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Effect of Different Physical and Chemical Treatments on Germination and Seedling Establishment in Spine gourd (*Momordica dioica* Roxb.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted at Department of Vegetable Science, OUAT, Bhubaneswar from 2019-2021. Stored spine gourd seeds of six months old were used in this experiment. The seeds were first given various physical treatments (T_1: control, T_2: 48 hours soaking in water, T_3: hot water treatment for 20 minutes + 48 hours soaking in water, T_4: scarification by sand paper + 48 hours soaking in water, T_5: removal of seed coat + 48 hours soaking in water) followed by chemical treatments (C_1: GA_3 100 ppm, C_2: GA_3 200 ppm, C_3: KNO_3 1%, C_4: KNO_3 2%, C_5: Thiourea 1%, C_6: Thiourea 2% & C_7: control). The experiment was laid out in factorial CRD design with 35 treatment combinations replicated twice. The seeds were sown in plastic trays containing coco peat media. The effect of these treatments on number of days taken for initial germination, length of shoot, root, number of roots per seedling and percentage of seedling establishment in main field were recorded. From the data recorded, it was observed that among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water), among the chemical treatments, C_1 (GA_3 100 ppm) and between the interactions, T_5C_1 (removal of seed coat + 48 hours soaking in water + GA_3 100 ppm) took minimum number of days for initial germination with highest shoot and root length, maximum number of roots per seedling and highest establishment percentage in field. The lowest values were recorded in case of control. So, it can be concluded that removal of seed coat followed by 48 hour soaking in water and GA_3 100 ppm treatment resulted early germination with desirable seedling traits and highest establishment percent in main field.

Keywords: Physical; chemical; germination; establishment; GA_3; spine gourd.

1. INTRODUCTION

Spine gourd (*Momordica dioica* Roxb.) is a tuberous, perennial and one of the dioecious species of cucurbitaceous family which is mostly cultivated in tribal regions of Odisha, Jharkhand, Bihar, North East states and in Konkan region of western Maharashtra. Naturally it is found in Punjab, Rajasthan, Madhya Pradesh, Kerala and Maharashtra especially in areas with least human interference. This is liked for its typical taste with high seed protein content. It has prominent position among cucurbitaceous vegetables owing to its good nutritional and medicinal value, high keeping quality, ability to withstand long distant transportation and high market price [1]. This popular vegetable has high demand in market but still remains as underutilized and underexploited due to vegetative mode of propagation and dioecious nature. Commercial propagation of spine gourd largely depends on tuberous roots, followed by stem cuttings and seeds. Multiplication using the tuberous roots is critically limited due to inadequate availability of tuberous roots and low multiplication rate [2] which occupies the valuable cultivable land until next planting season [3,4]. Storage of tubers in field condition is also difficult. Vine cuttings containing 2-3 nodes from dark green vines of 2-3 months old plants are planted but only 36% of the plants sprout and survive [4]. Seed germination is always a problem in spine gourd even with the seeds of high germinability due to thick seed coat and prolonged dormancy (4-5 months). Some pre-sowing treatments like soaking or priming of seeds or physical treatments can be practised to overcome the problem of low germination. The seeds can also be treated with some growth regulators and chemicals to break the dormancy. Pre-sowing seed treatments resulted in earlier seedling emergence and higher establishment in main field. Overall seed treatment to break seed dormancy leads to improved plant population and thus higher productivity [5]. So, there is a necessity to find out suitable treatments which can be useful in breaking the dormancy of spine gourd seeds and enhancing early germination and seedling establishment.

2. MATERIALS AND METHODS

This investigation was carried out in the experimental field of Department of Vegetable Science, OUAT, Bhubaneswar from 2019-21. Stored spine gourd seeds of six months old were used for this experiment and the seeds were first exposed to different physical treatments *i.e.*, T_1: control, T_2: 48 hours soaking in water, T_3: hot water treatment for 20 minutes + 48 hours soaking in water, T_4: scarification by sand paper + 48 hours soaking in water and T_5: removal of seed coat + 48 hours soaking in water followed by soaking in different concentrations of chemicals (C_1: GA_3 100 ppm, C_2: GA_3 200 ppm, C_3: KNO_3 1%, C_4: KNO_3 2%, C_5: Thiourea 1%,

C_6: Thiourea 2% & C_7: control) .The seeds were sown in plastic trays filled with coco peat. The experiment consisted of 35 treatment combinations replicated twice. 100 seeds were sown in each tray. The trays were kept under poly house and watered regularly. Number of days taken for initial germination, length of shoot (cm), length of root (cm), total number of roots per seedling were recorded till 50 days after sowing. The number of days taken from the date of sowing to first germination in all the treatments were recorded and reported as days taken for initial germination. Shoot length was measured in cm from 5 seedlings in each treatment in each replication 30 days after germination and the mean was computed. Seedlings were uprooted carefully 30 days after germination without causing any damage to the roots and the length of root was measured in cm from 5 seedlings in each treatment in each replication and mean was calculated. Total number of roots per seedling was counted in 5 seedlings in each treatment in each replication and mean was expressed. The number of seedlings established in the main field in each treatment per replication were counted and expressed in percentage as percentage of seedling establishment in main field. The data were subjected to statistical analysis as per CRD with factorial concept. The data in percentages were transformed to square root transformed values for statistical analysis. Critical difference values were tabulated at 5 % probability where 'f 'test was significant.

3. RESULTS

3.1 Number of Days taken for Initial Germination

The data presented in Tables 1 and 2 indicated a significant difference in both physical and chemical treatments during the years and pooled analysis. Though there was no significant difference in interaction effect between physical and chemical treatments in 2020-21 and pooled analysis, the number of days taken for initial germination during 2019-20 showed significant differences among the treatment combinations.

In 2019-20, 2020-21 and pooled analysis, significantly less number of days were taken for germination of spine gourd seed in T_5: removal of seed coat + 48 hours soaking in water (21.79, 20.57 and 21.18, respectively) and more number of days to germination was recorded in T_1: control (41.00, 39.57 and 40.29, respectively) among the different physical treatments. Among the different chemical treatments, significantly less number of days to germination during 2019-20 and pooled analysis were recorded in seeds treated with GA_3 100 ppm (28.10 and 27.25 respectively) and more number of days to germination were recorded in control (39.60 and 38.35, respectively).During 2020-21,minimum number of days to germination was observed in GA_3 100 ppm treatment (26.40) which was at par with Thiourea 2% treatment (28.40) and maximum number of days was taken in case of control (37.10).

Among the treatment combinations, during 2019-20, significantly less number of days to germination was noticed in T_5C_1 (15.00), closely followed by T_6C_1 (18.50). In contrast, more number of days to germination was noticed in T_1C_7 (45.50). No significant difference was noticed in the interaction between physical and chemical treatments during 2020-21 and pooled analysis, where less number of days to germination of seeds was noticed in T_5C_1 (14.00 and 14.50, respectively). More days to germination of spine gourd were noticed in T_1C_7 (44.50 and 45.00, respectively).

3.2 Length of Shoot (cm)

The data presented in Tables 3 and 4 showed significant differences in shoot length during 2019-20,2020-21 and pooled analysis in case of physical and chemical treatments. However, the interaction between physical and chemical treatments was found non-significant.

During 2019-20, significant difference was observed in shoot length in case of physically treated seeds. Among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded highest length of shoot (29.15 cm) followed by T_4 (scarification + 48 hours soaking in water) *i.e*., 26.43 cm. The lowest shoot length was observed in case of control (21.23 cm). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest shoot length (27.72 cm) and the lowest was recorded in control (19.55 cm). Among the interaction between physical and chemical treatments, T_5C_1 recorded highest shoot length (32.14 cm) followed by T_5C_2 (31.23 cm) and the lowest was observed in T_1C_7 (15.33 cm).

During 2020-21, among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded highest shoot length (29.08 cm)

followed by T_4 (scarification + 48 hours soaking in water) *i.e.,* 26.45 cm. The lowest shoot length was observed in case of control (21.03 cm). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest shoot length (27.99 cm) and the lowest was recorded in control (19.80 cm). Among the interaction between physical and chemical treatments, T_5C_1 recorded highest length of shoot (32.98 cm) followed by T_5C_6 (31.83 cm) and the lowest was observed in T_1C_7 (17.21 cm).

In case of pooled analysis over the years, among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded highest shoot length (29.12 cm) followed by T_4 (scarification + 48 hours soaking in water) *i.e.,* 26.44 cm. The lowest shoot length was observed in case of control (21.13 cm). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest shoot length (27.86 cm) and the lowest was recorded in control (19.67 cm).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest length of shoot (32.56 cm) followed by T_5C_2 (30.70 cm) and the lowest was observed in T_1C_7 (16.27 cm).

3.3 Length of Root (cm)

The data presented in Tables 5 and 6 showed significant differences in root length during 2019-20,2020-21 and pooled analysis in case of physical and chemical treatments. However, in case of interaction, significant differences were recorded in both years and non-significant in case of pooled analysis.

During 2019-20, among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded highest length of root (4.50 cm) followed by T_4 (scarification + 48 hours soaking in water) *i.e.,* 4.26 cm. The lowest root length was observed in case of control (3.66 cm). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest root length (4.57 cm) which was at par with GA_3 200 ppm (4.37cm) and the lowest was recorded in control (3.52 cm). Among the interaction between physical and chemical treatments, T_5C_1 recorded highest shoot length (4.95 cm) which was at par with T_5C_2 (4.90 cm),T_5C_6 (4.54 cm),T_4C_1 (4.72 cm),T_4C_2 (4.71 cm),T_4C_6 (4.53 cm),T_3C_1 (4.65 cm) and T_3C_2 (4.50 cm) . The lowest root length was observed in T_1C_7 (3.17 cm).

During 2020-21, among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded highest length of root (4.54 cm) followed by T_4 (scarification + 48 hours soaking in water) *i.e.,* 4.25 cm. The lowest root length was observed in case of control (3.59 cm). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest root length (4.52 cm) which was at par with GA_3 200 ppm (4.34 cm) and the lowest was recorded in control (3.47 cm). Among the interaction between physical and chemical treatments, T_5C_1 recorded highest shoot length (5.15 cm) which was at par with T_5C_2 (4.82 cm), T_5C_3 (4.69 cm), T_5C_6 (4.76 cm), T_4C_1 (4.90 cm) and T_4C_2 (4.58 cm). The lowest root length was observed in T_1C_7 (2.91 cm).

In case of pooled analysis, among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded highest length of root (4.52 cm) followed by T_4 (scarification + 48 hours soaking in water) *i.e.,* 4.26 cm. The lowest root length was observed in case of control (3.63 cm). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest root length (4.55 cm) and the lowest was recorded in control (3.50 cm). Among the interaction between physical and chemical treatments, T_5C_1 recorded highest shoot length (5.05 cm) followed by T_5C_2 (4.86 cm) and the lowest was observed in T_1C_7 (3.04 cm).

3.4 Number of Roots per Seedling

The data presented in Tables 7 and 8 showed significant differences in number of roots per seedling during 2019-20,2020-21 and pooled analysis in case of physical and chemical treatments. Significant differences were observed in number of roots in case of interaction between physical and chemical treatments in pooled analysis. However, the interaction effect was non-significant during both the years.

During 2019-20, among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded maximum number of roots per seedling (4.99) followed by T_4 (scarification + 48 hours soaking in water) *i.e,* 4.43. Minimum number of roots per seedling was recorded in case of control (3.61). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded maximum number of roots (4.80) and the minimum was recorded in control (3.76). Among the interaction between physical and chemical treatments, T_5C_1 recorded maximum number of roots (5.60) followed by T_5C_6 (5.30) and the minimum was recorded in T_1C_7 (3.30).

Table 1. Effect of different physical and chemical treatments on number of days taken for initial germination during 2019-20 & 2020-21

	2019-20						2020-21					
	T_1	T_2	T_3	T_4	T_5	Mean	T_1	T_2	T_3	T_4	T_5	Mean
C_1 (GA_3 100 ppm)	38.00	33.50	30.00	24.00	15.00	28.10	35.50	34.50	28.00	20.00	14.00	26.40
C_2 (GA_3 200 ppm)	42.00	36.00	31.50	26.00	21.50	31.40	38.00	38.00	33.50	27.00	18.50	31.00
C_3 (KNO_3 1%)	43.00	39.50	37.00	30.50	21.00	34.20	40.00	37.50	33.00	25.50	24.00	32.00
C_4 (KNO_3 2%)	39.50	34.50	32.00	30.00	22.50	31.70	38.50	37.50	30.00	24.00	19.50	29.90
C_5 (Thiourea 1%)	40.50	37.00	34.50	26.00	25.00	32.60	41.50	38.00	33.50	27.00	26.00	33.20
C_6 (Thiourea 2%)	38.50	36.50	33.00	27.50	18.50	30.80	39.00	34.50	30.00	23.00	15.50	28.40
C_7 (Control)	45.50	44.00	42.50	37.00	29.00	39.60	44.50	42.00	39.50	33.00	26.50	37.10
Mean	41.00	37.29	34.36	28.71	21.79	32.63	39.57	37.43	32.50	25.64	20.57	31.14
	T		**C**		**T × C**		**T**		**C**		**T × C**	
SEm (±)	0.452		0.535		1.195		0.613		0.725		1.621	
CD @ 5%	1.29		1.53		3.43		1.75		2.08		NS	

(T_1 – control, T_2 – 48 hours soaking in water, T_3 – hot water treatment for 20 minutes + 48 hours soaking in water, T_4 – scarification + 48 hours soaking in water, T_5 - removal of seed coat + 48 hours soaking in water)

Table 2. Effect of different physical and chemical treatments on number of days taken for initial germination (Pooled)

	Pooled					
	T_1	T_2	T_3	T_4	T_5	Mean
C_1 (GA_3 100 ppm)	36.75	34.00	29.00	22.00	14.50	27.25
C_2 (GA_3 200 ppm)	40.00	37.00	32.50	26.50	20.00	31.20
C_3 (KNO_3 1%)	41.50	38.50	35.00	28.00	22.50	33.10
C_4 (KNO_3 2%)	39.00	36.00	31.00	27.00	21.00	30.80
C_5 (Thiourea 1%)	41.00	37.50	34.00	26.50	25.50	32.90
C_6 (Thiourea 2%)	38.75	35.50	31.50	25.25	17.00	29.60
C_7 (Control)	45.00	43.00	41.00	35.00	27.75	38.35
Mean	40.29	37.36	33.43	27.18	21.18	31.89
	T	**C**	**T x C**	**Y X T**	**Y X C**	**Y X T X C**
SEm (±)	0.381	0.450	1.007	0.538	0.637	1.424
CD @ 5%	1.07	1.27	NS	NS	NS	NS

(T_1 – control, T_2 – 48 hours soaking in water, T_3 – hot water treatment for 20 minutes + 48 hours soaking in water, T_4 – scarification + 48 hours soaking in water, T_5 - removal of seed coat + 48 hours soaking in water)

During 2020-21, among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded maximum number of roots per seedling (5.01) followed by T_4 (scarification + 48 hours soaking in water) *i.e.,* 4.66. Minimum number of root per seedling was recorded in case of control (3.33). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded maximum number of roots (4.48) which was at par with Thiourea 2% treatment (4.34) and the minimum was recorded in control (3.48). Among the interaction between physical and chemical treatments, T_5C_1 recorded maximum number of roots (5.40) followed by T_5C_2 (5.30) and the minimum was recorded in T_1C_7 (2.70).

In pooled analysis over both the years, among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded maximum number of roots per seedling (5.00) followed by T_4 (scarification + 48 hours soaking in water) *i.e.,* 4.54. Minimum number of roots per seedling was recorded in case of control (3.47). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded maximum number of roots (4.64) and the minimum was recorded in control (3.62). Among the interaction between physical and chemical treatments, T_5C_1 recorded maximum number of roots (5.50) which was at par with T_5C_2 (5.20), T_5C_6 (5.20), T_4C_1 (5.20) and T_5C_4 (5.10) .The minimum number of roots was recorded in T_1C_7 (3.00).

3.5 Percentage of Seedling Establishment in Main Field

The data presented in Tables 9 and 10 showed significant differences in percentage of seedling establishment in main field during 2019-20,2020-21 and pooled analysis in case of physical and chemical treatments. However, the interaction effects were found non-significant.

During 2019-20, among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded maximum seedling establishment percentage in main field (94.51) followed by T_4 (scarification + 48 hours soaking in water) *i.e.,* 92.78. The minimum establishment percentage was recorded in case of control (87.03). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded maximum seedling establishment percentage in main field (95.54) and the minimum was recorded in control (73.31). Among the interaction between physical and chemical treatments, T_5C_1 recorded maximum seedling establishment percent in main field (99.25) followed by T_5C_6 (98.21) and the minimum was recorded in T_1C_7 (70.06).

During 2020-21, among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded maximum seedling establishment percent in main field (93.32) followed by T_4 (scarification + 48 hours soaking in water) *i.e.,* 92.52. The minimum establishment percentage was recorded in case of control (86.01). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded maximum seedling establishment percent in main field (94.34) and the minimum was recorded in control (74.13).Among the interaction between physical and chemical treatments, T_5C_1 recorded maximum seedling establishment percent in main field (98.23) followed by T_5C_6 (97.12) and the minimum was recorded in T_1C_7 (70.71).

In pooled analysis, among the physical treatments, T_5 (removal of seed coat + 48 hours soaking in water) recorded maximum seedling establishment percent in main field (93.91) followed by T_4 (scarification + 48 hours soaking in water) *i.e.,* 92.65. The minimum establishment percentage was recorded in case of control (86.52). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded maximum seedling establishment percent in main field (94.94) and the minimum was recorded in control (73.72).Among the interaction between physical and chemical treatments, T_5C_1 recorded maximum seedling establishment percent in main field (98.74) followed by T_5C_6 (97.66) and the minimum was recorded in T_1C_7 (70.39).

4. DISCUSSION

Presence of hard seed coat is a major barrier in seed germination in spine gourd. The results of this experiments showed that when we are employing physical treatments like water soaking, hot water treatment, scarification or removing the seed coat, then the seed coat is becoming permeable to water and oxygen and thus favouring germination and subsequent growth. In case of the physical treatments, removal of seed coat followed by soaking in water for 48 hours showed early germination, highest shoot and root length, maximum number of seeds per seedling and highest establishment percentage in main field. High establishment in field may be due to presence of more number of roots. Similar results were also confirmed by Heidari *et al.* [6], Pandey *et al.* [7] and Chaodumrikul *et al.* [8].

Table 3. Effect of different physical and chemical treatments on shoot length of seedlings (cm) during 2019-20 & 2020-21

	2019-20						2020-21					
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**Mean**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**Mean**
C_1 (GA_3 100 ppm)	23.73	24.63	27.68	30.41	32.14	27.72	23.57	25.11	28.16	30.15	32.98	27.99
C_2 (GA_3 200 ppm)	22.27	23.55	24.73	26.73	31.23	25.70	21.61	22.35	25.43	27.86	30.17	25.48
C_3 (KNO_3 1%)	20.76	21.67	23.95	25.83	28.11	24.06	18.98	21.29	23.19	24.59	28.25	23.26
C_4 (KNO_3 2%)	22.35	24.04	26.01	25.96	29.66	25.60	22.53	23.44	25.17	26.92	28.42	25.30
C_5 (Thiourea 1%)	20.71	22.51	24.34	25.53	31.17	24.85	20.63	21.75	23.94	26.31	28.18	24.16
C_6 (Thiourea 2%)	23.49	24.50	26.31	28.74	27.90	26.19	22.67	23.86	27.19	28.12	31.83	26.73
C_7 (Control)	15.33	17.03	19.73	21.80	23.86	19.55	17.21	17.69	19.17	21.18	23.74	19.80
Mean	21.23	22.56	24.68	26.43	29.15	24.81	21.03	22.21	24.61	26.45	29.08	24.68
	T		**C**		**T × C**		**T**		**C**		**T × C**	
SEm (±)	0.312		0.369		0.824		0.303		0.359		0.802	
CD @ 5%	0.89		1.05		NS		0.87		1.02		NS	

(T_1 – control, T_2 – 48 hours soaking in water, T_3 – hot water treatment for 20 minutes + 48 hours soaking in water, T_4 – scarification + 48 hours soaking in water, T_5 - removal of seed coat + 48 hours soaking in water)

Table 4. Effect of different physical and chemical treatments on shoot length of seedlings (cm) (Pooled)

	Pooled					
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**Mean**
C_1 (GA_3 100 ppm)	23.65	24.87	27.92	30.28	32.56	27.86
C_2 (GA_3 200 ppm)	21.94	22.95	25.08	27.30	30.70	25.59
C_3 (KNO_3 1%)	19.87	21.48	23.57	25.21	28.18	23.66
C_4 (KNO_3 2%)	22.44	23.74	25.59	26.44	29.04	25.45
C_5 (Thiourea 1%)	20.67	22.13	24.14	25.92	29.68	24.51
C_6 (Thiourea 2%)	23.08	24.18	26.75	28.43	29.87	26.46
C_7 (Control)	16.27	17.36	19.45	21.49	23.80	19.67
Mean	21.13	22.39	24.64	26.44	29.12	24.74
	T	**C**	**T x C**	**Y X T**	**Y X C**	**Y X T X C**
SEm (±)	0.217	0.257	0.575	0.307	0.364	0.813
CD @ 5%	0.61	0.72	NS	NS	NS	NS

(T_1 – control, T_2 – 48 hours soaking in water, T_3 – hot water treatment for 20 minutes + 48 hours soaking in water, T_4 – scarification + 48 hours soaking in water, T_5 - removal of seed coat + 48 hours soaking in water)

Table 5. Effect of different physical and chemical treatments on root length of seedlings (cm) during 2019-20 & 2020-21

	2019-20						2020-21					
	T_1	T_2	T_3	T_4	T_5	Mean	T_1	T_2	T_3	T_4	T_5	Mean
C_1 (GA_3 100 ppm)	4.20	4.35	4.65	4.72	4.95	4.57	4.02	4.15	4.39	4.90	5.15	4.52
C_2 (GA_3 200 ppm)	3.75	4.00	4.50	4.71	4.90	4.37	4.00	4.12	4.16	4.58	4.82	4.34
C_3 (KNO_3 1%)	3.19	3.85	3.51	3.95	4.39	3.78	3.35	3.65	3.71	3.77	4.69	3.83
C_4 (KNO_3 2%)	3.63	3.37	3.90	4.23	4.48	3.92	3.79	3.52	3.70	4.47	4.20	3.94
C_5 (Thiourea 1%)	3.56	3.93	3.61	4.10	4.13	3.87	3.32	3.77	3.77	3.96	4.21	3.81
C_6 (Thiourea 2%)	4.13	4.06	4.23	4.53	4.54	4.30	3.75	3.88	3.99	4.43	4.76	4.16
C_7 (Control)	3.17	3.21	3.49	3.60	4.12	3.52	2.91	3.43	3.39	3.66	3.98	3.47
Mean	3.66	3.82	3.98	4.26	4.50	4.05	3.59	3.79	3.87	4.25	4.54	4.01
	T		**C**		**T × C**		**T**		**C**		**T × C**	
SEm (±)	0.060		0.071		0.159		0.075		0.089		0.199	
CD @ 5%	0.17		0.20		0.45		0.21		0.25		0.57	

(T_1 – control, T_2 – 48 hours soaking in water, T_3 – hot water treatment for 20 minutes + 48 hours soaking in water, T_4 – scarification + 48 hours soaking in water, T_5 - removal of seed coat + 48 hours soaking in water)

Table 6. Effect of different physical and chemical treatments on root length of seedlings (cm) (Pooled)

	Pooled					
	T_1	T_2	T_3	T_4	T_5	Mean
C_1 (GA_3 100 ppm)	4.11	4.25	4.52	4.81	5.05	4.55
C_2 (GA_3 200 ppm)	3.88	4.06	4.33	4.65	4.86	4.35
C_3 (KNO_3 1%)	3.27	3.75	3.61	3.86	4.54	3.81
C_4 (KNO_3 2%)	3.71	3.45	3.80	4.35	4.34	3.93
C_5 (Thiourea 1%)	3.44	3.85	3.69	4.03	4.17	3.84
C_6 (Thiourea 2%)	3.94	3.97	4.11	4.48	4.65	4.23
C_7 (Control)	3.04	3.32	3.44	3.63	4.05	3.50
Mean	3.63	3.81	3.93	4.26	4.52	4.03
	T	**C**	**T x C**	**Y X T**	**Y X C**	**Y X T X C**
SEm (±)	0.048	0.057	0.127	0.068	0.080	0.180
CD @ 5%	0.13	0.16	NS	NS	NS	NS

(T_1 – control, T_2 – 48 hours soaking in water, T_3 – hot water treatment for 20 minutes + 48 hours soaking in water, T_4 – scarification + 48 hours soaking in water, T_5 - removal of seed coat + 48 hours soaking in water)

Table 7. Effect of different physical and chemical treatments on number of roots per seedling during 2019-20 & 2020-21

	2019-20						2020-21					
	T_1	T_2	T_3	T_4	T_5	MEAN	T_1	T_2	T_3	T_4	T_5	MEAN
C_1 (GA_3 100 ppm)	4.10	4.30	4.70	5.30	5.60	4.80	3.70	3.90	4.30	5.10	5.40	4.48
C_2 (GA_3 200 ppm)	3.90	3.80	4.50	4.60	5.10	4.38	3.10	3.80	4.10	4.80	5.30	4.22
C_3 (KNO_3 1%)	3.30	3.70	3.90	4.00	4.80	3.94	3.10	3.30	3.30	4.20	5.00	3.78
C_4 (KNO_3 2%)	3.60	3.50	4.10	4.50	5.10	4.16	3.60	3.70	3.70	4.90	5.10	4.20
C_5 (Thiourea 1%)	3.40	3.30	3.70	3.70	4.50	3.72	3.20	3.50	3.70	4.90	4.90	4.04
C_6 (Thiourea 2%)	3.70	4.00	4.30	4.80	5.30	4.42	3.90	3.80	3.90	5.00	5.10	4.34
C_7 (Control)	3.30	3.50	3.40	4.10	4.50	3.76	2.70	3.30	3.40	3.70	4.30	3.48
MEAN	3.61	3.73	4.09	4.43	4.99	4.17	3.33	3.61	3.77	4.66	5.01	4.08
	T		**C**		**T × C**		**T**		**C**		**T × C**	
SEm (±)	0.052		0.061		0.136		0.063		0.074		0.166	
CD @ 5%	0.14		0.17		NS		0.18		0.21		NS	

(T_1 – control, T_2 – 48 hours soaking in water, T_3 – hot water treatment for 20 minutes + 48 hours soaking in water, T_4 – scarification + 48 hours soaking in water, T_5 - removal of seed coat + 48 hours soaking in water)

Table 8. Effect of different physical and chemical treatments on number of roots per seedling (Pooled)

	Pooled					
	T_1	T_2	T_3	T_4	T_5	Mean
C_1 (GA_3 100 ppm)	3.90	4.10	4.50	5.20	5.50	4.64
C_2 (GA_3 200 ppm)	3.50	3.80	4.30	4.70	5.20	4.30
C_3 (KNO_3 1%)	3.20	3.50	3.60	4.10	4.90	3.86
C_4 (KNO_3 2%)	3.60	3.60	3.90	4.70	5.10	4.18
C_5 (Thiourea 1%)	3.30	3.40	3.70	4.30	4.70	3.88
C_6 (Thiourea 2%)	3.80	3.90	4.10	4.90	5.20	4.38
C_7 (Control)	3.00	3.40	3.40	3.90	4.40	3.62
Mean	3.47	3.67	3.93	4.54	5.00	4.12
	T	**C**	**T x C**	**Y X T**	**Y X C**	**Y X T X C**
SEm (±)	0.041	0.048	0.108	0.057	0.068	0.152
CD @ 5%	0.11	0.13	NS	0.16	0.19	0.42

(T_1 – control, T_2 – 48 hours soaking in water, T_3 – hot water treatment for 20 minutes + 48 hours soaking in water, T_4 – scarification + 48 hours soaking in water, T_5 - removal of seed coat + 48 hours soaking in water)

Table 9. Effect of different physical and chemical treatments on percentage of seedling establishment in main field during 2019-20 & 2020-21

	2019-20						2020-21					
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**Mean**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**Mean**
C_1 (GA_3 100 ppm)	91.44 (9.59)	93.71 (9.71)	95.67 (9.81)	97.67 (9.91)	99.25 (9.99)	95.54 (9.80)	90.83 (9.56)	91.44 (9.59)	94.50 (9.75)	96.73 (9.86)	98.23 (9.94)	94.34 (9.74)
C_2 (GA_3 200 ppm)	88.42 (9.43)	91.06 (9.57)	93.00 (9.67)	96.38 (9.84)	97.73 (9.91)	93.32 (9.68)	90.46 (9.54)	89.71 (9.50)	91.83 (9.61)	95.88 (9.82)	95.33 (9.79)	92.64 (9.65)
C_3 (KNO_3 1%)	88.33 (9.42)	88.38 (9.43)	92.67 (9.65)	94.90 (9.77)	96.00 (9.82)	92.05 (9.62)	86.83 (9.35)	88.71 (9.44)	90.50 (9.54)	95.38 (9.79)	94.25 (9.73)	91.13 (9.57)
C_4 (KNO_3 2%)	89.50 (9.49)	92.04 (9.62)	92.56 (9.65)	96.06 (9.83)	97.38 (9.89)	93.51 (9.69)	87.21 (9.37)	89.59 (9.49)	93.42 (9.69)	94.06 (9.72)	96.21 (9.83)	92.10 (9.62)
C_5 (Thiourea 1%)	90.50 (9.54)	89.83 (9.50)	92.88 (9.66)	95.21 (9.78)	96.83 (9.87)	93.05 (9.67)	87.00 (9.35)	90.00 (9.51)	90.38 (9.53)	94.54 (9.75)	95.43 (9.79)	91.47 (9.59)
C_6 (Thiourea 2%)	91.00 (9.57)	93.00 (9.67)	93.38 (9.69)	94.73 (9.76)	98.21 (9.94)	94.06 (9.72)	89.00 (9.46)	91.00 (9.57)	92.48 (9.64)	95.54 (9.80)	97.12 (9.88)	93.03 (9.67)
C_7 (Control)	70.06 (8.40)	72.09 (8.52)	73.75 (8.62)	74.50 (8.66)	76.17 (8.76)	73.31 (8.59)	70.71 (8.44)	73.13 (8.58)	74.67 (8.67)	75.50 (8.72)	76.67 (8.79)	74.13 (8.64)
Mean	87.03 (9.35)	88.59 (9.43)	90.56 (9.53)	92.78 (9.65)	94.51 (9.74)	90.69 (9.54)	86.01 (9.29)	87.65 (9.38)	89.68 (9.49)	92.52 (9.64)	93.32 (9.68)	89.83 (9.50)
	T	**C**	**T × C**				**T**	**C**	**T × C**			
SEm (±)	0.014	0.017	0.038				0.014	0.016	0.036			
CD @ 5%	0.04	0.04	NS				0.03	0.04	NS			

** Numbers in parenthesis indicate the square root transformed values*

(T_1 – control, T_2 – 48 hours soaking in water, T_3 – hot water treatment for 20 minutes + 48 hours soaking in water, T_4 – scarification + 48 hours soaking in water, T_5 - removal of seed coat + 48 hours soaking in water)

Table 10. Effect of different physical and chemical treatments on percentage of seedling establishment in main field (Pooled)

	Pooled					
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**MEAN**
C_1 (GA_3 100 ppm)	91.13 (9.57)	92.57 (9.65)	95.08 (9.78)	97.20 (9.88)	98.74 (9.96)	94.94 (9.77)
C_2 (GA_3 200 ppm)	89.44 (9.48)	90.39 (9.53)	92.42 (9.64)	96.13 (9.83)	96.53 (9.85)	92.98 (9.67)
C_3 (KNO_3 1%)	87.58 (9.39)	88.54 (9.44)	91.58 (9.60)	95.14 (9.78)	95.13 (9.78)	91.59 (9.60)
C_4 (KNO_3 2%)	88.36 (9.43)	90.81 (9.56)	92.99 (9.67)	95.06 (9.78)	96.79 (9.86)	92.80 (9.66)
C_5 (Thiourea 1%)	88.75 (9.45)	89.92 (9.51)	91.63 (9.60)	94.87 (9.77)	96.13 (9.83)	92.26 (9.63)
C_6 (Thiourea 2%)	90.00 (9.51)	92.00 (9.62)	92.93 (9.67)	95.13 (9.78)	97.66 (9.91)	93.54 (9.70)
C_7 (Control)	70.39 (8.42)	72.61 (8.55)	74.21 (8.64)	75.00 (8.69)	76.42 (8.77)	73.72 (8.62)
MEAN	86.52 (9.32)	88.12 (9.41)	90.12 (9.51)	92.65 (9.64)	93.91 (9.71)	90.26 (9.52)
	T	**C**	**T x C**	**Y X T**	**Y X C**	**Y X T X C**
SEm (±)	0.010	0.012	0.026	0.014	0.017	0.037
CD @ 5%	0.02	0.03	NS	NS	0.04	NS

** Numbers in parenthesis indicate the square root transformed values*

(T_1 – control, T_2 – 48 hours soaking in water, T_3 – hot water treatment for 20 minutes + 48 hours soaking in water, T_4 – scarification + 48 hours soaking in water, T_5 - removal of seed coat + 48 hours soaking in water)

There are several instances, where different kinds of chemicals when applied exogenously to dormant seeds results better germination. Some of these chemicals have potential value in agriculture and horticulture to accelerate germination or break the dormancy of seeds [9,10]. Dormancy offers a setback to plant breeders who would like to grow plant generations in rapid succession. It also impedes seed testing work, as the results of planting value of seed cannot be assessed quickly in case of dormant seeds. The significance of seed dormancy lies in the ability of the seed to overcome the unfavourable conditions so as to remain viable till the commencement of favourable environment. In the present investigation, it was observed that GA_3 100 ppm recorded early germination along with other desirable seedling characters (length of shoot, root and number of roots per seedlings) and highest establishment percentage. The lowest values were recorded in case of control. All the chemicals were found superior to control. This could be due to the beneficial effect of these chemicals in breaking seed dormancy. Similar results were also reported by Devi and Selvaraj [11] in bitter gourd and Panchbhai *et al.* [12] in spine gourd. The external application of gibberellin interacts with growth inhibitors present in dormant spine gourd seeds lowering the inhibitors concentration and facilitating germination by breaking seed dormancy at an early date [13]. Among the interaction effect, seed coat removed seeds soaked in water for 48 hours followed by GA_3 100 ppm treatment found superior than rest of the treatment combinations.

5. CONCLUSION

From the present investigation, it is concluded that, among different physical treatments, removal of seed coat followed by 48 hours soaking in water and in case of chemicals, GA_3 100 ppm treatment recorded early germination, highest length of shoot and root, more number of roots per seedling and highest establishment percent in main field. Among the interaction between physical and chemical treatments, seed coat removed seeds soaked for 48 hours followed by treatment with GA_3 100 ppm was found superior to others.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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