Original Research Article

Seed Germination and Seedling Vigour of Spine gourd (*Momordicadioica*Roxb.) in Response to Different Physical and Chemical treatments

ABSTRACT

The present investigation was carried out at Department of Vegetable Science, OUAT, Bhubaneswar during 2019-2021. 5-6 months old stored spine gourd seeds were exposed to various physical (T_1: Control, T_2: 48 hour soaking, T_3: Hot water treatment for 20 minutes + 48 hours soaking, T_4: Scarification by sand paper + 48 hour soaking, T_5: Removal of seed coat + 48 hours soaking) and chemical (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) treatments. The experiment was laid out in factorial CRD design with 35 treatment combinations replicated twice. The seeds were sown in plastic trays containing cocopeat media. The effect of these treatments on percentage of germination,length of seedling, seedling dry weight ,seedlingvigour index- I and II were studied. From 2019-20, 2020-21 and pooled analysis data, it was concluded that among the physical treatments, T_5 (Removal of seed coat + 48 hours soaking), among the chemical treatments, C_1(GA_3 100 ppm) and between the interactions, T_5C_1 recorded highest germination percentage, seedling length, seedling dry weight, vigour index- I and vigour index – II. The lowest values were recorded in control. So, seed coat removed seeds soaked for 48 hours followed by treatment with GA_3 100 ppm recorded highest germination percentage and seedling vigour in spine gourd.

Key words: Physical,chemical,germination,vigourindex,spine gourd

1. INTRODUCTION

Spine gourd (*Momordicadioica*Roxb.) belongs to family cucurbitaceae with chromosome number 2n=2x=28 (Raj *et al.,* 1993). It is native of Indo-Malayan region (Rashid, 1976) and distributed in India, Bangladesh, China, Malaysia, Nepal, Myanmar, Pakistan, and Sri Lanka (Rakh and Chaudhari, 2010). It is widely distributed in tropical and sub-tropical parts of India and adapted to different soil and climatic conditions (Basumatara*et al.,* 2014). It is an economically important vegetable with high food and medicinal value cultivated mainly for its fruits which is used as vegetable. This popular vegetable has high demand in market owing to its good nutritional, medicinal value, high keeping quality, ability to withstand long distance transportation, high market price and good export potential (Rasul,2003).However, the potentiality of this crop is not fully exploited due to several limitations; one of them is presence of hard seed coat. The seeds of spine gourd are shiny,small with hard seed coat. Freshly harvested seeds possess dormancy up to 4-6 months. The seeds germinate but at very low frequency which is a major hindrance in commercial cultivation of this crop. Germination is the sequence of events that initiate with the uptake of water and nutrients by the quiescent dry seed and ends with the elongation of the

embryonic axis (Bewley and Black, 1994). To overcome the problem in germination, the seeds may be given some physical and chemical treatments which will enhance the germination. Therefore, by using physical treatments and seed priming with chemicals, the problems of farmers such as dormancy of seeds, delay in germination, lower germination percentage, less vigour seedlings can be solved. Thus this research will be very helpful to farmers in getting more germination and vigourous seedlings.

2. MATERIALS AND METHODS

This research work was carried out in the experimental field of Department of Vegetable Science,OUAT,Bhubaneswar during 2019-20 and 2020-21(March-April). 5-6 months old stored spine gourd seeds were used for this investigation. The seeds were first given different physical treatments *i.e.*, T_1: Control, T_2: 48 hour soaking, T_3: Hot water treatment for 20 minutes + 48 hours soaking, T_4: Scarification by sand paper + 48 hour soaking and T_5: Removal of seed coat + 48 hours soaking. Then the seeds were soaked 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) for 2 hours followed by thorough washing with distilled water and shade drying. The seeds are then sown in plastic trays filled with cocopeat. The experiment consisted of 35 treatment combinations with 2 replications. 100 seeds were sown in each tray. The trays were kept under poly house and watered regularly. The number of seeds germinated in each tray was recorded till 50 days after sowing to calculate the percentage of germination. Seedling length and dry weight (mg) were calculated by taking average of 5 seedlings 30 days after germination.

Germination percentage was calculated by following formula:

$$\textbf{Germination percentage} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds sown}} \times 100$$

Five seedlings were uprooted carefully 30 days after germination without any damage to the root system and the length was measured from the base of the root to the tip of the shoot and their mean was computed and expressed in centimeters.

The uprooted seedlings were kept in oven overnight at 100^0F and next day their dry weight was taken and mean was expressed in mg.

Vigour index- I was calculated by adopting the following formula and expressed as number.

Vigour index – I = Germination percentage x Seedling length

Vigour index – II was calculated by adopting the following formula and expressed as number.

Vigour index – II = Germination percentage x Seedling dry weight

The data were subjected to statistical analysis as per CRD with factorial concept. The data in percentages were transformed to angular values for statistical analysis. Critical difference values were tabulated at 5 % probability where ‘f ’test was significant.

3. RESULTS AND DISCUSSION

3.1 Percentage of germination

The data pertaining to percentage of germination of spine gourd seeds as affected by different chemicals, temperatures and their interaction are presented in table 1 and 2. The percentage of germination was significantly affected by physical and chemical treatments and their interactions during 2019-20, 2020-21 and in pooled analysis.

During 2019-20, significant difference was observed in germination percentage in case of physically treated seeds. Among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest germination percentage (76.93) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 69.36. The lowest germination percentage was observed in case of control (33.43). Among the chemical treatments, the seeds treated with GA_3 100 ppm (C_1) recorded highest germination percentage (65) followed by C_6 (58.60) and the lowest was recorded in control (37.50).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest germination percentage (93) followed by T_5C_6 (85) and the lowest was observed in T_1C_7 (25).

During 2020-21, similar trend was observed and significant difference was noticed among the physically, chemically treated seeds and their interactions. T_5 (Seed coat removal + 48 hr soaking) recorded highest germination percentage (76.79) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 69.29 with lowest germination percentage in case of control (31.21) were recorded in case of physical treatments. Among the chemical treatments, the seeds treated with GA_3 100 ppm (C_1) recorded highest germination percentage (63.40) followed by C_6 (60.60) and the lowest was recorded in control (39.19). Among the interaction between physical and chemical treatments, T_5C_1 recorded highest germination percentage (88.50) followed by T_5C_6 (87) and the lowest was observed in T_1C_7 (22).

Table 1. Effect of different physical and chemical treatments on percentage of 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)	41.50 (40.11)	48.50 (44.14)	61.50 (51.65)	80.50 (63.84)	93.00 (74.81)	65.00 (54.91)	39.00 (38.64)	43.00 (40.98)	63.50 (52.84)	83.00 (65.73)	88.50 (70.22)	63.40 (53.68)
C_2 (GA_3 200 ppm)	32.50 (34.74)	33.00 (35.04)	57.00 (49.03)	71.00 (57.45)	74.00 (59.36)	53.50 (47.12)	34.50 (35.96)	39.00 (38.64)	51.00 (45.57)	65.00 (53.75)	80.00 (63.46)	53.90 (47.48)
C_3 (KNO_3 1%)	30.00 (33.21)	31.50 (34.14)	49.50 (44.71)	62.00 (51.98)	85.50 (67.64)	51.70 (46.34)	27.00 (31.27)	29.00 (32.57)	46.50 (42.99)	69.50 (56.48)	81.00 (64.28)	50.60 (45.52)
C_4 (KNO_3 2%)	35.50 (36.56)	33.00 (35.05)	53.00 (46.72)	75.00 (60.00)	78.50 (62.39)	55.00 (48.15)	32.50 (34.74)	38.50 (38.35)	60.00 (50.79)	71.00 (57.43)	69.50 (56.51)	54.30 (47.56)
C_5 (Thiourea 1%)	32.00 (34.45)	35.00 (36.25)	55.50 (48.16)	72.50 (58.37)	69.50 (56.48)	52.90 (46.74)	28.00 (31.93)	30.00 (33.21)	47.00 (43.28)	66.50 (54.66)	71.00 (57.42)	48.50 (44.10)
C_6 (Thiourea 2%)	37.50 (37.76)	35.50 (36.57)	57.50 (49.31)	77.50 (61.68)	85.00 (67.26)	58.60 (50.52)	35.50 (36.57)	42.00 (40.40)	58.50 (49.90)	80.00 (63.46)	87.00 (68.92)	60.60 (51.85)
C_7 (Control)	25.00 (30.00)	25.00 (29.98)	37.50 (37.74)	47.00 (43.28)	53.00 (46.72)	37.50 (37.54)	22.00 (27.95)	26.50 (30.98)	43.00 (40.97)	50.00 (45.00)	60.50 (51.07)	40.40 (39.19)
MEAN	33.43 (35.26)	34.50 (35.88)	53.07 (46.76)	69.36 (56.66)	76.93 (62.09)	53.46 (47.33)	31.21 (33.87)	35.43 (36.45)	52.79 (46.62)	69.29 (56.65)	76.79 (61.70)	53.10 (47.05)
	T		**C**		**T × C**		**T**		**C**		**T × C**	
SEm (±)	0.498		0.589		1.318		0.578		0.684		1.529	
CD @ 5%	1.43		1.69		3.78		1.65		1.96		4.38	

* Numbersin parenthesis indicate the angular transformed values

Table 2. Effect of different physical and chemical treatments on percentage of germination(Pooled)

	Pooled					
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**MEAN**
C_1 (GA_3 100 ppm)	40.25 (39.37)	45.75 (42.56)	62.50 (52.25)	81.75 (64.79)	90.75 (72.51)	64.20 (54.30)
C_2 (GA_3 200 ppm)	33.50 (35.35)	36.00 (36.84)	54.00 (47.30)	68.00 (55.60)	77.00 (61.41)	53.70 (47.30)
C_3 (KNO_3 1%)	28.50 (32.24)	30.25 (33.35)	48.00 (43.85)	65.75 (54.23)	83.25 (65.96)	51.15 (45.93)
C_4 (KNO_3 2%)	34.00 (35.65)	35.75 (36.70)	56.50 (48.75)	73.00 (58.72)	74.00 (59.45)	54.65 (47.85)
C_5 (Thiourea 1%)	30.00 (33.19)	32.50 (34.73)	51.25 (45.72)	69.50 (56.52)	70.25 (56.95)	50.70 (45.42)
C_6 (Thiourea 2%)	36.50 (37.16)	38.75 (38.48)	58.00 (49.61)	78.75 (62.57)	86.00 (68.09)	59.60 (51.18)
C_7 (Control)	23.50 (28.97)	25.75 (30.48)	40.25 (39.36)	48.50 (44.14)	56.75 (48.90)	38.95 (38.37)
MEAN	32.32 (34.56)	34.96 (36.16)	52.93 (46.69)	69.32 (56.65)	76.86 (61.90)	53.28 (47.19)
	T	**C**	**T x C**	**Y X T**	**Y X C**	**Y X T X C**
SEm (±)	0.381	0.451	1.009	0.539	0.638	1.427
CD @ 5%	1.07	1.27	2.84	NS	1.80	4.02

* Numbers in parenthesis indicate the angular transformed values

In case of pooled analysis, significant difference was observed in germination percentage in physically and chemically treated seeds and among their interactions. Among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest germination percentage (76.86) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 69.32. The lowest germination percentage was observed in case of control (32.32). Among the chemical treatments, the seeds treated with GA_3 100 ppm (C_1) recorded highest germination percentage (64.20) followed by C_6 (59.60) and the lowest in control (38.95). Among

the interaction between physical and chemical treatments, T_5C_1 recorded highest germination percentage (90.75) followed by T_5C_6 (86) and the lowest was observed in T_1C_7 (23.50).

3.2 Seedling length (cm)

The data presented in table 3 and 4 showed significant differences in seedling length during 2019-20,2020-21 and pooled analysis in case of physical and chemical treatments. However, the interaction effects were found non-significant.

Table 3.Effect of different physical and chemical treatments on seedling length (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)	27.93	28.98	32.33	35.13	37.09	32.29	27.59	29.26	32.55	35.05	38.13	32.52
C_2 (GA_3 200 ppm)	26.02	27.55	29.23	31.44	36.13	30.07	25.61	26.47	29.59	32.44	34.99	29.82
C_3 (KNO_3 1%)	23.95	25.52	27.46	29.78	32.50	27.84	22.33	24.94	26.90	28.36	32.94	27.09
C_4 (KNO_3 2%)	25.98	27.41	29.91	30.19	34.14	29.53	26.32	26.96	28.87	31.39	32.62	29.23
C_5 (Thiourea 1%)	24.27	26.44	27.95	29.63	35.30	28.72	23.95	25.52	27.71	30.27	32.39	27.97
C_6 (Thiourea 2%)	27.62	28.56	30.54	33.27	32.44	30.49	26.42	27.74	31.18	32.55	36.59	30.90
C_7 (Control)	18.50	20.24	23.22	25.40	27.98	23.07	20.12	21.12	22.56	24.84	27.72	23.27
MEAN	24.90	26.39	28.66	30.69	33.65	28.86	24.62	26.00	28.48	30.70	33.63	28.69
	T		**C**		**T × C**		**T**		**C**		**T × C**	
SEm (±)	0.313		0.371		0.829		0.316		0.374		0.836	
CD @ 5%	0.90		1.06		NS		0.90		1.07		NS	

During 2019-20, among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest seedling length (33.65 cm) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 30.69 cm. The lowest root length was observed in case of control (24.90 cm). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest seedling length (32.29 cm) and the lowest was recorded in control (23.07 cm).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest seedling length (37.09 cm) followed by T_5C_2 (36.13 cm) and the lowest was observed in T_1C_7 (18.50 cm).

During 2020-21, among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest seedling length (33.63 cm) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 30.70 cm. The lowest root length was observed in case of control (24.62 cm). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest seedling length (32.52 cm) and the lowest was recorded in control (23.27 cm).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest seedling length (38.13 cm) followed by T_5C_6 (36.59 cm) and the lowest was observed in T_1C_7 (20.12 cm).

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

	Pooled					
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**MEAN**
C_1 (GA_3 100 ppm)	27.76	29.12	32.44	35.09	37.61	32.40
C_2 (GA_3 200 ppm)	25.82	27.01	29.41	31.94	35.56	29.95
C_3 (KNO_3 1%)	23.14	25.23	27.18	29.07	32.72	27.47
C_4 (KNO_3 2%)	26.15	27.19	29.39	30.79	33.38	29.38
C_5 (Thiourea 1%)	24.11	25.98	27.83	29.95	33.85	28.34
C_6 (Thiourea 2%)	27.02	28.15	30.86	32.91	34.52	30.69
C_7 (Control)	19.31	20.68	22.89	25.12	27.85	23.17
MEAN	24.76	26.19	28.57	30.70	33.64	28.77
	T	**C**	**T x C**	**Y X T**	**Y X C**	**Y X T X C**
SEm (±)	0.222	0.263	0.589	0.315	0.372	0.833
CD @ 5%	0.62	0.74	NS	NS	NS	NS

In case of pooled analysis over the years, among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest seedling length (33.64 cm) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 30.70 cm. The lowest root length was observed in case of control (24.76 cm). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest seedling length (32.40 cm) and the lowest was recorded in control (23.17 cm).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest seedling length (37.61 cm) followed by T_5C_2 (35.56 cm) and the lowest was observed in T_1C_7 (19.31 cm).

3.3 Seedling dry weight (mg)

Table 5. Effect of different physical and chemical treatments on seedling dry weight (mg) 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)	464.70	491.50	536.70	558.30	601.40	530.52	460.20	481.30	526.30	576.70	583.10	525.52
C_2 (GA_3 200 ppm)	416.20	448.30	488.50	550.70	562.30	493.20	430.80	466.50	516.10	536.50	575.50	505.08
C_3 (KNO_3 1%)	406.10	417.70	480.50	521.10	539.70	473.02	386.30	436.90	464.90	509.10	521.50	463.74
C_4 (KNO_3 2%)	441.30	469.50	480.10	525.70	561.00	495.52	428.50	433.20	508.70	536.30	552.30	491.80
C_5 (Thiourea 1%)	410.90	445.10	493.60	528.50	534.50	482.52	415.80	434.70	468.10	517.20	549.70	477.10
C_6 (Thiourea 2%)	439.50	463.90	508.20	549.30	592.90	510.76	456.10	478.50	520.50	567.00	570.80	518.58
C_7 (Control)	364.60	381.30	446.30	482.20	483.80	431.64	376.20	397.10	450.30	463.30	502.10	437.80
MEAN	420.47	445.33	490.56	530.83	553.66	488.17	421.99	446.89	493.56	529.44	550.71	488.52
	T		**C**		**T × C**		**T**		**C**		**T × C**	
SEm (±)	6.589		7.797		17.434		6.406		7.580		16.949	
CD @ 5%	18.91		22.38		NS		18.39		21.75		NS	

The data presented in table 5 and 6 showed significant differences in seedling dry weight during 2019-20,2020-21 and pooled analysis in case of physical and chemical treatments. However, the interaction effects were found non-significant.

Among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest seedling dry weight (553.66 mg) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 530.83 mg during 2019-20. The lowest seedling dry weight was recorded in case of control (420.47 mg). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest seedling dry weight (530.52 mg) and the lowest was recorded in control (483.80 mg).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest seedling dry weight (601.40 mg) followed by T_5C_6 (592.90 mg) and the lowest was recorded in T_1C_7 (364.60 mg).

Table 6. Effect of different physical and chemical treatments on seedling dry weight (mg) (Pooled)

	Pooled					
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**MEAN**
C_1 (GA_3 100 ppm)	462.45	486.40	531.50	567.50	592.25	528.02
C_2 (GA_3 200 ppm)	423.50	457.40	502.30	543.60	568.90	499.14
C_3 (KNO_3 1%)	396.20	427.30	472.70	515.10	530.60	468.38
C_4 (KNO_3 2%)	434.90	451.35	494.40	531.00	556.65	493.66
C_5 (Thiourea 1%)	413.35	439.90	480.85	522.85	542.10	479.81
C_6 (Thiourea 2%)	447.80	471.20	514.35	558.15	581.85	514.67
C_7 (Control)	370.40	389.20	448.30	472.75	492.95	434.72
MEAN	421.23	446.11	492.06	530.14	552.19	488.34
	T	**C**	**T x C**	**Y X T**	**Y X C**	**Y X T X C**
SEm (±)	4.595	5.437	12.158	6.498	7.689	17.193
CD @ 5%	12.95	15.33	NS	NS	NS	NS

During 2020-21, T_5 (seed coat removal + 48 hr soaking) recorded highest seedling dry weight (550.71 mg) followed by T_4 (scarification + 48 hr soaking) *i.e.*,529.44 mg among the physical treatments. The lowest seedling dry weight was recorded in case of control (421.99 mg). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest seedling dry weight (525.52 mg) and the lowest was recorded in control (437.80 mg).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest seedling dry weight (583.10 mg) followed by T_5C_2 (575.50 mg) and the lowest was recorded in T_1C_7 (376.20 mg).

In pooled analysis, among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest seedling dry weight (552.19 mg) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 530.14 mg. The lowest seedling dry weight was recorded in case of control (421.23 mg). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest seedling dry weight (528.02 mg) and the lowest was recorded in control (434.72 mg).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest seedling dry weight (592.25 mg) followed by T_5C_6 (581.85 mg) and the lowest was recorded in T_1C_7 (370.40 mg).

3.3 Vigour index –I

Table 7. Effect of different physical and chemical treatments on seedling Vigour index-I 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)	1159.00 (1120.10)	1404.84 (1278.78)	1988.61 (1670.09)	2827.44 (2242.28)	3447.35 (2772.44)	2165.45 (1816.74)	1076.51 (1066.37)	1257.92 (1198.79)	2067.45 (1720.35)	2908.76 (2303.58)	3372.99 (2675.95)	2136.73 (1793.01)
C_2 (GA_3 200 ppm)	844.75 (903.41)	905.64 (963.22)	1665.01 (1432.43)	2228.70 (1803.88)	2671.76 (2143.43)	1663.17 (1449.27)	882.77 (920.40)	1032.63 (1022.98)	1507.77 (1347.80)	2105.66 (1741.78)	2796.82 (2218.83)	1665.13 (1450.36)
C_3 (KNO_3 1%)	718.50 (795.40)	804.42 (871.49)	1358.79 (1227.56)	1840.16 (1544.33)	2778.18 (2197.96)	1500.01 (1327.35)	597.54 (694.84)	724.38 (813.00)	1250.56 (1156.34)	1968.89 (1600.55)	2666.62 (2116.19)	1441.60 (1276.19)
C_4 (KNO_3 2%)	921.44 (949.30)	903.59 (960.21)	1587.37 (1398.66)	2263.46 (1811.01)	2681.43 (2130.94)	1671.46 (1450.02)	854.90 (914.08)	1037.24 (1033.44)	1727.92 (1463.75)	2226.35 (1801.26)	2272.41 (1846.75)	1623.76 (1411.86)
C_5 (Thiourea 1%)	776.64 (836.10)	928.40 (960.34)	1552.65 (1346.94)	2147.87 (1729.39)	2453.64 (1993.85)	1571.84 (1373.32)	671.26 (765.24)	764.60 (846.84)	1303.18 (1199.67)	2010.82 (1653.32)	2299.44 (1859.69)	1409.86 (1264.95)
C_6 (Thiourea 2%)	1037.13 (1043.68)	1013.19 (1043.93)	1756.36 (1506.22)	2578.12 (2052.05)	2758.28 (2182.55)	1828.62 (1565.69)	939.59 (967.10)	1165.90 (1121.05)	1822.48 (1554.99)	2602.58 (2064.67)	3185.03 (2523.30)	1943.12 (1646.22)
C_7 (Control)	460.66 (553.70)	507.72 (607.98)	872.57 (877.44)	1192.06 (1098.24)	1482.02 (1306.73)	903.01 (888.82)	439.36 (560.07)	559.25 (654.06)	967.92 (923.00)	1240.84 (1117.14)	1676.31 (1415.20)	976.74 (933.89)
MEAN	845.45 (885.96)	923.97 (955.14)	1540.19 (1351.33)	2153.97 (1754.45)	2610.38 (2103.99)	1614.79 (1410.17)	780.28 (841.16)	934.56 (955.74)	1521.04 (1337.99)	2151.99 (1754.61)	2609.95 (2093.70)	1599.56 (1396.64)
	T		C		T × C		T		C		T × C	
SEm (±)	16.557		19.591		43.806		18.487		21.874		48.912	
CD @ 5%	47.52		56.23		125.74		53.06		62.79		140.40	

* Numbers in parenthesis indicate multiplication product with the angular transformed values

Table 8. Effect of different physical and chemical treatments on seedling Vigour index-I (Pooled)

	Pooled					
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**MEAN**
C_1 (GA_3 100 ppm)	1117.76 (1093.24)	1331.38 (1238.78)	2028.03 (1695.22)	2868.10 (2272.93)	3410.17 (2724.19)	2151.09 (1804.87)
C_2 (GA_3 200 ppm)	863.76 (911.91)	969.14 (993.10)	1586.39 (1390.12)	2167.18 (1772.83)	2734.29 (2181.13)	1664.15 (1449.82)
C_3 (KNO_3 1%)	658.02 (745.12)	764.40 (842.24)	1304.68 (1191.95)	1904.53 (1572.44)	2722.40 (2157.07)	1470.80 (1301.77)
C_4 (KNO_3 2%)	888.17 (931.69)	970.42 (996.83)	1657.65 (1431.20)	2244.91 (1806.13)	2476.92 (1988.85)	1647.61 (1430.94)
C_5 (Thiourea 1%)	723.95 (800.67)	846.50 (903.59)	1427.92 (1273.31)	2079.35 (1691.36)	2376.54 (1926.77)	1490.85 (1319.14)
C_6 (Thiourea 2%)	988.36 (1005.39)	1089.55 (1082.49)	1789.42 (1530.60)	2590.35 (2058.36)	2971.66 (2352.93)	1885.87 (1605.95)
C_7 (Control)	450.01 (556.89)	533.49 (631.02)	920.25 (900.22)	1216.45 (1107.69)	1579.17 (1360.97)	939.87 (911.36)
MEAN	812.86 (863.56)	929.27 (955.44)	1530.62 (1344.66)	2152.98 (1754.53)	2610.16 (2098.84)	1607.18 (1403.41)
	T	**C**	**T x C**	**Y X T**	**Y X C**	**Y X T X C**
SEm (±)	12.409	14.682	32.831	17.549	20.764	46.429
CD @ 5%	34.99	41.40	92.58	NS	58.55	130.93

* Numbers in parenthesis indicate multiplication product with the angular transformed values

The data presented in table 7 and 8 showed significant differences in seedling vigour index- I during 2019-20, 2020-21 and pooled analysis in case of physical and chemical treatments and their interactions.

During 2019-20, among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest vigour index- I (2610.38) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 2153.97. The lowest vigour index- I was recorded in case of control (845.45). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest vigour index-I (2165.45) and the lowest was recorded in control (903.01).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest vigour index-I (3447.35) followed by T_5C_3 (2778.18) and the lowest was recorded in T_1C_7 (460.66).

During 2020-21, among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest vigour index- I (2609.95) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 2151.99. The lowest vigour index- I was recorded in case of control (780.28). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest vigour index-I (2136.73) and the lowest was recorded in control (976.74).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest vigour index-I (3372.99) followed by T_5C_6 (3185.03) and the lowest was recorded in T_1C_7 (439.36).

In pooled analysis, among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest vigour index- I (2610.16) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 2152.98. The lowest vigour index- I was recorded in case of control (812.16). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest vigour index-I (2151.09) and the lowest was recorded in control (939.87).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest vigour index-I (3410.17) followed by T_5C_6 (2971.66) and the lowest was recorded in T_1C_7 (450.01).

3.4 Vigour index – II

The data presented in table 9 and 10 showed significant differences in seedling vigour index- II during 2019-20, 2020-21 and pooled analysis in case of physical and chemical treatments and their interactions.

Among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest vigour index- II (42997.74) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 37034.44 during 2019-20. The lowest vigour index- II was recorded in case of control (14195.50). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest vigour index-II (35413.94) and the lowest was recorded in control (16734.98).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest vigour index-II (55966.60) followed by T_5C_6 (50351.10) and the lowest was recorded in T_1C_7 (9102.80).

During 2020-21, among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest vigour index- II (42476.59) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 37030.07. The lowest vigour index- II was recorded in case of control (13326.99). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest vigour index-II (34324.86) and the lowest was recorded in control (18338.28).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest vigour index-II (51632.10) followed by T_5C_6 (49616.80) and the lowest was recorded in T_1C_7 (8252.40).

In case pooled analysis, among the physical treatments, T_5 (seed coat removal + 48 hr soaking) recorded highest vigour index- II (42737.16) followed by T_4 (scarification + 48 hr soaking) *i.e.,* 37032.26. The lowest vigour index- II was recorded in case of control (13761.24). Among the chemical treatments, the seeds treated with GA_3 100 ppm recorded highest vigour index-II (34869.40) and the lowest was recorded in control (17536.63).Among the interaction between physical and chemical treatments, T_5C_1 recorded highest vigour index-II (53799.35) followed by T_5C_6 (49983.95) and the lowest was recorded in T_1C_7 (8677.60).

Table 9.Effect of different physical and chemical treatments on seedling Vigour index-II (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)	19280.30 (18634.42)	23852.90 (21703.52)	32982.00 (27706.75)	44987.90 (35673.68)	55966.60 (45032.45)	35413.94 (29750.16)	17956.20 (17787.08)	20706.20 (19727.35)	33408.80 (27804.57)	47921.00 (37949.14)	51632.10 (40967.56)	34324.86 (28847.14)
C_2 (GA_3 200 ppm)	13563.00 (14481.57)	14847.60 (15741.36)	27901.10 (23982.56)	39057.40 (31608.99)	41636.00 (33394.45)	27401.02 (23841.79)	14898.10 (15511.87)	18229.70 (18046.85)	26211.10 (23458.07)	34915.40 (28860.88)	46066.20 (36541.11)	28064.10 (24483.76)
C_3 (KNO_3 1%)	12183.00 (13486.95)	13128.90 (14241.03)	23792.90 (21489.51)	32248.70 (27052.20)	46171.80 (36529.70)	25505.06 (22559.88)	10490.40 (12119.49)	12631.10 (14205.11)	21610.00 (19982.89)	35364.00 (28744.37)	42168.30 (33467.07)	24452.76 (21703.79)
C_4 (KNO_3 2%)	15634.40 (16114.53)	15421.70 (16413.24)	25389.10 (22398.62)	39438.40 (31551.53)	44025.60 (34990.88)	27981.84 (24293.76)	13893.50 (14866.50)	16624.50 (16580.84)	30635.20 (25902.17)	38056.30 (30786.55)	38415.30 (31230.83)	27524.96 (23873.38)
C_5 (Thiourea 1%)	13148.80 (14155.46)	15611.80 (16156.37)	27332.80 (23736.85)	38322.00 (30853.69)	37155.30 (30192.17)	26314.14 (23018.91)	11632.40 (13271.82)	13030.50 (14428.92)	22077.20 (20301.89)	34433.00 (28295.04)	39013.60 (31554.52)	24037.34 (21570.44)
C_6 (Thiourea 2%)	16456.20 (16579.68)	16446.70 (16950.29)	29212.50 (25056.00)	42579.70 (33889.63)	50351.10 (39840.66)	31009.24 (26463.25)	16165.90 (16662.74)	20081.50 (19320.30)	30433.00 (25963.65)	45394.80 (36007.85)	49616.80 (39304.06)	32338.40 (27451.72)
C_7 (Control)	9102.80 (10928.32)	9564.70 (11453.57)	16722.60 (16836.09)	22607.00 (20835.76)	25677.80 (22624.66)	16734.98 (16535.68)	8252.40 (10497.97)	10515.20 (12297.74)	19374.00 (18454.60)	23126.00 (20826.15)	30423.80 (25669.28)	18338.28 (17549.15)
MEAN	14195.50 (14911.56)	15553.47 (16094.20)	26190.43 (23029.48)	37034.44 (30209.36)	42997.74 (34657.85)	27194.32 (23780.49)	13326.99 (14388.21)	15974.10 (16372.44)	26249.90 (23123.98)	37030.07 (30210.00)	42476.59 (34104.92)	27011.53 (23639.91)
	T		C		T × C		T		C		T × C	
SEm (±)	404.137		478.182		1069.247		447.962		530.035		1185.195	
CD @ 5%	1160.10		1372.65		3069.35		1285.90		1521.50		3402.18	

* Numbers in parenthesis indicate multiplication product with the angular transformed values

Table 10. Effect of different physical and chemical treatments on seedling Vigour index-II (Pooled)

	Pooled					
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**MEAN**
C_1 (GA_3 100 ppm)	18618.25 (18210.75)	22279.55 (20715.43)	33195.40 (27755.66)	46454.45 (36811.41)	53799.35 (43000.00)	34869.40 (29298.65)
C_2 (GA_3 200 ppm)	14230.55 (14996.72)	16538.65 (16894.11)	27056.10 (23720.32)	36986.40 (30234.94)	43851.10 (34967.78)	27732.56 (24162.77)
C_3 (KNO_3 1%)	11336.70 (12803.22)	12880.00 (14223.07)	22701.45 (20736.20)	33806.35 (27898.28)	44170.05 (34998.39)	24978.91 (22131.83)
C_4 (KNO_3 2%)	14763.95 (15490.51)	16023.10 (16497.04)	28012.15 (24150.40)	38747.35 (31169.04)	41220.45 (33110.86)	27753.40 (24083.57)
C_5 (Thiourea 1%)	12390.60 (13713.64)	14321.15 (15292.65)	24705.00 (22019.37)	36377.50 (29574.36)	38084.45 (30873.35)	25175.74 (22294.67)
C_6 (Thiourea 2%)	16311.05 (16621.21)	18264.10 (18135.29)	29822.75 (25509.82)	43987.25 (34948.74)	49983.95 (39572.36)	31673.82 (26957.49)
C_7 (Control)	8677.60 (10713.15)	10039.95 (11875.66)	18048.30 (17645.34)	22866.50 (20830.96)	28050.80 (24146.97)	17536.63 (17042.41)
MEAN	13761.24 (14649.89)	15763.79 (16233.00)	26220.16 (23076.73)	37032.26 (30209.68)	42737.16 (34381.39)	27102.92 (23710.20)
	T	**C**	**T x C**	**Y X T**	**Y X C**	**Y X T X C**
SEm (±)	301.661	356.930	798.119	426.613	504.775	1128.711
CD @ 5%	850.72	1006.58	2250.80	1203.10	1423.53	31833.11

* Numbers in parenthesis indicate multiplication product with the angular transformed values

One of the most common germination inhibitor is hard and water impermeable seed coat for which the seeds of some species cannot germinate under favourable climate conditions or germination occurs in a delayed manner even if their embryos develop. Majority of the cucurbits have hard and water impermeable seed coats, which inhibits seed germination and causes dormancy. Although hard seed coat is a structure which protects the embryo from mechanical effects, it has negative impact on germination. The main inhibition to water and oxygen penetration inside the spine gourd seeds is the presence of hard seed coat. In seeds which underwent no treatment, very less germination is reported, whereas other physical treatments significantly increased the germination percent. Removal of seed coat was found most effective in increasing germination followed by scarification by sand paper. The reason may be due to the removal of hard endocarp which did not allow water and oxygen penetration.Scrapping the seed coat with sand paper also damaged the seed coat and allowed penetration of water and oxygen. Similar results were also confirmed by Heidari*et al*., (2008), Pandey *et al*., (2013) and Chaodumrikul*et al,*. (2016). Hot water treatment followed by soaking also had a positive effect on germination rate. This treatment might have softened the hard and thick seed coat, as a result of which, germination rate might have increased due to water and oxygen penetration inside the seeds. Similar finding was also reported by Rincon *et al*., (2003) who observed that soaking the seeds in hot water induced seed germination.

In the present investigation different chemicals such as GA_3, KNO_3 and thiourea were tested in combination with different physical treatments to know its effect on seed germination and seedling vigour. It was observed that GA_3 100 ppm recorded highest germination and produced vigourous seedlings. 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(1994) in bitter gourd, Vijayaraghavan (1999) in Bhendi and Panchbhai*et al*., (2005) in spine gourd. The antagonism between growth promoters and naturally occurring germination inhibitors plays an important role in seed dormancy and the external application of gibberellin interacts with growth inhibitors in dormant seeds lowering the inhibitors concentration and facilitating germination by breaking seed dormancy at an early date (Wareing*et al*., 1973) and increasing germination. Therefore dormancy in kakrol seeds seems to be controlled by the balance between inhibitors and promoters. The exogenous application of gibberellic acid might have shifted the balance towards promoter side there by breaking the seed dormancy. Further GA_3 at higher concentration (200 ppm) might have triggered alternative respiration which may be detrimental for seed germination resulting in lower percentage of germination. Similar results were also reported by Caisini and Salvadori (1980) in jujuba, Vijayaraghavan (1999) in bhendi and Ram Asrey*et al.* (2003) in muskmelon. Compared to control, the seeds treated with thiourea and KNO3 showed higher germination, seedling length, dry weight and vigour. The stimulative effect of thiourea on seed germination can be attributed to a reduction of the preventive effect of seed coat and its cytokinin activity in overcoming inhibition. Similar results regarding the effects of thiourea on germination were recorded in some other species by Stidham*et al*., (1980) & Agrawal and Dadlani (1995).Use of KNO_3 has been an important seed treatment in seed testing

laboratories for many years without a good explanation for its action (Hartmann *et al.*,1997).$KNO_3$was found to be effective in breaking dormancy of many species (Agrawal and Dadlani, 1995).

Among the interaction effect, seed coat removed seeds soaked in water for 48 hrs followed by $GA_3$100 ppm treatment found superior than rest of the treatment combinations.Removing the seed coat with application of GA_3 100 ppm may have allowed the seeds to soak in a solution of gibberellic acid which promotes production of α-amylase enzyme which transmutes starch into its simple sugar units which transfer to the embryo to be used as food.This treatment combination favoured the seedling growth and the increase in seedling vigour index –I & II may be due to increased germination,seedling length and dry weight.

4. Conclusion

From the present investigation, it was concluded that, among different physical treatments, removal of seed coat followed by 48 hour soaking in water and in case of chemicals, GA_3 100 ppm treatment were found most effective in enhancing germination, seedling length, dry weight and seedling vigour. 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. Thus, these treatments can be recommended for breaking seed dormancy and enhancing germination and seedling vigour in spine gourd.

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