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RESEARCH ARTICLE

Impact of seedbed types and scarification methods on germination percentage and growth performance of Bambara groundnut (*Vigna subterranea* (L.) Verdc.) in the Sudan Savanna zone of Nigeria

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ABSTRACT

The field experiments were conducted during the 2021 and 2022 wet seasons at The National Institute for Horticultural Research, Bagauda, 11° 33' North, 8° 23' E at 481m elevation, and Hadejia-Jama'are River Basin Development Authority, Wudil, 11° 85' 98.6" N, 8° 42' 0.37" E 575m elevation, both in Kano State within the Sudan Savannah agro-ecological zone of Nigeria. The study aimed to find a better seedbed arrangement and the best scarification methods for good germination and growth of Bambara groundnut cultivars. The treatments consisted of four seedbed types (ridge, ridge+earthing, flat, and flat+earthing), four scarification methods (zero, mechanical, acid, and hot water treatments), and three cultivars (cream, black, and speckled). The treatments were factorially combined and laid out in a split-split plot design with three replications. Seedbed was assigned to the main plot, scarification methods were assigned to the subplot, and cultivars were assigned to the sub-subplot. Data collected were days to first emergence, establishment count (%), canopy height (cm), and kernel yield (kg ha^{-1}). The result indicated that mechanically scarified Bambara groundnut seeds resulted in a higher establishment count and uniform canopy height (cm), which led to more dry matter accumulation and a higher kernel yield (kg ha^{-1}).

Keywords: bambara groundnut, scarification, seedbed, variety, *Vigna subterranea*.

INTRODUCTION

The Bambara groundnut (*Vigna subterranea*) exhibits remarkable drought tolerance and requires minimal agricultural inputs for successful production (Azam-Ali, *et al*., 2014). Thriving in conditions of limited rainfall and poor soil fertility—where many other crop species would struggle—it matures within 110 to 150 days, depending on the cultivar and environment. Well-drained sandy loam soils with a pH range of 5.0 to 6.5 are ideal for its establishment, high pod yields, and ease of harvest. Additionally, the crop can fix atmospheric nitrogen through a symbiotic association with Rhizobium bacteria contributing to its resilience (Singh and Basu, 2006). Primarily grown for human consumption, Bambara groundnut serves as a rich protein source, potentially alleviating nutritional challenges in regions where staple foods are predominantly carbohydrate-based (Massawe et al., 2005; Okpuzor et al., 2010).

Despite its significant importance, Bambara groundnut faces several challenges, including poor germination and establishment, which hinder its successful production. According to Legwaila et al. (2013), Bambara groundnut exhibits poor emergence rates of less than 30%. This issue can be attributed to physical seed dormancy commonly observed in legumes, characterized by the presence of palisade or radially elongated cells in the seed coat, causing hardness and impermeability that restricts water passage to the embryo (Barker, 2001). Consequently, seed coat impermeability prolongs dormancy periods, delaying germination and resulting in uneven crop stands that limit the crop's efficient utilization of resources such as light and water. Furthermore, the poor performance of cultivars is linked to impure cultivars and inadequate agronomic practices. Additional challenges arise during flowering and pegging stages, where pegs encounter difficulty penetrating untilled soil, a phenomenon known as heaving. This issue occurs due to the absence of soil earthing up at 7 weeks after sowing (WAS), just before the onset of pegging, approximately 30 to 35 days after sowing (DAS).

The embryos of most hard seeds, including Bambara groundnut, exhibit vigorous growth once resistant layers in the seed coat are disrupted or removed under appropriate germination conditions. Hence, pre-germination treatments are essential to accelerate this process. Scarification is a method utilized to enhance seed coat permeability (Ibiang et al., 2012) by mechanically or chemically disrupting the seed coat while ensuring seed viability. Aliero (2004) previously demonstrated successful overcoming of physical dormancy through such scarification techniques.

Utilizing pure cultivars of Bambara groundnut with desirable traits, along with implementing sound agronomic practices, can significantly enhance crop yield and quality. In light of these considerations, a trial was conducted to evaluate Bambara groundnut's response to seed treatments, cultivar types, and agronomic practices, focusing on the following objectives, (1), Assessing the effect of scarification methods on establishment count and growth performance, (2) Investigating the influence of cultivar selection on establishment count and growth performance and (3) Examining the impact of seedbed type on establishment count and growth performance of Bambara groundnut.

MATERIALS AND METHODS

The trial was conducted in the 2021 and 2022 rainy seasons at the National Institute for Horticultural Research Bagauda, (11^0 33' N, 8^0 23' E) 481 m elevation and Hadejia-Jama'are River Basin Development Authority Wudil, (11^o 85' 98.6" N, 8^o 42' 03.7" E) 575 m elevation, both in Kano State within the Sudan savannah zone of Nigeria.

Soil Sampling and Analysis

Soil samples from the experimental fields were collected randomly at depths of 0 – 30 cm using a soil auger. Each depth increment involved five sampling units per replication, totaling fifteen units across three replications. These samples were thoroughly mixed to achieve uniformity within each location. From these mixtures, composite samples were collected and analyzed for physical and chemical properties following standard procedures outlined by Black (1965).

Treatment and Experimental Design

The experimental treatments consisted of four types of seedbeds (ridge, ridge+earthing, flat, and flat+earthing), four scarification methods (zero treatment, mechanical scarification, acid scarification, and hot water treatment), and three cultivars (cream, black, and speckled). These treatments were factorial combinations arranged in a split-split plot design with three replications. Seedbed types were assigned to the main plots, scarification methods to the subplots, and cultivars to the sub-subplots. Meteorological data, including mean annual rainfall, minimum and maximum temperatures for Bagauda and Hadejia-Jama'are during the rainy seasons of 2021 and 2022, were obtained from the Center for Dry Land Agriculture (CDA) weather station at Bayero University Kano.

Planting Materials

Three certified cultivars of Bambara groundnut were utilized in the study: cream, black, and speckled types. The cream variety is round-shaped without an eye, small to medium-sized. The black variety is also round-shaped without an eye, medium-sized. The speckled variety is kidney-shaped with a black eye, medium to large-sized. All three cultivars are classified as long-duration types, requiring 110 to 150 days for maturity.

Scarification Methods

a. Control: Seeds were sown without any treatment. b. Mechanical: Seeds of the three cultivars were scraped on four regions of the circumference using sandpaper before sowing, following the method suggested by Silindile and Albert (2017). c. Chemical: Seeds were treated with 97% undiluted sulphuric acid, immersed for 10 minutes at room temperature, and then thoroughly washed in running distilled water for 5 minutes, as described by Bonner et al. (1974). d. Hot water: Seeds were immersed in boiling water (100°C) for 15 minutes, then allowed to cool before immediate sowing, following the procedure outlined by Ramamoorthy et al. (1989).

Cultural Practices

Each of the two experimental sites underwent clearing, ploughing, and harrowing to achieve fine soil tilth. Subsequently, the entire area was ridged and plots were manually demarcated according to the treatment design. Each experimental site covered a total area of 2607.75 m^2, divided into three replications with 1 meter alleys between them. Replications were further subdivided into main plots measuring 4.5m by 3m, with 0.5m alleys between each. Plots consisted of 6 ridges, each 4.5m wide and 3m long. The gross area of each plot was 13.5m^2 (4.5m width x 3m length), and the net area was 4.5m^2 (1.5m width x 3m length).

Seeds were treated with seed dressing chemicals to protect against soil-borne diseases and pests. Sowing was performed using the dibbling method at a depth of 3 cm, with a seeding rate of one seed per hole and intra-row and inter-row spacing of 20 cm and 75 cm, respectively. Manual hoe weeding was conducted at 3 weeks after sowing (WAS), followed by earthing-up at 7 WAS. Earthing-up involved raising the soil around the crown area of the plants, performed in both flat and ridged plots according to assigned treatments.

Economic pests and diseases were managed as needed, and SSP (60 kg Pha-1) fertilizer was applied at 3 WAS using the dibbling method, following the recommendations of Toungos et al. (2010). Harvesting was carried out after the yellowing of leaves, indicating pod maturity. Plants were manually pulled out of the ground using a hand hoe, ensuring the attached nuts were harvested according to the treatment allocation.

Sampling and Data Collection

Days to first emergence

The number of days from sowing to first emergence after planting was counted for each plot and recorded.

Establishment Count (%)

Crop stand establishment percentage count was determined after two weeks of sowing by counting the number of plants physically observed for each net plot and divided by the number of stands expected times 100;

Establishment count (%) = Actual/Expected x 100

Canopy height (cm)

Canopy height was measured using a meter rule, starting from ground level to the tip of the highest terminal leaf of five randomly tagged plants within the sampling rows at 3, 6, and 9 weeks after sowing (WAS).

Kernel yield (kg ha^{-1})

Kernel yield was determined by weighing all threshed kernels harvested from each net plot and then extrapolating to a kg ha-1 basis using the formula:

Kernel yield (kg ha^{-1}) = Yield per net plot (kg)/Net plot area (m^2) x 10000m^2

Data Analysis

The collected data underwent analysis of variance (ANOVA) using Statistix-10. Significant differences among treatment means were separated using Tukey's Honestly Significant Difference (HSD) test at a 5% level of probability. Additionally, a simple correlation analysis was conducted to evaluate the nature and strength of associations between the variables tested and kernel yield.

RESULTS AND DISCUSSION

Days to First Emergence

The influence of seedbed types, scarification methods, cultivars, and their interactions on the days to first emergence of Bambara groundnut during the 2021 and 2022 rainy seasons at Bagauda and Hadejia-Jama'are is summarized in Table 1. The results showed that seedbed types, scarification methods, and cultivars did not exert a significant effect on the days to first emergence across various sampling periods, locations, and seasons. However, a significant interaction (P<0.05) was observed between the seedbed and cultivar specifically in the 2021 season at Hadejia-Jama'are (Table 2). Notably, the cream cultivar x flat+earthing resulted in the shortest days to emergence compared to all other interactions, whereas the cream cultivar combined with ridge seedbed exhibited the longest duration to emergence.

Table 1. Days to First Emergence of Bambara Ground nut as Affected by Seedbed, Scarification, Cultivar and their Interaction

Treatment	Bagauda		HJM	
	2021	2022	2021	2022
Seedbed (SBD)				
1 RDG+ETH	6.22	5.36	5.97	5.36
2 RDG	6.22	5.25	5.47	5.30
3 FLT+ETH	6.11	5.19	5.50	5.19
4 FLT	6.50	5.27	5.30	5.27
P-Value	0.54	0.58	0.51	0.51
SE (±)	0.26	0.12	0.44	0.10
Scarification (SCR)				
1 CTL	6.22	5.00	5.50	5.02
2 MCNL	6.30	5.63	5.77	5.61
3 ACD	6.22	5.61	5.75	5.66
4 HTWT	6.30	4.83	5.22	4.83
P-Value	0.95	0.03	0.27	0.03
SE (±)	0.20	0.32	0.31	0.32
Cultivar (CLT)				
1 Cream	6.31	5.29	5.56	5.31
2 Black	6.08	5.33	5.54	5.35
3 Speckled	6.39	5.18	5.58	5.18
P-Value	0.21	0.40	0.98	0.30
SE (±)	0.18	0.11	0.23	0.11
Interaction				
SDBD*SCRF	0.06	0.87	0.23	0.92
SDBD*CLT	0.24	0.54	0.03	0.42
SCRF*CLT	0.64	0.86	0.88	0.74
SDBD*SCRF*CLT	0.33	0.46	0.72	0.54

Table 2. Interaction between seed bed and cultivar of bambara groundnut for days to emergence at Hadeja Jama'are during 2021 wet season

	SDBD			
CLV	FLT	RDG+ETH	RDG	FLT+ETH
Cream	5.08a	5.42a	6.83a	4.92a
Black	5.00a	6.00a	5.42a	5.75a
Speckled	5.50a	5.17a	5.83a	5.81a
SE±	0.32	0.47	0.41	0.39

Establishment Count

Establishment count as affected by seedbed types, scarification, cultivars and their interactions of Bambara groundnut during 2021 and 2022 rainy seasons (combined) at Bagauda and Hadejia-Jama'are are presented in Table 3. There was no significant effect due to seedbeds type on establishment count across year locations. However, significant effect of scarification methods on establishment count was observed at Hadejia-Jama'are in 2022. Mechanical scarification significantly produced the highest number of establishment count which was statistically similar with those due to acid and hot water treaments. Control shows the lowest establishment count and no significant effects of cultivar on establishment count from both locations. Significant interaction effects of seedbed and cultivar on establishment count at Bagauda in both seasons were observed. Table 4 shows that cream X flat+earthing produced significantly ($P<0.01$) the highest number of establishment counts in 2021. The lowest establishment count observed was between speckled and flat+earthing. Similarly, in 2022, significant ($P<0.05$) differences between seedbed types and cultivars (Table 5) were observed. Cream X flat+earthing produced the highest number of establishment count, and lowest was from cream X ridge.

Canopy Height (cm)

The effects of seedbed types, scarification methods, cultivars and their interactions at Bagauda and Hadejia Jama'are during the 2021 and 2022 rainy seasons are presented in Table 6. There were no significant differences in canopy height due to seedbed types across locations. Significant difference between scarification methods on canopy height was however observed at 6WAS in Hadejia Jama'are in 2022. Mechanical scarification was observed to produce the highest canopy height which was statistically similar with that of acid and hot water. Control treatment had the lowest plant canopy. There was no significant difference between cultivars on canopy height at both locations. Significant ($P<0.05$) interaction was observed between scarification methods and cultivars (Table 7). This indicated that the black cultivar scarified mechanically shows the highest plant canopy and speckled had the lowest among treatments.

Table 3. Establishment Count of Bambara Ground nut as Affected by Seedbed, Scarification, Ccultivar and their Interaction at Bagauda and Hadejia Jamaare Wudil during the 2021 and 2022 Wet Seasons.

Treatment	Bagauda		HJM	
	2021	2022	2021	2022
Seedbed (SBD)				
1 RDG+ETH	34.46	61.46	52.48	66.22
2 RDG	33.62	61.31	47.99	61.66
3 FLT+ETH	36.00	61.80	54.35	62.76
4 FLT	34.54	61.90	52.22	63.75
P-Value	0.821	0.989	0.075	0.224
SE (±)	2.521	1.985	1.935	1.976
Scarification (SCR)				
1 CTRL	28.44	63.99	51.57	58.73[b]
2 MCNL	33.65	66.96	53.33	68.90[a]
3 ACD	39.44	58.04	50.77	65.88[ab]
4 HTWT	37.08	57.48	51.37	60.88[ab]
P-Value	0.474	0.042	0.987	0.012
SE (±)	7.269	3.657	7.293	3.022

Cultivar (CLV)				
1 Cream	37.16	61.77	52.46	63.55
2 Black	33.14	62.74	51.05	63.55
3 Speckled	33.67	60.35	51.77	63.69
P-Value	0.517	0.204	0.968	0.996
SE (±)	3.782	1.331	5.536	1.740
Interaction				
SDBD*SCRF	0.20	0.66	0.16	0.20
SDBD*CLV	0.00	0.05	0.09	0.09
SCRF*CLV	0.52	0.20	0.89	0.43
SDBD*SCRF*CLV	0.81	0.11	0.92	0.12

Means along the same column with unlike letter (s) are statistically different at a 5% level of probability.

Table 4. Interaction between Seedbed and Cultivar of Bambara Groundnut on Establishment Count at Bagauda during 2021 wet season

		SDBD		
CLV	RDG+ETH	RDG	FLT+ETH	FLT
Cream	30.01^{bcd}	24.58^{d}	49.84^{a}	43.22^{a}
Black	31.49^{bcd}	35.02^{bcd}	35.44^{abcd}	30.63^{bcd}
Speckled	43.79^{abc}	38.39^{ab}	22.72^{d}	29.79^{d}
SE±	12.0	10.5	10.8	9.5

Means along the same column with unlike letter (s) are statistically different at 5% level of probability.

Table 5. Interaction between Seedbed and Cultivar of Bambara Groundnut for Establishment Count at Bagauda during 2022 wet season

		SDBD		
CLV	RDG+ETH	RDG	FLT+ETH	FLT
Cream	45.35^{c}	40.05^{ac}	69.86^{a}	54.61^{a}
Black	50.02^{ac}	48.96^{ab}	48.58^{ab}	56.68^{ab}
Speckled	62.08^{a}	54.98^{a}	44.64^{ab}	45.39^{ac}
SE±	11.1	11.0	10.2	9.8

Table 6. Canopy Height (cm) of Bambara Ground nut as Affected by Seedbed, Scarification, Cultivar and their Interaction at Bagauda and Hadejia Jamaare Wudil during the 2021 and 2022 Wet Seasons.

Treatment	Bagauda						HJM					
	2021			2022			2021			2022		
	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS
Seedbed (SBD)												
1 RDG+ETH	20.56	25.58	28.19	19.90	21.49	22.90	18.01	20.75	21.73	18.51	19.53	20.17
2 RDG	20.57	26.11	29.18	19.90	21.53	23.11	18.29	20.63	22.35	18.23	19.06	19.64
3 FLT+ETH	20.33	25.90	29.43	19.99	21.86	23.53	17.96	20.49	21.90	17.69	18.80	19.38
4 FLT	19.62	24.77	27.16	19.48	21.25	23.08	17.73	20.17	21.46	17.77	18.78	19.43
P-Value	0.047	0.194	0.169	0.533	0.538	0.275	0.850	0.341	0.104	0.320	0.229	0.262
SE (±)	0.286	0.567	0.948	0.357	0.398	0.292	0.628	0.305	0.295	0.459	0.359	0.390
Scarification (SCR)												
1 CTRL	20.01	25.72	28.66	20.12	21.80	23.30	17.91	19.957b	21.34	18.16	18.97	19.57
2 MCNL	20.78	25.97	29.10	19.63	21.41	23.18	18.19	21.33a	22.08	17.90	19.07	19.68
3 ACD	20.27	25.65	28.36	19.82	21.51	22.92	17.97	20.50ab	21.89	18.24	19.22	19.85
4 HTWT	20.02	25.02	27.83	19.70	21.41	23.21	17.92	20.26ab	22.11	17.91	18.91	19.52
P-Value	0.195	0.487	0.470	0.520	0.554	0.755	0.838	0.014	0.183	0.615	0.770	0.733
SE (±)	0.393	0.620	0.804	0.348	0.311	0.364	0.342	0.398	0.380	0.319	0.316	0.308
Cultivar (CLV)												
1 Cream	20.47	25.89	28.74	19.91	21.56	23.18	18.06	20.57	21.56	18.31	19.26	19.85
2 Black	20.01	25.47	28.33	19.79	21.63	23.30	18.27	20.85	22.29	18.17	19.15	19.71
3 Speckled	20.34	25.40	28.40	19.76	21.41	22.98	17.67	20.11	21.72	17.68	18.72	19.41
P-Value	0.427	0.439	0.765	0.875	0.754	0.535	0.115	0.171	0.202	0.149	0.244	0.357
SE (±)	0.358	0.411	0.597	0.326	0.301	0.286	0.286	0.389	0.421	0.336	0.338	0.307
Interaction												
SDBD*SCRF	0.62	0.10	0.58	0.98	0.78	0.96	0.06	0.23	0.67	0.22	0.22	0.25
SDBD*CLV	0.80	0.66	0.83	0.58	0.71	0.85	0.89	0.50	0.90	0.15	0.47	0.54
SCRF*CLV	0.09	0.12	0.12	0.36	0.32	0.91	0.05	0.27	0.73	0.36	0.43	0.33
SB*SCRF*CLV	0.64	0.15	0.74	0.80	0.89	0.37	0.10	0.59	0.52	0.86	0.71	0.57

Means along the same column with unlike letter (s) are statistically different at 5% level of probability.

Table 7. Interaction between Scarification and Cultivar of Bambara Groundnut for Canopy Height (cm) at 3WAS at Hadeja Jama’are during 2021 Wet Season

	SDBD			
CLV	HTWT	CTRL	MCNL	ACD
Cream	18.40a	17.64a	18.43a	17.78a
Black	18.41a	17.59a	18.57a	18.52a
Speckled	16.97a	18.52a	17.59a	17.61a
SE±	0.51	0.48	0.57	0.56

Kernel Yield (kg ha^{-1})

Effects of seedbed, scarification, cultivar and their interactions on kernel yield of Bambara groundnut at Bagauda and Hadejia-Jama'are during 2021 and 2022 (combined) rainy seasons are presented in Table 8. A significant (P<0.05) effect of seedbed on kernel yield was observed only at Bagauda in 2021 season. Ridge+earthing was observed to have the highest kernel yield ha^{-1}, however, this was statistically similar with ridge and flat+earthing. The lowest kernel yield was observed on flat seedbed. There was no significant difference between statistical means of kernel yield as affected by scarification methods at both locations. Significant effects of cultivar on kernel yield ha^{-1} were observed at Bagauda in 2022 season. This indicated that, black cultivar produced the highest kernel yield ha^{-1} which was however, statistically similar with cream cultivar. The lowest kernel yield ha^{-1} was observed on speckled cultivar.

Significant (P<0.05) interaction effects of seedbed, scarification and cultivar on kernel yield ha^{-1} was observed at Hadejia-Jama'are in 2021 (Table 9). It was observed that cream cultivar X ridge+earthing X mechanical scarification resulted in the highest kernel yield ha^{-1}. The lowest kernel yield ha^{-1} was realized on cream X flat+earthing X control. Black cultivar X ridge+earthing X mechanical also produced the highest kernel yield, whereas, the lowest was obtained on black X flat X control. The highest kernel yield ha^{-1} realized on speckled cultivar was observed on speckled X ridge+earthing X mechanical scarification, while the lowest kernel yield was observed on speckled X flat X mechanical scarification.

Table 8. Kernel Yield (kg ha^{-1}) of Bambara Groundnut as affected by Seedbed, Scarification, Cultivar and their Interactions at Bagauda and Hadejia-Jama'are Wudil during the 2021 and 2022 Wet Seasons.

Treatment	BGD		HJM	
	2021	2022	2021	2022
Seedbed (SBD)				
1 RDG+ETH	35.67^{ab}	8.60	26.59	4.97
2 RDG	39.17^{a}	8.26	28.77	4.72
3 FLT+ETH	33.64^{ab}	9.03	23.76	4.14
4 FLT	33.48^{b}	8.60	20.57	4.04
P-Value	0.14	0.59	0.071	0.36
SE (±)	2.29	0.53	2.517	0.56
Scarification (SCR)				
1 CTRL	33.29	9.72	23.51	4.97
2 MCNL	34.89	7.77	26.66	4.36
3 ACD	37.78	7.22	25.09	3.75
4 HTWT	35.99	9.78	24.43	4.79
P-Value	0.664	0.25	0.52	0.17
SE (±)	3.661	1.54	2.14	0.57
Cultivar (CLV)				
1 Cream	36.85	8.52^{ab}	24.62	4.47
2 Black	36.76	9.62^{a}	25.60	4.40
3 Speckled	32.86	7.73^{b}	24.55	4.54
P-Value	0.23	0.01	0.75	0.95
SE (±)	2.65	0.60	1.53	0.43
Interaction				
SDBD*SCRF	0.61	0.78	0.53	0.92
SDBD*CLV	0.35	0.86	0.11	0.10
SCRF*CLV	0.88	0.25	0.06	0.31
SDBD*SCRF*CLV	0.42	0.14	0.03	0.15

Means along the same column with unlike letter (s) are statistically different at 5% probability level.

Table 9. Interaction between Seedbed, Scarification and Cultivar of Bambara Groundnut for Kernel Yield (kg ha^{-1}) at Hadejia-Jama'are during 2021 wet season

		SCRF			
CLV	SDBD	CTRL	MCNL	ACD	HTWT
Cream	RDG+ETH	28.60	32.35	16.79	25.68
	RDG	20.74	28.89	30.44	27.41
	FLT+ETH	14.32	31.90	20.98	22.71
	FLT	20.98	27.16	22.47	22.74
Black	RDG+ETH	20.61	39.20	26.55	30.62
	RDG	25.44	36.93	31.36	25.81
	FLT+ETH	18.76	35.81	24.69	22.96
	FLT	11.36	24.94	16.05	15.56
Speckled	RDG+ETH	21.98	40.98	21.36	19.83
	RDG	26.74	31.67	26.62	18.02
	FLT+ETH	24.94	30.17	18.02	26.92
	FLT	21.73	17.04	21.98	24.94
SE±		6.10	5.95	5.82	6.05

CONCLUSION

According to the findings of this research, significant effect of scarification methods on establishment count was observed. Seedbeds of flat and ridge treated with earthing up gave the highest kernel yield (kg ha^{-1}), while seedbeds without earthing up resulted in the lowest yield. Scarification by mechanical method resulted in the highest kernel yield (kg ha^{-1}) compared to acid, hot water and control treatments. A black cultivar with high performance in this research was due to its high vigour.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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