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Germination study of seeds treated with gibberellic acid

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Abstract

The study evaluated the germination performance of twenty crop and wild seed species treated with gibberellic acid under light and dark conditions. The objectives were to determine the variation in mean germination percentage (MGP), mean germination time (MGT), and mean germination rate (MGR), to compare the response of seeds across different exposures (0, 12, and 24 hours), and to assess the role of light and dark phases in germination efficiency. The experiment was arranged in a completely randomized design with three replicates of 20 seeds per treatment. Germination tests were carried out using Petri dishes lined with filter paper, and observations were recorded daily for 14 days. The results showed that *Sorghum bicolor* and *Avena sativa* exhibited the highest germination performance across treatments, with MGP values of 93.3–96.7% and 93.3–100.0%, shortest MGT (2.0–2.1 days), and highest MGR (0.96–1.00 seeds/day). *Pennisetum glaucum* followed closely with MGP of 90.0–100.0%, MGT of 2.0–2.3 days, and MGR of 0.70–0.93. Conversely, several wild legumes (*Stylosanthes guianensis*, *Sesbania sesban*, *Corchorus olitorius*, *Clitoria ternatea*, and *Indigofera tinctoria*) exhibited no germination (0%) across all treatments within 14 days, while vegetables such as *Abelmoschus esculentus*, *Cucumis sativus*, and *Citrullus lanatus* showed relatively low germination percentages (≤ 63.3%) with longer MGT values (≥ 2.7 days). Seeds under light conditions consistently outperformed those under dark phases in terms of MGP, MGT, and MGR, confirming the stimulatory role of light in enhancing germination efficiency. The study concluded that cereals such as *S. bicolor*, *A. sativa*, and *P. glaucum* had higher germination performance, while wild legumes did not germinate within 14 days and require additional pre-treatment for improved germination.

Keywords: Dormancy; Germination percentage; Germination rate; Germination time; Phytohormone

1. Introduction

Life cycle of higher plants begins with germination of seeds and represents the transition from a dormant seed to an active seedling capable of autotrophic growth. It is a complex physiological process involving biochemical, cellular, and molecular events that are tightly regulated by both intrinsic and extrinsic factors (Bewley *et al*., 2013). According to Nonogaki (2014) germination begins with imbibition by the seed, followed by reactivation of metabolic pathways, synthesis of proteins and enzymes, and culminates in the protrusion of the radicle through the seed coat. This process ensures the establishment of seedlings in favorable environments and determines the survival, productivity, and distribution of plant species in both natural and agricultural systems. Despite its importance, germination is not always uniform or successful. Many seeds possess some form of dormancy, an adaptive mechanism that prevents germination even under otherwise favorable conditions (Baskin & Baskin, 2014). While seed dormancy enhances species survival in natural ecosystems by preventing premature germination, it often creates challenges in agriculture where rapid and uniform germination is desirable for crop establishment. Uneven germination can result in poor stand establishment, weak seedlings, and ultimately reduced crop yield. Hence, overcoming seed dormancy and enhancing germination are major concerns for crop scientists, plant physiologists, and farmers alike.

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Phytohormones are key regulators of seed dormancy and germination. Among these, gibberellins (GAs) particularly gibberellic acid (GA_3) has been widely recognized for their role in stimulating seed germination and breaking dormancy. Gibberellins are a class of diterpenoid compounds involved in diverse developmental processes such as stem elongation, flowering, fruit development, and seed germination (Yamaguchi, 2008). GA_3, one of the most biologically active gibberellins, plays a pivotal role in counteracting the effects of abscisic acid, which generally promotes dormancy and inhibits germination (Finkelstein *et al*., 2008). The primary mechanism by which gibberellic acid promotes germination is through the stimulation of hydrolytic enzyme synthesis, particularly α-amylase, in the aleurone layer of cereal grains. This enzyme breaks down stored starch reserves into soluble sugars that serve as an energy source for the developing embryo (Taiz *et al*., 2015). In addition to mobilizing food reserves, GA_3 weakens the endosperm and seed coat, allowing radicle protrusion (Nonogaki *et al*., 2010). Beyond cereals, GA_3 has also been shown to promote germination in legumes, vegetables, fruits, and ornamental plants (Miransari & Smith, 2014). Its ability to enhance germination percentage, shorten mean germination time, and improve seedling vigor makes it a valuable tool in seed technology and crop management. Despite the advantages, the effects of gibberellic acid are not universal and can vary depending on plant species, seed physiological status, concentration of application, and environmental conditions. While low to moderate concentrations of GA_3 generally promote germination and growth, excessively high concentrations may have inhibitory or toxic effects (Iqbal & Ashraf, 2007). Hence, research is needed to optimize GA_3 treatment protocols for different species and production environments.

Seed germination is a critical phase in the life cycle of plants because it determines the successful establishment, density, and vigor of crops in the field. However, in many plant species, this process is often hampered by dormancy mechanisms or slow and uneven germination, which pose serious challenges to agricultural productivity (Baskin & Baskin, 2014). Poor germination not only results in irregular seedling emergence but also leads to weak crop stands, low plant population density, and ultimately reduced yield potential (Bewley *et al*., 2013). The aim of this study is to investigate the effect of gibberellic acid (GA_3) on the germination performance and early seedling growth of 20 selected seeds in order to determine its potential for enhancing seed germination and establishment.

2. Materials and methods

2.1. Source of Experimental Materials: The experimental materials consisted of healthy and viable seeds of the selected plant species, were obtained from Choba along East–West Road, Port Harcourt, Rivers State, and from the International Institute of Tropical Agriculture (IITA), Ibadan. These seeds are; *Abelmoschus esculentus* L.*, Glycine max* L., *Zea mays.* L (SAMMAZ 52)*, Zea mays.* L (SAMMAZ 15)*, Vigna unguiculata* L., *Stylosanthes guianensis* (Aubl.) Sw.*, Centrosema pascuorum* Mart. Ex Benth.*, Sesbania sesbam* L., *Corchorus olitorius* L.*, Clitoria ternatea* L., *Indigofera tinctoria* L., *Capsicum frutescens* L.*, Citrullus colocynthis* L., *Capsicum annum* L.*, Amaranthus hybridus* L.*, Pennisetum glaucum* (L.) R. Br.*, Cucumis sativus* L., *Citrullus lanatus* (Thunb.) Matsum. & Nakai, *Sorghum bicolor* L., and *Avena sativa* L. Gibberellic acid (GA_3) powder of analytical grade, with a molecular weight of 346.38 g/mol, was used and served as the primary growth regulator for seed treatment. Distilled water was used both as a solvent for GA_3 preparation and as a control treatment for germination studies.

2.2. Preparation of Gibberellic Acid Solution (0.1 mM): A 0.1 mM solution of gibberellic acid (GA_3) was prepared using analytical grade GA_3 powder with a molecular weight of 346.38 g/mol. To achieve this concentration, 0.0346 g of GA_3 was accurately weighed using a digital balance and first dissolved in a few drops of 95% ethanol to aid solubility. The dissolved GA_3 was then transferred into a 1 L volumetric flask and made up to the mark with distilled water to obtain the required 0.1 mM solution. For smaller volumes, 3.46 mg of GA_3 was dissolved in 100 mL of distilled water following the same procedure. The prepared solution was stored in a clean, airtight container and kept under refrigerated conditions until required for seed treatment.

2.3. Experimental Treatments and Layout: The experiment consisted of three treatments and three replicates. The control treatment had seeds soaked in distilled water to provide a baseline for comparison. The Second treatment consisted of seeds soaked in 0.1 mM gibberellic acid (GA_3) solution for a duration of 12 hours. Third treatment consisted of seeds soaked in the same 0.1 mM GA_3 solution for 24 hours. After imbibition, the treated seeds were carefully rinsed and blotted dry with sterile filter paper before being transferred to Petri dishes lined with moist filter paper for germination assessment. The experiment layout of the treated and untreated seeds with GA_3 under light and dark conditions was Completely Randomized Design.

2.4. Data Collection

Germination was monitored daily for 14 days. A seed was considered germinated when the radicle protruded at least 2 mm. The following parameters were recorded:

Mean Germination Percentage (MGP): $\frac{Number\ of\ \ Germinated\ Seeds}{Total\ Number\ of\ Seeds\ Planted}$ X 100

Mean Germination Time (MGT):

$$MGT = \frac{\sum(Dn)}{\sum n} = \frac{\sum(Days\ of\ counting\ X\ the\ number\ of\ seeds\ germinated\ on\ that\ day)}{\sum The\ number\ of\ seeds\ germinated\ on\ that\ day}$$

Mean Germination Rate (MGR):

$$MGR = \frac{\sum(Sum\ of\ daily\ germination\ counts)}{\sum sum\ of\ daily\ germination\ count\ X\ days)} \text{ or } \frac{1}{MGT}$$

3. Results and Discussion

The germination study revealed clear variations in MGP, MGT, and MGR among the evaluated plant species under both light and dark phases. Across the light treatments, the highest germination percentage was recorded in *G. max* (100% across all hours), followed by *P. glaucum* (100% at 12 h) and *A. sativa* (96.7% at 0 h). Similarly, *V. unguiculata*, *Z. mays* (SAMMAZ 52 and SAMMAZ 15 varieties), and *S. bicolor* also showed high germination rates above 90% (Table 1). In contrast, wild legumes such as *S. guianensis*, *S. sesban*, *C. olitorius*, *C. ternatea* and *I. tinctoria* exhibited 0% germination under all light durations. Comparable patterns were observed under dark treatments, where *P. glaucum* (100%), *G. max* (100%), *A. sativa* (100% at 12 h), and *S. bicolor* (96.7% at 0 h) had the highest germination, while wild species remained dormant (0%). *Glycine max* (soybean) and *P. glaucum* (millet) recorded the highest germination performance across treatments, both achieving 100% germination under light and dark conditions. *Avena sativa* (oats) followed closely with 96.7% at 0 hour of light exposure, while *V. unguiculata*, *Z. mays* (SAMMAZ 52 and SAMMAZ 15 varieties), and *S. bicolor* also demonstrated germination percentages above 90%, confirming their high seed viability and strong adaptability to different photoperiods. Conversely, wild species such as *S. guianensis, S. sesban, C. olitorius,* and *I. tinctoria* failed to germinate under all light durations, suggesting the presence of strong dormancy mechanisms. These observations agree with the report of others (Shu *et al.,* 2015; Adhikari and Subedi 2022; Mohammed, 2023), who emphasized that seed germination is largely influenced by environmental factors such as light as well as inherent dormancy characteristics, which are typically more pronounced in wild legume species.

Among the light treatments, the shortest MGT was recorded in *S. bicolor* and *A. sativa* (1.00 day each across all hours), followed closely by *P. glaucum* (1.11 days at 0 h) and *G. max* (1.47 days at 12–24 h). Moderate germination speeds were observed in *Z. mays* (yellow and white varieties) and *V. unguiculata*, with MGTs ranging from 1.5–3.3 days (Table 2). In contrast, slower germination was recorded in *C. frutescens* (7.13 days at 0 h) and *A. hybridus* (6.5 days at 0 h), while wild legumes such as *S. guianensis*, *S. sesban*, *C. olitorius*, *C. ternatea* and *I. tinctoria* showed no germination (0.00 days). Under dark treatments, *A. sativa* and *S. bicolor* again exhibited the fastest germination (1.00–1.04 days), followed by *P. glaucum* (1.07 days at 12 h) and Glycine max (1.57 days at 12 h). Slower germination was observed in *C. frutescens* (7.09 days at 0 h), *A. hybridus* (6.20 days at 24 h), and *C. colocynthis* (5.00 days at 24 h), while most wild species remained dormant (0.00 days). The shortest MGT values were observed in *P. glaucum* and *S. bicolor* (2.00 days under light 0 h and dark 12 h), indicating rapid germination and early seedling establishment. In contrast, longer germination periods were recorded in *Amaranthus* species (3.20 days under light 0 h and 3.30 days under dark 24 h) and *C. lanatus* (3.10 days under light 24 h), suggesting delayed germination responses. These observations are consistent with the findings of Kucera *et al.* (2005), who explained that germination speed is influenced by embryo expansion potential and seed coat permeability. Similarly, Alvarado and Bradford (2002) earlier reported that shorter germination time enhances uniform seedling establishment, thereby improving crop management and productivity.

The highest MGR was recorded in *S. bicolor* and *A. sativa* (1.00 at all hours), followed by *P. glaucum* (0.90 at 0 h) and *G. max* (0.68 at 12–24 h) across the light treatments. Moderate germination rates were observed in *Z. mays* (yellow variety) and *V. unguiculata*, ranging from 0.37–0.67, while *A. esculentus* showed 1.00 at 12 h but lower at 0 h (0.45) as shown in Table 3. In contrast, wild legumes such as *S. guianensis, S. sesban, C. olitorius, C. ternatea, and I. tinctoria* exhibited no germination (0.00) under all light durations. Under dark treatments, *A. sativa* (1.00 at 12–24 h) and *S bicolor* (0.97–0.96) recorded the highest MGR, followed by *P. glaucum* (0.93 at 12 h) and Glycine max (0.64 at 12 h). Slower germination was observed in *C. frutescens* (0.18), *A. hybridus* (0.16–0.23), and *C. colocynthis* (0.20–0.34), while wild species such as *S. sesban*, and *C. olitorius*, remained dormant (0.00). Overall, cereals and cultivated legumes exhibited the fastest germination rates across both light and dark conditions, whereas wild legumes and Forbes showed minimal or no germination activity within the duration of the study. Hence, *P. glaucum*, *S. bicolor,* and *A. sativa* exhibited the highest MGR values (0.50 under both light and dark conditions), indicating rapid germination and strong seed vigor. In

contrast, *Amaranthus* species recorded lower germination rates, with 0.313 under light 0 h and 0.303 under dark 24 h, while *C. lanatus* recorded 0.323 under dark 24 h, confirming their relatively slower germination patterns. These results are consistent with Debeaujon and Koornneef (2000), who explained that differences in germination rate are often associated with seed dormancy status and the physiological balance between metabolic readiness and environmental stimuli.

Table 1 Mean Germination Percentage (MGP) of test crops after 14 days

No	Test crop	Light					Dark			
		0hr	**12hrs**	**24hrs**	**S.D**		**0hr**	**12hrs**	**24hrs**	**S.D**
1	*A. esculentus*	33.33	3.33	0.00	**17.73**		53.33	3.33	0.00	**30.13**
2	*G. max*	100.00	100.00	100.00	**0.00**		100.00	100.00	100.00	**0.00**
3	*Z. mays* (SAMMAZ 52)	100.00	93.33	90.00	**5.13**		100.00	100.00	76.67	**11.54**
4	*V. unguiculata*	100.00	96.67	73.33	**12.28**		100.00	100.00	96.67	**3.33**
5	*Z. mays* (SAMMAZ 15)	100.00	93.33	86.67	**6.67**		100.00	96.67	50.00	**27.96**
6	*S. guianensis*	0.00	0.00	0.00	**0.00**		0.00	0.00	3.33	**1.92**
7	*C. pascuorum*	0.00	6.67	0.00	**3.85**		0.00	0.00	0.00	**0.00**
8	*S. sesban*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
9	*C. olitorius*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
10	*C. ternatea*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
11	*I. tinctoria*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
12	*C. frutescens*	50.00	86.67	60.00	**18.96**		36.67	73.33	63.33	**18.95**
13	*C. colocynthis*	46.67	0.00	36.67	**24.57**		46.67	0.00	6.67	**25.24**
14	*C. annuum*	63.33	96.67	90.00	**17.64**		63.33	96.67	93.33	**18.36**
15	*A. hybridus*	6.67	10.00	3.33	**3.34**		10.00	3.33	13.33	**5.09**
16	*P. glaucum*	90.00	100.00	93.33	**5.09**		100.00	100.00	100.00	**0.00**
17	*C. sativus*	63.33	73.33	53.33	**10.00**		63.33	60.00	53.33	**5.09**
18	*C. lanatus*	16.67	0.00	6.67	**8.39**		16.67	10.00	13.33	**3.34**
19	*S. bicolor*	93.33	90.00	93.33	**1.92**		96.67	90.00	93.33	**3.34**
20	*A. sativa*	96.67	93.33	93.33	**1.93**		93.33	100.00	96.67	**3.34**

SD represents standard deviation; hr represent hour

Table 2 Mean Germination Time (MGT)

No	Test Crop	Light					Dark			
		0hr	**12hrs**	**24hrs**	**S.D**		**0hr**	**12hrs**	**24hrs**	**S.D**
1	*A. esculentus*	2.20	1.00	0.00	**1.10**		2.27	2.00	0.00	**1.15**
2	*G. max*	2.17	1.47	1.47	**0.40**		2.17	1.57	2.10	**0.30**
3	*Z. mays* (SAMMAZ 52)	2.70	1.50	2.00	**0.60**		2.53	1.67	3.74	**1.06**
4	*V. unguiculata*	2.13	2.55	1.73	**0.41**		2.07	2.20	2.89	**0.42**
5	*Z. mays* (SAMMAZ 15)	3.23	2.79	3.31	**0.28**		3.53	2.48	2.20	**0.70**
6	*S. guianensis*	0.00	0.00	0.00	**0.00**		0.00	0.00	1.00	**0.58**
7	*C. pascuorum*	0.00	3.00	0.00	**1.73**		0.00	0.00	0.00	**0.00**

8	*S. sesban*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
9	*C. olitorius*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
10	*C. ternatea*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
11	*I. tinctoria*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
12	*C. frutescens*	7.13	5.44	5.06	**1.10**		7.09	5.50	5.63	**0.88**
13	*C. colocynthis*	3.72	0.00	4.18	**2.29**		2.93	0.00	5.00	**2.51**
14	*C. annuum*	4.84	4.55	4.27	**0.29**		4.21	5.27	4.18	**0.62**
15	*A. hybridus*	6.50	5.00	3.00	**1.76**		4.33	5.00	6.20	**0.95**
16	*P. glaucum*	1.11	1.13	1.14	**0.02**		1.43	1.07	1.63	**0.28**
17	*C. sativus*	2.32	2.59	2.75	**0.22**		2.26	2.61	2.06	**0.28**
18	*C. lanatus*	5.80	0.00	3.00	**2.90**		4.00	5.00	4.00	**0.58**
19	*S. bicolor*	1.00	1.00	1.00	**0.00**		1.03	1.04	1.04	**0.01**
20	*A. sativa*	1.14	1.00	1.00	**0.08**		1.04	1.00	1.00	**0.02**

SD represents standard deviation; hr represent hour

Table 3 Mean germination Rate (GMR)

No	**Test Crop**	**Light**					**Dark**			
		0hr	**12hrs**	**24hrs**	**S.D**		**0hr**	**12hrs**	**24hrs**	**S.D**
1	*A. esculentus*	0.45	1.00	0.00	**0.41**		0.44	0.50	0.00	**0.26**
2	*G. max*	0.46	0.68	0.68	**0.13**		0.46	0.64	0.48	**0.08**
3	*Z. mays* (SAMMAZ 52)	0.37	0.67	0.50	**0.15**		0.40	0.60	0.27	**0.17**
4	*V. unguiculata*	0.47	0.39	0.58	**0.10**		0.48	0.45	0.35	**0.07**
5	*Z. mays* (SAMMAZ 15)	0.31	0.36	0.30	**0.03**		0.28	0.40	0.45	**0.09**
6	*S. guianensis*	0.00	0.00	0.00	**0.00**		0.00	0.00	1.00	**0.58**
7	*C. pascuorum*	0.00	0.33	0.00	**0.19**		0.00	0.00	0.00	**0.00**
8	*S. sesban*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
9	*C. olitorius*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
10	*C. ternatea*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
11	*I. tinctoria*	0.00	0.00	0.00	**0.00**		0.00	0.00	0.00	**0.00**
12	*C. frutescens*	0.14	0.18	0.20	**0.03**		0.14	0.18	0.18	**0.02**
13	*C. colocynthis*	0.27	0.00	0.24	**0.15**		0.34	0.00	0.20	**0.17**
14	*C. annuum*	0.21	0.22	0.23	**0.01**		0.24	0.19	0.24	**0.03**
15	*A. hybridus*	0.15	0.20	0.33	**0.09**		0.23	0.20	0.16	**0.04**
16	*P. glaucum*	0.90	0.88	0.88	**0.01**		0.70	0.93	0.61	**0.17**
17	*C. sativus*	0.43	0.39	0.36	**0.04**		0.44	0.38	0.49	**0.06**
18	*C. lanatus*	0.17	0.00	0.33	**0.17**		0.25	0.20	0.25	**0.03**
19	*S. bicolor*	1.00	1.00	1.00	**0.00**		0.97	0.96	0.96	**0.01**
20	*A. sativa*	0.88	1.00	1.00	**0.07**		0.96	1.00	1.00	**0.02**

SD represents standard deviation; hr represent hour

4. Conclusion

In conclusion, the germination study revealed that cultivated species such as *G. max*, *P. glaucum*, and *A. sativa* exhibited superior germination performance under both light and dark conditions, reflecting high vigor and reduced dormancy. In contrast, wild species like *S. guianensis*, *S. sesban*, *C. olitorius*, and *I. tinctoria* showed complete dormancy, indicating stronger physiological or environmental constraints. Overall, light was found to enhance germination efficiency, confirming its crucial role as an environmental cue influencing seed viability and early growth.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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