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Impact of Seed Hardening and Foliar Application of Growth Substances on Morphological Parameters of Groundnut (*Arachis hypogaea* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors worked together to complete this work. Author KUP collected and analyzed the data periodically and according to stages, scripted and wrote the manuscript. Authors, KUP, SJM, ASB collaborated on the study. Author JJG helped in research analysis and wrote the manuscript. Author SJM designed the experiment and oversighted the work. Author ASB provided guidance during the field test procedures. The final manuscript was reviewed and approved by all authors.

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ABSTRACT

An experiment was carried out during summer and *kharif*, 2022. A Factorial Randomized Block Design with three replications was used for an experiment that included seed hardening as one factor with nine levels while foliar spray of Chlorocholine Chloride @500 mg/L as another factor with

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two levels. Different morphological parameters were analyzed for the experiment at different time durations like 30, 50, 70, 90 DAS and at harvest. Days to initiation of flowering, days to 50% flowering, days to maturity were significantly minimum with GA_3-150 mg/L seed hardening treatment. Meanwhile, plant height, number of primary branches per plant were also found significantly higher in seed hardening with GA_3-150 mg/L while all these morphological parameters were found significantly lower after application of foliar spray of CCC @500 mg/L as compared to control. Thus seed hardening with GA_3-150 mg/L and foliar application of CCC @500 mg/L is suitable for enhancing the yield of groundnut.

Keywords: Seed hardening; foliar spray; CCC; plant height; number of primary branches per plant; number of leaves per plant.

1. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is popularly known as peanut, a self-pollinated crop and allotetraploid. It is a member of the order fabales and family Fabaceae. It is regarded as It ranks 13th among the principal economic crops. It is also called wonder nuts, earth nuts, monkey nuts, goobers, pindea, manilla nuts and poor men's cashew nut [1].

Groundnut is also known as "KING OF OILSEEDS CROPS" on account of its diversified uses for food, feed, fodder and industrial purpose. It is valued as a rich source of energy contributed by oil (48–50%) and protein (25–28%) in the kernels [2]. In addition, the groundnut kernels contain many health enhancing nutrients such as minerals such as K, Na, Ca, Mn, Fe, and Zn among others, antioxidants, and vitamins and are also rich in mono-unsaturated fatty acids. They contain antioxidants like p-coumaric acid and resveratrol, Vitamin E, and many important B-complex groups of thiamine, pantothenic acid, vitamin B6, folates, and niacin. Groundnut is a dietary source of biologically active polyphenols, flavonoids, and isoflavones.

Groundnut cultivation in India spans all three primary agricultural seasons: *kharif*, *rabi* and *summer*, primarily under rainfed conditions. Among these seasons, *kharif* cultivation alone constitutes a substantial 75% share of the total groundnut production [3].

The low productivity of crops in rainfed areas is contributed by the use of poor-quality seeds. The features like rapid and identical seedling emergence are the two essential prerequisites to increase seed yield and seed quality in a number of field crops [4].

The hardening resulting from pre-sowing treatments is due to a number of physico-chemical changes within the cytoplasm including greater hydration of colloids, higher viscosity and elasticity of the protoplasm, increase in hydrophilic and decrease in lipophilic colloids, increase in the temperature required for protein coagulation and increase in bound water content [5]. Seed hardening accelerated rapid germination, better root development and rapid growth of seedlings which enabled absorption of more moisture. It induces drought tolerance by increasing the resistance to protoplasmic dehydration in young seedlings subjected to moisture stress. Flowering is also slightly accelerated in hardened seeds [6].

Plants developed from hardened seeds often exhibit a faster growth due to an improved nutrient use efficiency besides higher relative growth rate. It is a well-established fact that pre-soaking seeds with optimal concentration of phytohormones enhance their germination, growth and yield of some crop species under conditions of environmental stress by increasing nutrient reserves through increased physiological activities and root proliferation [7].

Chlorocholine Chloride is gibberellin biosynthesis inhibitor involved in the inhibition of cyclization of geranyl-geranyl pyrophosphate to copalyl pyrophosphate. Growth regulators which inhibit the biosynthesis of gibberellins have been shown to enable the plants to impart tolerance against abiotic stress due to water [8].

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment is conducted at Regional Research Station, Anand Agricultural University, Anand, India during Summer and *kharif*, 2022.

2.2 Treatment Details

Eighteen treatment combinations involving nine levels of seed hardening treatments and two levels of foliar spray were incorporated in the study. Thus, eighteen treatment combinations with two factors were embedded as factorial randomized block design with three replications. Details of the treatments with their symbols are given as under.

Factor-1: Seed Hardening (A)

A1 : $CaCl_2$ 1%
A2 : Ethrel-50 mg/L
A3 : Ethrel-100 mg/L
A4 : Ethrel-150 mg/L
A5 : GA_3-50 mg/L
A6 : GA_3-100 mg/L
A7 : GA_3-150 mg/L
A8 : Soaking in water
A9 : Control

Factor-2: Foliar Spray (B)

B1 : Control no foliar spray
B2 : CCC @500 mg/L

*Foliar spray of CCC was given at 35 and 55 DAS in all treatments

There were eighteen treatment combinations were evaluated in the present study *viz.,* A1B1:$CaCl_2$ 1% seed hardening+Control (No foliar spray), A2B1:Ethrel-50 mg/L seed hardening+Control (No foliar spray), A3B1:Ethrel-100 mg/L seed hardening+Control (No foliar spray), A4B1:Ethrel-150 mg/L seed hardening+Control (No foliar spray), A5B1: GA_3-50 mg/L seed hardening+Control (No foliar spray), A6B1:GA_3-100 mg/L seed hardening+Control (No foliar spray), A7B1:GA_3-150 mg/L seed hardening+Control (No foliar spray), A8B1:Water soking as seed hardening+Control (No foliar spray), A9B1:Control (Without hardening)+Control (No foliar spray), A1B2:$CaCl_2$ 1% seed hardening+CCC 500 mg/L foliar spray, A2B2:Ethrel-50 mg/L seed hardening+CCC 500 mg/L foliar spray, A3B2:Ethrel-100 mg/L seed hardening+CCC 500 mg/L foliar spray, A4B2: Ethrel-150 mg/L seed hardening+CCC 500 mg/L foliar spray, A5B2: GA_3-50 mg/L seed hardening+CCC 500 mg/L foliar spray, A6B2:GA_3-100 mg/L seed hardening+CCC 500 mg/L foliar spray, A7B2: GA_3-150 mg/L seed hardening+CCC 500 mg/L foliar spray.

2.3 Methods of Seed Hardening and Foliar Application of Growth Substances

$CaCl_2$ 1% was prepared by dissolving 10 g of $CaCl_2$ in 1 liter of distilled water. Ethrel-50 mg/L, Ethrel-100 mg/L and Ethrel-150 mg/L were prepared by dissolving 50, 100 and 150 mg of Ethrel in one liter of water respectively. GA_3-50 mg/L, GA_3-100 mg/L and GA_3-150 mg/L were prepared by dissolving 50, 100 and 150 mg of GA_3 in one liter of water respectively.

Seed hardening treatments were applied to Groundnut seeds, soaking them in double volume solutions for four hours to prevent germination. After drying, seeds were ready for sowing in the field and under laboratory conditions, ensuring their original moisture level.

This experiment uses Chlorocholine Chloride (CCC) as a foliar spray. A stock solution of 50 % CCC was prepared, and a final solution of 10 liters was prepared. Spraying was carried out at 35 and 55 DAS in respective plots during both seasons.

2.4 Morphological Parameters

2.4.1 Days to initiation of flowering (days)

The number of days taken from sowing to the opening of the first flower in an experimental plot was expressed in days.

2.4.2 Days to 50% flowering (days)

The number of days required for 50% flowering was recorded from the date of sowing in all treatments in all three replications.

2.4.3 Days to maturity (days)

The number of days required from sowing to the date of 50% of plants becoming dry were recorded as the date of physiological maturity in all treatments in three replications.

2.4.4 Plant height (cm)

Plant height was recorded by a non-destructive method. Plant height of groundnut crop was measured from five plants selected randomly in each treatment for recording observations of average plant height at 30, 50, 70, 90 DAS and at harvest from the base of the plant (ground level) to the tip of upper most fully opened leaf and finally the mean height of plant in centimeter (cm) at each period in each treatment was worked out and were recorded for statistical analysis. These same five plants were also used for other observations.

2.4.5 Number of primary branches/plant

Number of branches per plant was counted from previously selected five plants from each net plot at 30, 50, 70, 90 DAS and at harvest of the crop. The mean number of primary branches per plant was worked out and recorded separately for each treatment.

2.4.6 Number of leaves/plant

The number of green leaves from top to bottom of the plants was counted in the randomly tagged five plants at 30, 50, 70, 90 DAS and at harvest. The average was worked out and expressed as the number of green leaves per plant.

3. RESULTS AND DISCUSSION

3.1 Effect of Seed Hardening on Morphological Parameters

3.1.1 Effect of seed hardening on days to initiation of flowering (Days)

The data summarized in Table 1 showed that the days to initiation of flowering was influenced significantly by the use of different seed hardening treatments in groundnut crop. The data regarding days to initiation of flowering (28.28, 27.53 and 27.91 days) showed that significantly in seed hardening treatment with GA_3-150 mg/L seed hardening (A7) during summer and *kharif*-2022 and in pooled results, respectively.

3.1.2 Effect of seed hardening on days to 50% flowering (Days)

The data (Table 1) regarding days to 50% flowering (32.07, 32.60 and 32.33 days) showed significantly lower with GA_3-150 mg/L seed hardening (A7) during the summer and *kharif*, 2022 and in pooled results, respectively. Whereas, higher days to 50% flowering (37.14, 37.11 and 37.12 days) was recorded with control (A9) in both seasons and in pooled results, respectively.

3.1.3 Effect of seed hardening on days to maturity (Days)

The significantly (Table 1) lower days to maturity (120.13, 120.72 and 120.43 days) was recorded GA_3-150 mg/L seed hardening (A7) which was statistically at par with GA_3-100 mg/L seed hardening in the summer and *kharif*, 2022 and pooled data, respectively.

3.1.4 Effect of seed hardening on plant height (cm)

The plant height (Table 2) at 30, 50, 70, 90 DAS and at harvest affects significantly due to seed hardening treatment during summer and *kharif* 2022, as well as in the pooled results. Among the treatments, GA_3-150 mg/L seed hardening (A7) showed higher plant height (11.36, 14.44 and 12.90 cm) at 30 DAS, while Ethrel-50 mg/L seed hardening (A2) showed that significantly higher plant height of 20.91 cm which was statistically at par with GA_3-150 mg/L seed hardening, A7 (20.36 cm) during summer-2022 while $CaCl_2$ 1% seed hardening (A1) showed higher plant height 22.44 cm which was statistically at par with A7 (21.90 cm) during *kharif* season. Also plant height was recorded higher with A1 (21.13 cm) in pooled results during 50 DAS. The significant higher plant height (31.15 cm) was recorded in seed hardening with GA_3-150 mg/L (A7) during summer, while 35.75 cm was noted in GA_3-100 mg/L (A6) during *kharif* seasons which was statistically at par with GA_3-150 g/L seed hardening (35.33 cm). A7, GA_3-150 mg/L seed hardening recorded higher plant height (33.24 cm) during pooled analysis at 70 DAS. Significantly higher plant height at 90 DAS (37.22, 38.37 and 37.24 cm) was recorded with GA_3-150 mg/L (A7), ethrel-150 mg/L (A4) and GA_3-150 mg/L (A7) in both the seasons 2022, and pooled data, respectively which was at par with GA_3-150 mg/L seed hardening (37.26 cm) during *kharif* season, 2022. Data (Table 3) clearly indicated that the significantly higher plant height was observed in GA_3-150 mg/L seed hardening (A7) (38.43, 49.64 and 44.03 cm) during summer and *kharif*-2022 and pooled analysis during harvest, respectively.

The beneficial effect on growth regulators at particular concentration can be attributed to the cell elongation and quick cell multiplication. This appears the most probable reason for increase in the plant height in GA_3 treatments in present investigation as well. The present findings are in close agreement with those reported by Hasan and Ismail [9], Agwane and Parhe [10] in soyabean, Keykha et al. [11] in Mungbean, Narayanreddy and Biradapatil [12] in sunflower.

Table 1. Effect of seed hardening and foliar spray on days to initiation of flowering, days to 50% flowering and days to maturity in groundnut during summer and *kharif,* 2022 as well as in pooled analysis

	Days to Initiation of Flowering			Days to 50% Flowering			Days to Maturity		
	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled
Seed Hardening (A)									
A1	30.30	30.13	30.22	36.14	36.26	36.20	122.36	122.51	122.43
A2	30.05	30.00	30.03	35.81	35.21	35.51	121.95	122.12	122.04
A3	29.95	29.42	29.68	35.44	35.13	35.29	122.57	122.72	122.64
A4	28.93	28.53	28.73	34.05	34.07	34.06	121.12	121.59	121.36
A5	29.50	28.82	29.16	34.93	34.81	34.87	121.04	121.37	121.20
A6	28.45	28.35	28.40	33.35	33.50	33.42	120.78	120.96	120.87
A7	28.28	27.53	27.91	32.07	32.60	32.33	120.13	120.72	120.43
A8	30.65	30.62	30.63	36.51	36.24	36.37	122.99	123.30	123.14
A9	31.84	31.47	31.66	37.14	37.11	37.12	123.02	123.39	123.20
S.Em.(±)	0.278	0.246	0.185	0.731	0.887	0.575	0.945	0.438	0.521
C.D. $_{(0.05)}$	0.798	0.707	0.523	2.101	2.549	1.622	NS	NS	1.469
Foliar Spray (B)									
B1	29.77	29.44	29.61	35.09	34.98	35.04	121.98	122.21	122.09
B2	29.77	29.42	29.60	35.00	35.00	35.00	121.57	121.94	121.76
S.Em.(±)	0.131	0.116	0.087	0.345	0.418	0.271	0.445	0.207	0.245
C.D. $_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
AxS	-	-	NS	-	-	NS	-	-	NS
BxS	-	-	NS	-	-	NS	-	-	NS
AxB	NS	NS	NS	NS	NS	NS	NS	NS	NS
AxBxS	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	2.28	2.05	2.17	5.11	6.21	5.68	1.90	0.88	1.48

**NS=Non-Significant, DAS- Days After Sowing*

Table 2. Effect of seed hardening and foliar spray on plant height in groundnut during summer and *kharif,* 2022 as well as in pooled analysis

	Plant Height (cm)														
	30 DAS			50 DAS			70 DAS			90 DAS			At Harvest		
	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled
Seed Hardening (A)															
A1	8.77	12.76	10.77	19.51	22.44	20.98	28.45	30.98	29.71	29.13	32.23	30.68	35.01	36.73	35.87
A2	8.06	8.47	8.27	20.91	18.46	19.69	29.57	29.27	29.42	30.65	30.83	30.74	34.67	34.58	34.63
A3	8.19	5.51	6.85	18.58	20.43	19.51	32.11	29.42	30.76	35.80	31.96	33.88	35.21	36.63	35.92
A4	8.98	13.50	11.24	18.33	20.98	19.65	25.72	26.43	26.07	30.91	38.37	34.64	38.37	35.22	36.80
A5	9.47	13.86	11.67	19.02	21.20	20.11	25.87	30.74	28.30	31.93	36.45	34.19	35.36	33.68	34.52
A6	8.51	12.16	10.34	18.22	19.66	20.06	27.33	35.75	31.54	33.25	31.56	32.41	34.82	34.37	34.59
A7	11.36	14.44	12.90	20.36	21.90	21.13	31.15	35.33	33.24	37.22	37.26	37.24	38.43	49.64	44.03
A8	7.76	10.92	9.34	19.78	19.87	19.83	28.73	31.12	29.92	32.59	32.44	32.51	34.87	32.81	42.25
A9	7.52	5.10	6.31	18.58	19.16	18.87	26.82	30.17	28.49	30.10	27.08	28.59	34.54	39.39	36.96
S.Em.(±)	0.210	0.229	0.155	0.381	0.355	0.260	1.084	0.744	0.657	1.066	1.081	0.759	1.038	1.122	0.764
C.D.$_{(0.05)}$	0.603	0.657	0.438	1.096	1.019	0.735	3.115	2.138	1.855	3.063	3.106	2.142	2.983	3.226	2.157
Foliar Spray (B)															
B1	8.73	10.79	9.76	20.45	22.03	21.24	30.80	32.15	31.48	33.24	36.48	34.86	38.70	37.84	38.27
B2	8.75	10.70	9.73	18.06	18.65	18.36	27.03	29.00	28.02	29.79	31.56	30.67	36.17	32.70	34.44
S.Em.(±)	0.099	0.108	0.073	0.180	0.167	0.123	0.511	0.351	0.310	0.502	0.509	0.358	0.489	0.529	0.360
C.D.$_{(0.05)}$	NS	NS	NS	0.517	0.480	0.346	1.468	1.008	0.874	1.444	1.464	1.010	1.406	1.521	1.017
Interaction															
AxS	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.
BxS	-	-	NS	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.
AxB	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
AxBxS	-	-	NS	-	-	NS	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	5.89	5.21	5.52	4.85	4.27	4.55	9.34	5.96	7.72	8.06	7.99	8.02	7.12	7.43	7.28

**Sig.-Significant*

Table 3. Effect of seed hardening and foliar spray on number of primary branches/plant in groundnut during summer and *kharif,* 2022 as well as in pooled analysis

	Number of Primary Branches/Plant														
	30 DAS			50 DAS			70 DAS			90 DAS			At Harvest		
	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled
Seed Hardening (A)															
A1	3.35	2.80	3.07	4.36	3.15	3.76	4.93	3.52	4.22	6.20	5.89	6.04	7.45	5.88	7.06
A2	2.85	2.83	2.84	4.39	3.10	3.75	4.42	4.20	4.31	5.18	4.71	4.95	6.53	6.10	6.31
A3	3.23	2.77	3.00	4.41	3.03	3.72	4.62	3.67	4.15	5.36	5.20	5.28	6.87	6.33	6.60
A4	3.00	2.77	2.88	4.34	3.13	3.73	6.09	3.25	4.67	7.38	6.91	7.14	7.84	6.36	7.10
A5	3.30	2.90	3.10	4.37	2.89	3.63	4.59	3.25	3.92	4.90	4.35	4.62	5.97	5.53	5.75
A6	3.32	2.63	2.97	4.42	3.18	3.80	4.50	3.89	4.20	6.09	4.95	5.52	7.19	6.97	7.08
A7	3.70	3.03	3.39	4.57	3.23	3.90	6.32	4.80	5.56	8.08	6.48	7.28	8.85	6.67	7.36
A8	2.90	3.00	2.95	4.39	2.86	3.63	4.85	4.03	3.94	5.25	4.15	4.70	6.36	5.24	5.80
A9	2.90	2.83	2.87	3.19	3.12	3.15	3.41	4.04	3.72	3.94	4.27	4.11	5.14	4.60	4.87
S.Em.(±)	0.069	0.089	0.056	0.066	0.059	0.044	0.067	0.125	0.071	0.174	0.148	0.114	0.234	0.191	0.151
C.D.$_{(0.05)}$	0.199	0.255	0.159	0.189	0.169	0.177	0.193	0.361	0.201	0.501	0.425	0.323	0.673	0.548	0.426
Foliar Spray (B)															
B1	3.17	2.97	2.97	4.62	3.16	3.89	4.70	3.92	4.31	6.04	5.69	5.86	7.51	6.37	6.74
B2	3.17	2.91	3.04	3.95	3.01	3.48	4.40	3.78	4.09	5.60	4.62	5.11	6.32	5.56	6.14
Mean	3.17	2.84	3.01	4.28	3.08	3.68	4.55	3.85	4.20	5.82	5.15	5.49	6.91	5.97	6.44
S.Em.(±)	0.033	0.042	0.027	0.031	0.028	0.021	0.032	0.059	0.034	0.082	0.070	0.054	0.110	0.090	0.071
C.D.$_{(0.05)}$	NS	NS	NS	0.089	0.080	0.059	0.091	0.170	0.095	0.236	0.201	0.152	0.317	0.259	0.201
Interaction															
AxS	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.
BxS	-	-	NS	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.
AxB	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
AxBxS	-	-	NS	-	-	NS	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	5.35	7.66	6.49	3.68	4.68	4.10	3.61	7.98	5.87	7.33	7.04	7.22	8.30	7.84	8.13

Table 4. Effect of seed hardening and foliar spray on number of primary branches/Plant in groundnut during summer and *kharif,* 2022 as well as in pooled analysis

	Number of Leaves/Plant														
	30 DAS			50 DAS			70 DAS			90 DAS			At Harvest		
	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled	Summer	*kharif*	Pooled
Seed Hardening (A)															
A1	30.80	74.90	52.85	121.23	149.24	135.23	475.85	452.29	464.07	485.14	216.58	350.86	473.07	213.42	343.25
A2	31.91	76.57	54.24	126.86	174.43	150.65	394.57	418.07	406.32	499.02	207.08	353.05	503.88	222.20	363.04
A3	43.53	79.23	61.38	122.46	174.02	148.24	392.07	417.87	404.97	516.87	223.68	370.27	511.97	222.80	367.39
A4	44.41	82.82	63.61	121.02	174.57	147.80	462.67	408.13	435.40	485.59	282.72	384.16	583.57	261.54	422.56
A5	43.67	85.30	64.48	120.87	174.22	147.55	460.09	414.85	437.47	534.98	263.99	399.49	565.56	256.36	410.96
A6	46.23	86.03	66.13	116.92	173.95	145.43	395.22	443.97	419.59	598.28	206.19	402.23	562.82	184.03	373.42
A7	46.97	85.87	66.42	123.04	176.76	149.90	488.07	497.27	492.67	542.72	310.37	426.55	667.41	264.10	465.76
A8	43.74	78.57	61.16	118.99	171.34	145.17	462.67	422.98	442.82	531.99	257.38	394.68	525.38	269.43	397.41
A9	31.64	74.48	53.06	115.35	160.04	137.69	390.30	438.80	414.55	477.74	230.18	353.96	460.33	181.27	320.80
S.Em.(±)	1.074	1.826	1.059	2.107	4.168	2.335	18.025	11.840	10.783	20.760	4.652	10.637	22.105	4.270	11.257
C.D.$_{(0.05)}$	3.088	5.249	2.990	6.055	11.980	6.590	51.805	34.030	30.430	59.664	13.371	30.019	63.530	12.272	31.767
Foliar application (B)															
B1	40.99	80.47	60.73	139.03	202.38	170.71	512.79	475.89	494.34	608.59	316.24	462.41	650.19	291.84	471.01
B2	39.65	80.37	60.01	102.47	137.30	119.88	358.66	393.94	376.30	429.71	172.24	300.97	428.48	169.31	298.89
S.Em.(±)	0.506	0.861	0.499	0.993	1.965	1.101	8.497	5.582	5.083	9.786	2.193	5.015	10.420	2.013	5.306
C.D.$_{(0.05)}$	NS	NS	NS	2.854	5.647	3.107	24.421	16.042	14.345	28.126	6.303	14.151	29.948	5.785	14.975
Interaction															
AxS	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.
BxS	-	-	NS	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.
AxB	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
AxBxS	-	-	NS	-	-	NS	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	6.53	5.56	6.08	4.27	6.01	5.57	10.13	6.67	8.58	9.80	4.67	9.80	10.04	4.54	10.13

3.1.5 Effect of seed hardening on number of primary branches per plant

The number of primary branches/plant at 30 DAS (Table 3) showed statistically significant due to seed hardening treatments. Highest number of primary branches/plant were observed in GA_3-150 mg/L seed hardening (3.70, 3.03, and 3.39) at 30 DAS, (4.57, 3.23 and 3.90) at 50 DAS, (6.32, 4.80, 5.56) at 70 DAS during the summer and kharif 2022, as well as in the pooled results respectively. Maximum number of primary branches/plant was observed in GA_3-150 mg/L seed hardening, A7 (8.08) during summer-2022 while ethrel-150 mg/L, A4 (6.91) showed highest number of primary branches/plant in kharif-2022 which was at par with GA_3-150 mg/L seed hardening (A7, 6.48). In the pooled result, A7 (7.28) presented a higher number of primary branches/plant for 90 DAS. Meanwhile, higher number of primary branches/plant was observed in GA_3-150 mg/L (8.85), GA_3-100 mg/L (6.97) and GA_3-150 mg/L (7.36) seed hardening during the summer, kharif -2022, as well as in the pooled basis which was statistically at par with GA_3-150 mg/L (A7) ranged 6.67 during kharif, 2022.

The improvement in plant growth by increasing the number of primary branches/plant because of the use of GA_3 might be attributed to cell elongation and cell division. GA_3 influences the action of various enzymes, particularly amylase and enhances the movement of starch particles in the cotyledons, consequently triggering growth. The result was in accordance with Hasan and Ismail [9] in groundnut.

3.1.6 Effect of seed hardening on number of leaves per plant

The number of leaves/plant at 30, 50, 70, 90 DAS and at harvest (Table 4) was significantly affected by seed hardening treatments. The higher number of leaves/plant were found with seed hardening with GA_3-150 mg/L (A7, 46.97 and 66.42) during summer, 2022 and pooled result while seed hardening with GA_3-100 mg/L (A6, 86.03) showed maximum number of leaves/plant which was at par with A4 (82.82), A5 (85.30) and A7 (85.87) during *kharif*-2022 at 30 DAS. Number of leaves/plant at 50 DAS (126.86, 176.76 and 150.65) showed that significantly higher with seed hardening with ethrel-50 mg/L (A2), GA_3-150 mg/L (A7) and ethrel-50 mg/L (A2) during summer, *kharif* and in pooled results, respectively. Maximum number of leaves were found with seed hardening with GA_3-150 mg/L (488.07497.27, 492.66) during summer, *kharif*-2022 and pooled analysis. An examination of data given in Table 4 indicated that the significantly higher number of leaves/plant at 90 DAS was recorded with seed hardening with GA_3 100 mg/L (A6, 598.28) which was statistically at par with A7 (542.72) in summer, 2022. Whereas, seed hardening with GA_3-150 mg/L (310.37, 426.54) recorded higher leaves/plant during *kharif*, 2022 and pooled the result. According to Data (Table 4) higher number of leaves/plant were significantly found in A7 (667.41, 465.76) during summer, 2022 and pooled analysis, whereas seed hardening with water soaked treatment, A8 (269.43) during *kharif*, 2022 at harvest.

Improvement of vegetative growth represented by enhancement of number of leaves/plant in groundnut showed the positive effect with seed hardening treatment. These results may be attributed to healthy germination of seeds, which in turn gave the plant better start and induced further growth of groundnut seedling. The number of leaves per plant, an additional parameter of growth, is greatly influenced by growth regulators. The effect of growth regulators on the number of leaves was observed, at the peak stage of the plant. It is a well established fact that GA_3 acts in cell elongation or enlargement resulting in increased number of functional leaves. Elongation of the cell may also have resulted in larger blade size of the leaves.

3.2 Effect of Foliar Spraying of CCC on Morphological Parameters

3.2.1 Effect of foliar spray of CCC on days to initiation of flowering, days to 50% flowering and days to maturity (days)

As per result (Table 1) the effect of foliar spray of CCC @500 mg/L on days to initiation of flowering,days to 50% flowering and days to maturity during summer and *kharif*, 2022 and in pooled results was found to be non-significant.

3.2.2 Effect of foliar spray of CCC on plant height (cm)

First foliar spray of CCC was done at 35 DAS, so there is no significant result found for foliar spraying of CCC at 30 DAS.

According to Table 2 plant height showed significantly lower after foliar application of CCC @500 mg/L at 50 DAS (38.43, 49.64 and 44.03 cm), 70 DAS (27.03, 29.00 and 28.02 cm), 90 DAS (29.79, 31.56 and 30.67 cm) and at harvest

(29.79, 31.56 and 30.67 cm) as compared to control (B1) during summer and kharif, 2022 and in pooled analysis, respectively.

Chlorocholine chloride (CCC) reduces plant height by inhibiting gibberellin biosynthesis, a plant growth hormone, responsible for the stem elongation. As gibberellin promotes cell division and elongation, their inhibition stunted growth and reduced plant height. The findings are in conformity with the results of Singh and Jambukiya [13] in green gram, Bhadane et al. [14] in green gram and Prajapati et al. [15] in blackgram.

3.2.3 Effect of foliar spray of CCC on number of primary branches per plant

Number of primary branches/plant was significantly minimum after foliar application of CCC @500 mg/L, B2 (3.95, 3.01, 3.48) at 50 DAS, (4.40, 3.78, 4.09) at 70 DAS, (5.60, 4.62, 5.11) at 90 DAS and (6.32, 5.56, 6.14) at harvest as compared to control (B1) during summer and *kharif*, 2022 and pooled analysis (Table 3).

As, chlorocholine chloride (CCC) plant growth retardants, particularly onium compounds are able to increase the partitioning of assimilates to roots and thereby improve yield through the inhibition of gibberellin biosynthesis or action. According to the result, the number of primary branches per plant decreased after foliar application of CCC indicated indirect growth of the below ground part.

3.2.4 Effect of foliar spray of CCC on number of leaves per plant

Number of leaves/plant at 50, 70, 90 DAS and at harvest (Table 4) was recorded significantly decrease with foliar spraying of CCC @500 mg/L (B2) during summer, *kharif* as well as in pooled results, respectively. The higher number of leaves/plant at 50 DAS were recorded with control (B1). Lower number of leaves/plant was observed (102.47, 137.30 and 119.85) at 50 DAS, (358.66, 393.94 and 376.30) 70 DAS, (429.71, 172.24, 300.97) 90 DAS and (428.48, 169.31, 298.89) at harvest was recorded with foliar spraying of CCC @500 mg/L (B2) during both the seasons and in pooled analysis, respectively.

The result might be due to the response of CCC being antagonistic to GA_3. Similar results were found with Mohammed [16] in Chrysanthemum and El- Kheir *et al.* [17] in groundnut.

3.3 Interaction Effect of Seed Hardening and Foliar Spray of CCC on Morphological Parameters

The interaction effect between different seed hardening treatments and foliar spraying of CCC @500 mg/L for all morphological parameters like days to initiation of flowering, days to 50% flowering, days to maturity, plant height, number of primary branches per plant and number of leaves per plant were found non-significant at 30, 50, 70, 90 DAS and at harvest**.**

4. CONCLUSION

The study's findings indicated that treating groundnuts with GA_3-150 mg/L seed hardening treatment and applying CCC as foliar application at a dose of 500 mg/L were effective in positive manner of morphological characteristics such as the days to initiation of flowering, days to 50% flowering, days to maturity, plant height, number of primary branches per plant and number of leaves per plant. To put it succinctly, growers aiming to get a higher morphological produce were advised to use GA_3 at 150 mg/L and Chlorocholine Chloride (CCC) at 500 mg/L by foliar spraying.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors of this paper therefore confirm that throughout the drafting and editing of manuscripts, NO generative AI tools, such as text-to-image generators and large language models (ChatGPT, COPILOT, etc.), were employed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gadhiya HA, Borad PK, Bhut JB. Effectivness of synthetic insecticides against *Helicoverpa armigera* (Hubner) Hardwick and Spodoptera litura (Fabricius) infesting groundnut. The Bioscan. 2014;9 (1):23-6.
2. Jambunathan R. Uses of tropical grain legumes; 1991.
3. Barman M, Gunri SK, Puste AM, Paul S. Effect of paclobutrazol on growth and yield of kharif groundnut (*Arachis hypogaea* L.). International Journal of Agriculture, Environment

and Biotechnology. 2017;10(4):513-8.
4. Krishnotar B, Srivastava AK, Shahi JP. Response of rabi maize crop to seed invigoration with magnesium nitrate and distilled water. Seeds. 2009;900:119.
5. Solaimalai A, Subburamu K. Seed hardening for field crops–A review. Agricultural Reviews. 2004;25(2):129 -40.
6. Jain LK, Verma MP, Ram N, Choudhary A, Parewa HP. Seed hardening: A way to tolerate against abiotic stress in rainfed areas. International Journal of Economic Plants. 2022;9(Feb,1):018-21.
7. Bozcuk S. Effects of kinetin and salinity on germination of tomato, barley and cotton seeds. Annals of Botany. 1981;48(1):81-4.
8. Lone NA, Khan NA, Bhat MA, Mir MR, Razvi SM, Baht KA, Rather GH, Nawsheeba W, Sabina A, Bukhari SA. Effect of chlorocholine chloride (CCC) on plant growth and development. Int. J. Curr. Res. 2010;6(2):1-7.
9. Hasan M, Ismail BS. Effect of gibberellic acid on the growth and yield of groundnut (*Arachis hypogaea* L.). Sains Malaysiana. 2018 Feb 1;47(2):221-5.
10. Agawane RB, Parhe SD. Effect of seed priming on crop growth and seed yield of soybean [*Glycine max* (L.) Merill]. The Bioscan. 2015;10(1):265-70.
11. Keykha, Mojtaba, Hamid Reza Ganjali, and Hamid Reza Mobasser. Effect of salicylic acid and gibberellic acid on some characteristics in mungbean (*Vigna radiata*). 2014; 70-75.
12. Narayanareddy AB, Biradarpatil NK. Effect of pre-sowing invigouration seed treatments on seed quality and crop establishment in sunflower hybrid KBSH-1. 2012;43-46.
13. Singh, C., and H. Jambukiya. Effect of foliar application of plant growth regulators on growth and yield attributing characters of green gram (*Vigna radiata* L. Wilczek). 2020:258-264.
14. Bhadane RS, Prajapati KR, Patel DB. Effect of seed hardening on morpho-physiological characters in Mung bean (*Vigna radiata* L.). International Journal of Chemical Studies. 2019;7(4):1760-3.
15. Prajapati KR, Patel DB, Patil K, Bhadane RS. Effect of seed hardening on morpho-physiological and yield parameters in black gram (*Vigna mungo* L.). International Journal of Chemical Studies. 2017;5(4): 439-41.
16. Mohammed AR. Effects of foliar application of plant growth regulators on growth and flowering characteristics of chrysanthemum cv. paintball. Pakistan Journal of Life & Social Sciences. 2017 ;15(2).
17. El-Kheir MS, Kandil SA, Mekki BB. Physiological response of two soybean cultivars grown under water stress conditions as affected by CCC treatment. 1991;179-200.

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