldest month) and 25°C and 41°C in April (the hottest month), respectively (Figure 1). The soil exhibits characteristics typical of tropical ferruginous leached soils, derived from a granitic parent rock. These soils have a predominantly loamy-sandy texture and are characterized by relatively low physicochemical fertility. A soil analysis of the experimental plot conducted by the National Soil Bureau in 2013 revealed the following composition: total nitrogen (0.028%), total phosphorus (192.2 ppm), and total potassium (2172.3 ppm).

Plant material

The plant material consisted of nine okra genotypes (Table 1). Five of these genotypes, identified by the codes UAE22, Pusa sawani, Gourcy1, O2, and G116, were selected from the germplasm of the Plant Genetics and Improvement Team (EGAP) at the Biosciences Laboratory of Joseph Ki-Zerbo University in Ouagadougou. Among these, Gourcy1, O2, and G116 were the result of participatory selection carried out in 2015 in Burkina Faso. UAE22 was specifically developed by the Plant Genetics and Improvement Team at the Biosciences Laboratory of Joseph Ki-Zerbo University, while Pusa Sawani is an early-maturing variety of Indian origin. These genotypes were selected based on their agronomic and morphological characteristics, which make them among the most cultivated varieties by farmers, and their fruits meet consumer expectations (Ouédraogo, 2016). The four other genotypes, namely TOT2786, PI538068, PI496676, and Sasilon, originated from the germplasm of the World Vegetable Center-AVRDC Mali. They were selected as part of research and improvement of local varieties.

Experimental design

The experimental design was a split-plot with two factors: sowing date and okra genotype. For each sowing date, a set of 27 elementary plots was used in the experimental design (9 genotypes x 3 replications). Considering all three sowing dates, the total number of elementary plots was 81 (3 dates x 9 genotypes x 3 replications). Each genotype was sown in two rows in each elementary plot, and a distance of 1.5 meters was maintained between the different replications. The spacing between rows and between plants was 0.7 meters and 0.5 meters, respectively, in accordance with the recommendations established by Ouédraogo (2016). A distance of 2 meters was maintained between the plots of each sowing date. The entire experimental design was installed on a total area of 636.65 m².

Cultural practices

The experiments were conducted during the dry season of 2023, with sowing carried out every 21 days. In total, three sowing dates were considered: DS1= 01/16/2023, DS2= 02/06/2023, and DS3= 02/27/2023. The chosen sowing dates align with the off-season period in Burkina Faso when okra production is common, selected to avoid the cold weather of December and early January. All recommended cultural practices were uniformly applied to all three sowing dates and all genotypes. At each sowing date, seeds were sown in tilled soil at a rate of three seeds per hill. A basal application of compost fertilizer at a rate of 20 tons per hectare was applied during plowing. To maintain the crops, weeding and pest control treatments were carried out. Weeding was performed as needed to prevent competition between okra plants and weeds, while promoting optimal vegetative development. Between the second and third weeks after sowing, thinning was carried out to maintain a single plant per hill, favoring the most vigorous plants. On the 30th day after sowing, after a weeding operation, an NPK (10-20-20) fertilizer was applied to the plants at a rate of 165 kg/ha. Periodic pest control treatments with deltamethrin (Decis 12.5 CE) at a dose of 1 liter/ha were carried out to prevent and control insect attacks. Irrigation was performed with borehole water every two days (Nana *et al.*, 2009).

Data collection in the field

Observations and measurements were carried out on:

- ✓ Growth parameters**:** plant height (HPL) and stem diameter (DTI).
- ✓ Phenological stage dates: date of 50% emergence (50% Lev), date of 50% bud formation (50% Bou), and date of 50% flowering (50% Flo).
- ✓ Yield components: capsule length (LOC), number of capsules per plant (NCP), number of seeds per capsule (NGC), seed weight per capsule (PGC), and thousand-seed weight (PMIG).

Seed yield (RDTg) was calculated for each genotype using the following formula:

$$RDTg\ (Kg/ha) = PGC \times NCP \times Np.$$

Legend:

- RDTg: Seed yield (Kg/ha)
- PGC: Average seed weight per capsule (Kg)
- NCP: Number of capsules per plant
- nP: Number of plants per hectare

Stem growth parameters were measured every eight days from the bud formation stage. For most characteristics, these measurements were made on four central plants per experimental plot. These plants were randomly selected and marked with strings for easy tracking of measurements. The dates of phenological stages were recorded for all plants in each elementary plot. Yield components were determined from nine capsules per genotype.

Laboratory germination test

The laboratory germination test aimed to evaluate the germination capacity of okra seeds from three different sowing dates. The Between Paper (BPH2O) method (ISTA, 2018) was used for the test, with three replications of 100 seeds per genotype. The seeds, previously soaked in water for 15 to 30 minutes, were placed between two moistened filter paper layers. The seeds contained in the rolled filter paper were then incubated at an optimal temperature of 25±2°C for seven days. A photoperiod of 12 hours per 24 hours was applied throughout the test. The germination criterion was the emergence of the radicle approximately 1.5 mm from the seed coat (Ben Dkhil and Denden, 2010). The germination rate was determined for each genotype and for each sowing date using the following formula:

$$\text{Germination rate} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds tested}} \times 100$$

Data analysis

The collected data were processed and analyzed using Microsoft Excel 2016 and the XLSTAT software version 2016. Excel was used for data entry, verification, and graph construction. Using XLSTAT, the data collected in the field and laboratory were subjected to an analysis of variance at a probability threshold of 5% to highlight significant or non-significant effects between the studied factors or their interactions.

The Student Newman Keuls test was performed to separate means in cases where significant effects were detected (Gomez and Gomez, 1984).

Results

Plant growth dynamics

Plant height

Statistical analysis of plant height, measured from bud formation to 40 days after bud formation (DAB), revealed significant differences ($p < 0.0001$) between sowing dates (Table 2). During this period, plant heights ranged from 8.69 to 19.59 cm, 10.85 to 25.86 cm, and 14.71 to 27.25 cm for plants from the first, second, and third sowing dates, respectively.

Table 1. Origin and cycle of the studied genotypes.

Code	Source	Cycle
UAE22	EGAP	Early (45-50 days)
Pusa Sawani	EGAP	Early (40-45 days)
Gourcy1	EGAP	Medium (50-55 days)
O2	EGAP	Medium (50-55 days)
G116	EGAP	Late (60-65 days)
TOT2786	World Vegetable Center- Mali	Early (45-50 days)
PI538068	World Vegetable Center- Mali	Medium (50-55 days)
PI496676	World Vegetable Center- Mali	Late (60-65 days)
Sasilon	World Vegetable Center- Mali	Early (45-50 days)

The interaction between genotypes and sowing dates was also significant ($p < 0.0001$) for plant height (Table 3). Among the genotypes G116, PI496676, Sasilon, PI538060, O2, and UAE22, plant heights were statistically equivalent for the three sowing dates. In contrast, a significant variation in heights was observed according to sowing dates for the Gourcy1 genotype. Plant heights from DS3 were higher than those from DS1 from bud formation to 40 DAB. This result was also observed for TOT2786 at bud formation, 8 and 16 DAB, and for Pusa Sawani at bud formation.

Table 2. Effect of sowing date on plant height

Sowing date	LB	L8	L16	L24	L32	L40
DS1	8,690±1,13 ^{c}	12,381±1,59 ^{c}	13,671±1,35 ^{b}	15,795±1,52 ^{b}	17,556±1,85 ^{b}	19,591±2,08 ^{b}
DS2	10,847±1,23 ^{b}	15,347±2,01 ^{b}	20,523±3,07 ^{a}	22,792±3,44 ^{a}	24,472±3,62 ^{a}	25,861±3,80 ^{a}
DS3	14,713±3,03 ^{a}	18,824±3,49 ^{a}	22,616±3,66 ^{a}	24,796±3,98 ^{a}	25,856±4,05 ^{a}	27,254±4,42^{a}
Pr > F	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001
Significant	*	*	*	*	*	*

Table 3. Average plant heights for different sowing dates and genotypes.

Génotype	Sowing date	LB	L8	L16	L24	L32	L40
G116	DS1	6,500 ^{e}	9,667 ^{e}	11,333 ^{e}	13,000 ^{e}	14,458 ^{d}	16,000 ^{c}
	DS2	10,042 ^{de}	13,292 ^{cde}	16,583 ^{bcde}	17,750 ^{bcde}	18,833 ^{abcd}	19,958 ^{abc}
	DS3	13,667 ^{abcd}	16,625 ^{abcde}	18,917 ^{abcde}	19,708 ^{abcde}	20,250 ^{abcd}	21,458 ^{abc}
PI496676	DS1	8,292 ^{de}	11,333 ^{de}	13,125 ^{de}	15,028 ^{de}	15,042 ^{cd}	17,050 ^{bc}
	DS2	9,583 ^{de}	12,875 ^{de}	18,292 ^{abcde}	19,958 ^{abcde}	21,167 ^{abcd}	22,500 ^{abc}
	DS3	11,167 ^{de}	14,583 ^{abcde}	18,208 ^{abcde}	20,542 ^{abcde}	21,792 ^{abcd}	23,125 ^{abc}
Gourcy1	DS1	8,250 ^{de}	12,375 ^{de}	13,542 ^{cde}	14,792 ^{de}	16,958 ^{bcd}	19,083 ^{abc}
	DS2	12,250 ^{bcde}	17,000 ^{abcde}	23,792 ^{abc}	27,250 ^{abc}	29,167 ^{ab}	30,375 ^{ab}
	DS3	18,000 ^{ab}	22,250 ^{ab}	27,167 ^{a}	29,625 ^{a}	31,292 ^{a}	32,500 ^{a}
Sasilon	DS1	8,875 ^{de}	12,000 ^{de}	13,500 ^{cde}	16,458 ^{cde}	18,333 ^{bcd}	20,083 ^{abc}
	DS2	10,333 ^{de}	15,417 ^{abcde}	20,292 ^{abcde}	22,583 ^{abcde}	24,417 ^{abcd}	25,125 ^{abc}
	DS3	12,792 ^{abcd}	17,292 ^{abcde}	22,750 ^{abcd}	25,750 ^{abcd}	27,458 ^{abc}	28,167 ^{abc}
PI538060	DS1	8,583 ^{de}	12,667 ^{de}	13,708 ^{cde}	16,083 ^{cde}	18,583 ^{bcd}	21,333 ^{abc}
	DS2	11,417 ^{cde}	15,708 ^{abcde}	23,458 ^{abcd}	26,292 ^{abcd}	29,000 ^{ab}	30,792 ^{a}
	DS3	12,750 ^{abcd}	16,833 ^{abcde}	21,375 ^{abcde}	23,750 ^{abcde}	25,458 ^{abcd}	27,250 ^{abc}
O2	DS1	8,875 ^{de}	11,653 ^{de}	13,708 ^{cde}	16,250 ^{cde}	18,875 ^{abcd}	20,583 ^{abc}
	DS2	10,125 ^{de}	14,167 ^{bcde}	17,625 ^{abcde}	19,792 ^{abcde}	22,083 ^{abcd}	23,667 ^{abc}
	DS3	13,250 ^{abcd}	17,750 ^{abcde}	22,042 ^{abcd}	24,208 ^{abcde}	24,992 ^{abcd}	26,575 ^{abc}
UAE22	DS1	8,333 ^{de}	13,194 ^{cde}	15,000 ^{cde}	16,708 ^{bcde}	18,125 ^{bcd}	20,250 ^{abc}
	DS2	11,958 ^{bcde}	16,792 ^{abcde}	21,208 ^{abcde}	23,833 ^{abcde}	25,750 ^{abcd}	28,292 ^{abc}
	DS3	14,500 ^{abcd}	19,708 ^{abcd}	23,667 ^{abc}	25,333 ^{abcd}	26,750 ^{abcd}	29,292 ^{abc}
TOT2786	DS1	9,458 ^{de}	13,083 ^{cde}	13,167 ^{de}	15,375 ^{de}	18,417 ^{bcd}	21,833 ^{abc}
	DS2	11,417 ^{cde}	16,292 ^{abcde}	22,000 ^{abcd}	24,542 ^{abcd}	26,208 ^{abcd}	27,000 ^{abc}
	DS3	18,750 ^{a}	22,833 ^{a}	25,708 ^{ab}	28,083 ^{ab}	27,875 ^{ab}	28,667 ^{abc}
Pusa sawani	DS1	11,042 ^{de}	15,458 ^{abcde}	15,958 ^{bcde}	18,458 ^{abcde}	19,208 ^{abcd}	20,100 ^{abc}
	DS2	10,500 ^{de}	16,583 ^{abcde}	21,458 ^{abcde}	23,125 ^{abcde}	23,625 ^{abcd}	25,042 ^{abc}
	DS3	17,542 ^{abc}	21,542 ^{abc}	23,708 ^{abc}	26,167 ^{abcd}	26,833 ^{abcd}	28,250 ^{abc}
Pr > F		<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001
Significant		*	*	*	*	*	*

Legend: LB: plant height at budding; L8: plant height at 8 days after budding (DAB); L16: plant height at 16 DAB; L24: plant height at 24 DAB; L32: plant height at 32 DAB; L40: plant height at 40 DAB (in cm).

ns : non-significant effect ; *: significant effect.

Means followed by the same letters and characters in the same column are not significantly different at the 5% level (Student Newman Keuls test).

Stem diameter

Regarding stem diameter, analyses conducted from bud formation to 40 days after bud formation (DAB) showed significant differences ($p < 0.0001$) between sowing dates (Table 4). Stem diameters ranged from 4.54 to 9.06 mm for plants from the first sowing date (DS1), 6.49 to 13.47 mm for those from the second sowing date (DS2), and 7.83 to 11.72 mm for those from the third sowing date (DS3). The interaction between genotypes and sowing dates was also significant (p < 0.0001) for stem diameter (Table 5). For genotypes G116, PI538060, O2, and Pusa Sawani, stem diameters were statistically equivalent for the three sowing dates. In contrast, significant variations in diameters were observed for the PI496676 genotype depending on sowing dates. Plants from DS3 had larger diameters than those from DS1 at bud formation. Moreover, for UAE22 and TOT2786, the largest diameters were observed at bud formation and 8 DAB. However, from 16 DAB to 32 DAB, the largest diameters were noted in DS2 for PI496676 and UAE22. The same was true for Sasilon at 16 and 24 DAB, for Gourcy1 from 24 to 40 DAB, and for TOT2786 from 16 to 40 DAB.

Table 4. Effect of sowing date on stem diameter.

Sowing date	DB	D8	D16	D24	D32	D40
DS1	4,542±0,65 c	5,307±0,62 b	6,174±0,61 c	6,956±0,71 c	7,917±0,90 c	9,062±1,28 c
DS2	6,488±0,70 b	8,669±0,91 a	10,963±1,25 a	11,785±1,27 a	12,894±1,20 a	13,471±1,13 a
DS3	7,834±1,22 a	8,829±1,27 a	9,689±1,31 b	10,386±1,27 b	11,139±1,26 b	11,716±1,19 b
Pr > F	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001
Significant	*	*	*	*	*	*

Table 5. Average stem diameters for different sowing dates and genotypes.

Génotypes	Sowing date	DB	D8	D16	D24	D32	D40
G116	DS1	4,906 abcde	5,548 bcde	6,492 cdef	7,433 cdef	8,496 cdef	9,683 abcde
	DS2	7,025 abcde	9,158 abc	11,028 abcd	11,988 abc	13,153 abc	13,723 ab
	DS3	7,900 abcd	8,958 abcd	9,789 abcde	10,592 abcdef	11,337 abcdef	11,908 abcde
	DS1	4,828 bcde	5,467 bcde	7,167 bcdef	7,983 bcdef	8,989 bcde	10,440 abcde
PI496676	DS2	6,767 abcde	9,200 abc	12,313 a	13,104 a	14,180 a	14,672 a
	DS3	8,697 a	9,658 ab	10,744 abcdef	11,370 abcde	12,138 abcde	12,630 abcde
	DS1	4,180 de	5,173 cde	5,862 gh	6,475 f	7,348 ef	8,177 de
Gourcy1	DS2	6,392 abcde	8,588 abcde	10,485 abcdefg	11,450 abcde	12,944 abc	13,308 abc
	DS3	7,791 abcd	8,490 abcde	9,354 abcdefgh	10,135 abcdef	10,965 abcdef	11,329 abcde
	DS1	4,556 de	5,347 cde	5,983 gh	6,458 f	7,683 def	8,871 bcde
Sasilon	DS2	5,908 abcde	8,517 abcde	10,666 abcdef	11,346 abcde	12,533 abcd	13,096 abcde
	DS3	7,303 abcde	8,294 abcde	8,942 abcde	9,361 abcde	10,326 abcde	10,889 abcd
	DS1	4,666 cde	5,491 bcde	6,242 fgh	7,333 def	8,742 bcdef	10,643 abcde
PI538060	DS2	6,608 abcde	8,292 abcde	10,875 abcdef	11,958 abcd	12,742 abc	13,324 abc
	DS3	7,388 abcde	8,665 abcde	9,701 abcdef	10,738 abcdef	11,408 abcdef	11,991 abcde
	DS1	4,197 de	4,923 de	5,750 h	6,550 f	7,002 f	8,084 e
O2	DS2	5,800 abcde	7,883 abcde	9,851 abcde	10,348 abcde	11,742 abcdef	12,502 abcde
	DS3	6,681 abcde	7,913 abcde	8,643 abcde	9,796 abcdef	10,561 abcdef	11,321 abcde
	DS1	4,762 cde	5,519 bcde	6,333 efgh	6,975 ef	7,650 ef	8,692 bcde
UAE22	DS2	7,075 abcde	9,292 abc	11,058 abc	11,908 abcd	12,634 abc	13,210 abcd
	DS3	8,619 ab	9,868 a	10,916 abcde	11,430 abcde	12,058 abcde	12,634 abcde
	DS1	3,958 e	4,613 e	5,367 h	6,517 f	7,642 ef	8,613 cde
TOT2786	DS2	7,038 abcde	8,900 abcd	11,703 ab	12,570 ab	13,563 ab	14,216 a
	DS3	8,402 abc	9,214 abc	9,861 abcdefgh	10,304 abcdef	10,970 abcdef	11,623 abcde
	DS1	4,828 bcde	5,685 abcde	6,367 defgh	6,875 ef	7,703 def	8,353 cde
Pusa sawani	DS2	5,783 abcde	8,188 abcde	10,686 abcdef	11,398 abcde	12,560 abcd	13,193 abcd
	DS3	7,727 abcde	8,402 abcde	9,248 abcde	9,750 abcdef	10,490 abcdef	11,123 abcde
Pr > F		<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001
Significant		*	*	*	*	*	*

Legend: DB: stem diameter at budding; D8: stem diameter at 8 days after budding (DAB); D16: stem diameter at 16 DAB; D24: stem diameter at 24 DAB; D32: stem diameter at 32 DAB; D40: stem diameter at 40 DAB (in mm). ns: non-significant effect; *: significant effect.

Means followed by the same letters and characters in the same column are not significantly different at the 5% level (Student Newman Keuls test).

Phenological stages

Statistical analysis revealed a significant effect ($p < 0.0001$) of sowing date on the date of 50% emergence, 50% bud formation, and 50% flowering of okra (Table 6). Similarly, the interaction between genotype and sowing date had a significant effect ($p < 0.0001$) on these phenological variables (Table 7).

Table 6. Effect of sowing date on phenological stage dates.

Sowing date	50%Lev	50%Bout	50%Flo
DS1	9,907±1,15 [a]	37,074±2,30 [a]	60,296±6,31 [b]
DS2	9,778±1,70 [a]	34,667±2,44 [b]	63,407±2,42 [a]
DS3	8,815±1,35 [b]	29,704±2,69 [c]	52,185±5,63 [b]
Pr > F	<0,0001	<0,0001	<0,0001
Significant	*	*	*

Table 7. Average dates of okra phenological stages according to different sowing dates and genotypes.

Génotypes	Sowing date	50%Lev	50%Bout	50%Flo
G116	DS1	11,000 [abcd]	38,667 [ab]	59,000 [bcde]
	DS2	11,333 [abc]	35,000 [abcde]	62,333 [bcd]
	DS3	9,000 [bcdef]	28,667 [fghi]	50,333 [def]
PI496676	DS1	8,333 [cdef]	39,333 [ab]	59,333 [bcde]
	DS2	7,333 [ef]	35,333 [abcde]	62,000 [bcd]
	DS3	7,000 [f]	30,667 [efghi]	52,000 [cdef]
Gourcy1	DS1	8,667 [bcdef]	36,000 [abcde]	66,000 [bc]
	DS2	7,667 [ef]	32,333 [cdefghi]	63,667 [bcd]
	DS3	7,333 [ef]	28,333 [ghi]	49,333 [def]
Sasilon	DS1	9,500 [abcdef]	39,500 [ab]	83,000 [a]
	DS2	9,667 [abcdef]	39,667 [a]	66,000 [bc]
	DS3	9,667 [abcdef]	35,667 [abcde]	62,333 [bcd]
PI538060	DS1	12,000 [ab]	37,500 [abcd]	59,000 [bcde]
	DS2	8,667 [bcdef]	34,667 [abcdef]	68,000 [ab]
	DS3	8,000 [def]	27,333 [hi]	57,000 [bcdef]
O2	DS1	11,333 [abc]	38,333 [abc]	58,000 [bcde]
	DS2	12,667 [a]	35,667 [abcde]	64,333 [bcd]
	DS3	11,000 [abcd]	32,000 [defghi]	55,000 [bcdef]
UAE22	DS1	9,667 [abcdef]	37,000 [abcd]	55,667 [bcdef]
	DS2	11,667 [ab]	36,667 [abcde]	64,333 [bcd]
	DS3	11,333 [abc]	31,333 [defghi]	55,333 [bcdef]
TOT2786	DS1	10,000 [abcdef]	34,000 [abcdefg]	52,667 [cdef]
	DS2	10,333 [abcde]	31,333 [defghi]	60,667 [bcde]
	DS3	8,333 [cdef]	27,000 [i]	45,667 [ef]
Pusa sawani	DS1	8,667 [bcdef]	33,333 [bcdefgh]	50,000 [def]
	DS2	8,667 [bcdef]	31,333 [defghi]	59,333 [bcde]
	DS3	7,667 [ef]	26,333 [i]	42,667 [f]
	Pr > F	<0,0001	<0,0001	<0,0001
Significant		*	*	*

Legend: 50%Lev: date of 50% emergence (in days after sowing, DAS); 50%Bout: date of 50% budding (in DAS); 50%Flo: date of 50% flowering (in DAS).
ns: non-significant effect; *: significant effect.
Means followed by the same letters and characters in the same column are not significantly different at the 5% level (Student Newman Keuls test).

On average, the earliest emergence, bud formation, and flowering were observed with DS3 (8.81 days, 29.70 days, and 52.19 days, respectively), while the latest emergence, bud formation, and flowering were observed with DS1 (9.91 days, 37.07 days, and 60.30 days, respectively). For all genotypes, the dates of 50% emergence were statistically equivalent except for PI538060, where emergence was faster for the February 27 sowing (DS3) and later for the January 16 sowing (DS1).

Table 8. Effect of sowing date on yield components.

Sowing date	NCP	LOC	NGC	PGC	PMIG	RDTg
DS1	2,046±1,13 ^{ab}	11,179±2,28 ^{b}	52,022±12,47 ^{a}	2,702±0,75 ^{a}	51,908±7,82 ^{ab}	155,286±83,00 ^{a}
DS2	2,173±0,86 ^{a}	12,963±2,81 ^{a}	52,543±10,37 ^{a}	2,989±0,83 ^{a}	55,929±7,42 ^{a}	183,225±87,34 ^{a}
DS3	1,593±0,79 ^{b}	12,565±2,19 ^{a}	52,753±10,26 ^{a}	2,555±0,75 ^{a}	48,344±11,3 ^{b}	119,190±71,27 ^{a}
Pr > F	<0,0001	<0,0001	0,931	0,243	0,149	0,085
Significant	*	*	ns	ns	ns	ns

Table 9. Average okra yield parameters for different sowing dates and genotypes.

Génotypes	Sowing date	NCP	LOC	NGC	PGC	PMIG	RDTg
G116	DS1	1,250 ^{bcde}	14,333 ^{abc}	54,778 ^{a}	3,017 ^{a}	59,064 ^{a}	100,832 ^{a}
	DS2	2,222 ^{abcde}	16,750 ^{a}	54,333 ^{a}	3,280 ^{a}	59,361 ^{a}	221,711 ^{a}
	DS3	1,333 ^{bcde}	16,167 ^{a}	49,333 ^{a}	2,757 ^{a}	51,330 ^{a}	115,141 ^{a}
PI496676	DS1	1,500 ^{bcde}	7,658 ^{e}	49,111 ^{a}	2,737 ^{a}	54,257 ^{a}	141,117 ^{a}
	DS2	1,833 ^{abcde}	8,250 ^{cde}	56,333 ^{a}	3,527 ^{a}	62,759 ^{a}	183,870 ^{a}
	DS3	1,167 ^{cde}	8,278 ^{cde}	54,333 ^{a}	2,967 ^{a}	53,087 ^{a}	107,189 ^{a}
Gourcy1	DS1	1,583 ^{abcde}	12,281 ^{abcde}	49,111 ^{a}	2,317 ^{a}	44,856 ^{a}	117,022 ^{a}
	DS2	2,167 ^{abcde}	13,750 ^{abcd}	40,444 ^{a}	2,037 ^{a}	50,920 ^{a}	124,284 ^{a}
	DS3	1,333 ^{bcde}	14,111 ^{abc}	54,000 ^{a}	2,283 ^{a}	42,177 ^{a}	85,491 ^{a}
Sasilon	DS1	1,500 ^{bcde}	11,325 ^{abcde}	74,917 ^{a}	3,715 ^{a}	49,553 ^{a}	123,689 ^{a}
	DS2	1,444 ^{bcde}	14,500 ^{ab}	70,000 ^{a}	3,867 ^{a}	54,140 ^{a}	170,759 ^{a}
	DS3	0,556 ^{e}	14,222 ^{abc}	64,056 ^{a}	2,387 ^{a}	36,966 ^{a}	31,174 ^{a}
PI538060	DS1	2,500 ^{abcde}	11,313 ^{abcde}	45,000 ^{a}	2,125 ^{a}	46,960 ^{a}	183,807 ^{a}
	DS2	2,222 ^{abcde}	14,083 ^{abc}	48,333 ^{a}	2,420 ^{a}	49,571 ^{a}	153,775 ^{a}
	DS3	1,056 ^{cde}	12,111 ^{abcde}	61,000 ^{a}	2,270 ^{a}	37,713 ^{a}	77,729 ^{a}
O2	DS1	0,750 ^{de}	7,767 ^{de}	58,833 ^{a}	3,360 ^{a}	56,667 ^{a}	70,475 ^{a}
	DS2	1,111 ^{cde}	7,833 ^{de}	52,111 ^{a}	3,210 ^{a}	55,889 ^{a}	110,951 ^{a}
	DS3	0,778 ^{de}	8,972 ^{bcde}	55,500 ^{a}	2,920 ^{a}	51,278 ^{a}	57,713 ^{a}
UAE22	DS1	1,583 ^{abcde}	11,333 ^{abcde}	53,444 ^{a}	2,587 ^{a}	47,713 ^{a}	127,165 ^{a}
	DS2	1,556 ^{abcde}	15,750 ^{a}	59,111 ^{a}	3,377 ^{a}	57,242 ^{a}	150,982 ^{a}
	DS3	1,444 ^{bcde}	13,000 ^{abcde}	48,222 ^{a}	2,130 ^{a}	42,830 ^{a}	84,761 ^{a}
TOT2786	DS1	4,333 ^{a}	12,767 ^{abcde}	40,556 ^{a}	2,220 ^{a}	55,522 ^{a}	278,377 ^{a}
	DS2	3,000 ^{abcde}	13,750 ^{abcd}	50,333 ^{a}	2,610 ^{a}	51,848 ^{a}	234,568 ^{a}
	DS3	3,667 ^{abc}	13,611 ^{abcde}	43,556 ^{a}	2,607 ^{a}	59,253 ^{a}	287,107 ^{a}
Pusa sawani	DS1	3,417 ^{abcd}	11,833 ^{abcde}	42,444 ^{a}	2,243 ^{a}	52,578 ^{a}	224,901 ^{a}
	DS2	4,000 ^{ab}	12,000 ^{abcde}	41,889 ^{a}	2,573 ^{a}	61,627 ^{a}	298,123 ^{a}
	DS3	3,000 ^{abcde}	12,611 ^{abcde}	44,778 ^{a}	2,677 ^{a}	60,462 ^{a}	226,409 ^{a}
	Pr > F	<0,0001	<0,0001	0,397	0,801	0,332	0,052
Significant		*	*	ns	Ns	ns	ns

Legend: NCP: number of capsules per plant; LOC: capsule length (in cm); NGC: number of seeds per capsule; PGC: seed weight per capsule (in g); PMIG: weight of one thousand seeds (in g); RDTg: grain yield (in kg/ha).
ns: non-significant effect; *: significant effect.
Means followed by the same letters and characters in the same column are not significantly different at the 5% level (Student Newman Keuls test).

Similarly, the dates of 50% flowering were statistically equivalent except for Gourcy1 and Sasilon. For these genotypes, plants from the February 27 sowing (DS3) flowered faster, while those from the January 16 sowing (DS1) flowered later. However, for the date of 50% bud formation, only Sasilon and UAE22 showed statistically equivalent results. For the other genotypes, flower buds appeared faster in plants from the February 27 sowing (DS3) and later in plants from the February 6 sowing (DS2). Among all genotypes studied, TOT2786 and Pusa Sawani were the genotypes that reached their 50% bud formation and flowering dates earlier than all other genotypes (respectively: DS1 = 34 days, DS2 = 31 days, DS3 = 27 days and DS1 = 33 days, DS2 = 31 days, DS3 = 26 days).

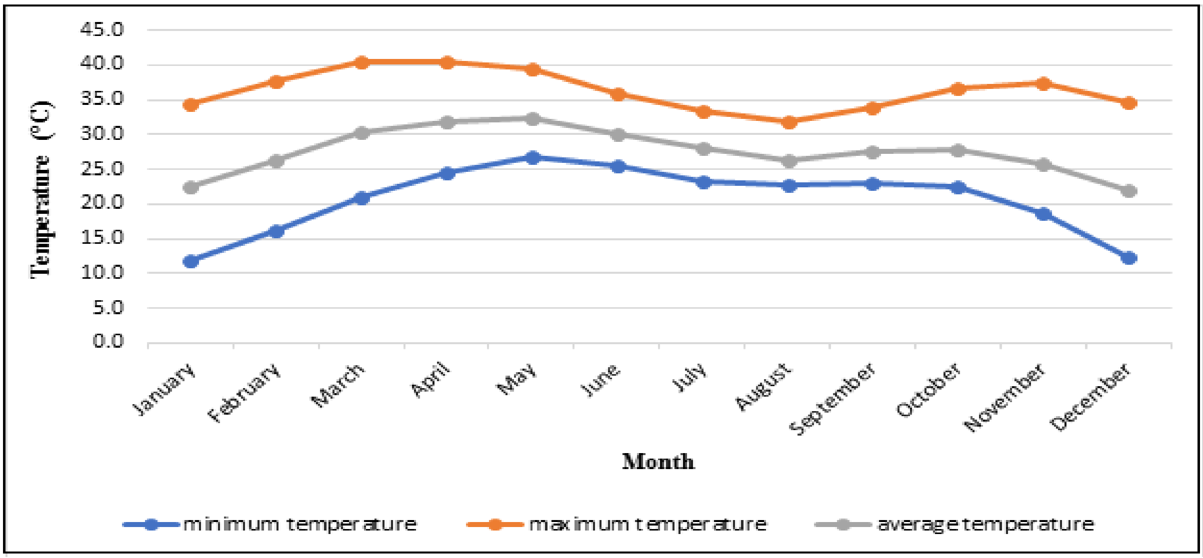

Fig. 1. Monthly variation of average temperatures (maximum, minimum, and average) at the Gampela station in 2023 (Gampela, 2023).

Yield parameters

Statistical analysis revealed a significant difference ($p < 0.0001$) between sowing dates in terms of the number of capsules per plant and capsule length of okra. However, there was no significant difference between sowing dates for other yield parameters such as the number of seeds per capsule ($p = 0.931$), seed weight per capsule ($p = 0.243$), thousand-seed weight ($p = 0.149$), and seed yield ($p = 0.085$) (Table 8). Similarly, the interaction between sowing dates and genotypes was significant ($p < 0.0001$) for the number of capsules per plant and capsule length, but not for the number of seeds per capsule ($p = 0.397$), seed weight per capsule ($p = 0.801$), thousand-seed weight ($p = 0.332$), and seed yield ($p = 0.052$) (Table 9). For plants from the February 27 sowing (DS3), the average number of capsules per plant was 1.60, the lowest among the three sowing dates. In contrast, for plants from the February 6 sowing (DS2), the average number of capsules per plant was 2.17, the highest among sowing dates. Regarding capsule length, the longest capsules were observed in plants from the February 6 sowing (DS2), with an average length of 12.96 cm. In comparison, the shortest capsules were found in plants from the January 16 sowing (DS1), with an average length of 11.18 cm. For all genotypes, the number of capsules per plant and capsule length were statistically equivalent for the three sowing dates.

Germination rate

Analysis of variance revealed a significant difference ($p < 0.0001$) between sowing dates regarding germination rate (Figure 15). Additionally, the interaction between the two studied factors was found to be significant ($p < 0.0001$) (Figure 16). Among all seeds subjected to the tests, those from DS2 exhibited the best germination rates (75.67%), followed closely by those from DS1 (67%) and DS3 (55.74%). For genotypes TOT2786, Pusa Sawani, O2, and G116, germination rates of seeds from the three sowing dates were statistically equivalent.

Discussion

The results show a significant influence of sowing date on plant height and stem diameter in okra. In particular, DS3 favored the most marked height growth, and DS2 favored the development of diameters. The low temperatures in January at the time of the experiment (T.min. = 11.9°C) could be the cause of the low diameters and heights obtained in plants from DS1 (January 16). Indeed, optimal temperatures favor vigorous okra growth. Moreover, warm, but not excessively high, temperatures are beneficial for photosynthesis and metabolism. This leads to an accumulation of biomass and an increase in the size and mass of plant organs. This observation is in agreement with the results of Das *et al.* (2018), Tandel *et al.* (2017), and Shahid *et al.* (2015) who showed that low temperatures contribute to limiting the growth in length and thickness of okra stems.

Doumbia *et al.* (2008) also showed this sensitivity of okra to low temperatures. According to them, temperatures below 15°C and above 35°C were critical for okra growth. Nana *et al.* (2009) found that okra is a thermolabile plant, as relatively low ambient temperatures cause a reduction in okra growth.

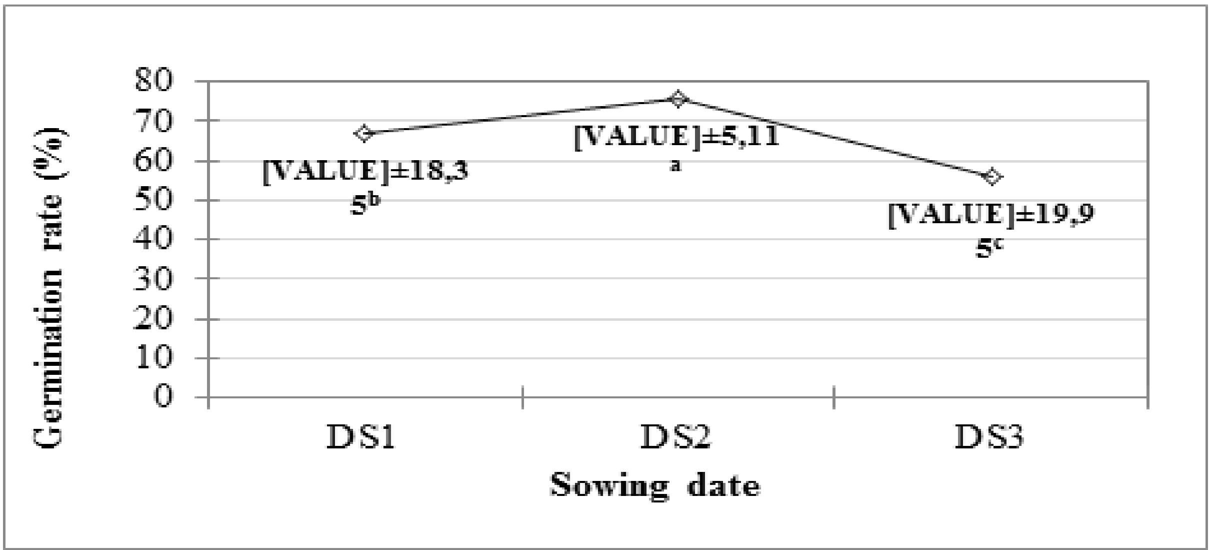

Fig. 2. Effect of sowing date on germination rate**.**

Considering that okra is a photoperiodic plant (Siemonsma and Hamon, 2004), the better growth of plants from the second and third sowing dates could be explained by their exposure to longer day conditions. Indeed, unlike the period from December to March, which falls in winter (almost equal day and night length), as we move from March to June, the length of the day increases (longer days). Oyolu (1977) indicated that the difference between the duration of these two types of days is certainly small in the subequatorial regions, but it is sufficient to influence the duration of the vegetative period of okra. Fondio (2005) in a study in Côte d'Ivoire showed that photoperiod had an influence on the development of Tomi okra varieties. The data analysis reveals that sowing date does not have a significant influence on the key seed yield parameters of okra, namely the number of seeds per capsule, seed weight per capsule, thousand-seed weight, and seed yield.

This lack of effect suggests that okra seed yield parameters are relatively insensitive to variations in the sowing period during the dry season. Faced with moderate water stress associated with dry season cultivation, okra plants develop adaptation mechanisms, such as reducing stomatal openings to limit water loss. This adaptation potentially affects photosynthesis and the production of capsules and seeds at all three sowing dates, tending to yield fairly similar yields. This observation corresponds to the results of Amjad *et al.* (2001), who found that sowing at different dates within the same season did not impact okra capsule yields. However, these results contradict those of Ashoka *et al.* (2002), Dilruba *et al.* (2009), and Mike (2010), who reported that okra sown during the hottest months of the dry season significantly yielded better than during the coldest months of the dry season.

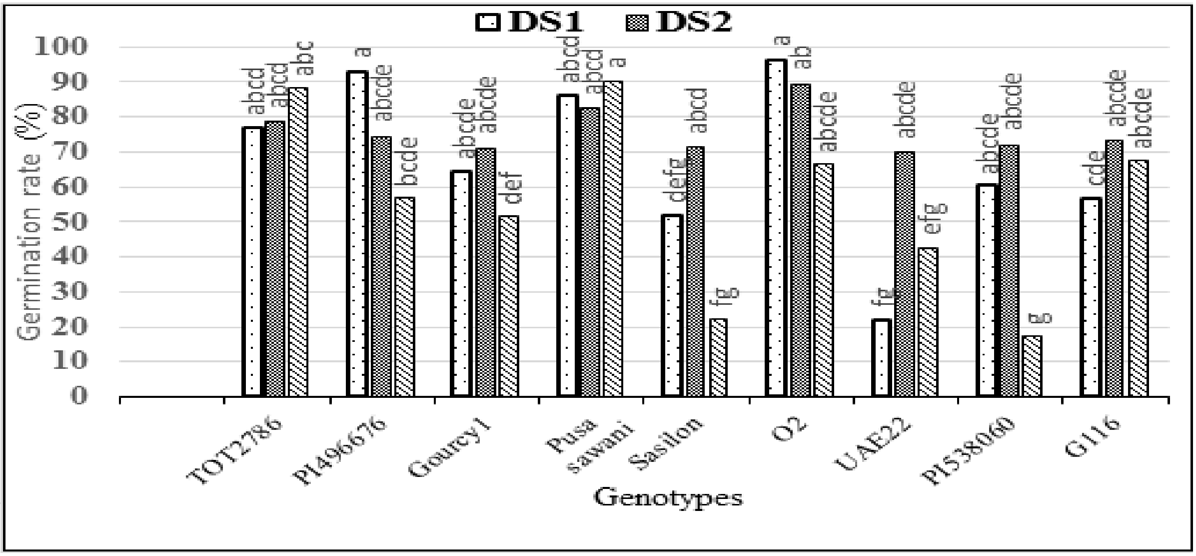

Fig. 3. Germination rate as a function of genotype and sowing date.

Regarding the germination rate of seeds, the observed variations among genotypes can be attributed to genetic factors. Each genotype possesses a unique set of genes that influence various aspects of plant growth and development, including germination. Ouédraogo (2016) showed that control of the germination power of okra seeds is genetic, as the observed variability within accessions is largely influenced by the genotype factor.

The low germination rate observed in seeds from the third sowing date could be explained by insufficient seed filling. Indeed, variations in seed maturity at harvest time can impact their germination potential. Seeds were less developed, as evidenced by the data on thousand-seed weight (48.344 g). Ouédraogo in 2016 showed that germination power and seed weight are two positively linked traits, justifying the better germination rates of heavier seeds compared to lighter seeds. These results corroborate those of El Balla *et al.* (2011), who showed that insufficiently mature seeds have more difficulty germinating. In addition, certain genotypes like Pusa Sawani, O2, and TOT2786, which exhibited relatively stable and high germination rates despite variations in sowing date, can be considered more robust and better adapted to a wide range of conditions. These results provide crucial information for farmers seeking to maximize their okra seed production.

Conclusion

The results of this study highlight the crucial importance of sowing date on okra seed production in Burkina Faso. Temperature, a determining climatic factor, significantly influences the different phases of plant development. High temperatures in late February and early March favor rapid germination and early flowering, thus optimizing yields. It is therefore recommended to prioritize late sowing, between mid-February and late February, to take full advantage of these favorable thermal conditions. Among the studied genotypes, Pusa Sawani, O2, and TOT2786 distinguished themselves by their ability to maintain high germination rates, even under variable conditions. These varieties therefore present interesting potential for more stable and adaptable okra seed production. However, to further improve the quality and quantity of seeds produced, it would be relevant to deepen research on the health status of okra seeds.

Acknowledgments

We gratefully acknowledge the financial support provided by the European Union and the Dutch Ministry of Foreign Affairs through the "Local Production of Safe Vegetables for West African Consumers (SAFEVEG)" project (ID-4000003936), under the DeSIRA program. This project was implemented by the World Vegetable Center, CIRAD, and Wageningen University.

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