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Effect of Different Dormancy Breaking Treatments on Seed Germination Parameters of Okra (*Abelmoschus esculentus* L. Moench) Genotypes

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ABSTRACT

A laboratory experiment was conducted to identify the best seed dormancy breaking treatment for enhancement of seed germination in okra (*Abelmoschus esculentus* (L.) Moench) at Department of Seed Science and Technology, CoA, UAS, GKVK, Bengaluru during 2023. The treatments include both physical, chemical and biological methods. The physical treatments-involve scarification with sand paper for 2 minutes, hot water immersion at 100°C for 1 minute and dry heating at 70°C for 5 minutes. The chemical treatments consist of soaking in KNO_3 at 0.5 per cent for 18 hours, scarification in hydrochloric acid (HCl) for 5 and 10 minutes and sulfuric acid (H_2SO_4) for 1 minute and biological treatment consist of soaking in buttermilk for 4 hours. Untreated seeds were used as control. The results revealed that, among the treatments, seeds treated with sulphuric acid (98%) for 1 minute (T_7), recorded highest (95.00%) seed germination, root length (27.61 cm), shoot length (15.16 cm), mean seedling length (42.77 cm), mean seedling dry weight (158.83 mg), SVI-I (4076), SVI-II (15166) and lowest (2.52%) hard seed percentage, respectively which was followed by seeds treated with soaking in buttermilk (T_2) for 4 hours (88.31%, 25.80 cm, 14.48 cm, 40.27 cm, 148.87 mg, 3582 and 13280, respectively) and recorded least hard seed (6.23%) compared to control (29.60%, 12.82 cm, 8.40 cm, 21.22 cm, 114.58 mg, 785 and 3606), respectively and highest (56.81%) number of hard seeds. Thus, T_7 (seeds treated with sulphuric acid (98%) for 1 minute) and T_2 (soaking in buttermilk for 4 hours) found to be best treatments to enhance the seed quality of okra compared to other dormancy breaking treatments and control. Hence, these two treatments could be utilised for breaking seed dormancy commercially for better plant stand.

Keywords : Okra genotypes, Malvaceae, Dormancy, Quality, H_2SO_4, Buttermilk, Germination

OKRA is one of the most widely known vegetable species of Malvaceae family. It is an economically significant vegetable crop grown in tropical and subtropical regions worldwide. Okra is an often cross pollinated crop having chromosome number 2n = 130. It is a nutrient-dense food containing proteins, carbohydrates and vitamin C (Lamont, 1999; Owolarafe and Shotonde, 2004) and plays a vital role in human diet. The consumption of young and immature okra pods are particularly important, as fresh vegetables and prepared in various forms like boiling, frying and cooking. The nutritional composition of okra pods per 100 grams of the edible portion (81% of the product with ends trimmed) is as follows: water 88.6 g, energy 144.00 kJ (36 kcal), protein 2.10 g, carbohydrates 8.20 g, fat 0.20 g, fiber 1.70 g, calcium 84.00 mg, phosphorus 90.00 mg, iron 1.20 mg, β-carotene 185.00 mg, riboflavin 0.08 mg, thiamine 0.04 mg, niacin 0.60 mg and ascorbic acid 47.00 mg. Additionally, okra seeds

contain approximately 20 per cent protein and 20 per cent oil. Due to its robust nature, dietary fiber content and distinct seed protein balance of both lysine and tryptophan amino acids, okra has been referred to as 'a perfect villager's vegetable' (Holser & Bost, 2004 and Sanjeet *et al*., 2010).

In India, okra is cultivated in an area of 523,000 hectares, with a production of 6,416 metric tons and productivity is 0.081 tons per hectare (NHB, 2020/21). The major okra-producing states in India include Uttar Pradesh, Bihar, West Bengal, Odisha, Assam, Andhra Pradesh and Karnataka. In Karnataka, okra is grown on 5.35 thousand hectares, with the production of 64.01 metric tons and productivity rate is 0.083 tons per hectare (NHB, 2020/21).

Seed Dormancy

Seed dormancy is a temporary phenomenon which block viable seed to germinate under normal favourable conditions (Baskin and Baskin, 2004). Okra plants exhibit seed hardness that complicates their management. Seed hardness interferes with seed germination, weed control, harvesting and other management factors (Mohammadi *et al.,* 2011). Tough seed coats may regulate germination by establishing a permeability barrier that can interfere with the water uptake required for imbibition and subsequent radicle emergence; for gaseous exchange, particularly oxygen uptake required for respiration and for the outward diffusion of endogenous germination inhibitors. Typical characteristics of hard seeds are seed coats, having permeability to water but not to gases or vice versa (Budy *et al.,* 1986).

Hard seededness can vary in a population of seeds. It is increased by environmental (dry) conditions during seed maturation and seed storage (Baskin and Baskin, 1998). It is reported that thick walls in some okra seeds delay germination; the seeds coats are often hard and the embryo can be slow to develop during germination. Consequently, treatments to seed coats which overcome hard seededness are generally required for good germination (Balla *et al.,* 2011). The occurrence of hard seededness and the low percentage of seed germination are major challenges in growing okra. The percentage of seed germination of okra is frequently low due to tegument impermeability and is the major barrier to obtain higher germination and plant stand. The percentage of hard seededness varies among the cultivars. Some cultivars not having hard seedness or having a low percentage of hard seeds that doesn't impose any impedance on their germination, whereas, for cultivars the high percentage of hard seeds does not allow them to germinate or results in low germination percentage.

Seed dormancy in okra (*Abelmoschus* spp.) typically lasts between 2 to 6 months, depending on the genotype, environmental conditions and seed maturity at harvest. Dormancy is primarily caused by the presence of a hard seed coat, which restricts water uptake and gas exchange, as well as by chemical inhibitors such as abscisic acid (ABA). The natural breakdown of dormancy occurs over time. Late harvesting (e.g., 50 days after pollination) often ensures that seeds are physiologically mature, leading to a more natural and consistent breakdown of dormancy. One released variety of okra, *Arka Anamika*, is reported to exhibit seed dormancy. This dormancy is primarily associated with a hard seed coat, which can delay germination under standard conditions. It is considered a residual trait, possibly inherited from wild or semi-wild ancestors and varies depending on seed maturity and environmental factors during seed development.

Early germination and plant establishment in field is essential for timely harvesting and marketing of the vegetable (Denton *et al*., 2013 & Rama and Naik, 2017). Several methods, including heat treatment, chemical (acid) and mechanical scarification can be used to open the seed coat (Mavengahama and Lewu, 2012). Various pre-treatments, such as chemical and physical treatments were tried and reported that only scarification at the radicle end improved the germination of seeds (Ochuodho *et al*., 2004). Demir (2001) that mechanical scarification is tedious and time-consuming while heat treatments have greater potential for commercial application and have been found to be effective in improving germination rate.

Material and Methods

Freshly harvested seeds of six okra genotypes belonging to three different species *viz., Abelmoschus esculentus*, *Abelmoschus tetraphyllus* and *Abelmoschus caillei* were obtained from Noble seeds Pvt. Limited, Yelahanka, Bengaluru. The laboratory experiments were carried out at Department of Seed Science and Technology, GKVK and Seed Technology Research Unit, NSP, UAS, GKVK, Bengaluru during 2023.

Table 1

Treatment details of the experiment

Genotypes (G)		Treatment details (T)	
G_1	NOK-2 (*Abelmoschus esculentus*)	T_1	Scarification for 2 minutes
G_2	NOK-8 (*Abelmoschus esculentus*)	T_2	Soaking in Buttermilk for 4 hours
G_3	NOK-31 (*Abelmoschus tetraphyllus*)	T_3	KNO_3 @ 0.5 % for 18 hours
G_4	NOK-39 (*Abelmoschus tetraphyllus*)	T_4	Hot water at 100ºC for 1 minute
G_5	NOK-49 (*Abelmoschus caillei*)	T_5	Hydrochloric acid (75%) for 5 minutes
G_6	NOK-50 (*Abelmoschus caillei*)	T_6	Hydrochloric acid (75%) for 10 minutes
		T_7	Sulphuric acid (98 %) for 1 minute
		T_8	Dry heating at 70ºC for 5 minutes
		T_9	Control

Experimental Design : Factorial Completely Randomized Design with three Replications.

Note : NOK-2, NOK-8 (*Abelmoschus esculentus*) species
NOK-31, NOK-39 (*Abelmoschus tetraphyllus*) species
NOK-49, NOK-50 (*Abelmoschus caillei*) species

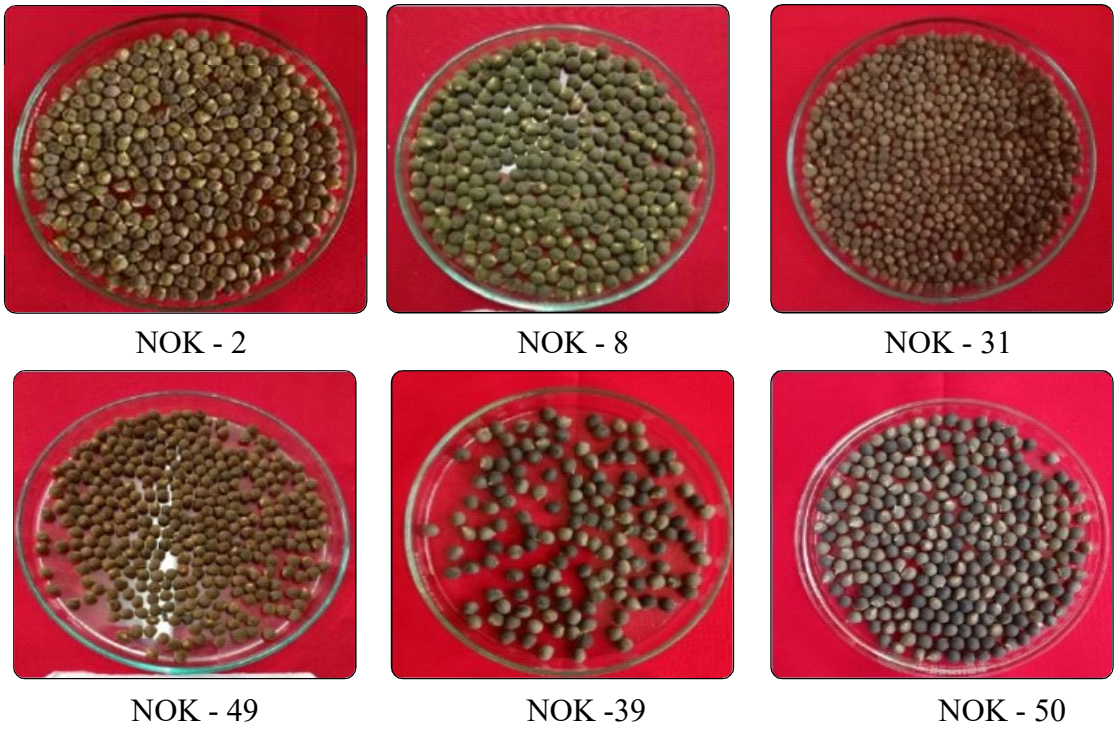


Fig. 1 : Selected dormant genotypes used for dormancy breaking study

Procedure for Dormancy Breaking Treatments

Scarification with Sand Paper for 2 Minutes : Hundred seeds in four replication which were required for seed germination were lightly rubbed against sandpaper focusing on the hardest part of the seed coat for about 2 minutes, depending on seed hardness. After scarification, the seeds were tested for germination.

Soaking in Buttermilk for 4 hours : Seeds were soaked in freshed-butter milk for 4 hours. After soaking, the buttermilk was drained and the seeds were rinsed thoroughly with clean water to remove any residue on the seed coat before being tested for germination.

KNO_3 @ 0.5 per cent for 18 hours : The 0.5 per cent of KNO_3 solution was prepared by dissolving 0.5 g of KNO_3 in 100 ml of distilled water and seeds were soaked in 0.5 per cent KNO_3 for 18 hrs (choice of 18 hours soaking in 0.5 per cent KNO is grounded in empirical evidence suggesting it provides sufficient time for nitrate ions to penetrate the seed coat and stimulate the physiological and enzymatic processes that overcome the dormancy (Bewley *et al*. 2013), later dried at room temperature to bring back to the original moisture content and seed samples were subjected to germination test.

Hot Water at 100° C for 1 Minute : Boil the water at 100° C and then seeds were placed in hot water bath for 1 minute. After treatment, seeds were dried at room temperature to bring back to the original moisture content and seed samples were subjected to germination test.

Hydrochloric Acid (75%) for 5 and 10 Minutes : Concentrated hydrochloric acid was diluted to 75 per cent poured over seeds and soaked for 5 and 10 minutes. After treatment, the seeds were rinsed thoroughly with water and tested for germination.

Sulphuric Acid (98%) for 1 minute : Sulfuric acid (98%) was prepared and carefully poured over the seeds and ensured that they were fully submerged. The seeds were soaked in the acid for 1 minute. After the treatment, the acid was poured off and the seeds were thoroughly rinsed with large amount of water to neutralize any residual acid. Arefi *et al*. (2012).

Dry Heating at 70 °C for 5 Minutes : Seeds were kept in open petri dishes and placed in hot air oven adjusted at temperature of 70 °C for 5 minutes. After this, seeds were cooled and tested for germination.

Control : Untreated seeds were tested for germination

Seed Germination Parameters : Seed germination parameters like standard germination (%), number of hard seeds, root length (cm), shoot length (cm), mean seedling dry weight (mg), seedling vigour indices were determined as indicated below;

- *Seed Germination (%)* : The standard germination test was carried out by following between paper method as per ISTA procedure (Anonymous, 2021). Hundred seeds in four replications were taken from each treatment and placed on germination paper uniformly. The roll towels were kept in a germination chamber maintained at 25 ± 2^0C temperature and 90 ± 5 per cent relative humidity. The first count was taken on 4th day and final count on 21st day. The number of normal seedlings from each replication were counted and the mean germination was expressed in percentage.

$$\text{Seed germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds used for the test}} \times 100$$

- *Hard Seeds (%)* : Hard seeds are those which remain hard at the end of the prescribed test period because they have not absorbed water due to an impermeable seed coat and expressed in percentage.

$$\text{Hard seeds (\%)} = \frac{\text{Number of hard seeds}}{\text{Total number of seeds used for the test}} \times 100$$

- *Root Length (cm)* : From the germination test, ten normal seedlings were selected randomly from each treatment from all the replications on 21st day. The root length was measured from the tip of the

primary root to base of hypocotyl and mean root length was expressed in centimeter.

- *Shoot Length (cm)* : From the germination test, ten normal seedlings were selected randomly from each treatment from all replications on 21st day. The shoot length was measured from the base of the primary leaf to the base of the hypocotyl and meanshoot length was expressed in centimeter.
- *Mean Seedling Dry Weight (mg)* : From the germination test the same ten seedlings used for measuring the root and shoot length were kept in a butter paper packet and dried in hot air oven maintained at 80° ± 2°C for 24 hours. Then the seedlings were cooled in a desiccator for 30 minutes and the weight of the dry seedlings was recorded using electronic balance and was expressed in milligrams/10 seedlings.
- Seedling vigour indices were computed as per Abdul- Baki and Anderson (1973)
- Seedling vigour index-I (SV-I) = Seed germination (%) × Mean seedling length (cm)
- Seedling vigour index-II (SV-II) = Seed germination (%) × Mean seedling dry weight (mg)

Data Analysis

The data collected from the experiment were analysed statistically by following the procedure suggested as by Panse and Sukhatme (1967). Whenever 'F' test was found significant, the critical difference (CD) values were calculated and the treatment mean were compared at one per cent for laboratory experiment.

Results and Discussion

The effect of different dormancy breaking treatments on seed germination showed that seeds treated with

Table 2

Effect of different dormancy breaking treatments on seed germination (%) of okra genotypes

Treatments	Seed germination (%)						
	G_1	G_2	G_3	G_4	G_5	G_6	Mean
T_1	85.73	89.40	74.36	75.94	92.00	93.39	85.14
T_2	88.42	92.02	78.17	79.45	95.86	95.93	88.31
T_3	71.49	73.13	62.35	63.12	74.01	80.25	70.72
T_4	50.17	47.48	56.69	57.20	55.52	56.51	53.93
T_5	83.90	85.03	64.89	65.10	86.09	86.52	78.59
T_6	80.20	80.20	60.95	64.86	82.52	84.49	75.54
T_7	96.07	97.50	90.00	90.67	97.60	98.18	95.00
T_8	83.09	84.07	64.01	64.89	84.50	85.90	77.74
T_9	36.67	36.72	2.31	5.07	48.35	48.51	29.60
Mean	75.08	76.17	61.52	62.92	79.61	81.07	
	S.Em±	CD(P=0.05)	CV(%)				
G	0.59	1.65	4.20				
T	0.72	2.02					
G x T	1.76	4.94					

Legend - G: Genotypes - G_1: NOK-2, G_2: NOK-8 G_3: NOK-31 G_4: NOK-39 G_5: NOK-49 G_6: NOK-50
T:Treatments - T_1: Scarification with sand paper for 2 minutes T_2: Soaking in Buttermilk for 4 hours T_3: KNO_3 @ 0.5 % for 18 hours
T_4: Hot water at 100º C for 1 minute T_5: Hydrochloric acid (75%) for 5 minute T_6: Hydrochloric acid (75%) for 10 minutes
T_7: Sulphuric acid (98 %) for 1 minute T_8: Dry heating at 70 ºC for 5 minutes T_9: Control

NOK-50: Seed treatment with H_2SO_4 (T_7) Control (T_9)

Fig. 2 : Effect of sulphuric acid 98 % for 1 min. (H_2SO_4) treatment on seed germination (%) of okra genotypes

sulphuric acid 98 per cent for 1 minute (H_2SO_4) and buttermilk soaking for 4 hours performed better than other treatments and control through initial improvement in seedling quality attributes *viz*., seed germination (%), hard seed (%), mean seedling dry weight (mg) and vigour indices. Data are presented in Table 2-6, Fig. 1-3 and discussed in the following paragraph.

Seed Germination (%)

Data reflects the germination performance of six genotypes (G_1 to G_6) under nine treatments (T_1 to T_9). The genotypes belong to three okra species: *Abelmoschus esculentus* (G_1, G_2), *Abelmoschus tetraphyllus* (G_3, G_4) and *Abelmoschus caillei* (G_5, G_6) and their interaction is presented in Table 2.

Among different genotypes, significant difference was observed on seed germination percentage of okra genotypes. The germination was found highest (81.07 %) in genotype NOK- 50 (*Abelmoschus caillei*) followed by (79.61 %) in NOK-49 (G_5) and the lowest (61.52 %) was observed in NOK-31 (*Abelmoschus tetraphyllus*). Among different treatments, significant difference was observed on germination percentage of okra genotypes. The germination percentage was highest (95.00 %) in sulphuric acid (98 %) for 1 minute (T_7), followed by (88.31 %) soaking in buttermilk for 4 hours (T_2) and lowest (29.60 %) germination percentage was observed in control (T_9). The interactions between genotypes and different dormancy breaking treatments showed significant difference on germination percentage of okra genotypes. The germination percentage was noticed highest (98.18 %) in sulphuric acid (98 %) for 1 minute in genotype NOK-50 (T_7G_6) followed by (97.60 %) in sulphuric acid (98 %) for 1 minute in

genotype NOK-49 (T_7G_5) and the lowest in NOK-31 (2.31%) was observed in G_3T_9.

The effectiveness of H_2SO_4 concentration of 98 per cent for 1 minute could be attributed to successful removal of several lignified layers in the testae, which are packed tightly together and contain water repelling compounds (Baskin, 2003). These layers act as a mechanical (physical) barrier to water absorption and gaseous exchange (Colling, 2009). This improved the germination capacity of the seeds and the time of 1 minute, probably seed structure was damaged by over exposure.

The dramatic increase in germination from 2.31 per cent to 90 per cent for G_3 (*Abelmoschus tetraphyllus*) after treatment with sulfuric acid can be attributed to the acid's effectiveness in breaking seed dormancy. *Abelmoschus tetraphyllus* seeds have a hard and impermeable seed coat, which is a major cause of physical dormancy. Treatment with concentrated sulfuric acid (H_2SO_4) chemically etches or softens the seed coat, thereby enabling improved water uptake (imbibition) which facilitates the hydration necessary for metabolic activation and enhanced gas exchange (oxygen diffusion) which allows sufficient oxygen to reach the embryo, which is critical for cellular respiration and germination. So, sulfuric acid treatment effectively eliminates the primary barrier imposed by the hard seed coat, enabling the dormant seeds to germinate.

Scarification using acid may also enhance the seed germination capacity by increasing the leaching of growth inhibitors from the seed. Baskin (1998) noted that the whole idea behind treating the seeds is to either completely remove the germination impeding seed coat or to reduce its thickness so that the seed could emerge.

Removal or reduction in thickness of the seed coat allows the seed to take up water and respiratory gases thus the germination process can be initiated. It is

TABLE 3

Effect of different dormancy breaking treatments on hard seed (%) of okra genotypes

Treatments	Hard seed (%)						
	G_1	G_2	G_3	G_4	G_5	G_6	Mean
T_1	8.47	5.70	16.10	12.43	3.80	2.33	8.14
T_2	6.13	3.13	12.47	12.13	2.03	1.50	6.23
T_3	13.93	12.67	19.97	16.17	12.00	6.80	13.59
T_4	19.60	15.13	25.40	22.20	13.17	8.53	17.34
T_5	10.37	8.50	20.53	16.87	5.80	5.67	11.29
T_6	10.77	10.00	25.27	18.57	9.43	5.33	13.23
T_7	1.47	1.33	5.47	5.07	1.13	0.63	2.52
T_8	8.43	8.40	21.80	20.80	6.57	5.70	11.95
T_9	43.17	42.67	91.07	81.87	41.60	40.50	56.81
Mean	13.59	11.95	26.45	22.90	10.61	8.56	
	S.Em±	CD(P=0.05)	CV(%)				
G	0.14	0.38	4.54				
T	0.17	0.47					
GxT	0.41	1.15					

Legend : G: Genotypes - G_1: NOK-2 G_2: NOK-8 G_3: NOK-31 G_4: NOK-39 G_5: NOK-49 G_6: NOK-50

T:Treatments: T_1: Scarification with sand paper for 2 minutes T_2: Soaking in Buttermilk for 4 hours T_3: KNO_3 @ 0.5 % for 18 hours T_4: Hot water at 100º C for 1 minute T_5: Hydrochloric acid (75%) for 5 minute T_6: Hydrochloric acid (75%) for 10 minutes T_7: Sulphuric acid (98 %) for 1 minute T_8: Dry heating at 70 ºC for 5 minutes T_9: Control

highly probable that treating seeds with H_2SO_4 reduced the thickness of the seed coat compared to the other scarification techniques.

Hard Seed (%)

The hard seed (%) which indicate the presence of physical dormancy as influenced by different dormancy breaking treatments in okra genotypes and their interactions is presented in Table 3.

There is a significant difference with respect to hard seed (%) among the genotypes. The lowest (8.56%) hard seed (%) was recorded in genotype NOK-50 (G_6) followed by (10.61%) in NOK-49 (G_5) and the highest (26.45%) was recorded in NOK-31 (G_3). The hard seed (%) differed significantly with the different dormancy breaking treatments. The hard seed (%) found lowest (2.52%) in sulphuric acid (98%) for 1 minute (T_7) followed by (6.23%) in soaking in buttermilk for 4 hours and highest (56.81%) was recorded in control (T_9). The interaction between genotypes and different dormancy breaking treatments showed significant difference on hard seed (%). The lowest (0.63%) was recorded in sulphuric acid (98%) for 1 minute in genotype NOK- 50 (T_7G_6) followed by (1.13%) in sulphuric acid (98%) for 1 minute in genotype NOK- 49 (T_7G_5) and the highest (91.07%) hard seed (%) was in control for the genotype NOK-31 (T_9G_3).

According to Baskin and Baskin (1999), the longer time soaked in acid the more permeable to water becomes for endocarp. They proposed that the endocarp of the seed coat is important in determining physical dormancy. The endocarp has three distinct layers of brachysclereids on the outside (Rhus species), osteosclereids in the middle and macrosclereids on the inside. When concentrated sulphuric enters seed coat, it erodes the brachysclereids and osteosclerids in the capillary micropyle region. As a result, water passes through the endocarp via the capillary micropyle and causes the seed to germinate and subsequently reduces number of hard seeds. Moaisi and Phillips (1991) found that five minutes of soaking in acid had little effect on the seeds of some common arable weeds. Singh and Dhillon (1996) achieved 98 per cent germination with legume forage species soaked for 15 minutes in acid, while Potter *et al*. (1984) found that the hard seeds of *Opuntia* spp. required 30-60 minutes of soaking in concentrated sulphuric acid. Elastin (1984) had to soak *Sesbania rummondii* seeds for as long as 1.5 h in acid to achieve good germination. Similar results were observed by Adhithya and Siddaraju, (2022) in greengram and Mohammadi *et al*. (2012) in okra.

Root Length (cm)

The data on effect of different dormancy breaking treatments on root length in okra genotypes and their interactions is presented in Table 4.

The significant difference was found among genotypes for root length. The root length was recorded highest (24.37 cm) in genotype NOK-50 (G_6) followed by (23.00 cm) in genotype NOK-49 (G_5) and the lowest (17.20 cm) was observed in NOK-31 (G_3). The root length differed significantly with the different dormancy breaking treatments. The root length was registered highest (27.61 cm) in sulphuric acid (98%) for 1 minute (T_7) followed by (25.80 cm) buttermilk soaking for 4 hours (T_2) and the lowest (12.82 cm) was found in the control (T_1). The interaction between genotypes and different dormancy breaking treatments showed significant difference on root length. The highest (29.80 cm) root length was recorded in sulphuric acid (98 %) for 1 minute in NOK-50 (T_7G_6) which was on par with (29.50 cm) in sulphuric acid (98 %) for 1 minute in NOK-49 (T_7G_5).

It might be because of the acid's property that causes the cell wall to soften and become more flexible, which leads to better cell growth in the process of cell elongation and ultimately leads to better longitudinal growth of the roots (Adams and TeBeest, 2017) and also H_2SO_4 treatment increases seed coat permeability, leading to higher water imbibition. Water uptake is essential for activating metabolic pathways that trigger seedling emergence and root growth (Bewley *et al*., 2013). Once the seed coat barrier is overcome, internal tissues can absorb water, which is required for cell division and elongation in the

TABLE 4

Effect of different dormancy breaking treatments on root length and shoot length (cm) of okra genotypes

Treatments	Root length (cm)							Shoot length (cm)						
	G_1	G_2	G_3	G_4	G_5	G_6	Mean	G_1	G_2	G_3	G_4	G_5	G_6	Mean
T_1	25.20	25.52	21.25	21.96	25.80	26.10	24.31	12.70	12.75	12.10	12.00	14.35	16.40	13.38
T_2	26.20	26.40	22.50	23.62	27.80	28.27	25.80	13.30	14.30	12.80	13.10	15.40	17.95	14.48
T_3	14.33	15.63	14.36	15.12	19.84	24.57	17.31	10.80	11.50	9.50	9.50	12.75	13.52	11.26
T_4	12.20	13.33	11.00	11.50	17.50	19.50	14.17	10.10	10.50	9.00	11.80	11.80	12.12	10.89
T_5	21.50	22.10	19.50	19.80	24.92	25.10	22.15	11.98	12.45	11.60	11.50	14.20	16.20	12.99
T_6	17.78	17.90	17.50	17.55	21.50	22.33	19.09	11.09	11.75	10.50	10.08	13.40	14.55	11.89
T_7	27.19	29.33	24.65	25.20	29.50	29.80	27.61	14.06	15.20	13.15	13.25	16.90	18.40	15.16
T_8	19.40	19.80	19.00	20.55	23.60	24.99	21.22	11.68	12.10	11.00	11.10	14.15	15.70	12.62
T_9	15.03	16.25	5.00	5.50	16.50	18.65	12.82	9.06	10.10	4.53	4.60	11.10	10.98	8.40
Mean	19.87	20.70	17.20	17.87	23.00	24.37		11.64	12.29	10.46	10.77	13.78	15.09	
	S.Em±	CD(P=0.05)	CV (%)					S.Em±	CD (P=0.05)	CV (%)				
G	0.16	0.45	4.05					0.09	0.26	3.90				
T	0.20	0.55						0.11	0.32					
GxT	0.48	1.34						0.28	0.78					

Legend - G: Genotypes - G_1: NOK-2 G_2: NOK-8 G_3: NOK-31 G_4: NOK-39 G_5: NOK-49 G_6: NOK-50

T: Treatments - T_1: Scarification with sand paper for 2 minutes, T_2: Soaking in Buttermilk for 4 hours, T_3: KNO_3 @ 0.5 % for 18 hours, T_4: Hot water at 100º C for 1 minute, T_5: Hydrochloric acid (75%) for 5 minute, T_6: Hydrochloric acid (75%) for 10 minutes, T_7: Sulphuric acid (98 %) for 1 minute, T_8: Dry heating at 70 ºC for 5 minutes, T_9: Control

radicle (embryonic root). These results agree with Abdul-Baki and Stommel (1995) and Demir and Mavi (2004) in okra.

Shoot Length (cm)

The data on shoot length as influenced by dormancy breaking treatments in okra genotypes and their interactions is presented in Table 4.

The shoot length varied significantly between the genotypes. The shoot length was noticed highest (15.09 cm) in genotype NOK-50 (G_6) followed by (13.78 cm) in NOK-49 (G_5) and the lowest (10.46 cm) was observed in NOK-31 (G_3). The shoot length differed significantly with the different dormancy breaking treatments. The shoot length was recorded highest (15.16 cm) in sulphuric acid 98 per cent for 1 minute (T7) followed by in buttermilk (14.48 cm) soaking for 4 hours and the lowest (8.40 cm) was found in control (T9). There was significant difference noticed between genotypes and different dormancy breaking treatments for shoot length. The highest (18.40 cm) shoot length was recorded in sulphuric acid 98 per cent for 1 minute in NOK-50 (T_7G_6) followed by sulphuric acid 98 per cent for 1 minute (16.90 cm) in NOK-49 (T_7G_5) and the lowest (4.53 cm) found control in NOK-31 (T_9G_3).

This might be due to concentrated sulfuric acid corrodes the outer layers of the seed coat, specifically targeting the brachysclereids and osteosclereids. These layers are dense, lignified and act as a barrier to water and gas exchange, contributing to seed dormancy. The acid treatment breaks down these layers, particularly at weak points such as the capillary micropyle, thereby increasing the seed coat's permeability. As a result, water readily enters the seed, hydrating the tissues. This water uptake triggers the expansion of cells in the embryo, which is essential for radicle protrusion-the first visible step of germination.

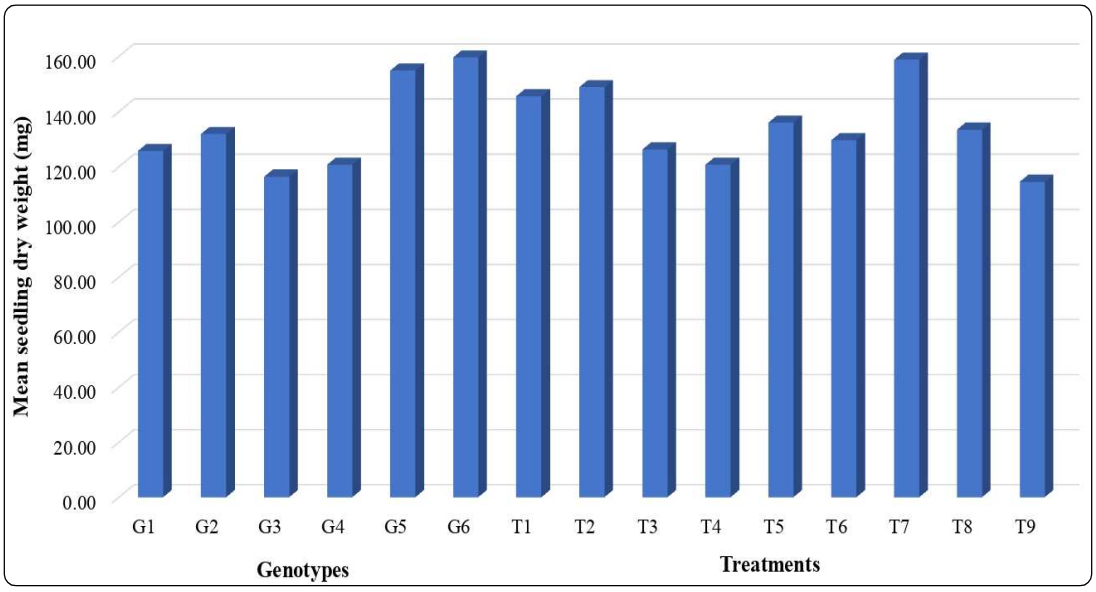
Water absorption causes the seed to swell, activating the embryonic tissues, including the shoot apex. The presence of water leads to rapid cell division and elongation in the shoot, which contributes to increased shoot length and also H_2SO_4 treatment allows more

oxygen to diffuse into the seed. Oxygen is critical for cellular respiration, which provides the energy required for both root and shoot growth. The availability of oxygen supports the metabolic processes that promote elongation of the shoot. These results are in accordance with the Hossain *et al*. (2005) in leguminous plants and Yadav and Singh (2011) in okra.

Mean Seedling Dry Weight (mg) - (Presented in graphs) : The mean seedling dry weight as influenced by different dormancy breaking treatments in okra genotypes and their interactions is presented in Fig. 3.

The genotypes differed significantly for mean seedling dry weight. The genotype NOK-50 (G_6) was recorded highest (159.64 mg) mean seedling dry weight followed by (154.88 mg) in NOK-49 (G_5) and the lowest (116.40 mg) mean seedling dry weight recorded in NOK-31 (G_3). The mean seedling dry weight differed significantly with the different dormancy breaking treatments. The mean seedling dry weight registered highest (158.83 mg) in sulphuric acid 98 per cent for 1 minute (T_7) followed by (148.87 mg) soaking in buttermilk for 4 hours (T_2) and the lowest (114.58 mg) was observed in control (T_9). The interaction between genotypes and different dormancy breaking treatments showed significant difference on mean seedling dry weight. The highest (196.10 mg) mean seedling dry weight was recorded in sulphuric acid 98 per cent for 1 minute in NOK-50 (T_7G_6) followed by (189.30 mg) sulphuric acid 98 per cent for 1 minute in NOK-49 (T_7G_6) and the lowest (98.74 mg) was seen in control in NOK-31 (T_9G_3).

This might be due to sulphuric acid treatment activates enzymes like amylases and proteases that break down stored food reserves in the seed, such as starches and proteins. This conversion provides readily available energy and nutrients for seedling growth. As the seed uses its stored reserves more effectively, it can accumulate greater biomass and consequently, a higher seedling dry weight. These results are consistent with Oliveira *et al*. (2014) that sulphuric acid significantly improved germination percentages in okra and the seedlings showed greater dry weight due to better nutrient mobilization and early root development.



Legend - G: Genotypes - G_1: NOK-2 G_2: NOK-8 G_3: NOK-31 G_4: NOK-39 G_5: NOK-49 G_6: NOK-50
T: Treatments - T_1: Scarification with sand paper for 2 minutes, T_2: Soaking in Buttermilk for 4 hours, T_3: KNO_3 @ 0.5 % for 18 hours, T_4: Hot water at 100º C for 1 minute, T_5: Hydrochloric acid (75%) for 5 minute, T_6: Hydrochloric acid (75%) for 10 minutes, T_7: Sulphuric acid (98 %) for 1 minute, T_8: Dry heating at 70 ºC for 5 minutes, T_9: Control

Fig. 3 : Effect of different dormancy breaking treatments on mean seedling dry weight of okra genotypes

TABLE 5

Effect of different dormancy breaking treatments on seedling vigour index-I of okra genotypes

Treatments	Seedling vigour index-I						
	G_1	G_2	G_3	G_4	G_5	G_6	Mean
T_1	3250	3421	2480	2580	3694	3970	3233
T_2	3494	3745	2760	2919	4141	4435	3582
T_3	1797	1984	1488	1555	2413	3058	2049
T_4	1119	1132	1134	1333	1628	1784	1355
T_5	2810	2938	2018	2038	3369	3575	2791
T_6	2315	2379	1707	1793	2879	3117	2365
T_7	3963	4342	3402	3487	4529	4735	4076
T_8	2583	2682	1921	2055	3190	3501	2655
T_9	882	967	22	51	1336	1449	785
Mean	2468	2621	1881	1979	3020	3291	
	S.Em±	CD(P=0.05)	CV(%)				
G	23.37	65.52	4.77				
T	28.62	80.24					
GxT	70.12	196.55					

Legend - G: Genotypes - G_1: NOK-2 G_2: NOK-8 G_3: NOK-31 G_4: NOK-39 G_5: NOK-49 G_6: NOK-50
T: Treatments - T_1: Scarification with sand paper for 2 minutes, T_2: Soaking in Buttermilk for 4 hours, T_3: KNO_3 @ 0.5 % for 18 hours, T_4: Hot water at 100ºC for 1 minute, T_5: Hydrochloric acid (75%) for 5 minute, T_6: Hydrochloric acid (75%) for 10 minutes, T_7: Sulphuric acid (98 %) for 1 minute, T_8: Dry heating at 70 ºC for 5 minutes, T_9: Control

Seedling Vigour Index-I

The seedling vigour index-I differed significantly among genotypes for different dormancy breaking treatments and their interactions is presented in Table 5.

There is a significant difference with respect to seedling vigour index-I among the genotypes. The genotype NOK-50 (G_6) was recorded highest (3291) and the lowest (1881) seedling vigour index-I was recorded in NOK-31 (G_3). The seedling vigour index-I differed significantly with different dormancy breaking treatments. The seedling vigour index-I registered the highest (4076) in sulphuric acid 98 per cent for 1 minute (T_7) and lowest (785) was recorded in control (T_9). The interaction between genotypes and different dormancy breaking treatments showed significant difference on seedling vigour index-I. The highest (4735) was recorded in sulphuric acid 98 per cent for 1 minute in genotype NOK-50 (T_7G_6) and the lowest (22) seedling vigour index-I noticed in control in genotype NOK-31 (T_9G_3).

The observed enhancement in seedling vigor after sulfuric acid treatment may be explained by multiple possible mechanisms. To break seed coat dormancy and speed up water absorption, sulfuric acid may be used as a scarification agent. This will ultimately encourage stronger and faster germination. Additionally, by acidifying the surrounding media and increasing the accessibility of critical minerals for the budding seedlings, the acid treatment may improve nutrient availability. Additionally, sulfuric acid may have sterilizing qualities that lower the likelihood of pathogenic infections in the early stages of seedling growth. Sulfuric acid treatment may, all things considered, foster better seedling vigor and a robust start to plant growth (Pandita *et al*., 2010).

Seedling Vigour Index-II

The seedling vigour index-II as influenced different dormancy breaking treatments in okra genotypes and their interactions is presented in Table 6.

TABLE 6

Effect of different dormancy breaking treatments on seedling vigour index-II of okra genotypes

Treatments	Seedling vigour index-II						
	G_1	G_2	G_3	G_4	G_5	G_6	Mean
T_1	11361	13044	9407	9860	15587	15831	12515
T_2	12400	13775	9670	10453	16612	16772	13280
T_3	8560	8762	6847	7167	10801	11945	9014
T_4	5770	5535	6163	6255	7336	8068	6521
T_5	10828	11252	7773	7975	13176	13798	10800
T_6	9647	10068	7043	7688	12193	12701	9890
T_7	14316	15320	11486	12142	18477	19258	15166
T_8	10505	10971	7510	7797	12802	13312	10483
T_9	3653	4029	228	545	6376	6806	3606
Mean	9671	10306	7347	7765	12596	13166	
	S.Em±	CD (P=0.05)	CV (%)				
G	94.03	263.59	4.82				
T	115.16	322.83					
GxT	282.09	790.76					

Legend - G : Genotypes - G_1: NOK-2; G_2: NOK-8; G_3: NOK-31 ; G_4: NOK-39; G_5: NOK-49; G_6: NOK-50;
T : Treatments - T_1: Scarification with sand paper for 2 minutes, T_2: Soaking in Buttermilk for 4 hours, T_3: KNO_3 @ 0.5 % for 18 hours, T_4: Hot water at 100º C for 1 minute, T_5: Hydrochloric acid (75%) for 5 minute, T_6: Hydrochloric acid (75%) for 10 minutes, T_7: Sulphuric acid (98 %) for 1 minute, T_8: Dry heating at 70 ºC for 5 minutes, T_9: Control

The variation among the genotypes is significant for the seedling vigour index-II. The genotype NOK-50 (G_6) recorded highest (13166) and the NOK-31 (G_3) recorded lowest (7347) seedling vigour index-II.

The seedling vigour index significantly varied with the different dormancy breaking treatments. The sulphuric acid 98 per cent for 1 minute (T_7) registered the highest (15166) seedling vigour index-II and lowest (3606) recorded in control.

The interaction between genotypes and different dormancy breaking treatments showed significant difference on seedling vigour index-II. The seedling vigour index-II was recorded highest (19258) in sulphuric acid 98 per cent for 1 minute in NOK-50 (T_7G_6) and the lowest (228) in control in NOK-31 (T_9G_3).

This might be due to scarifying the seeds with concentrated sulphuric acid resulted in a significant increase in germination percentage and vigour values due to the ability of the acid to break the exogenous dormancy (Babeley *et al*., 1986, Rai *et al*., 1986 and Sur *et al*., 1987). Similar results were reported in Anola by Nayaka (2006) as he reported that acid scarified seeds gave maximum germination and had very high seedling vigour as compared to control. This may be due to their corresponding standard germination, seedling length and seedling dry weight.

The experiment was demonstrated with significant improvements for seed quality parameters in okra genotypes through different dormancy breaking treatments. Treatment with sulphuric acid and buttermilk effectively enhanced seedling growth and vigour indices. Treatment of concentrated sulfuric acid (98%) for 1 min. (T_7) and soaking in buttermilk for 4 hours (T_2) were very effective for breaking seed dormancy of okra genotypes which enhances overall

seed quality parameters. These findings offer practical pathways to enhance seedling establishment, vigour in okra crop.

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