International Journal of Plant & Soil Science

Volume 38, Issue 8, Page 243-251, 2026; Article no.IJPSS.162504
ISSN: 2320-7035

Germination and Flowering Dynamic Modeling of Okra Cultivars (*Abelmoschus esculentus* L.) in Niger

Adamou Ibrahim Maman Laouali [a*], Moumouni Seyni Charifatou [a], Alio Moussa Abdourazak [a], Mahamane Adamou [a], Rafiou Ousmane Abdoulaye [a], IDI Saidou Sani [b] and Bakasso Yacoubou [a]

[a] *Department of Biology, Faculty of Science and Technology, Abdou Moumouni University, Niamey, Niger.*
[b] *Faculty of Science and Technology, University of Diffa, Niamey, Niger.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2026/v38i86214

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/162504

Original Research Article

Received: 12/05/2026
Accepted: 18/07/2026
Published: 21/07/2026

Abstract

Okra (*Abelmoschus esculentus*) is a fruit vegetable of the family Malvaceae and exhibits considerable morphological and phenological diversity in West Africa. In Niger, this diversity may support varied consumer preferences and market requirements. This study aimed to improve understanding of the phenological characteristics of ten okra cultivars in Niger. The experiment was conducted in the botanical garden of the Faculty of Science and Technology, Abdou Moumouni University, Niamey, using a randomised complete block design with three replications. Observations focused on germination and flowering, and the Kaplan-Meier survival-analysis model was used to examine cultivar dynamics over time.

**Corresponding author: E-mail: amamanlaouali@gmail.com;*

Cite as: *Laouali, A. I. M., Charifatou, M. S., Abdourazak, A. M., Adamou, M., Abdoulaye , R. O., Sani, I. S., & Yacoubou, B. (2026). Germination and Flowering Dynamic Modeling of Okra Cultivars (Abelmoschus esculentus L.) in Niger. International Journal of Plant & Soil Science, 38(8), 243–251. https://doi.org/10.9734/ijpss/2026/v38i86214*

Germination occurred between 3 and 10 days after sowing. The median germination time was approximately 5 days, corresponding to the point at which 50% of the seeds had germinated. Cultivar 10 germinated earliest, followed by Cultivars 8, 7, 2, and 1. Flowering occurred between 42 and 73 days after sowing. The median flowering time was approximately 53 days, corresponding to the point at which the estimated probability of remaining unflowered first fell below 50%. Cultivars 8, 6, 10, 9, 1, and 7 flowered earliest. The findings demonstrate temporal variation in germination and flowering among the evaluated cultivars and provide preliminary information for identifying early-performing materials under the local growing conditions of Niamey.

Keywords: Okra; Abelmoschus esculentus; germination dynamics; flowering dynamics; Kaplan–Meier analysis; phenology; cultivar earliness; survival analysis; Niger; Sahelian agriculture.

1. Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is one of the most important vegetable crops in tropical and subtropical regions, where it contributes substantially to food security, dietary quality, and the incomes of smallholder farmers (Kaleri et al., 2024). Its high content of fibre, vitamins, minerals, and bioactive compounds, together with its capacity to adapt to relatively harsh environmental conditions, makes it a strategic crop for sustainable agriculture in arid and semi-arid areas (Haq et al., 2023; Kaleri et al., 2024). Okra is therefore of considerable nutritional and economic importance, particularly in tropical and subtropical regions. The dynamics of germination and flowering in okra cultivars, which are influenced by biotic and abiotic factors, play an important role in crop productivity and resilience. This study was conducted in a context in which water stress and climate variability threaten agricultural production, creating a need for accurate modelling to improve understanding of the interactions between genotype and environmental conditions (Sawadogo et al., 2009). Modelling the germination and flowering dynamics of okra cultivars (*Abelmoschus esculentus*) can support the optimisation of agricultural practices and adaptation to environmental variation. Okra is subject to climatic constraints that influence germination, growth, flowering, and productivity. Furthermore, advances in the phenotypic and genetic characterisation of okra genetic resources have revealed considerable diversity in growth and developmental responses among genotypes, thereby creating opportunities for plant breeding and the selection of cultivars adapted to different agroecological contexts (Mishra et al., 2024). These approaches can help predict okra responses under different climatic scenarios by considering factors such as seed type, planting depth, and soil type (Diallo et al., 2022). Studies conducted in Senegal on local and introduced cultivars have also highlighted the importance of cultural practices, including fertilisation methods and cultivar selection, in optimising critical stages of the crop cycle, particularly emergence and flowering (Thiaw et al., 2019).

Recent evidence further indicates that okra phenology and early establishment vary among genotypes and can be influenced by seed priming and cultivar-specific seed characteristics (Sheferie et al., 2023; Gul et al., 2025). Fertiliser management has also been associated with differences in flowering time and the germination quality of harvested okra seed (Yadav et al., 2026). Likewise, organic nutrient inputs can influence okra growth and yield performance, indicating that management conditions should be considered when cultivars are compared (Devi et al., 2025).

Despite evidence that genotype, environment, and crop management affect okra development, comparative time-to-event information on germination and flowering among locally cultivated okra materials in Niger remains limited. In particular, the temporal progression of these stages has rarely been evaluated using survival-analysis methods that can accommodate events occurring at different times.

This research was designed to identify the cultivars that germinate and flower earliest under local conditions. Therefore, the study aimed to model the germination and flowering dynamics of ten okra cultivars grown under the local conditions of Niamey, Niger, using the Kaplan-Meier method and to identify cultivars with relatively early germination and flowering.

2. Methodology

2.1 Experimental Site

The study was conducted in the botanical garden of the Faculty of Science and Technology (FAST), Abdou Moumouni University, Niamey, Niger (Fig. 1). The garden covers an area of 5.19 ha. The experimental site is located at 13°30′09.4″ N and 02°05′56.3″ E. It is characterised by a southern Sahelian climate (Saadou, 1990). The mean annual rainfall recorded in this area is approximately 422.7 mm. The soil at the site is sandy loam (Garba et al., 2020).

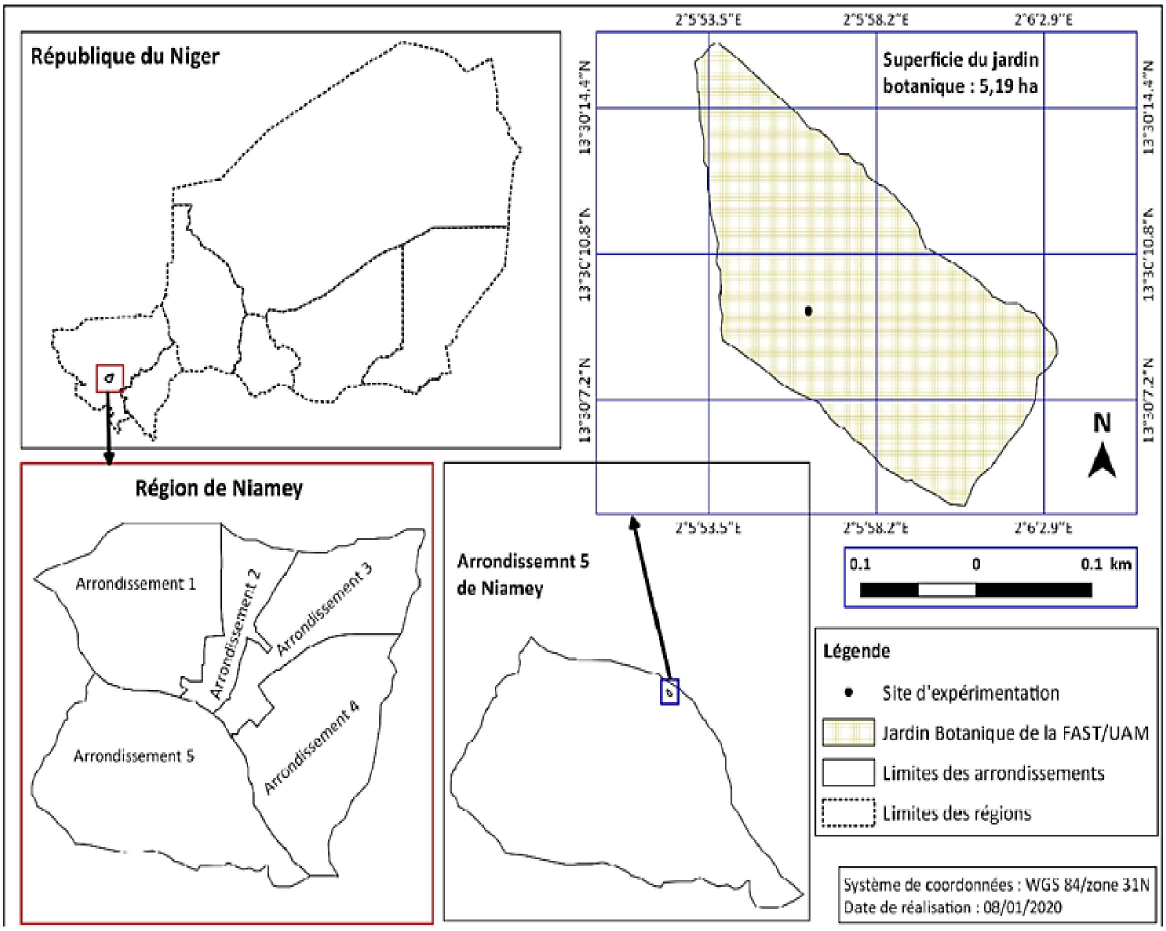

Fig. 1. Map of the study area (Garba et al., 2020)

2.2 Plant Material

The plant material (Table 1) comprised ten (10) okra cultivars originating from various locations in Niger.

Table 1. Some characteristics of the cultivars studied

Cultivars	Name	Origin
Cultivar 1	Harey garey	Tillabéry
Cultivar 2	Gombo de Gueskerou	Diffa (Gueskerou)
Cultivar 3	Gombo de Lada	Diffa (Lada)
Cultivar 4	Gombo de Diffa	Diffa (Diffa)
Cultivar 5	Gombo long	-
Cultivar 6	Gombo court	-
Cultivar 7	Gazelle	-
Cultivar 8	Gombo de Sakoira	Sakoira
Cultivar 9	Gombo de Tillabéry	Tillabéry
Cultivar 10	Gombo de Balleyara	Balleyara

2.3 Experimental Design and Data Collection

The experiment was conducted during the 2024 rainy season in the botanical garden of the Faculty of Science and Technology (FAST), Abdou Moumouni University, Niamey, Niger. The trial used a randomised complete block design with three replicates, with the third block divided into two parts of five rows each and distributed across the first two blocks. Cultivar was the only factor studied, with 10 treatments corresponding to the different cultivars. The total trial area was 93 m² (6 m × 15.5 m). Each block comprised ten (10) rows of five (05) plots each, giving a total of fifty (50) plots per block. Of the five plots in each row, the three central plots were used for the study, giving a total of 90 plots across all blocks. In each block, each cultivar was represented by a 2 m row containing five (05) planting holes spaced 0.5 m apart. The area of an entire block was 18 m², and the distance between rows was 1 m (Fig. 3). Germination and flowering dates were recorded for the three replicates in each block and for each cultivar. Planting holes in which germination did not occur were treated as censored observations, as required by the Kaplan-Meier model.

2.4 Data Analysis

Statistical methods, including the Kaplan-Meier model, were used to analyse the germination and flowering dynamics of okra cultivars over time. The recorded data were entered into a Microsoft Excel spreadsheet.

Kaplan-Meier Model

$$G(t) = P(T > t)$$
$$F(t) = P(T > t)$$

Where: T= time until the event occurs; t = given time; $G(t)$ or $F(t)$ = the probability that an individual will germinate or flower after time t.

In particular, the method made it possible to describe the distribution of the times at which the events of interest occurred, compare event times among several groups (cultivars), and estimate the median times to germination and flowering.

All statistical analyses were performed using R software, version 4.2.1 (R Core Team, 2025).

3. Results and Discussion

3.1 Results

The analysis of variation in germination over time (Table 2) showed that germination occurred from the third (03) to the tenth (10) day after sowing. Of the 90 central planting holes, 16 had germinated by the third day after sowing, corresponding to an estimated probability of 82.22% that germination had not yet occurred. At the start of the tenth day, seven (07) seeds remained at risk, and two germination events were recorded. The median germination time for the okra cultivars in Niger was approximately five (05) days, corresponding to the time at which 50% of the seeds had germinated (Table 2).

Table 2. Germination trends as a function of time

Time (day)	Number of individuals tested	Number of events	Probability	Standard Errors	Lower 95% CI	Upper 95% CI
3	90	16	0.8222	0.0403	0.74323	0.901
4	74	25	0.5444	0.0525	0.44155	0.647
5	49	7	0.4667	0.0526	0.3636	0.57
6	42	3	0.4333	0.0522	0.33096	0.536
7	39	20	0.2111	0.043	0.1268	0.295
8	19	6	0.1444	0.0371	0.07182	0.217
9	13	6	0.0778	0.0282	0.02245	0.133
10	7	2	0.0556	0.0241	0.00823	0.103

Fig. 2 shows the change in seed germination over time. At time T0, 100% of the seeds had not yet germinated. Once germination began on the third day, the estimated probability of remaining ungerminated decreased progressively until the tenth day. The median time at which 50% of the seeds had germinated was five (05) days after sowing (Fig. 2).

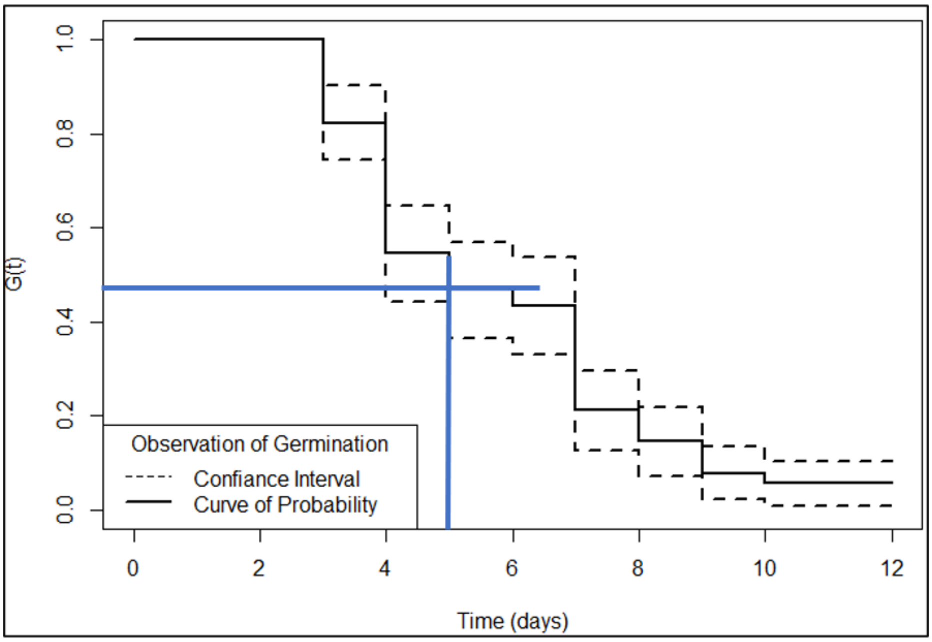

Fig. 2. Germination dynamics of okra seeds over time

Analysis of variation in germination among cultivars over time (Fig. 3) showed that Cultivar 10 germinated earliest, followed by Cultivars 8, 7, 2, and 1, respectively.

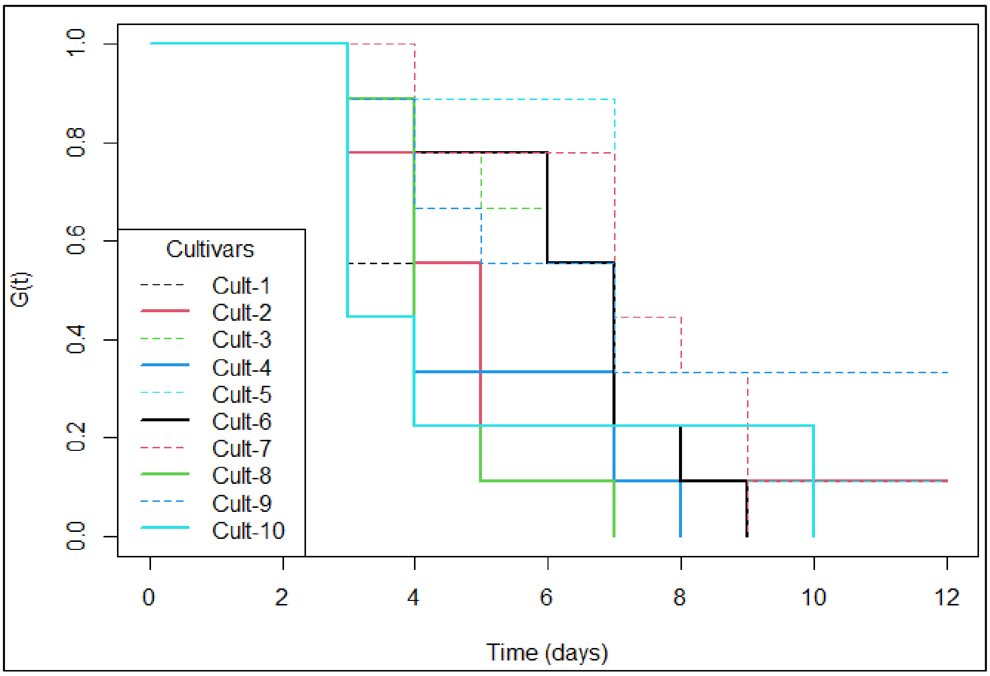

Fig. 3. Germination dynamics of cultivars over time

Legend: Cult-1 =Harey garey, Cul-t2=Gueskerou, Cult-3=Lada, Cult4=Diffa, Cult5=Long, Cult-6=Court, Cult-7=Gazelle, Cult-8=Sakoira, Cult-9=Tillabery, Cult-10=Balleyara

The analysis of variation in flowering over time (Table 3) showed that flowering occurred from the forty-second (42nd) to the seventy-third (73rd) day after sowing. Of the 55 central plots considered, only one had flowered by the forty-second day after sowing, corresponding to an estimated probability of 98% that flowering had not yet occurred. At the start of the seventy-third day, two (02) plants remained at risk, and one flowering event was recorded. The median flowering time for the okra cultivars in Niger was approximately fifty-three (53) days, corresponding to the time at which the estimated probability of remaining unflowered first fell below 50% (Table 3).

Table 3. Changes in okra flowering over time

Time (day)	Number of individuals tested	Number of events	Probability	Standard Errors	Lower 95% CI	Upper 95% CI
42	55	1	0.982	0.018	0.947	1.000
43	54	1	0.964	0.025	0.914	1.000
44	53	7	0.836	0.050	0.739	0.934
45	46	1	0.818	0.052	0.716	0.920
46	45	3	0.764	0.057	0.651	0.876
47	42	1	0.746	0.059	0.630	0.861
48	41	2	0.709	0.061	0.589	0.829
49	39	2	0.673	0.063	0.549	0.797
50	37	2	0.636	0.065	0.509	0.764
51	35	1	0.618	0.066	0.490	0.747
52	34	3	0.564	0.067	0.433	0.695
53	31	4	0.491	0.067	0.359	0.623
54	27	2	0.455	0.067	0.323	0.586
55	25	2	0.418	0.067	0.288	0.549
56	23	1	0.400	0.066	0.271	0.530
57	22	6	0.291	0.061	0.171	0.411
58	16	3	0.236	0.057	0.124	0.349
60	13	1	0.218	0.056	0.109	0.327
62	12	1	0.200	0.054	0.094	0.306
63	11	1	0.182	0.052	0.080	0.284
65	10	2	0.146	0.048	0.052	0.239
66	8	1	0.127	0.045	0.039	0.215
67	7	1	0.109	0.042	0.027	0.192
68	6	3	0.055	0.031	0.000	0.115
71	3	1	0.036	0.025	0.000	0.086
73	2	1	0.018	0.018	0.000	0.054

Fig. 4 shows the change in flowering over time. At time T0, 100% of the plants had not yet flowered. Once flowering began on the forty-second day, the estimated probability of remaining unflowered decreased progressively through the seventy-third day. The median flowering time for the okra cultivars in Niger was approximately fifty-three (53) days (Fig. 4).

Analysis of variation in the number of days to flowering among the cultivars (Fig. 5) showed that Cultivars 8, 6, 10, 9, 1, and 7 were the earliest to flower, whereas Cultivars 4, 5, 2, and 3 were the latest.

4. Discussion

The results showed that okra seed germination began on the third day after sowing (DAS) for Balleyara okra (C10) and continued until the tenth day. The median time to 50% germination was approximately five days after sowing. The observed variation in germination may reflect cultural practices or environmental factors. De Lannoy (2001) and Pizongo (2014) reported that germination and early growth are strongly influenced by cultural practices. Flowering began on the forty-second (42nd) day after sowing for Sakoira okra (C8) and on the seventy-third (73rd) day after sowing for Lada okra (C3). These results are consistent with Hamon and Charrier (2001), who stated that flowering in okra (*Abelmoschus esculentus*) begins one (1) to two (2) months after sowing, depending on the cultivar, and continues over time. The differences in flowering observed in this study may reflect the environmental conditions to which the cultivars were exposed during the experiment. According to Sawadogo et al. (2006), biotic and abiotic factors can disrupt bud formation and flowering. Differences were also observed in the interval from germination to flowering among cultivars. Based on flowering time, the cultivars evaluated in this experiment included both early- and late-flowering types.

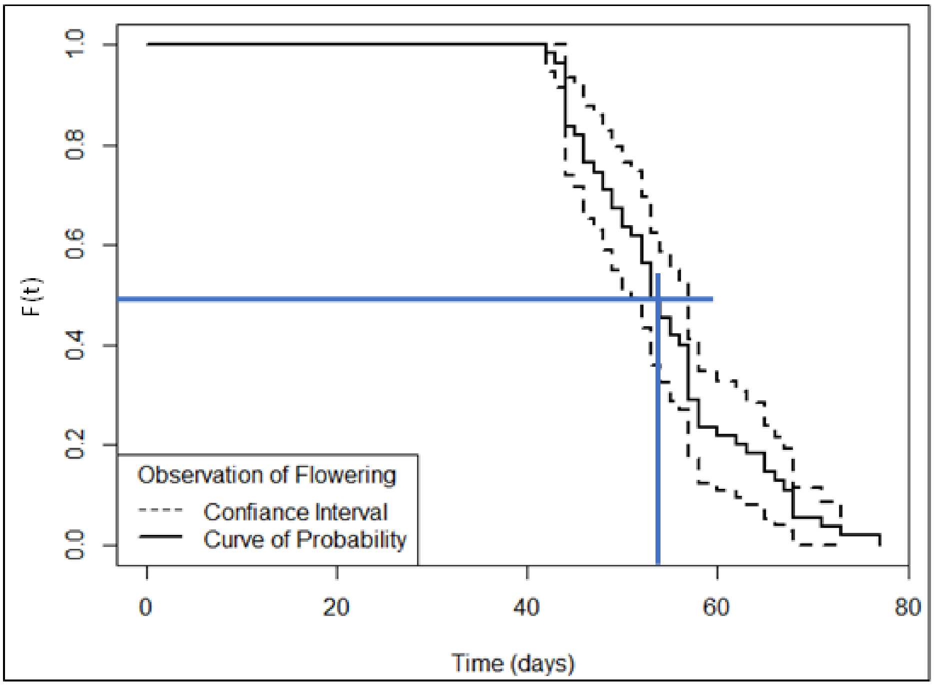

Fig. 4. Flowering dynamics of okra seeds over time

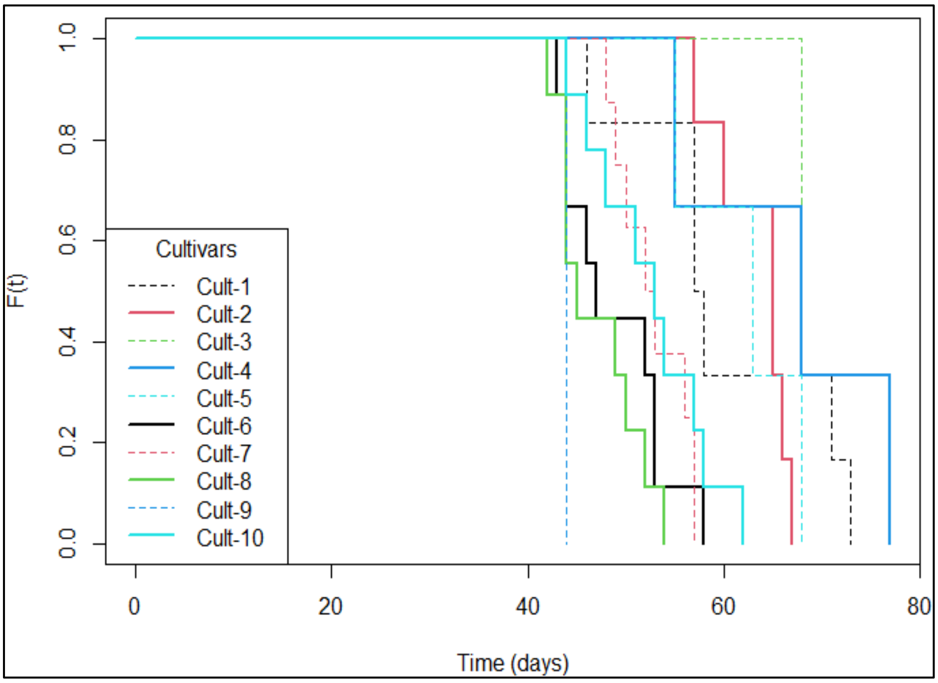

Fig. 5. Flowering dynamics of okra cultivars as a function of time

Legend: Cult-1 =Harey garey, Cult-2=Gueskerou, Cult-3=Lada, Cult-4=Diffa, Cult-5=Long, Cult-6=Court, Cult-7=Gazelle, Cult-8=Sakoira, Cult-9=Tillabery, Cult-10=Balleyara

5. Conclusions

The study showed that the okra cultivars evaluated under the experimental conditions in Niamey differed in their germination and flowering dynamics. Germination began on the third day after sowing and continued until the tenth day, whereas flowering occurred from 42 to 73 days after sowing. The median germination and flowering times were approximately 5 and 53 days after sowing, respectively. The results indicated the presence of both early- and late-phenological types among the evaluated cultivars. Balleyara, Sakoira, Gazelle, Gueskerou, and Harey garey germinated relatively early, whereas Sakoira, Court, Balleyara, Tillabéry, Harey garey, and Gazelle were among the earlier-flowering cultivars. These findings provide preliminary information for identifying cultivars that may be suitable for production systems requiring early establishment or flowering under local growing conditions in Niger.

6. Limitations

This study was conducted at a single experimental site during one rainy season, which limits the extent to which the findings can be generalised across agroecological zones or years. The analysis focused on germination and flowering time; other agronomic traits, including plant height, fruit yield, fruit quality, and stress tolerance, were not evaluated. The effects of soil moisture, temperature, pest pressure, and other environmental variables were not quantified separately. The difference between the numbers of observations used for germination and flowering also requires clarification. Multi-location and multi-season trials are therefore needed.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

References

De Lannoy, G. (2001). Gombo: *Abelmoschus esculentus* (L.) Moench. In R. H. Raemaekers (Ed.), *Agriculture en Afrique tropicale: Légumes* (pp. 478–484). Direction Générale de la Coopération Internationale.

Devi, N. L., Singh, A. H., Nongthombam, J., Devi, Y. P., & Singh, L. K. (2025). Effect of fish waste compost pellets, bio-pesticides, and vermiwash on growth, yield, and quality of okra (*Abelmoschus esculentus* L.). *Uttar Pradesh Journal of Zoology, 46*(22), 148–154. https://doi.org/10.56557/upjoz/2025/v46i225368

Diallo, F., Legros, S., Diarra, K., & Feder, F. (2022). Varying effects of organic waste products on yields of market garden crops in a 4-year field experiment under tropical conditions. *Agronomy, 12*(1), Article 32. https://doi.org/10.3390/agronomy12010032

Garba, A., Amani, A., Karim, S., Morou, B., Sina, A. K. S., & Mahamane, A. (2020). Effets des prétraitements sur la germination des graines de *Tamarindus indica* L. (Fabaceae-Caesalpinioideae) en pépinière : Proposition pour une restauration de l'espèce au Sahel. *Journal of Applied Biosciences, 149*, 15362–15378. https://doi.org/10.35759/JABs.149.10

Gul, E. N., Polat, E., Altuntas, E., & Mahawar, M. K. (2025). Engineering and germination characteristics of okra (*Abelmoschus esculentus* L.) cultivars: Implications for processing and cultivar selection. *Journal of the Saudi Society of Agricultural Sciences, 24*, Article 61. https://doi.org/10.1007/s44447-025-00062-3

Hamon, S., & Charrier, A. (2001). Okra. In A. Charrier, M. Jacquot, S. Hamon, & D. Nicolas (Eds.), *Tropical plant breeding* (pp. 361–380). CIRAD; Science Publishers. https://doi.org/10.1201/9781482279863-16

Haq, I. U., Azam, N., Ashraf, M., Javaid, M. M., Murtaza, G., Ahmed, Z., Riaz, M. A., Iqbal, R., Rahman, M. H. U., Alwahibi, M. S., Elshikh, M. S., Aslam, M. U., & Arslan, M. (2023). Improving the genetic potential of okra (*Abelmoschus esculentus* L.) germplasm to tolerate salinity stress. *Scientific Reports, 13*, Article 21504. https://doi.org/10.1038/s41598-023-48370-4

Kaleri, H. B., Memon, S. A., Kaleri, A. A., Magsi, M. A., Manzoor, D., Achakzai, A., Khan, A., Nasir, M., Wafa, M., Khashkheli, W. A., & Niazi, F. U. (2024). The impact of various organic manures on the germination, development, and growth of okra (*Abelmoschus esculentus* L.). *Scientific Inquiry and Review, 8*(3), 119–134. https://doi.org/10.32350/sir.83.06

Mishra, B., Tiwari, A., Pandey, S. K., & Ramgiry, M. (2024). DUS-based agro-morphological characterisation and genetic variability in okra [*Abelmoschus esculentus* (L.) Moench]. *Vegetable Science, 51*(1), 78–85. https://doi.org/10.61180/vegsci.2024.v51.i1.11

Pizongo, I. N. W. (2014). *Réponse de variétés de gombo (Abelmoschus esculentus L.) aux engrais chimiques et à la fumure organique* [Master's thesis, Université Polytechnique de Bobo-Dioulasso]. https://beep.ird.fr/greenstone/collect/upb/index/assoc/IDR-2014-PIZ-REP/IDR-2014-PIZ-REP.pdf

R Core Team. (2025). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Saadou, M. (1990). *La végétation des milieux drainés nigériens à l'est du fleuve Niger* [Doctoral dissertation, Université de Niamey]. https://www.fao.org/4/x6813f/X6813F14.htm

Sawadogo, M., Balma, D., Nana, R., & Sumda, R. M.-K. L. (2009). Diversité agromorphologique et commercialisation du gombo (*Abelmoschus esculentus* L.) à Ouagadougou et ses environs. *International Journal of Biological and Chemical Sciences, 3*(2), 326–336. https://doi.org/10.4314/ijbcs.v3i2.44502

Sawadogo, M., Zombré, G., & Balma, D. (2006). Expression de différents écotypes de gombo (*Abelmoschus esculentus* L.) au déficit hydrique intervenant pendant la boutonnisation et la floraison. *Biotechnologie, Agronomie, Société et Environnement, 10*(1), 43–54. https://popups.uliege.be/1780-4507/index.php?id=1324

Sheferie, M. B., Ali, W. M., Wakjira, K. W., & Atinku Bekele, E. (2023). Fruit yield and yield-related traits of okra [*Abelmoschus esculentus* (L.) Moench] genotypes as influenced by different seed priming techniques in Dire Dawa, Ethiopia. *Heliyon, 9*(7), Article e17830. https://doi.org/10.1016/j.heliyon.2023.e17830

Thiaw, M. A., Ndiaye, D., Séne, M., Mbaye, T., & Baldé, M. (2019). Évaluation du rendement de six variétés de gombo (*Abelmoschus esculentus* (L.) Moench) dans les conditions agro-climatiques de Sédhiou au Sénégal. *Revue Africaine d'Environnement et d'Agriculture, 2*(1), 69–75. https://rafea-congo.com/admin/pdfFile/Artcile-RAFEA-MAME-2019.pdf

Yadav, B., Singh, S. P., Duhan, D. S., Yashica, Kaur, M., Apoorva, & Deepika. (2026). Optimizing okra growth, seed productivity and quality using nanourea along with conventional fertilization. *Journal of Experimental Agriculture International, 48*(1), 467–474. https://doi.org/10.9734/jeai/2026/v48i14019

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/162504