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RESEARCH ARTICLES

Effect of GA_3 Application on the Germination of 5-Year Stored Bambara Groundnut (*Vigna subterranea* (L.) Verdc.)

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Abstract

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is a leguminous crop originating from North Africa, valued for its high protein and carbohydrate content, as well as its ability to adapt to marginal environments. These characteristics make it a promising candidate to support food and nutritional security, particularly in tropical regions. However, its cultivation and seed quality management remain limited, requiring strategies to improve germination and seedling establishment. Gibberellic acid (GA_3) is a plant growth regulator widely known to stimulate seed germination and enhance vigor. This study aimed to assess the effect of GA_3 on the germination performance of Bambara groundnut seeds stored for five years. Three genotypes (SS 3.4.2, BBL 1.1, and TVSU 8.6) were treated with GA_3 at concentrations of 0, 75, 150, and 225 ppm, and germination and vigor parameters were evaluated. The results showed that GA_3 application improved the performance of aged seeds, with 225 ppm identified as the most effective dose. Genotype SS 3.4.2 responded particularly well at this concentration, while BBL 1.1 consistently exhibited superior overall performance across treatments. These findings highlight the potential of GA_3 to mitigate the adverse effects of seed aging and enhance seedling establishment. The application of GA_3 represents a practical approach for improving the viability of stored seeds.

Keywords: bambara groundnut, gibberellic acid, seed deterioration, seed quality

Introduction

The increasing demand for food presents a significant challenge for Indonesia in maintaining national food security. One approach to address this issue is the development of alternative crops with high nutritional value and adaptability to marginal environments. Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is an underutilized legume that contains 64.4% carbohydrates, 23.6% protein, 6.5% fat, and 5.5% fiber, and is also rich in essential minerals such as magnesium, iron, and potassium (Tan et al., 2020). These characteristics make the Bambara groundnut a promising candidate for supporting sustainable food availability, especially as an affordable plant-based protein source. However, despite its nutritional benefits, the crop remains underutilized and has not been cultivated optimally in Indonesia.

Originating from Africa, the Bambara groundnut is highly adaptable to dry or semi-arid conditions but can also thrive in tropical climates. Its relatively long growth duration and generally low productivity, with an average yield potential of 0.85 t/ha (Jahanshiri et al., 2022), limit its development. One major constraint is low seed quality, which is strongly influenced by environmental factors such as rainfall, light intensity, temperature, and nutrient availability (Sari et al., 2023). Improving seed quality

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through careful seed preparation is therefore critical for enhancing productivity (Maytawanti & Damanhuri, 2022). Consequently, it is crucial to identify the most suitable genotypes and treatments for Bambara groundnut.

Bambara groundnut seeds will experience a decline in viability and vigor if stored for an extended period due to seed inhibitors or substances that hinder germination. Normal seeds or those nearing normal condition can still be treated to improve their quality, even after being stored for several years. gibberellic acid (GA_3), a plant hormone or plant growth regulator (PGR), can stimulate plant development, particularly from the germination phase to the vegetative stage. Seed treatment with gibberellin, often done through soaking in a GA_3 solution, not only accelerates germination but also increases the percentage of seeds that germinate, especially in seeds whose germination quality has declined due to prolonged storage. In essence, GA_3 solution enhances seedling quality by stimulating metabolic processes within the seeds, thereby promoting germination (Pandya et al., 2023). Such treatment is particularly beneficial for improving the physiological quality of Bambara groundnut seeds, which often experience a decline in viability during storage.

Seed storage is also a significant factor in determining plant quality, as seeds that have been stored for an extended period do not necessarily germinate optimally. As seed age increases, the physiological quality of the seed's declines. Seeds can experience a decrease in germination or a condition where the seed meristem is inhibited, but this can be overcome with treatments appropriate to the cause (Sari et al., 2023). The decline in seed viability after prolonged storage can be a focus to ensure the sustainability of Bambara groundnut cultivation. Additionally, genotypes are a key factor in determining seed viability and vigor, as each genotype has distinct germination capabilities. Seeds with larger diameters have more food reserves and a larger surface area, allowing for better nutrient absorption, which also affects the germination process.

The suboptimal cultivation of Bambara groundnuts can still be improved to achieve better results. Therefore, research is needed to maximize the potential of this crop. This can be supported by investigating whether Bambara groundnut seeds that have been stored for 5 years are still capable of germination. This test can then be conducted using GA_3 soaking treatments, which are expected to improve seed quality. For comparison, this study is conducted using several genotypes of Bambara groundnut.

Materials and Methods

Materials

The tools used to conduct this study included stationery, petri dishes, a germinator, calipers, a camera, an oven, a ruler, tweezers, a shovel, a sprayer, a TDS meter, an analytical balance, and trays. The materials used in this study were seeds of three Bambara groundnut genotypes that had been stored in plastic bags and kept in a refrigerator for five years. (SS 3.4.2, BBL 1.1, and TVSU 8.6), distilled water, gibberellic acid, rubber bands, label paper, rice husk paper, plastic, soil, sand, organic fertilizer, and 25 cm x 30 cm polybags.

Experimental Design

The methods in this study were divided into four stages: (assessment of physical quality and seed integrity in aged Bambara groundnut), experiment 1 (viability test of Bambara groundnut genotypes with GA_3 treatments), experiment 2 (vigor test of Bambara groundnut genotypes with GA3 treatments), which were conducted in the laboratory, and experiment 3 (the growth of several genotypes of Bambara groundnut with GA_3 treatments), which was carried out in the greenhouse. These four activities aimed to determine the quality of Bambara groundnut seeds that had been stored for 5 years and treated with GA_3. The experimental design consisted of two factors with three replications. The first factor was the GA_3 soaking dose (0 ppm (P0), 75 ppm (P1), 150 ppm (P2), and 225 ppm (P3), and the second factor was the Bambara groundnut seed

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genotypes (SS 3.4.2 (G1), BBL 1.1 (G2), and TVSU 8.6 (G3)). Based on these factors, there were 12 treatment combinations, each repeated 3 times, resulting in 36 experimental units. Each unit consisted of 10 Bambara groundnut seeds, requiring a total of 360 seeds per experiment. From each treatment, five samples were taken, resulting in 180 samples per experiment.

Data Collection and Data Analysis

Observations conducted included seed diameter and seed soaking during the preliminary activities; germination rate and maximum growth potential in experiment 1 (viability test); vigor index in experiment 2 (vigor test). Additionally, germination rate, dry weight of normal seedlings, uniformity of growth, growth rate, seedling height, root length, and number of seedling leaves were observed in both experiments 1 and 2. For experiment 3 (planting), observations included plant height, root length, and number of leaves.

The data were analyzed using ANOVA based on a factorial completely randomized design for experiments 1 and 2, and a factorial randomized block design for experiment 3. When significant effects were observed, a least significant difference (LSD) test at the 5% significance level was performed to determine treatment differences, with the results notated using the STAR software.

Results and Discussion

Preliminary Tests: Assessment of Physical Quality and Seed Integrity in Aged Bambara Groundnut

The data were obtained from observations of 10 Bambara groundnut seeds for each treatment. For seed diameter measurements, seeds were separated according to each treatment, but had not yet been soaked. Meanwhile, the seed soaking percentage was determined after the Bambara groundnut seeds were soaked according to each treatment for 90 min, followed by calculations.

The differences in seed diameter can be attributed to the different genotypes of Bambara groundnut, as each genotype has a distinct size. The variation in seed diameter can affect

Table 1

Assessment of Physical Quality and Seed Integrity in Aged Bambara Groundnut (Preliminary Experiment)

Treatments	Seed diameter (cm)	Seed soaking (%)
GA_3 dosages (ppm)		
0	-	17.30a
75	-	20.50ab
150	-	22.75bc
225	-	27.07c
LSD 5%	-	4.72
Bambara groundnut genotypes		
SS 3.4.2	2.16b	16.61a
BBL 1.1	1.31a	30.80b
TVSU 8.6	1.14a	18.31a
LSD 5%	0.19	4.08
CV (%)	14.83	6.21

Note. Values followed by the same letters in the same columns show significant differences according to the least significant difference test at α = 0.05.

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subsequent growth phases because larger seeds contain more food reserves compared to smaller seeds. Seeds with larger sizes contain more stored nutrients, providing greater energy for germination and enabling optimal growth (Rolin et al., 2024). Based on the results, SS 3.4.2 has the highest average diameter compared to the other genotypes, indicating that it has more food reserves and can grow more optimally than the other genotypes.

GA_3 can accelerate the germination process by facilitating the absorption of substances that serve as energy sources for germination. GA_3 accelerates germination by activating enzymes such as amylases, proteases, and other enzymes involved in germination, thereby increasing the sugar content in the seed and subsequently enhancing water uptake (Fadhillah et al., 2022). The absorption process is influenced by seed size, where larger seeds absorb more than smaller seeds. This occurs because larger seeds absorb water more quickly due to their greater surface area. Consequently, seeds that absorb more water will swell more significantly because of the larger amount of fluid absorbed (Idrus & Faudiyah, 2021). The greater the fluid absorption by the seed, the more optimal the germination process will be.

Experiment 1: Viability Test of Bambara Groundnut Genotypes with GA_3 Treatments

Observations in experiment 1 included morphological and physiological assessments of 5 samples for each treatment combination.

The increase in root length along with higher doses of GA_3 is due to GA_3's effects on cell elongation. However, GA_3 did not have a significant effect on the Bambara groundnut in experiment 1. This may be because the seeds were able to germinate optimally under the favorable environmental conditions of experiment 1, regardless of the GA_3 treatment. In contrast, the results of different Bambara groundnut genotypes in experiment 1 showed variability among the genotypes. TVSU 8.6 was the least vigorous genotype compared to the other two. Differences in root length among genotypes can be attributed to the varying abilities of each seed to undergo the germination process. Each Bambara groundnut genotype has diverse characteristics influenced by genetic

Table 2

Bambara Groundnut Seedling Height and Root Length (Experiment 1)

Treatments	Seedling height (cm) at age (DAS)			Seedling root length (cm)
	4	7	10	
GA_3 dosages (ppm)				
0	0.67a	3.32a	13.76	9.97
75	1.05ab	4.83b	15.42	10.56
150	1.50bc	4.82b	16.60	11.64
225	1.97c	5.61b	17.20	12.33
LSD 5%	0.49	0.86	ns	ns
Bambara groundnut genotypes				
SS 3.4.2	1.03	4.49ab	16.07ab	12.88b
BBL 1.1	1.56	5.22b	17.34b	11.25b
TVSU 8.6	1.31	4.23a	13.83a	9.22a
LSD 5%	ns	0.75	2.30	1.84
CV (%)	38.51	19.09	17.35	19.63

Notes. Values followed by the same letters in the same columns show significant differences according to the least significant difference test at α = 0.05; ns: not significant (p > 0.05). DAS = day after sowing.

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factors (Maytawanti & Damanhuri, 2022). These differences may arise due to genetic variability among Bambara groundnut genotypes.

The results of physiological seed tests, such as germination rate, growth rate, and vigor index, are helpful in determining seed viability and vigor. The germination test is conducted to assess the seed's ability to grow and develop into a normal plant under optimal conditions, thus indicating seed quality (Sopian et al., 2021). The findings showed that the application of GA_3 at a dose of 225 ppm resulted in the highest germination rate, confirming that GA_3can enhance this factor by stimulating enzymes that support germination under both optimal and sub-optimal conditions. Gibberellins are a type of plant growth regulator that play a role in cell division and mobilization of food reserves during the early stages of growth (Murrinie et al., 2021). Among the genotypes tested, TVSU 8.6 exhibited the highest germination rate, indicating that this genotype has better growth potential under optimal environmental conditions compared to the others.

The germination rate in experiment 1 increased along with the rising GA_3 doses, with the 225 ppm dose showing the highest percentage. The germination rate, which is the speed at which seeds begin and complete the germination process, increased because GA_3 can stimulate and accelerate germination by activating and enhancing the activity of hydrolytic enzymes such as amylase, protease, and lipase. GA_3 solution can improve seed quality, one of which is by increasing the germination rate of plant seeds (Li et al., 2016). Among the different genotypes, the germination rate of BBL 1.1 in experiment 1 had the lowest percentage, while SS 3.4.2 had the highest germination rate percentage in experiment 1. This occurs because each genotype has its own advantages, where SS 3.4.2 is able to germinate well in optimum conditions.

The higher the maximum growth potential percentage of a seed, the better its growth ability. A high maximum growth potential indicates that the seed can grow faster, and it also affects the

Table 3

Bambara Groundnut Seed Germination and Seedling Growth (Experiment 1)

Treatments	Germination rate (%)	Germination velocity (%/etmal)	Maximum growth potential (%)	Dry weight of normal seedling (g)	Growth uniformity (%)	Growth rate (%/etmal)
GA_3 dosages (ppm)						
0	82.22a	5.90	82.22a	6.54	2.91a	0.40a
75	90.00b	5.81	90.00b	6.73	4.78b	0.51ab
150	96.67c	6.26	96.67c	7.01	5.96bc	0.58b
225	100.00c	6.60	100.00c	7.62	6.95c	0.74c
LSD 5%	4.59	ns	4.59	ns	1.38	0.04
Bambara groundnut genotypes						
SS 3.4.2	90.00a	6.68b	90.00a	8.25b	6.48b	0.44a
BBL 1.1	90.83a	5.51a	90.83a	6.76a	4.31a	0.66b
TVSU 8.6	95.83b	6.24	95.83b	5.93a	4.66a	0.58b
LSD 5%	3.97	0.64	3.97	0.91	1.19	0.04
CV (%)	5.11	12.43	5.11	15.55	17.46	24.13

Notes. Values followed by the same letters in the same columns show significant differences according to the least significant difference test at α = 0.05; ns: not significant (p > 0.05). DAS = day after sowing.

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growth rate of the seed (Wahyuni & Perdana, 2019). BBL 1.1 had the highest percentage of maximum growth potential compared to the other genotypes, indicating that it has better growth ability and a higher growth rate than the other genotypes.

The dry weight of normal seedlings increased with the increasing doses of GA_3,

Table 4

Bambara Groundnut Seedling Growth (Experiment 2)

Treatments	Seedling height (cm) (DAS)			Leaf number	Seedling root length (cm)
	4	7	10		
GA_3 dosages (ppm)					
0	0.09a	0.98a	4.99a	4.84	9.16a
75	0.18a	1.08ab	6.11ab	5.69	10.06ab
150	0.22ab	1.46b	7.39bc	5.20	10.50b
225	0.37b	1.90c	8.46c	5.69	11.82c
LSD 5%	0.51	0.41	2.25	ns	1.13
Bambara groundnut genotypes					
SS 3.4.2	0.21ab	1.03a	5.23	4.75	10.03
BBL 1.1	0.31b	1.52b	7.75	5.98	10.31
TVSU 8.6	0.14a	1.51b	6.93	5.33	10.81
LSD 5%	0.13	0.35	ns	ns	ns
CV (%)	71.45	30.98	34.33	28.11	11.18

Notes. Values followed by the same letters in the same columns show significant differences according to the least significant difference test at α = 0.05; ns: not significant ($p > 0.05$). DAS = days after sowing.

Table 5

Bambara Groundnut Seeding Physiological Growth (Experiment 2)

Treatments	Vigor index (%)	Germination velocity (%/etmal)	Dry weight of normal Seedling (g)	Growth uniformity (%)	Growth rate (%/ etmal)	Vigor index (%)
GA_3 dosages (ppm)						
0	52.22a	7.44a	7.11	1.54	0.37 a	52.22a
75	65.56ab	7.75b	7.33	2.02	0.49 a	65.56ab
150	70.00b	8.14c	7.58	2.29	0.62 a	70.00b
225	81.11b	8.63d	8.10	2.72	0.99 b	81.11b
LSD 5%	16.69	0.28	ns	ns	0.32	16.69
Bambara groundnut genotypes						
SS 3.4.2	57.50a	7.88	7.92	1.54a	0.51	57.50a
BBL 1.1	79.17b	8.10	7.70	2.86b	0.71	79.17b
TVSU 8.6	65.00ab	7.92	6.98	2.03ab	0.63	65.00ab
LSD 5%	14.46	ns	ns	0.84	ns	14.46
CV (%)	25.53	3.59	13.98	46.40	53.45	25.53

Notes. Values followed by the same letters in the same columns show significant differences according to the least significant difference test at α = 0.05; ns: not significant ($p > 0.05$). DAS = days after sowing.

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with the highest weight observed at the 225 ppm GA_3 dose. GA_3 helps accelerate the germination process, partly by stimulating the seeds to absorb more water. Seeds absorb more water after being stimulated by the gibberellin hormone (Idrus & Faudiyah, 2021). The dry weight of normal seedlings among different Bambara genotypes showed variation, with SS 3.4.2 having the highest value and TVSU 8.6 having the lowest. This is due to seed size, where SS 3.4.2 seeds are the largest among the genotypes. The nutrient reserves in a seed can be estimated from the dry weight of normal seedlings (Sopian et al., 2021). Therefore, SS 3.4.2 seeds, being larger, have greater nutrient reserves, which influences the dry weight results of the normal seedlings.

The application of GA_3 to seeds can accelerate seedling growth, making the seeds more stable during germination. The gibberellin hormone can activate hydrolytic enzymes and stimulate seed germination, thereby accelerating the germination process (Wijayanti, 2022). The higher the percentage of uniform growth, the better the seed quality. Differences in Bambara genotypes show significantly different percentages of uniform growth. Good seed quality results in uniform growth because uniformity is related to the efficient use of a seed's energy reserves (Yunefi et al., 2024). Different genotypes have varying energy reserves and abilities to utilize them. Experiment 1 demonstrated that SS 3.4.2 exhibited the highest uniformity, as it effectively maximized energy reserve utilization under optimal conditions.

The GA_3 at 225 ppm resulted in a faster growth rate of the seed, which in turn improved its germination ability. Seeds with good germination rates will also have good seedling growth (Yunefi et al., 2024). Seedling quality can improve since GA_3 assists the seed's metabolic processes during germination (Pandya et al., 2023). When seed metabolism increases, the seed will germinate faster. Among the Bambara genotypes, BBL 1.1 and TVSU 8.6 showed superior growth rates compared to SS 3.4.2.

Experiment 2: Vigor Test of Bambara Groundnut Genotypes with GA_3 Treatments

Seedling growth in the vigor test (experiment 2) is presented in Table 4. The seedling height in experiment 1 increased along with the rising GA_3 dosage, and a similar trend

Table 6

Bambara Groundnut Seedling Growth (Experiment 3)

Treatments	Plant height (cm) (DAP)				Leaf number (DAP)				Root length (cm)
GA_3 dosages (ppm)	7	14	28	35	7	14	21	28	
0	4.77a	12.84a	18.84a	23.91a	1.11a	3.60a	5.82a	6.24a	17.29a
75	6.89b	15.27b	22.13b	25.51b	1.71b	3.78b	6.11ab	6.82b	18.94b
150	7.47b	16.36bc	24.47c	28.15c	1.89bc	3.96b	6.51bc	7.40c	20.40c
225	7.29b	17.39c	26.00c	29.48d	2.16c	4.00c	6.87c	8.07d	21.90d
LSD 5%	1.25	1.19	2.21	0.77	0.27	0.51	0.58	0.58	1.13
Bambara groundnut genotypes									
SS 3.4.2	5.77a	15.73b	23.33	28.43c	1.62a	3.78	6.30	7.23	19.32a
BBL 1.1	6.90b	14.55a	21.90	24.58a	1.63a	3.83	6.30	7.00	18.57a
TVSU 8.6	7.14b	16.11b	23.35	27.28a	1.90b	3.88	6.38	7.18	21.02b
LSD 5%	1.08	1.03	ns	0.67	0.23	ns	ns	ns	0.98
CV (%)	19.35	7.88	9.87	2.95	16.07	4.04	9.35	8.28	5.90

Notes. Values followed by the same letters in the same columns show significant differences according to the least significant difference test at α = 0.05; ns: not significant (p > 0.05). DAP = day after planting.

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was observed for seedling height across different genotypes. The increasing height of Bambara groundnut seedlings with higher GA_3 dosages is due to GA_3 role in stimulating cell elongation, which influences plant height (Salmah, 2018).

Experiment 1 yielded better seedling height results compared to experiment 2, as the germination process in experiment 1 was not under stress and was carried out in an optimal environment suitable for Bambara groundnut seed requirements.

Measurements of seedling roots showed that root length increased with the increasing GA_3 dosage, as shown in the relevant tables. This increase occurred because GA_3 can stimulate cell elongation. However, GA_3 did not have a significant effect on Bambara groundnut in experiment 1. This may be due to the seeds' ability to germinate optimally under the favorable conditions of experiment 1, regardless of the GA_3 treatment. The variation in root length among genotypes may be attributed to each seed's inherent ability to undergo the germination process. Each Bambara groundnut genotype has diverse characteristics influenced by genetic factors (Maytawanti & Damanhuri, 2022). These

Table 7

Interaction Effects of GA_3 Dosage and Genotype on the Plant Height of Bambara Groundnut at 21 Days After Planting (Experiment 3)

Plant height (cm)			
GA_3 dosages (ppm)	Bambara groundnut genotypes		
	SS 3.4.2	BBL 1.1	TVSU 8.6
0	14.80Aa	16.40Aa	16.40Aa
75	18.47Ab	18.27Aab	18.87Aab
150	23.27Bc	20.07Ab	19.87Ab
225	23.53Bc	20.47Ab	20.80Ab
LSD 5%		2.51	
CV (%)		7.69	

Notes. Values followed by the same letters in the same row (capital letters) and in the same column (lowercase letters) in each treatment indicate no significant difference based on the least significant difference test at α = 0.05; ns: not significant (p > 0.05). DAP = days after planting.

Table 8

Bambara Groundnut Number of Leaves in Experiment 3 at 35 Days After Planting (DAP) Due to the Interaction Between GA_3 Dose Treatment and Bambara Groundnut Genotypes (Experiment 3)

GA_3 dosages (ppm)	Bambara groundnut genotypes		
	SS 3.4.2	BBL 1.1	TVSU 8.6
0	6.93Aa	8.40Ba	8.20Ba
75	8.20Ab	8.80Aa	8.60Aab
150	9.47ABc	9.73Bb	8.80Aab
225	10.27Bc	10.00ABb	9.20Ab
LSD 5%		2.51	
CV (%)		7.69	

Notes. Values followed by the same letters in the same row (capital letters) and in the same column (lowercase letters) in each treatment indicate no significant difference based on the least significant difference test at α = 0.05; ns: not significant (p > 0.05). DAP = days after planting.

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differing results among genotypes may occur due to genetic variability.

The physiological seed test was conducted to determine seed quality based on germination rate, germination speed, dry weight of normal seedlings, uniformity of emergence, and growth rate. According to Sopian et al. (2021), physiological parameters such as germination rate, growth rate, and vigor index are essential indicators of seed viability and vigor. Additionally, a germination test was conducted to evaluate the seeds' ability to germinate and develop into healthy plants under optimal conditions, which is a measure of seed quality (Sopian et al., 2021). Referring to the relevant tables, the highest germination rate was observed at a 225 ppm GA_3 dosage, indicating that GA_3 can enhance germination, particularly in five-year-old Bambara groundnut seeds. This is likely due to GA_3's ability to activate enzymes that support germination under both optimal and suboptimal conditions. Gibberellins are plant growth regulators that play a role in cell division and the mobilization of food reserves during early growth stages (Murrinie et al., 2021). Among the genotypes, TVSU 8.6 showed the highest germination rate, indicating that this genotype was better able to grow under optimal conditions compared to the others.

In experiment 1, the germination rate increased along with the rising GA_3 dosage, with the highest percentage observed at 225 ppm. The germination rate, which refers to the speed at which seeds initiate and complete the germination process, increases because GA_3 can stimulate and accelerate germination by activating and enhancing the activity of hydrolytic enzymes such as amylase, protease, and lipase. The GA_3 solution can improve seed quality, one way being through increased germination rates of plant seeds (Li et al., 2016). Among the different genotypes, BBL 1.1 showed the lowest germination rate in experiment 1, while SS 3.4.2 had the highest germination rate. This could be because each genotype has its own strengths, with SS 3.4.2 being better adapted to germinate under optimal environmental conditions.

Experiment 1 revealed that GA_3 doses did not significantly impact maximum growth potential, whereas significant differences were observed among the genotypes. The differing growth capacities of each seed may influence these variations. A higher percentage of maximum growth potential indicates a better ability of seeds to reach their full potential. High maximum growth potential also suggests that seeds have a faster growth rate, which directly affects the speed of seed growth (Wahyuni & Perdana, 2019). BBL 1.1 had the highest maximum growth potential among the genotypes, indicating that it has superior growth capacity and faster growth compared to the other genotypes.

The dry weight of normal seedlings increased in line with the rising GA_3 doses, with the highest weight observed at the 225 ppm GA_3 treatment. Seeds tend to absorb more water when stimulated by gibberellin hormones (Idrus & Faudiyah, 2021). The dry weight of normal seedlings also varied among Bambara groundnut genotypes, with SS 3.4.2 recording the highest value and TVSU 8.6 the lowest. This variation is influenced by seed size, as SS 3.4.2 has the largest seeds among the genotypes, resulting in a higher dry weight of normal seedlings. The dry weight of normal seedlings can reflect the food reserve content in a seed (Sopian et al., 2021). Therefore, the larger seed size of SS 3.4.2 indicates a greater food reserve, contributing to its higher dry seedling weight.

The results of uniformity of emergence in experiment 1 showed no interaction between GA_3 dosage and Bambara groundnut genotype. However, uniformity of emergence increased with higher GA_3 doses, with the highest percentage observed at the 225 ppm GA_3 treatment. Gibberellin hormones can activate hydrolytic enzymes and stimulate seed germination, thereby accelerating the germination process (Wijayanti, 2022). A higher percentage of uniform emergence indicates better seed quality. Among the Bambara groundnut genotypes, significant differences were observed in uniformity of emergence. High-quality seeds tend to germinate uniformly, as uniformity is related to how efficiently the seed utilizes its energy reserves (Yunefi et al., 2024). Different genotypes have

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varying energy reserves and capacities to use them.

Growth rate is one of the key parameters in determining seed quality. In experiment 1, the seed growth rate showed no interaction between GA_3 dosage and Bambara groundnut genotype; however, it increased with increasing GA_3 dosage. Seeds with good germination rates generally exhibit better growth rates as well (Yunefi et al., 2024). As the GA_3 dosage increased, so did the growth rate, because GA_3 supports the germination process in seeds. The quality of seedlings can be enhanced since GA_3 promotes seed metabolism, which is necessary for germination (Pandya et al., 2023). The superior performance of BBL 1.1 during the seed stage may be attributed to its larger size and stronger early growth capacity before the vegetative phase. This also demonstrates that Bambara groundnut seeds stored for five years remain viable and suitable for use.

Experiment 3 (The Growth of Several Genotypes of Bambara Groundnut with GA_3 Treatments)

Observations in experiment 3 were conducted over 35 days in the greenhouse. The measurements focused on plant morphological traits, including plant height, number of leaves, and root length (Table 6, 7, and 8).

The results of experiment 3 showed that the GA_3 dosage affected plant height across different Bambara groundnut genotypes. Gibberellin stimulates plant height by accelerating cell wall development, thereby promoting cell expansion and growth (Rifanto & Syaban, 2023). Based on the results obtained, GA_3 has a long-term effect as it not only influences seedling height but also affects the plant height of Bambara groundnut in the greenhouse.

The increase in the number of leaves with higher GA_3 dosages indicates that gibberellin can enhance leaf production in plants after the seedling phase. Gibberellin can aid in seed development, stem growth, and leaf development in plants (Tamonob et al., 2024). The variation in leaf number across different Bambara groundnut genotypes influenced by GA_3 dosage is due to the distinct characteristics of each genotype, resulting in differing responses.

Morphological measurements in experiment 3 also included root length, which showed no interaction between GA_3 dosage and Bambara groundnut genotypes (Table 6). Although there was no interaction, root length increased with increasing GA_3 dosage, with the 225 ppm GA_3 treatment showing the highest result in the morphological observation. The Bambara groundnut genotype TVSU 8.6 had the most extended average root length compared to the other genotypes, which may be due to its superior ability to absorb and distribute nutrients. The application of GA_3 treatment is feasible for farmers, as it involves a simple procedure, requires minimal time, and incurs low costs, making it a practical option for improving the germination of long stored Bambara groundnut seeds.

Conclusions

GA_3 treatment at 225 ppm consistently produced the best results across germination and growth traits, including seedling height, root length, vigor, and emergence. Among the genotypes, BBL 1.1 showed the most superior overall performance, followed by SS 3.4.2 and TVSU 8.6 in specific traits. These findings highlight that GA_3 at 225 ppm can significantly enhance the germination of 5-year-old stored Bambara groundnut seeds, thereby extending their usability. Future studies should evaluate the practicality of GA_3 application under field conditions, its economic feasibility, and its effectiveness on seeds stored for more than five years.

References

Fadhillah, Z., Hasanuddin, H., & Harnelly, E. (2022). The effect of mung bean sprout (*Vigna radiata* L.) extract and soaking duration on the viability of expired tomato (*Solanum lycopersicum* L.) seeds. *Bioleuser Journal*, *6*, 45–50.

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https://doi.org/10.29244/jtcs.13.01.148-159

Idrus, H. A., & Fuadiyah, S. (2021). Uji coba imbibisi pada kacang kedelai (*Glycine max*) dan kacang hijau (*Vigna radiata*). In *Prosiding Seminar Nasional Biologi* (pp. 710–716). Universitas Negeri Padang.

Jahanshiri, E., Goh, E. V., Wimalasiri, E. M., Azam-Ali, S., Mayes, S., Tengku, M. S. T. A. S., & Mohd, S. S. S. (2022). The potential of Bambara groundnut: An analysis for the People's Republic of China. *Food and Energy Security*, *11*, 614–628. https://doi.org/10.1002/fes3.358

Li, W., Yamaguchi, S., Khan, M. A., An, P., Liu, X., & Tran, L. S. P. (2016). Roles of gibberellins and abscisic acid in regulating germination of *Suaeda salsa* dimorphic seeds under salt stress. *Frontiers in Plant Science*, *6*, 1235. https://doi.org/10.3389/fpls.2015.01235

Maytawanti, R., & Damanhuri. (2022). Production potential and seed quality of five Bambara groundnut (*Vigna subterranea* L. Verdc) genotypes under organic and inorganic cultivation systems. *Journal of Plant Production*, *10*, 306–314. https://doi.org/10.21776/ub.protan.2022.010.10.04

Murrinie, E. D., Sudjianto, U., & Ma'rufa, K. M. R. (2021). Pengaruh giberelin terhadap perkecambahan benih dan pertumbuhan semai kawista (*Feronia Limonia* (L.) Swingle). *Agritech: Jurnal Fakultas Pertanian Universitas Muhammadiyah Purwokerto.* https://doi.org/10.30595/agritech.v23i2.12614

Pandya, J. B., Patani, A. N., Raval, V. H., Rajput, K. N., & Panchal, R. R. (2023). Understanding the fermentation potential for gibberellic acid (GA_3) production using fungi. *Current Microbiology*, *80*, 385. https://doi.org/10.1007/s00284-023-03454-2

Rifanto, A., & Syaban, R. A. (2023). Pengaruh pupuk organik cair dan hormon giberelin terhadap pertumbuhan dan produksi benih kacang hijau (*Vigna radiata* L.). In *Proceedings Penguatan Potensi Sumberdaya Lokal Guna Pertanian Masa Depan Berkelanjutan* (pp. 203-208). Agropross, National Conference Proceedings of Agriculture. https://doi.org/10.25047/agropross.2023.479

Rolin, N., Zamzami, A., & Qadir, A. (2024). Effect of seed size on the germination quality of mung bean (*Vigna radiata* L.) varieties 'Vima 4' and 'Vimil 1'. *Agrohorti Bulletin*, *12*, 123–135. https://doi.org/10.29244/agrob.v12i1.51528

Salmah, L. (2018). Pengaruh konsentrasi giberelin dan waktu perendaman benih terhadap pertumbuhan dan hasil tanaman kacang hijau (*Vigna radiata* L.). *Jurnal Agroswagati*, *6*, 657–666.

Sari, A. I., Zakiya, A., & Zainudin, A. (2023). Effect of seed soaking time in KNO_3 on germination, vegetative morphology, and results of Bambara chicken (*Vigna subterranea* (L.) Verdcourt). *Journal of Tropical Crop Science and Technology*, *5*, 37–54. https://doi.org/10.22219/jtcst.v5i1.32495

Sopian, K. A., Nurmauli, N., Ginting, Y. C., & Ermawati. (2021). Pengaruh varietas dan pelembaban pada viabilitas benih kedelai (*Glycine max* (L.) Merrill) pascasimpan tujuh belas bulan. *Jurnal Kelitbangan*, *9*, 327–340. https://doi.org/10.35450/jip.v9i03.274

Tamonob, A., Solichatun, S., & Suratman, S. (2024). The effect of seed priming using gibberellic acid (GA_3) on the growth of groundnut (*Arachis hypogaea* L.) and lurik groundnut (*Arachis hypogaea* L. var. *Lurik*). *Jurnal Ilmiah Biologi, 12*, 2583–2594. https://doi.org/10.33394/bioscientist.v12i2.13774

Tan, X. L., Azam-Ali, S., Goh, E. V., Mustafa, M., Chai, H. H., Ho, W. K., Mayes, S., Mabhaudhi, T., Azam-Ali, S., & Massawe, F. (2020). Bambara groundnut: An underutilized leguminous crop for global food security and nutrition. *Frontiers in Nutrition*, *7*. https://doi.org/10.3389/fnut.2020.601496

Wahyuni, A., & Perdana, O. C. P. (2019). Relationship between seed germination

Received 01/06/2025; Revised 19/09/2025; Accepted 03/12/2025
https://doi.org/10.29244/jtcs.13.01.148-159

tests and seedling emergence in the field for five rice lines. *Planta Simbiosa Journal*, *1*, 13–22.

Wijayanti, P. R. (2022). Review pematahan dormansi biji dengan metode skarifikasi mekanik dan kimia. *Jurnal Agroekoteknologi Tropika Lembab*, *5*, 109–116. https://doi.org/10.35941/jatl.5.2.2023.9965.109-116

Yunefi, F., Faisal, F., Nazimah, Yusuf, N., Rafli, M. M., & Fadhliani, F. (2024). Germination of expired yardlong bean (*Vigna unguiculata* (L.) Walp) seeds at various concentrations and soaking durations of coconut water. *Agroecotechnology Student Scientific Journal*, *3*, 1– 9. https://doi.org/10.29103/jimatek.v3i3.21044