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Research Article

Effect of Aging, Scarifcation and Pre Sowing Treatments on Seed Germination and Its Parameters in Sandalwood (*Santalum album* L.)

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ABSTRACT

The present investigation was conducted under greenhouse condition with an aim to study the effect of pre sowing treatments like aging [A_1 (8 months old seeds) and A_2 (new seeds)], scarification [S_1 (manual scarification with sandpaper) and S_2 (ultrasonic sound)] and different treatments [T_1 (GA_3 100 ppm), T_2 (GA_3 300 ppm), T_3 (KNO_3 at 2%), T_4 (cow dung for 24 hours), T_5 (cow dung for 48 hours), T_6 (ethrel 100 ppm) and T_7 (control)] on seed germination and its parameters in sandalwood. But aging factor was not considered as the number of germinated seeds is observed to be very less. The results indicated that 8 months old seeds had poor germination because of loss of viability. Observations viz., germination per cent (%), time taken for initiation of germination (TTIG), time taken for completion of germination (TTCG), speed of germination, mean weekly germination, root length of seedling (cm), shoot length of seedlings (cm), seedling length (cm), collar diameter (mm), seedling fresh weight (mg), seedling dry weight (mg), seedling vigour index (length) and seedling vigour index (mass) were analyzed by completely randomize design (factorial) in three repetitions. Manual scarification with sandpaper (S_1) produced significantly the earliest seed emergence and also resulted superior response in all the observations. Among different treatments GA_3 300 ppm (T_2) was best for 9 observations out of 13 observations. The treatment combination S_1T_2 (manual scarification with sandpaper treated with GA_3 @ 300 ppm) noted the earliest seed emergence and relatively the maximum germination percent.

Keywords: *Germination, Pre Sowing, Sandalwood, Sandpaper, Scarification, Ultrasonic sound.*

INTRODUCTION

Indian sandalwood is one of the most primitive precious useful plants since ancient times. It is second most expensive wood in the world. In sandalwood, germination is sporadic and takes 4-12 weeks time to complete germination (Srinivasan et al., 1992; & Srimathi et al., 1995). Fresh seeds show dormancy for two months period.

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It is likely that the enforced dormancy of seeds is due to presence of hard seed coat or due to the presence of chemical substances in the seed coat which are impervious to water and gases. Natural germination of sandalwood seeds is having very low germination capacity as well as time consuming. Therefore the seed germination needs to be improved by artificial methods. This study sets out to investigate appropriate seed germination techniques for sandalwood. As sandalwood seeds takes more time for its emergence, this study would also help in early emergence of seed without taking more time. Aging, scarification and different pre sowing treatments are considered important factors reflected in seed germination and its parameters in sandalwood. There is a negative relationship of germination percentage of sandalwood seeds over aging or storage time (Gamage et al., 2010). Pamungkas and Nichols (2019) showed that the cumulative germination was higher on the seed with scarification and soaked in GA_3 solution 300 and 500 ppm in sandalwood. Therefore, the present study was conducted to investigate the effect of aging, scarification and pre sowing treatments on seed germination and its parameters in sandalwood.

MATERIALS AND METHODS

The present investigation was conducted under greenhouse condition in the Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh during *rabi* 2019-20. The seeds of sandalwood was obtained from Paritalav botanical garden, Junagadh Agricultural University, Junagadh. The required amount of both old and new aged seeds which were treated with scarification and ultrasonic sound were soaked in 100 ppm GA_3, 300 ppm GA_3, 100 ppm ethrel, 2% KNO_3 for about 12 hrs and in cow dung slurry for about 12 and 24 hrs respectively. Required amount of old and new aged seeds were not treated with any one of the treatments is used as control for sowing. Analysis of variance for Completely Randomized Design (Factorial) was computed as per the method of Gomez and Gomez (1984). Vigour index in terms of length and mass were determined as per formulae given by Abdul-Baki and Anderson (1973).

RESULTS AND DISCUSSION

After sowing the old seeds and waiting for about 88 days hardly any of these had germinated due to loss of viability. Only for specific treatments and in some of the replications the old seeds showed positive results. Thereby, the number of germinated seeds is observed to be very less. Similar observations were reported by (Gamage et al., 2010) in the case of sandalwood. Therefore the old seeds were not preferred when compared to the new ones.

The intension of this work is to study the impact of aging, scarification and treatments (chemical/organic) on the growth of sandalwood seeds. However, it is evident from the data obtained from the old seeds is that there is no need to consider aging as one of the factors. Therefore, only two factors (scarification and treatments) were considered to find out the best combination of treatments when applied to the new seeds.

Germination percentage

Significantly the maximum germination per cent (35.38%) was recorded in manual scarification (S_1) over ultrasonic sound (S_2) (12.42%) (Table1). Increase in germination percentage might be due to reduction in dormancy period resulting from proper rupture of seed coat. Therefore, the seeds are capable of absorbing higher food reserves leading to higher germination percentage. The results are in accordance to the findings of Talei et al. (2012) in *Andrographis paniculata Nees*, Yildiztugay et al. (2012) in *sphaerophysa kotschyana* boiss and Jayawardena et al. (2015) in sandalwood. The seeds treated with T_2 (GA_3 @300 ppm) recorded significantly the highest germination percentage (34.66%) and it was remained at par with T_1 (GA_3 @ 100 ppm) (33.83%) (Table1). The enhancement of germination by GA_3 can be attributed to the fact that it antagonize the ill effect of inhibitors and induce *de novo* synthesis of proteolytic enzymes like alpha amylase and ribonuclease.

The results obtained in the present investigation are in accordance with the findings of Vira and Smith (1996), Nikam and Barmukh (2009), Jayawardena et al. (2015) and Sutheesh et al. (2016) in sandalwood. On comparison the maximum germination per cent was recorded in S_1T_2 (50.67%) followed by S_1T_1 (41.33%) while the minimum germination per cent was found in S_2T_5 (4.33%). The results are similar to the results reported earlier by Zaman et al. (2009) in *Helianthemum lippii* (L.), Tambat et al. (2006) in *Myristica swamps*, Jayawardena et al. (2015) and Karmakar et al. (2018) in sandalwood.

Time taken for initiation of germination (TTIG)

The time taken for initiation of germination was found faster in case of S_1 (manual scarification with sandpaper) (38.61 days) over S_2 (ultrasonic sound) (45.66 days) (Table 1). The results obtained in the present investigation are in accordance with the findings of Bhat et al. (2001) in forest species of the western ghat region of India. The TTIG was found faster in case of T_2 (GA_3 @ 300 ppm) (34.66 days) followed by T_3 (KNO_3 at 2%) (39.00 days) and late initiation in case of T_5 (cow dung for 48 hours) (48.33 days). The results are in accordance with the findings of Nikam and Barmukh (2009) in sandalwood. Gibberellins help to increase the availability of stored material for growing embryo by increasing the amylase enzyme activities in the seeds which leads to the faster germination of seeds. However, relatively the TTIG was found faster in S_1T_2 (28.67 days) which was at par with S_1T_3 (29.67 days) while the TTIG had taken long time in case of S_2T_5 (55.33 days).

Time taken for completion of germination (TTCG)

Time taken for completion of germination was found highest in S_1 (manual scarification with sandpaper) (84.66 days) when compared to S_2 (ultrasonic sound) (77.80 days) (Table 1). The results obtained in the present investigation are in accordance with the findings of Bhat et al. (2001) in forest species of the western ghat region of India. Seeds treated with T_1 (GA_3 @ 100 ppm) (85.33 days) followed by T_7 (control) (83.66 days) recorded significantly the maximum TTCG while significantly the minimum TTCG (75.83 days) was reported in T_5 (cow dung for 48 hours). An extended period of germination by manual scarification and GA_3 @ 100 ppm may be an advantage for continuation of germination leading to highest germination per cent. The extended period of germination by control may be an adaptation to allow them to wait for favorable conditions for germination. However, relatively the maximum TTCG was produced from treatment combination S_1T_1 and S_1T_7 (88.00 days) which were at par with S_1T_5 (87.33 days) while it was noted the minimum in treatment combination S_2T_5 (64.33 days).

Speed of germination

Significantly the maximum speed of germination was recorded in S_1 (manual scarification with sandpaper) (0.60) and minimum in case of S_2 (ultrasonic sound) (0.21) (Table 1). This may be due to rupture of hard seed coat leading to highest germination and speed of germination. Seeds treated with T_2 (GA_3 @ 300 ppm) recorded significantly the maximum speed of germination (0.64), while significantly the minimum speed of germination (0.26) was recorded in T_6 (ethrel 100 ppm). Maximum speed of germination by GA_3 might be due to enhanced enzymatic reactions along with suppression of inhibitors. The results obtained in the present investigation are in accordance with the findings of Anand et al. (2012) in *Melia* dubia. However, relatively the maximum speed of germination was produced from treatment combination S_1T_2 (0.96) followed by S_1T_1 (0.68), while the minimum speed of germination was recorded in S_2T_5 (0.07).

Mean weekly germination

It is evident from the results that maximum mean weekly germination was found in S_1 (manual scarification with sandpaper) (2.93) and minimum in case of S_2 (ultrasonic sound) (1.09) (Table 2). The results are in accordance with the findings of Fattahi et al. (2011) in *Dracocephalum kotschyi* Boiss and Yildiztugay et al. (2012) in *sphaerophysa*

kotschyana Boiss. Seeds treated with T_2 (GA_3 @ 300 ppm) had produced maximum (3.03) mean weekly germination followed by T_1 (GA_3 @ 100 ppm) (2.77) and minimum in T_6 (ethrel 100 ppm) (1.37). This may be due to inhibitory compounds in seed coat which affects the germination process are neutralized by GA_3 and promotes germination which leads to increase in mean weekly germination. The findings are in accordance with the work of Shankar and Devakumar (2018) and Pamungkas and Nichols (2019) in sandalwood. The treatment combination S_1T_2 produced the maximum mean weekly germination (4.34) followed by S_1T_1 (3.31). The results are similar to the findings of Tambat et al. (2006) in *Gymnacranthera canarica* Warb.

Root length (cm)

Significantly the highest root length (3.96 cm) was obtained in Manual scarification (S_1) over ultrasonic sound (S_2) (3.80 cm) (Table 2). Sufficient supplement of nutrients is perhaps the reason for longest root length in S_1 seeds. The determined results are in agreement with the results of Patil and Krishna (2016) in canes and Ribera and Vicient (2017) in Arabidopsis seeds. Significantly the highest root length was produced from the seeds treated with T_3 (KNO_3 at 2%) (4.25 cm) which was at par with T_2 (GA_3@ 300 ppm) (4.18 cm) and T_1 (GA_3@ 100 ppm) (4.08 cm). Similar inference was also drawn earlier by Pamei et al. (2017) in *Tectona grandis* L.f. The treatment combination S_1T_1 produced maximum (4.57 cm) root length followed by S_1T_3 (4.33 cm) while the minimum root length was noted in S_1T_7 (3.03 cm).

Shoot length (cm)

Manually scarified seeds (S1) produced significantly the highest shoot length (4.82 cm) when compared to S_2 (ultrasonic sound) (4.22 cm) (Table 2). The shoot length was found highest in case of T_3 (KNO_3 at 2%) (5.27 cm) followed by T_2 (GA_3@ 300 ppm) (4.81 cm) and T_1 (GA_3@ 100 ppm) (4.45 cm). This might be due to the fact that the KNO_3 and GA_3 treatments might have supplied more food materials to the growing seeds which resulted in longer shoot length. The determined results are in agreement with the results of Anand et al. (2012) in *Melia dubia* and Sujatha and Manjappa (2015) in *Melia azedarach* L. The treatment combination S_1T_3 produced the maximum shoot length (6.00 cm) followed by S_1T_1 (5.40 cm) which was at par with S_1T_2 (5.29 cm) while the minimum shoot length was observed in S_2T_1 (3.50 cm).

Seedling length (cm)

The data showed that the highest seedling length (8.79 cm) was observed in S_1 (manual scarification) (Table 2) while S_2 (ultrasonic sound) recorded (8.02 cm). Both root and shoot lengths had shown significantly maximum results in case of manual scarification, this resulted in maximum seedling length in case of S_1. Seedling length was noted significantly the highest (9.55 cm) for the seeds treated with T_3 (KNO_3 at 2%) followed by T_2 (GA_3@ 300 ppm) (8.98 cm) while the lowest seedling length (7.68 cm) was found in T_7 (control). The results obtained in the present investigation are in accordance with the findings of Anand et al. (2012) in *Melia dubia*, Pamei et al. (2017) in teak and Shankar and Devakumar (2018) in sandalwood.

Collar diameter (mm)

The results revealed that the effect of scarification was found non-significant for collar diameter. Manually scarified seeds (S1) and ultrasonic sound (S_2) showed results as (2.10 mm) and (2.11 mm) respectively (Table 2). The maximum collar diameter (2.23 mm) was recorded in T_2 (GA_3@ 300 ppm) which was at par with T_4 (cow dung for 24 hours) (2.21 mm) and T_6 (ethrel 100 ppm) (2.21 mm) while the lowest collar diameter was found in T_3 (KNO_3 at 2%) (1.86mm). The enhanced enzymatic reactions along with suppression of inhibitors might have acted in the absorption of food reserves properly, thus resulted in maximum collar diameter. Increase in collar diameter with pre-soaking treatments of seeds was also reported by Anand et al. (2012) in *Melia dubia*, Patil and Krishna (2016) in canes and Palepad et al. (2017) in *Annona squamosa* L. The treatment combination S_1T_6 produced the maximum collar diameter (2.40 mm)

followed by S_2T_1 (2.30 mm) which was at par with S_2T_2 (2.27 mm).

Seedling fresh weight (mg)

The seeds treated with S_1 (manual scarification) produced significantly maximum fresh weight (239.00 mg) followed by S_2 (ultrasonic sound) (197.52 mg) (Table 3). The results are in conformity with the results of Pamei et al. (2017) in teak. Significantly the highest fresh weight (243.16 mg) was recorded in T_2 (GA_3@ 300 ppm) which was at par with T_3 (KNO_3 at 2%) (236.66 mg) while the lowest seedling fresh weight was found in T_7 (control) (196.66 mg). Enhanced enzymatic reactions which promotes maximum water content, along with suppression of inhibitors by GA_3 and KNO_3 leads to production of maximum seedling fresh weight. The results obtained in the present investigation are in accordance with the findings of Sandeep et al. (2016) in *Delonix Regia* and Pamei et al. (2017) in *Tectona grandis* L. f. However, relatively the maximum seedling fresh weight was observed in treatment combination, S_1T_1 (293.33 mg) followed by S_1T_3 (273.33 mg). The results are in accordance to the findings of Zaman et al. (2009) in *Helianthemum lippii* (L.) Dum Cours.

Seedling dry weight (mg)

Significantly the maximum seedling dry weight was observed in S_1 (scarification) (47.19 mg) when compared to S_2 (ultrasonic sound) (37.38 mg) (Table 3). The results obtained in the present investigation are in accordance with the findings of Anand et al. (2012) in *Melia dubia* and Pamei et al. (2017) in teak. The seeds treated with T_2 (GA_3@ 300 ppm) (50.00 mg) followed by T_6 (ethrel 100 ppm) (46.33 mg) showed maximum seedling dry weight while the lowest seedling dry weight was found in T_4 (cow dung for 24 hours) (36.50 mg). The results obtained in the present investigation are in accordance with the findings of Sandeep et al. (2016) in *Delonix Regia* and Opoku et al. (2018) in *Bauhinia rufescens* Lam However, relatively the maximum seedling fresh weight was observed in treatment combination, S_1T_1 (54.33 mg) followed by S_1T_6 (51.33 mg) which was at par with S_1T_2 (50.67 mg).

Seedling vigour index (length)

Significantly the highest seedling vigour index (length) was observed in S_1 (scarification) (315.72) when compared to S_2 (ultrasonic sound) (98.74) (Table 3). As manual scarification resulted in maximum germination per cent and seedling length this leads to production of maximum SVI (length). The results obtained in the present investigation are in accordance with the findings of Fattahi et al. (2011) in *Dracocephalum kotschyi* Boiss and Patil and Krishna (2016) in canes. Significantly the maximum SVI (length) was found highest in case of T_2 (GA_3@ 300 ppm) (319.15) followed by T_1 (GA_3@ 100 ppm) (299.45), while the lowest seedling vigour index (length) was found in T_6 (ethrel 100 ppm) (129.58). The results obtained in the present investigation are in accordance with the findings of Patil and Krishna (2016) in canes, Shankar and Devakumar (2018) in sandalwood. The treatment combination S_1T_2 produced the maximum seedling vigour index (length) (479.63) followed by S_1T_1 (411.93). The results obtained in the present investigation are in accordance with the findings of Zaman et al. (2009) in *Helianthemum lippii* (L.) Dum Cours and Tambat et al. (2006) in *Myristica swamps*.

Seedling vigour index (mass)

Seeds treated with S_1 (manual scarification) (1687.57) produced significantly the maximum seedling vigour index (mass) over S_2 (ultrasonic sound) (476.23) (Table 3). Similar findings were also reported earlier by Fattahi et al. (2011) in *Dracocephalum kotschyi* Boiss and Patil and Krishna (2016) in canes. Significantly the maximum seedling vigour index (mass) was found highest in case of T_2 (GA_3@ 300 ppm) (1743.83) followed by T_1 (GA_3@ 100 ppm) (1557.33), while the lowest seedling vigour index (mass) was found in T_4 (cow dung for 24 hours) (685.16). The results obtained in the present investigation are in accordance with the findings of Patil and Krishna (2016) in canes, Thanuja et al. (2018) in *Pterocarpus marsupium* Roxb and Shankar and Devakumar (2018) in sandalwood. The treatment combination S_1T_2 (2566.67) produced the maximum seedling vigour index (mass) followed by S_1T_1 (2245.67).

Table 1: Effect of scarification and pre sowing seed treatments on seed germination and its parameters after 88 days of sowing on germination (%), TTIG, TTCG and speed of germination

Treatment	Germination (%)	TTIG	TTCG	Speed of germination
Scarification (S)				
S_1	35.38	38.61	84.66	0.60
S_2	12.42	45.66	77.80	0.21
S. Em±	**0.13**	**0.13**	**0.12**	**0.002**
CD at 5 %	**0.39**	**0.37**	**0.36**	**0.006**
Treatments (T)				
T_1	33.83	41.16	85.33	0.54
T_2	34.66	34.66	78.50	0.64
T_3	23.33	39.00	82.33	0.40
T_4	17.16	47.16	80.33	0.27
T_5	21.33	48.33	75.83	0.33
T_6	16.16	43.33	82.66	0.26
T_7	20.83	41.33	83.66	0.36
S. Em±	**0.25**	**0.24**	**0.23**	**0.004**
CD at 5 %	**0.72**	**0.70**	**0.68**	**0.01**
Scarification (S) x Treatments (T)				
S_1T_1	41.33	39.00	88.00	0.68
S_1T_2	50.67	28.67	81.67	0.96
S_1T_3	34.67	29.67	81.33	0.62
S_1T_4	26.67	51.67	84.33	0.40
S_1T_5	38.33	41.33	87.33	0.59
S_1T_6	23.67	44.67	82.00	0.39
S_1T_7	32.33	35.33	88.00	0.58
S_2T_1	26.33	43.33	82.67	0.42
S_2T_2	18.67	40.67	75.33	0.33
S_2T_3	12.00	48.33	83.33	0.20
S_2T_4	7.67	42.67	76.33	0.14
S_2T_5	4.33	55.33	64.33	0.07
S_2T_6	8.67	42.00	83.33	0.15
S_2T_7	9.33	47.33	79.33	0.16
Mean	**23.90**	**42.14**	**81.23**	**0.40**
S. Em±	**0.35**	**0.34**	**0.33**	**0.006**
CD at 5 %	**1.03**	**0.99**	**0.96**	**0.01**
CV %	**2.58**	**1.41**	**0.71**	**2.63**

Table 2: Effect of scarification and pre sowing seed treatments on seed germination and its parameters after 88 days of sowing on mean weekly germination, root length (cm), shoot length (cm), seedling length (cm) and collar diameter (mm)

Treatment	Mean weekly Germination	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Collar diameter (mm)
Scarification (S)					
S_1	2.93	3.96	4.82	8.79	2.10
S_2	1.09	3.80	4.22	8.02	2.11
S. Em±	**0.01**	**0.03**	**0.04**	**0.03**	**0.02**
CD at 5 %	**0.03**	**0.09**	**0.12**	**0.11**	**NS**

Treatments (T)					
T_1	2.77	4.08	4.45	8.53	2.06
T_2	3.03	4.18	4.81	8.98	2.23
T_3	2.00	4.25	5.27	9.55	1.86
T_4	1.45	3.84	4.35	8.18	2.21
T_5	1.77	3.68	4.36	8.03	2.13
T_6	1.37	3.61	4.27	7.88	2.21
T_7	1.70	3.55	4.13	7.68	2.05
S. Em±	**0.02**	**0.06**	**0.07**	**0.07**	**0.04**
CD at 5 %	**0.07**	**0.18**	**0.22**	**0.21**	**0.12**
Scarification (S) x Treatments (T)					
S_1T_1	3.31	4.57	5.40	9.97	1.83
S_1T_2	4.34	4.20	5.29	9.47	2.20
S_1T_3	2.99	4.33	6.00	10.40	1.87
S_1T_4	2.21	3.86	4.50	8.33	2.17
S_1T_5	3.09	4.03	4.47	8.50	2.10
S_1T_6	2.02	3.73	4.43	8.17	2.40
S_1T_7	2.59	3.03	3.67	6.70	2.20
S_2T_1	2.23	3.60	3.50	7.10	2.30
S_2T_2	1.73	4.17	4.33	8.50	2.27
S_2T_3	1.01	4.17	4.56	8.70	1.87
S_2T_4	0.70	3.83	4.21	8.03	2.27
S_2T_5	0.47	3.33	4.25	7.57	2.17
S_2T_6	0.73	3.50	4.11	7.60	2.03
S_2T_7	0.82	4.07	4.60	8.67	1.90
Mean	**2.01**	**3.88**	**4.52**	**8.40**	**2.11**
S. Em±	**0.03**	**0.09**	**0.10**	**0.10**	**0.06**
CD at 5 %	**0.10**	**0.26**	**0.31**	**0.30**	**0.18**
CV%	**2.98**	**4.05**	**4.20**	**2.16**	**5.16**

Table 3: Effect of scarification and pre sowing seed treatments on seed germination and its parameters after 88 days of sowing on seedling fresh weight (mg), seedling dry weight (mg), seedling vigour index (length) and seedling vigour index (mass)

Treatment	Seedling fresh weight (mg)	Seedling dry weight (mg)	Seedling Vigour Index (length)	Seedling Vigour Index (mass)
Scarification (S)				
S_1	239.00	47.19	315.72	1687.57
S_2	197.52	37.38	98.74	476.23
S. Em±	**1.36**	**0.16**	**1.59**	**6.74**
CD at 5 %	**3.96**	**0.48**	**4.63**	**19.54**
Treatments (T)				
T_1	228.33	43.66	299.45	1557.33
T_2	243.16	50.00	319.15	1743.83
T_3	236.66	41.83	232.45	1061.33
T_4	199.66	36.50	141.91	685.16
T_5	203.33	38.16	179.31	975.50
T_6	220.00	46.33	129.58	786.66
T_7	196.66	39.50	148.76	763.50
S. Em±	**2.56**	**0.31**	**2.99**	**12.62**

CD at 5 %	**7.42**	**0.91**	**8.67**	**36.56**
Scarification (S) x Treatments (T)				
S_1T_1	293.33	54.33	411.93	2245.67
S_1T_2	259.67	50.67	479.63	2566.67
S_1T_3	273.33	49.33	360.50	1710.33
S_1T_4	220.00	42.67	222.27	1137.67
S_1T_5	226.67	47.67	325.83	1827.00
S_1T_6	233.33	51.33	193.30	1215.33
S_1T_7	166.67	34.33	216.60	1110.33
S_2T_1	163.33	33.00	186.97	869.00
S_2T_2	226.67	49.33	158.67	921.00
S_2T_3	200.00	34.33	104.40	412.33
S_2T_4	179.33	30.33	61.57	232.67
S_2T_5	180.00	28.67	32.80	124.00
S_2T_6	206.67	41.33	65.87	358.00
S_2T_7	226.67	44.67	80.93	416.67
Mean	**218.26**	**42.28**	**207.23**	**1081.90**
S. Em±	**3.62**	**0.44**	**4.23**	**17.84**
CD at 5 %	**10.49**	**1.29**	**12.26**	**51.70**
CV%	**2.87**	**1.82**	**3.53**	**2.85**

CONCLUSION

The conclusion that can be reached from the present study is that the 8 months old seeds had poor germination because of loss of viability. Therefore, the old seeds should not be preferred over new seeds in sandalwood. Manual scarification with sandpaper (S_1) irrespective of different seed treatments significantly noted the highest values for all observations. Similarly, irrespective of scarification, seeds treated with GA_3 @300 ppm (T_2) treatment also produced significantly the faster initiation of germination and showed highest germination per cent, speed of germination, mean weekly germination, collar diameter, fresh weight, dry weight, seedling vigour index (length) and seedling vigour index (mass). Significantly the highest root length, shoot length and seedling length were noted in KNO_3 at 2% (T_3). Among the different combinations of scarification and treatments, manual scarification with sandpaper treated with GA_3 @ 300 ppm (S_1T_2) was found a best suited, as it having early seed emergence with the highest germination per cent, speed of germination, mean weekly germination, seedling vigour index (length) and seedling vigour index (mass). Therefore, looking to the different seed germination parameters it is suggested that the seeds treated with manual scarification with sandpaper should be treated with GA_3 @ 300 ppm for enhancement of germination and its parameters in sandalwood.

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