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Effect of Seed Hardening and Foliar Application of Growth Substances on Morpho-biochemical Parameters of Groundnut (*Arachis hypogaea* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. This study is a component of author KUP's doctoral thesis research project. Authors, KUP, SJM, and AAS, collaborated on the work, Author, KBC did research analysis and wrote the manuscript. Author KUP collected and analyzed the data, did formal analysis and wrote the manuscript. Author SJM designed the study. Author AAS guided the work procedures. All authors read and approved the final manuscript.

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ABSTRACT

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. Leaf dry weight and stem dry were significantly maximum with GA_3-150 mg/L seed hardening treatment. Meanwhile, total dry weight, protein content, oil content and anti-oxidant activity were found significantly higher in seed hardening with GA_3-100 mg/L while these morphological parameters were found significantly positive result after application of foliar spray of CCC @500 mg/L as compared to control which helps to increases the quality of groundnut.

Keywords: Seed hardening; GA3; foliar spray; CCC; dry weight; protein; oil; chlorophyll; total anti-oxidant activity.

1. INTRODUCTION

Groundnut is one of the most important leguminous crops, cultivated primarily as a food and feed source around the world [1]. It is an important legume crop in tropical and semi-arid areas, where it serves as a source of protein and edible oil. Groundnut kernels contain between 16% and 36% protein, between 36% and 54% oil and between 10% and 20% carbohydrates [2].

With annual all season coverage of about 70 lakh hectares, globally India ranks first in groundnut in acreage and with an output of approx. 80-85 lakh MT (in shell groundnuts), second in production.Groundnut is cultivated on 32.72 million ha, with an annual production of 53.93 million tons worldwide [3]. It is cultivated primarily as a rain-fed crop in the semi-arid tropics and sub-tropical regions where recurrent drought is widespread. 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 [4]. The country has exported 638,582.96 MT of groundnuts to the world for the worth of Rs. 5381.61 crores/ 727.35 USD Millions during the year 2020-21. About 85 % of the total groundnut in India is sown in the *kharif* season under rainfed conditions. Summer cultivation of groundnut is mainly taken in the states of Tamil Nadu, Andhra Pradesh, Karnataka, Gujarat and Maharashtra states.

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 [5]. Further, Seed priming/ hardening is a common practice followed to improve seed performance with respect to rate and consistency of germination [6].

Hardening of seeds resulted in the absorption of more water due to increase in the elasticity of the cell wall and development of a stronger and efficient root system [7]. Increased germination rate and uniformity have been attributed to metabolic repair processes occurring during imbibition, by enhancing metabolites [8] and reduced imbibition lag time [9], quick recovery of hardened plants from wilting than those from untreated plants, induction of resistance to salinity and drought situation, ability of seeds to withstand higher temperature for prolonged period, slight acceleration of flowering and capacity to compete more efficiently with weeds due to early emergence and finally resulting in higher yield.

Chlorocholine chloride (CCC) is one of the best-known substances that inhibits growth. It is a 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 [10]. Its action is an inhibition of choline metabolism included in lipid composition which effectively stops the growth elongation and increases the intensity of growth in width of the plants. The efficiency of the substance depends on its concentration in the species, the development phase of the plant, the method of application of the substance as well as external conditions [11].

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, consisting of nine levels of seed hardening treatments and two levels of foliar spray, were included in the study. Consequently, these eighteen treatment combinations with two factors were organized using a factorial randomized block design with three replications. The details of the treatments along with their symbols are provided below.

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

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 litters was prepared. Spraying was carried out at 35 and 55 DAS in respective plots during both seasons.

2.4 Morphological Parameters

2.4.1 Leaf dry weight (g)

Leaf dry weight of uprooted five randomly selected plant was measured for each treatment at 30, 50, 70, and 90 DAS and at harvest.

2.4.2 Stem dry weight (g)

Stem dry weight of uprooted five randomly selected was measured for each treatment at 30, 50, 70, and 90 DAS and at harvest.

2.4.3 Total dry weight (g)

Randomly selected five plants were taken for observing periodical changes in plant dry biomass of groundnut. The plants uprooted and sun dried for five to seven days until a constant weight was obtained and weighed on weighing balance.

2.4.4 Chlorophyll content of leaves at different duration (SPAD)

Total chlorophyll content was obtained by the SPAD (Soil plant analytical development) meter. The SPAD meter utilized was the OPTI-SCIENCE CCM-200 plus model. Randomly three leaves were taken from lower, middle and upper portions of the five tagged plants and their average was recorded as amount of total chlorophyll content present at 30, 50, 70, 90 DAS and at harvest for each treatment.

2.5 Biochemical Parameters

2.5.1 Protein content of seeds

The estimation of protein content of seed after harvest was done in the laboratory, Department of Biochemistry, Anand Agricultural University, Anand by following proper procedure. Protein content from seed powder was estimated as per the method described by Horwitz et al. [12].

2.5.2 Total anti-oxidant activity

Antioxidant activity was measured using ferric reducing antioxidant power (FRAP) method as described by Arnao et al. [12]. Leaf samples that were taken at 65 DAS and at harvest were used for the experiment.

2.5.3 Oil content of seed (%)

Soxhlet extraction method was used for the estimation of oil content of the groundnut seed. 10 g of groundnut seeds were extracted for 8 hr. with petroleum ether 60-80°C. The solvent was distilled out and the flasks were then transferred to an oven maintained at 80°C for 24 hr. The flasks were removed from the oven and kept in a desiccator until it comes to room temperature. The flasks were weighed and percent oil was calculated as,

$$\text{Oil (\%)} = \frac{Weight\ of\ Flask + Oil - Weight\ of\ flask}{Weight\ of\ sample\ (g)}$$

Table 1. Details of treatment combinations

Sr.No.	Treatment	Treatment combinations details
1	A1B1	$CaCl_2$ 1% seed hardening + Control (No foliar spray)
2	A2B1	Ethrel-50 mg/L seed hardening + Control (No foliar spray)
3	A3B1	Ethrel-100 mg/L seed hardening + Control (No foliar spray)
4	A4B1	Ethrel-150 mg/L seed hardening + Control (No foliar spray)
5	A5B1	GA_3-50 mg/L seed hardening + Control (No foliar spray)
6	A6B1	GA_3-100 mg/L seed hardening + Control (No foliar spray)
7	A7B1	GA_3-150 mg/L seed hardening + Control (No foliar spray)
8	A8B1	Soaking in water seed hardening + Control (No foliar spray)
9	A9B1	Control (Without hardening) + Control (No foliar spray)
10	A1B2	$CaCl_2$ 1% seed hardening + CCC 500 mg/L foliar spray
11	A2B2	Ethrel 50 mg/L seed hardening + CCC 500 mg/L foliar spray
12	A3B2	Ethrel 100 mg/L seed hardening + CCC 500 mg/L foliar spray
13	A4B2	Ethrel 150 mg/L seed hardening + CCC 500 mg/L foliar spray
14	A5B2	GA_3 50 mg/L seed hardening + CCC 500 mg/L foliar spray
15	A6B2	GA_3 100 mg/L seed hardening + CCC 500 mg/L foliar spray
16	A7B2	GA_3 150 mg/L seed hardening + CCC 500 mg/L foliar spray
17	A8B2	Soaking in water seed hardening + CCC 500 mg/L foliar spray
18	A9B2	Control (Without hardening) + CCC 500 mg/L foliar spray

3. RESULTS AND DISCUSSION

3.1 Effect of Seed Hardening on Morphological Parameters

3.1.1 Effect of seed hardening on leaf dry weight (g)

In the present investigation (Table 2), leaf dry wt. indicated significant differences at 30, 50, 70, 90 DAS and at harvest due to seed hardening treatments over absolute control. It was noted that seed hardening with GA_3-150 mg/L (A7) recorded higher dry leaf wt. (0.64, 1.82 and 1.23 g) at 30 DAS, (2.60, 6.24 and 4.42 g) at 50 DAS, (15.47, 13.14 and 14.31 g) at 70 DAS, (22.65, 14.78, 18.72 g) at 90 DAS and (23.35, 5.40 and 14.38 g) at harvest during summer, *kharif*, 2022 and pooled analysis, respectively.

Above results findings that seed hardening treatments increase the leaf dry weight. Significant increase in dry matter production by the application of seed hardening phytohormones might be due to enhance source to sink relationship, accumulation of photosynthate and efficient utilization of food reserves for retention of flowers and fruits which resulted into reduced leaf, flower and pod shedding and retention of a greater number of leaves, flower and pods [13].

3.1.2 Effect of seed hardening on stem dry weight (g)

Result illustrated in Table 3, showed significant difference among different seed hardening treatments at 30, 50, 70, 90 DAS and at harvest. Significantly higher stem dry wt. (0.42 g) was observed in GA_3-150 mg/L (A7) during summer, 2022 while GA_3-100 mg/L (A6) recorded higher stem dry wt. (1.21 and 0.80 g) in *kharif* and pooled results respectively. Meanwhile the significantly higher stem dry weight (2.01, 2.38 and 2.19 g) at 50 DAS, (8.48, 9.95 and 9.71 g) at 70 DAS, (8.67, 10.17 and 9.32 g) at 90 DAS and (9.15, 10.40 and 9.77 g) at harvest were recorded with GA_3-150 mg/L (A7) during the summer and *kharif*, 2022 and in pooled data, respectively.

3.1.3 Effect of seed hardening on total dry weight (g)

As mentioned in Table 4 indicated that the significantly higher total dry weight at 30, 50, 70, 90 DAS as well as at harvest in both the seasons, 2022 and pooled data. The significantly higher total dry weight (1.21, 3.24 and 2.22 g) at 30 DAS, (5.51, 9.01 and 7.26 g) at 50 DAS, (46.74, 36.31 and 41.52 g) at 70 DAS, (68.93, 57.30 and 63.11 g) at 90 DAS and (46.74, 36.31 and 41.52 g) at harvest were recorded with GA_3-100 mg/L (A6) seed hardening treatment in the summer, *kharif*-2022 and pooled data, respectively.

The amount of total dry matter produced is an indication of the overall efficiency of utilization of resources and better interception of light. The partitioning of total dry matter in leaf, stem and reproductive parts varied significantly due to plant growth substance treatments. The data pertaining to total dry weight indicated that it increased continuously from 30 DAS to harvest. This result is similar with Jeyakumar and Thangraj [14] in groundnut and Lone [15] in *Brassica juncea* cultivars.

3.1.4 Effect of seed hardening on chlorophyll content of leaves

The chlorophyll content of leaves at 30 DAS (Table 5) affects significantly due to seed hardening treatments during the summer and *kharif*, 2022, as well as in the pooled results. A6, GA_3-100 mg/L seed hardening (18.23) showed higher chlorophyll content during summer-2022 while, GA_3-150 mg/L seed hardening (A7) recorded maximum chlorophyll content (15.68 and 15.90) during *kharif*, 2022 and pooled analysis for 30 DAS. Seed hardening with $CaCl_2$ 1 % (A1) recorded higher chlorophyll content (18.13) during summer, 2022. GA_3-100 mg/L seed hardening (A6) (20.77, 18.33) showed maximum chlorophyll content during *kharif*-2022 and pooled basis at 50 DAS. At 70 DAS, GA_3-100 mg/L seed hardening recorded higher chlorophyll content (22.04) during summer, 2022 while GA_3-150 mg/L seed hardening (24.79, 23.25) showed maximum chlorophyll content during *kharif*-2022 and in pooled result. The significantly higher chlorophyll content of leaves at 90 DAS (25.50, 25.67 and 24.89) was recorded with ethrel-50 mg/L, GA_3-100 mg/L and ethrel-100 mg/L during both seasons and pooled data, respectively while at harvest (27.54, 25.43 and 25.08), it was recorded in seed hardening with $CaCl_2$ 1%, GA_3-100 mg/L and ethrel-50 mg/L during the summer and *kharif,* 2022 and in pooled data, respectively.

In the present investigation, all the growth substances treated plants contained higher chlorophyll content than control.

3.2 Effect of Seed Hardening on Biochemical Parameters

3.2.1 Effect of seed hardening on protein content of seeds (%)

Result of protein content showed the non-significant difference among the different seed hardening treatments.

3.2.2 Effect of seed hardening on oil content of seeds (%)

An examination of data given in Table 6 indicated that the oil content was found non-significant with seed hardening.

3.2.3 Effect of seed hardening on total anti-oxidant activity (%)

Total anti-oxidant activity at 65 DAS and at harvest as influenced by seed hardening during two consecutive seasons of 2022, and in pooled mean is depicted in Table 6. Significantly higher antioxidant activity (1.77 %) was observed under GA_3-100 mg/L (A6) seed hardening treatment during summer for 65 DAS. Meanwhile, ethrel-150 mg/L seed hardening recorded higher antioxidant activity (1.68 %) which was at par with GA_3-150 mg/L (1.65 %) seed hardening treatment during *kharif*, 2022. In pooled analysis, GA_3-100 mg/L (A6) seed hardening treatment noted maximum antioxidant activity (1.71 %) for 65 DAS. Data (Table 6) clearly indicated that the significantly higher total antioxidant activity at harvest (1.43, 1.36 and 1.39 %) was recorded with A6, GA_3-100 mg/L seed hardening during the both seasons, 2022 and in pooled data, respectively.

In general, seed hardening with various growth substances increases antioxidant activity. From the above result, it was observed that antioxidant content varied with different seed hardening treatment because of its chemical composition as well as concentration. Antioxidant activity was observed higher in GA_3 treated seeds may be due to GA_3 improved the activities of amylase in the aleurone layer, carbohydrate metabolizing enzymes and also antioxidant defence system.

3.3 Effect of Foliar Spray of CCC on Morphological Parameters

3.3.1 Effect of foliar spray of CCC on leaf dry weight (g)

A perusal of data presented in Table 2 indicated that the significantly lower leaf dry weight (16.18, 11.42 and 13.20 g) at 50 DAS, (11.86, 10.29 and 11.07 g) at 70 DAS, (16.18, 11.42 and 13.20 g) at 90 DAS and (17.52, 4.23 and 10.88 g) at harvest was recorded with foliar spraying of CCC @500 mg/L (B2) during both the seasons and in pooled analysis, respectively.

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

	Leaf Dry Weight (g)														
	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	0.43	1.68	1.06	2.29	5.63	3.96	12.59	10.67	11.63	18.42	12.70	15.56	19.64	4.80	12.22
A2	0.43	1.70	1.07	2.45	5.83	4.14	13.41	10.94	12.18	20.28	12.78	16.53	21.88	4.88	13.38
A3	0.45	1.73	1.09	2.46	5.96	4.21	14.18	11.22	12.70	20.36	12.95	16.66	21.91	4.95	13.43
A4	0.55	1.79	1.17	2.51	6.12	4.32	15.04	12.29	13.67	21.13	13.68	17.41	22.43	5.05	13.74
A5	0.47	1.75	1.11	2.50	6.10	4.30	14.87	11.68	13.28	21.09	13.65	17.37	22.34	5.04	13.69
A6	0.56	1.81	1.19	2.53	6.14	4.34	15.11	12.93	14.02	21.54	13.73	17.64	22.74	5.24	13.99
A7	0.64	1.82	1.23	2.60	6.24	4.42	15.47	13.14	14.31	22.65	14.78	18.72	23.35	5.40	14.38
A8	0.46	1.74	1.10	2.47	6.10	4.29	14.51	11.35	12.93	20.65	13.57	17.11	21.91	4.97	13.44
A9	0.33	1.62	0.98	2.16	5.20	3.68	12.56	9.22	10.89	17.00	11.87	14.44	19.09	4.72	11.91
S.Em.(±)	0.019	0.069	0.036	0.077	0.187	0.101	0.465	0.356	0.293	0.391	0.367	0.268	0.434	0.139	0.228
C.D.$_{(0.05)}$	0.055	0.198	0.101	0.222	0.537	0.285	1.336	1.022	0.826	1.125	1.055	0.757	1.248	0.487	0.644
Foliar Spray (B)															
B1	0.49	1.74	1.12	2.94	7.29	5.12	16.11	13.12	14.61	24.51	15.19	19.85	25.88	5.78	15.83
B2	0.48	1.73	1.10	1.94	4.58	3.26	11.86	10.29	11.07	16.18	11.42	13.80	17.52	4.23	10.88
S.Em.(±)	0.009	0.033	0.017	0.036	0.088	0.048	0.219	0.168	0.138	0.185	0.173	0.126	0.205	0.066	0.107
C.D.$_{(0.05)}$	NS	NS	NS	0.105	0.253	0.135	0.630	0.482	0.389	0.530	0.497	0.357	0.589	0.188	0.303
Interaction															
AxS	-	-	NS	-	-	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.(%)	9.74	9.73	11.18	7.74	7.71	8.36	8.14	7.44	7.89	4.71	6.76	5.52	4.90	6.80	5.92

**Sig.–Significant, NS-Non Significant*

Table 3. Effect of seed hardening and foliar spray on stem dry weight in groundnut during summer and *kharif*, 2022 as well as in pooled analysis

	Stem Dry Weight (g)														
	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	0.39	1.17	0.78	1.87	2.03	1.95	7.17	8.05	7.61	7.19	8.94	8.06	8.32	9.68	9.00
A2	0.38	1.14	0.76	1.80	2.03	1.92	5.99	6.32	6.16	7.46	9.46	8.46	8.03	9.77	8.89
A3	0.38	1.14	0.76	1.84	2.01	1.92	6.12	6.39	6.25	6.87	9.22	8.04	7.56	9.65	8.61
A4	0.37	1.17	0.77	1.63	1.99	1.81	5.68	6.32	6.00	6.31	9.08	7.69	7.89	9.67	8.78
A5	0.38	1.15	0.77	1.65	2.03	1.84	6.66	6.08	6.37	7.30	8.29	7.79	8.30	9.40	8.85
A6	0.40	1.21	0.80	1.83	1.94	1.88	7.05	9.11	8.58	8.31	9.53	8.92	8.39	9.93	9.16
A7	0.42	1.17	0.79	2.01	2.38	2.19	8.48	9.95	9.71	8.67	10.17	9.32	9.15	10.40	9.77
A8	0.37	1.09	0.73	1.97	2.08	2.02	5.88	6.68	6.28	8.05	8.92	8.48	8.45	9.85	9.15
A9	0.35	0.90	0.62	1.87	2.10	1.98	4.15	6.31	5.23	7.37	9.14	7.90	8.02	9.66	8.85
S.Em.(±)	0.008	0.035	0.018	0.053	0.061	0.040	0.195	0.332	0.193	0.384	0.795	0.441	0.342	1.307	0.675
C.D.(0.05)	0.023	0.101	0.051	0.152	0.174	0.113	0.559	0.955	0.543	1.103	2.286	1.245	0.983	3.757	1.906
Foliar Spray (B)															
B1	0.39	1.13	0.76	1.91	2.24	2.08	7.18	8.47	7.83	8.12	9.57	8.85	9.11	10.49	9.80
B2	0.38	1.13	0.75	1.75	1.89	1.82	5.08	6.46	5.77	6.67	8.82	7.75	7.34	9.06	8.21
S.Em.(±)	0.004	0.017	0.008	0.025	0.029	0.019	0.092	0.157	0.091	0.181	0.375	0.208	0.161	0.616	0.318
C.D.(0.05)	NS	NS	NS	0.071	0.082	0.053	0.264	0.450	0.256	0.520	1.078	0.587	0.464	1.771	0.899
Interaction															
AxS	-	-	Sig.	-	-	NS	-	-	Sig.	-	-	Sig.	-	-	NS
BxS	-	-	NS	-	-	Sig.	-	-	Sig.	-	-	NS	-	-	NS
AxB	NS	NS	NS	Sig.	Sig.	Sig.	NS	NS	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
AxBxS	-	-	NS	-	-	NS	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	5.08	7.61	8.24	7.05	7.19	7.15	7.77	10.90	9.81	12.55	11.44	12.48	10.46	10.90	12.52

Table 4. Effect of seed hardening and foliar spray on total dry weight in groundnut during summer and *kharif,* 2022 as well as in pooled analysis

	Total Dry Weight (g)														
	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	0.97	2.99	1.98	4.41	8.01	6.21	30.12	26.32	28.22	51.64	44.36	48.00	73.37	58.04	65.70
A2	1.03	3.01	2.02	4.57	8.12	6.34	32.30	26.44	29.37	52.54	44.32	48.43	76.24	59.79	68.01
A3	1.03	3.03	2.03	4.78	8.45	6.61	34.55	28.65	31.6	54.84	45.09	49.96	78.68	60.13	69.40
A4	1.11	3.11	2.11	4.87	8.56	6.71	42.29	32.97	37.63	63.35	49.79	56.57	84.33	63.25	73.79
A5	1.05	3.07	2.06	4.83	8.55	6.69	39.91	32.16	36.03	60.96	49.18	55.07	81.34	64.19	72.76
A6	1.21	3.24	2.22	5.51	9.01	7.26	46.74	36.31	41.52	68.93	57.30	63.11	93.66	82.29	87.97
A7	1.13	3.13	2.13	5.32	8.59	6.95	43.91	33.35	38.63	64.52	50.83	57.67	85.98	75.53	80.75
A8	1.04	3.05	2.04	4.81	8.48	6.64	37.29	29.60	33.44	56.34	46.02	51.18	80.14	61.06	70.6
A9	0.93	2.81	1.87	4.40	7.61	6.00	29.09	25.32	27.20	49.41	44.78	47.09	73.21	57.02	65.11
S.Em.(±)	0.036	0.083	0.045	0.197	0.365	0.207	1.176	0.610	0.662	1.749	1.084	1.029	1.811	1.638	1.221
C.D.(0.05)	0.104	0.240	0.128	0.567	1.049	1.159	3.381	1.752	1.870	5.028	3.114	2.904	5.205	4.709	3.446
Foliar Spray (B)															
B1	1.06	3.06	2.06	3.65	6.85	6.43	30.77	27.22	28.99	51.86	44.08	47.97	70.39	58.06	64.22
B2	1.06	3.04	2.05	6.02	9.90	6.77	43.87	34.58	39.23	63.93	52.01	57.97	91.16	71.12	81.14
S.Em.(±)	0.017	0.039	0.021	0.093	0.172	0.098	0.555	0.287	0.312	0.825	0.511	0.485	0.854	0.772	0.576
C.D.(0.05)	NS	NS	NS	0.267	0.494	0.276	1.594	0.826	0.881	2.370	1.468	1.369	2.454	2.220	1.624
Interaction															
AxS	-	-	NS	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.
BxS	-	-	NS	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.
AxB	NS	NS	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
AxBxS	-	-	NS	-	-	NS	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	8.40	6.70	7.67	10.00	10.69	10.89	8.36	4.89	7.06	7.96	5.63	7.06	6.32	6.59	6.45

Table 5. Effect of seed hardening and foliar spray on chlorophyll content of leaves (SPAD) in groundnut summer and *kharif*, 2022 as well as in pooled analysis

	Chlorophyll Content (SPAD)														
	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	13.54	10.51	12.03	18.13	15.16	16.64	21.14	18.79	19.96	23.63	23.25	24.36	22.51	22.38	22.44
A2	14.33	11.71	13.02	17.64	16.57	17.11	21.51	21.44	21.47	25.50	24.28	24.89	26.94	23.22	25.08
A3	12.75	12.58	12.67	15.89	16.63	16.26	21.98	20.48	21.23	24.85	24.32	24.58	26.54	22.71	24.63
A4	11.37	15.39	13.38	16.66	18.43	17.55	21.84	23.75	22.80	24.18	25.10	24.64	21.63	24.45	23.04
A5	12.34	11.50	11.92	16.67	17.80	17.24	22.47	21.86	22.17	24.41	24.63	24.52	22.87	23.75	23.31
A6	18.23	13.39	15.81	17.73	20.77	19.25	22.04	24.36	23.20	25.46	25.67	25.56	27.54	25.43	26.48
A7	16.11	15.68	15.90	15.23	19.49	17.36	21.71	24.79	23.25	20.01	25.53	22.77	21.79	25.36	23.58
A8	13.36	10.40	11.88	16.15	16.16	16.16	20.39	18.62	19.51	24.02	22.79	23.41	23.97	22.14	23.05
A9	13.58	8.66	11.12	17.47	13.54	15.50	21.16	18.19	19.67	25.11	20.38	22.74	25.65	21.86	23.76
S.Em.(±)	0.296	0.363	0.234	0.308	0.294	0.213	0.339	0.280	0.220	0.367	0.630	0.364	0.672	0.834	0.535
C.D.$_{(0.05)}$	0.850	1.044	0.661	0.885	0.845	0.601	0.973	0.803	0.620	1.055	1.809	1.028	1.931	2.397	1.511
Foliar Spray (B)															
B1	13.80	12.14	12.97	14.30	14.22	14.26	18.54	18.04	18.29	21.63	20.59	21.11	22.15	21.05	21.60
B2	14.11	12.27	13.19	19.38	20.12	19.75	24.62	24.69	24.65	26.63	27.39	27.01	26.61	25.91	26.26
S.Em.(±)	0.139	0.171	0.110	0.145	0.139	0.100	0.160	0.132	0.104	0.173	0.297	0.172	0.317	0.393	0.252
C.D.$_{(0.05)}$	NS	NS	NS	0.417	0.399	0.283	0.459	0.379	0.292	0.497	0.853	0.485	0.910	1.130	0.712
Interaction															
AxS	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.	-	-	Sig.
BxS	-	-	NS	-	-	Sig.	-	-	NS	-	-	Sig.	-	-	NS
AxB	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
AxBxS	-	-	NS	-	-	NS	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	5.19	7.29	6.20	4.48	4.20	4.34	3.84	3.21	3.54	3.73	6.43	5.25	6.75	8.70	7.75

Table 6. Effect of Seed hardening and foliar spray on protein content of seed, oil content, anti-oxidant activity at 65 DAS and anti-oxidant activity at harvest in groundnut summer and *kharif,* 2022 as well as in pooled analysis

	Protein (%)			Oil content (%)			Anti-oxidant Activity-65 DAS (%)			Anti-oxidant Activity-At harvest (%)		
	Summer	***kharif***	**Pooled**	**Summer**	***kharif***	**Pooled**	**Summer**	***kharif***	**Pooled**	**Summer**	***kharif***	**Pooled**
Seed Hardening (A)												
A1	23.06	22.84	22.95	50.74	50.93	50.84	0.68	0.66	0.67	0.51	0.46	0.48
A2	23.37	23.13	23.25	50.94	50.50	50.72	1.29	1.18	1.23	0.92	0.88	0.90
A3	23.05	22.90	22.98	50.90	50.94	50.92	1.04	0.95	0.99	0.54	0.59	0.57
A4	23.28	23.15	23.22	50.94	50.47	50.70	1.71	1.68	1.70	1.34	1.28	1.31
A5	23.31	23.15	23.23	50.94	50.61	50.77	1.42	1.36	1.39	1.02	0.97	0.99
A6	23.79	23.16	23.48	52.30	52.14	52.22	1.77	1.65	1.71	1.43	1.36	1.39
A7	23.52	23.00	23.26	51.11	50.21	50.66	1.66	1.56	1.61	1.28	1.21	1.25
A8	23.14	23.15	23.14	50.93	50.81	50.87	1.11	1.07	1.09	0.59	0.63	0.61
A9	23.08	22.67	22.87	50.26	49.61	49.93	0.45	0.44	0.44	0.35	0.35	0.35
S.Em.(±)	0.464	0.526	0.351	0.425	0.509	0.331	0.013	0.021	0.012	0.023	0.017	0.014
C.D.$_{(0.05)}$	NS	NS	NS	NS	NS	NS	0.037	0.061	0.035	0.067	0.048	0.040
Foliar Spray (B)												
B1	22.87	22.61	22.74	50.71	49.05	49.88	1.16	1.09	1.13	0.85	0.83	0.84
B2	23.71	23.32	23.51	51.30	52.33	51.82	1.31	1.25	1.28	0.92	0.89	0.91
S.Em.(±)	0.219	0.248	0.165	0.200	0.240	0.156	0.006	0.010	0.006	0.011	0.008	0.007
C.D.$_{(0.05)}$	0.629	0.713	0.467	0.576	0.689	0.441	0.018	0.029	0.016	0.020	0.023	0.019
Interaction												
AxS	-	-	NS	-	-	NS	-	-	Sig.	-	-	Sig.
BxS	-	-	NS	-	-	Sig.	-	-	NS	-	-	Sig.
AxB	NS	NS	NS	NS	NS	NS	Sig.	Sig.	Sig.	NS	NS	NS
AxBxS	-	-	NS	-	-	NS	-	-	NS	-	-	NS
C.V.(%)	4.88	5.61	5.26	2.04	2.46	2.26	2.58	4.42	3.57	6.44	4.76	5.69

After CCC spraying, leaf dry weight was gradually decreased due to decreased number of leaves or reduced vegetative growth of plant after growth retardant application. The amount of leaf dry matter produced is an indication of the overall efficiency of utilization of resources and better interception of light. The data indicate decreased trends of leaf dry weight toward maturity due to partitioning of total dry matter of leaf in reproductive parts of plant significantly due to the growth regulator treatments [16].

3.3.2 Effect of foliar spraying of CCC on stem dry weight (g)

Analysis of data furnished in Table 3 indicated that the stem dry weight at 30 DAS was non significantly affected by the foliar spray of CCC @500 mg/L.

Significantly lower stem dry wt. (1.75, 1.89 and 1.82 g) at 50 DAS, (5.08, 6.46 and 5.77 g) at 70 DAS, (6.67, 8.82 and 7.75 g) at 90 DAS and (7.34, 9.06 and 8.21 g) at harvest was observed after foliar application of CCC @500 mg/L during summer, *kharif* and pooled basis as compared to control.

This decline in stem dry weight of crops might be due to translocation of stored photosynthates towards reproductive organs. The data indicate decreased trends of stem dry weight toward maturity due to partitioning of total dry matter of stem in reproductive parts of plant significantly due to the growth substance treatments [16].

3.3.3 Effect of foliar spraying of CCC on total dry weight (g)

The data presented in Table 4 indicated that the significantly higher total dry weight at 50 DAS (6.02, 6.85 and 6.43 g), 70 DAS (43.87, 34.58 and 39.23 g), 90 DAS (63.93, 52.01 and 57.97 g) and at harvest (91.16, 71.12 and 81.14 g) was recorded with foliar application of CCC @500 mg/L (B2) during both the seasons and in pooled analysis, respectively.

3.3.4 Effect of foliar spraying of CCC on chlorophyll content of leaves (SPAD)

A perusal of data presented in Table 5 indicated that the significantly higher chlorophyll content of leaves at 50 DAS (19.38, 20.12 and 19.75), 70 DAS (24.62, 24.69 and 24.65), 90 DAS (26.63, 27.39 and 27.01) and at harvest (26.61, 25.91 and 26.26) was recorded with foliar application of CCC @500 mg/L (B2) during both the seasons and in pooled analysis, respectively as compared to control (B1).

The application of CCC in groundnut resulted in higher chlorophyll content without any modification of leaf anatomy and decreased chlorophyll degradation. The delay in leaf senescence could also be attributed to higher chlorophyll content. These results are in accordance with Jeyakumar and Thangaraj [14] in groundnut, Khaswan et al*.* [17] in Soybean, Saini et al*.* [18] in groundnut.

3.4 Effect of Foliar Spray of CCC on Biochemical Parameters

3.4.1 Effect of foliar spray of CCC on protein content of seeds (%)

The protein content recorded in groundnut crop was found significant differences among the foliar spray treatment. Significantly higher protein content was registered in the B2, foliar application (23.71, 23.32 and 23.51 %) during summer, *kharif* and pooled basis as compared to seed without treated with foliar spray.

The increase in protein content may be caused by the role of growth retardant CCC in protein synthesis, encouraging the conversion of amino acids into protein. The present results obtained are in accordance with the work of Nagarjun and Radder [19] who also finds increases in protein content in Spanish improved peanut due to foliar spray of plant hormone and Paterson et al. [20] who did not observe any degradation of protein with the plant hormone application. These results are in accordance with Karkar et al*.* [21] in groundnut, Kumar et al*.*, [22] in soybean, Nigania et al. [23] in groundnut and Manu et al. [24] in soybean.

3.4.2 Effect of foliar spraying of CCC on oil content of seeds (%)

Oil content of seed (Table 6) was found significant with the foliar application in both the seasons and pooled analysis. B2, foliar application with CCC @500 mg/L showed higher oil content (51.30, 52.33 and 51.82 %) during summer, *kharif* and pooled result.

Increased oil per cent in seeds could be due to increased accumulation of hexose sugars at the time of triacylglycerol synthesis. The increase in the oil content might be due to CCC increases the greater availability and translocation of mineral elements, especially sulphur which was directly involved in biosynthesis of oil. These results are in accordance with Rao [25] in groundnut, Reddy and Patil [26] in groundnut, Bramhankar et al*.* [27] in soybean and Manu et al*.* [24] in soybean.

3.4.3 Effect of foliar spraying of CCC on total anti-oxidant activity (%)

Total anti-oxidant activity at 65 DAS (Table 6) was recorded significantly higher (1.31, 1.25 and 1.28 %) with foliar spray of CCC @500 mg/L (B2) during summer, *kharif* and pooled result, respectively. Significantly (Table 6) higher total anti-oxidant activity at harvest (0.92, 0.89 and 0.91 %) was recorded with foliar spray @500 mg/L (B2) during the both seasons and pooled analysis.

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

3.5.1 Interaction effect of seed hardening and foliar spray of CCC on leaf dry weight (g)

Interaction effect (Table 2) of seed hardening and foliar spray of CCC was found non-significant with respect to leaf dry weight at 30, 50, 70, 90 DAS and at harvest during individual season as well as pooled basis.

3.5.2 Interaction effect of seed hardening and foliar spray of CCC on stem dry weight (g)

Interaction between seed hardening with GA_3-150 mg/L and without foliar spray of CCC (A7B1) recorded higher stem dry wt. (2.35, 2.87 and 2.61 g) during summer, *kharif* and pooled basis for 50 DAS which was at par with A6B1 (2.17 g) during summer, 2022 (Table 7). Similarly seed hardening with GA_3-150 mg/L without foliar spray of CCC (A7B1) showed higher stem dry wt. (9.46, 10.66 and 10.06 g) during both seasons as well as in pooled result respectively for 90 DAS (Table 8). Meanwhile, significantly lower stem dry weight at harvest (6.54, 8.88 and 7.71 g) was noted in treatment combination of seed hardening with GA_3-100 mg/L with foliar spray of CCC (A6B2) during summer while GA_3-150 mg/L without foliar application (A7B1) recorded higher stem dry wt. (10.94, 11.88 and 11.41 g) during summer and *kharif*, 2022 as well as pooled basis at harvest (Table 9).

3.5.3 Interaction effect of seed hardening and foliar spray of CCC on total dry weight (g)

Interaction effect (Table 10, 11, 12, 13) of seed hardening and foliar spray (A×B) was found significant with respect to total dry weight at 50, 70, 90 DAS and at harvest. Interaction between A6B2, GA_3-100 mg/L seed hardening with foliar application of CCC @500 mg/L value (8.05, 11.42 and 9.74 g) at 50 DAS, (51.82, 42.35 and 47.14 g) at 70 DAS, (73.13 62.98 and 68.05 g) at 90 DAS and (100.86, 92.91 and 96.89 g) at harvest recorded significantly maximum total dry wt. during both seasons, 2022 and pooled results respectively at 50 DAS.

3.5.4 Interaction effect of seed hardening and foliar spray of CCC on chlorophyll content of leaves (SPAD)

Interaction effect (Table 5) seed hardening and foliar spray of CCC was found non-significant with respect to chlorophyll content of leaves at 30, 50, 70, 90 DAS and at harvest during individual season as well as pooled basis.

3.5.5 Interaction effect of seed hardening and foliar spray of CCC on protein and oil content of seeds (%)

Data shown in Table showed that the interaction effect of seed hardening and foliar spray of CCC @500 mg/L on protein content of seed and oil content was found to be non-significant during both the season, 2022 and pooled results.

3.5.6 Interaction effect of seed hardening and foliar spray of CCC on total anti-oxidant activity (%)

Interaction effect (Table 14) of seed hardening and foliar spray was found significant with respect to total anti-oxidant activity at 65 DAS during individual season as well as pooled basis. Significantly higher anti-oxidant activity (1.89, 1.83 and 1.86 %) was observed in GA_3-100 mg/L seed hardening and with foliar spray of CCC @500 mg/L (A6B2) during summer, *kharif* and pooled basis respectively while interaction effect was found non-significant with respect to total anti-oxidant activity at harvest during individual season as well as pooled basis.

Table 7. Interaction effect between seed hardening and foliar spray on stem dry weight at 50 DAS during summer and *kharif*, 2022 as well as in pooled analysis

	Stem Dry Weight (g) – 50 DAS					
	Summer, 2022		***Kharif*, 2022**		**Pooled**	
A×B	B1	B2	B1	B2	B1	B2
A1	1.79	1.95	2.11	1.95	1.95	1.95
A2	1.77	1.84	2.14	1.91	1.95	1.88
A3	1.85	1.83	2.14	1.88	1.99	1.85
A4	1.77	1.48	2.20	1.78	1.99	1.63
A5	1.76	1.55	2.21	1.86	1.99	1.70
A6	2.17	1.49	2.19	1.69	2.18	1.59
A7	2.35	1.68	2.87	1.88	2.61	1.78
A8	1.97	1.97	2.21	1.95	2.09	1.96
A9	1.75	2.00	2.12	2.07	1.94	2.03
S.Em(±)	0.075		0.086		0.057	
$CD_{(0.05)}$	0.214		0.247		0.160	
CV (%)	7.05		7.19		7.15	

Table 8. Interaction effect between seed hardening and foliar spray on stem dry weight at 90 DAS during summer and *kharif*, 2022 as well as in pooled analysis

	Stem Dry Weight (g) – 90 DAS					
	Summer, 2022		***Kharif*, 2022**		**Pooled**	
A×B	B1	B2	B1	B2	B1	B2
A1	8.85	5.52	9.42	8.46	9.14	6.99
A2	8.18	6.73	9.45	9.47	8.82	8.10
A3	7.59	6.14	8.71	9.73	8.15	7.94
A4	7.03	5.58	10.46	7.71	8.75	6.65
A5	8.02	6.57	8.78	7.79	8.40	7.18
A6	9.21	7.40	10.03	9.04	9.62	8.22
A7	9.46	7.47	10.66	9.67	10.06	8.57
A8	8.77	7.32	10.12	7.71	9.45	7.52
A9	5.97	7.36	8.50	9.78	7.24	8.57
S.Em(±)	0.543		1.125		0.624	
$CD_{(0.05)}$	1.559		3.233		1.762	
CV (%)	12.55		11.44		12.48	

Table 9. Interaction effect between seed hardening and foliar spray on stem dry weight at harvest during summer and *kharif*, 2022 as well as in pooled analysis

	Stem Dry Weight (g) – At Harvest					
	Summer, 2022		***Kharif*, 2022**		**Pooled**	
A×B	B1	B2	B1	B2	B1	B2
A1	9.02	7.62	10.23	9.13	9.63	8.38
A2	8.73	7.32	10.33	9.21	9.53	8.27
A3	8.26	6.86	10.21	9.09	9.24	7.98
A4	8.59	7.19	10.21	9.12	9.40	8.16
A5	9.00	7.59	9.87	8.93	9.44	8.26
A6	10.24	6.54	10.98	8.88	10.61	7.71
A7	10.94	7.35	11.88	8.91	11.41	8.13
A8	9.15	7.74	10.58	9.12	9.87	8.43
A9	8.13	7.90	10.12	9.23	9.13	8.57
S.Em(±)	0.484		1.849		0.955	
$CD_{(0.05)}$	1.391		5.313		2.693	
CV (%)	10.46		10.90		12.52	

Table 10. Interaction effect between seed hardening and foliar spray on total dry weight at 50 DAS during summer and *kharif*, 2022 as well as in pooled analysis

	Total Dry Weight (g) – 50 DAS					
	Summer, 2022		***Kharif*, 2022**		**Pooled**	
A×B	B1	B2	B1	B2	B1	B2
A1	3.91	4.92	6.45	9.58	6.74	5.68
A2	4.49	4.66	6.84	9.41	6.95	5.75
A3	4.46	5.1	7.8	9.09	6.78	6.45
A4	3.32	6.42	8.51	8.62	5.97	7.46
A5	4.16	5.5	6.36	10.73	7.45	5.93
A6	2.96	8.05	7.68	11.42	6.65	9.74
A7	2.79	7.85	5.76	10.34	7.1	6.8
A8	3.15	6.48	7.3	9.65	6.4	6.89
A9	3.62	5.18	4.98	10.25	6.94	5.08
S.Em(±)	0.279		0.516		0.293	
$CD_{(0.05)}$	0.802		1.483		0.827	
CV (%)	10.00		10.69		10.89	

Table 11. Interaction effect between seed hardening and foliar spray on total dry weight at 70 DAS during summer and *kharif,* 2022 as well as in pooled analysis

	Total Dry Weight (g) – 70 DAS					
	Summer, 2022		***Kharif*, 2022**		**Pooled**	
A×B	B1	B2	B1	B2	B1	B2
A1	21.04	39.2	24.27	28.37	22.66	33.79
A2	27.33	37.27	21.36	31.52	24.34	34.39
A3	24.17	44.94	23.87	33.42	24.02	39.18
A4	38.42	46.17	31.93	34.01	35.17	40.09
A5	30.64	49.18	30.28	34.04	30.46	41.61
A6	40.95	51.92	30.27	42.35	35.61	47.14
A7	39.37	48.45	29.36	39.33	34.36	43.89
A8	33.41	41.17	27.35	31.85	30.38	36.51
A9	21.61	36.57	26.26	36.35	23.94	36.46
S.Em(±)	1.664		0.862		0.937	
$CD_{(0.05)}$	4.782		2.477		0.28	
CV (%)	8.36		4.89		9.73	

Table 12. Interaction effect between seed hardening and foliar spray on total dry weight at 90 DAS during summer and *kharif*, 2022 as well as in pooled analysis

	Total Dry Weight (g) – 90 DAS					
	Summer, 2022		***Kharif*, 2022**		**Pooled**	
A×B	B1	B2	B1	B2	B1	B2
A1	47.72	55.58	43.35	46.83	45.53	51.21
A2	43.72	61.36	41.62	47.03	42.67	54.19
A3	41.47	68.2	43.35	46.83	42.41	57.52
A4	58.51	68.2	42.27	57.32	50.39	62.76
A5	58.03	63.91	44.42	53.95	51.22	58.93
A6	64.73	73.13	51.58	62.98	58.16	68.05
A7	60.06	68.98	49.5	52.16	54.78	60.57
A8	51.32	61.36	41.05	50.99	46.18	56.17
A9	41.19	54.63	39.58	49.98	40.39	52.3
S.Em(±)	2.474		3.781		1.455	
$CD_{(0.05)}$	7.111		8.021		4.106	
CV (%)	7.96		5.63		7.06	

Table 13. Interaction effect between seed hardening and foliar application on total dry weight at harvest during summer and *kharif*, 2022 as well as in pooled analysis

	Total Dry Weight (g) – At harvest					
	Summer, 2022		***Kharif*, 2022**		**Pooled**	
A×B	B1	B2	B1	B2	B1	B2
A1	66.15	80.59	55.30	60.78	60.72	70.69
A2	59.68	92.8	55.20	64.38	57.44	78.59
A3	59.45	97.91	57.23	63.03	58.34	80.47
A4	76.30	92.36	51.75	74.75	64.02	83.56
A5	76.44	86.24	56.55	71.83	66.49	79.04
A6	86.46	100.86	71.67	92.91	79.06	96.89
A7	78.57	93.39	72.91	78.15	75.74	85.77
A8	70.91	89.37	52.88	69.24	61.90	79.30
A9	59.52	86.90	49.02	65.02	54.27	75.96
S.Em(±)	2.561		2.316		1.726	
$CD_{(0.05)}$	5.617		3.214		4.873	
CV (%)	6.31		6.58		6.45	

Table 14. Interaction effect between seed hardening and foliar application on total anti-oxidant activity at 65 DAS and at harvest during summer and *kharif*, 2022 and in pooled analysis

	Total Anti-oxidant Activity (%) At 65 DAS					
	Summer, 2022		***Kharif*, 2022**		**Pooled**	
A×B	B1	B2	B1	B2	B1	B2
A1	0.58	0.77	0.59	0.73	0.59	0.75
A2	1.25	1.32	1.15	1.21	1.20	1.27
A3	0.92	1.15	0.82	1.08	0.87	1.12
A4	1.54	1.83	1.52	1.70	1.53	1.78
A5	1.40	1.44	1.27	1.44	1.34	1.44
A6	1.70	1.89	1.60	1.83	1.65	1.86
A7	1.63	1.69	1.54	1.58	1.59	1.63
A8	1.05	1.16	1.00	1.13	1.02	1.15
A9	0.36	0.54	0.33	0.55	0.34	0.55
S.Em(±)	0.018		0.032		0.018	
$CD_{(0.05)}$	0.053		0.086		0.0494	
CV (%)	2.58		4.42		3.57	

4. CONCLUSION

The results of the study showed that GA_3-150 mg/L and GA_3-100 mg/L seed hardening treatments, as well as 500 mg/L of CCC applied externally as foliar spray, had a positive effect on groundnut morphological characteristics like leaf dry weight, stem dry weight, total dry weight, and chlorophyll content of leaves. Additionally, the applications of GA_3-100 mg/L seed hardening and foliar application of CCC at 500 mg/L significantly increased the protein content, oil content of seeds, and total anti-oxidant activity. In summary, farmers aiming to achieve higher quality yields were recommended to use GA_3 at 100 mg/L and Chlorocholine Chloride (CCC) at 500 mg/L by foliar spraying.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bediako KA, Ofori K, Offei SK, Dzidzienyo D, Asibuo JY, Amoah RA. Aflatoxin

contamination of groundnut (*Arachis hypogaea* L.): Predisposing factors and management interventions. Food Control. 2019;98:61-7. Available:https://doi.org/10.1016/j.foodcont.2018.11.020
2. Singh A, Raina SN, Sharma M, Chaudhary M, Sharma S, Rajpal VR. Functional uses of peanut (*Arachis hypogaea* L.) seed storage proteins. Grain and seed proteins functionality. 2021;121:142.
3. Faostat F. Food and agriculture organization of the United Nations. Statistical database; 2013.
4. 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.
5. Krishnotar B, Srivastava AK, Shahi JP. Response of rabi maize crop to seed invigoration with magnesium nitrate and distilled water. seeds. 2009;900:119.
6. De Lespinay A, Lequeux H, Lambillotte B, Lutts S. Protein synthesis is differentially required for germination in Poa pratensis and Trifolium repens in the absence or in the presence of cadmium. Plant Growth Regulation. 2010;61:205-14.
7. Krishnasamy V, Srimathi P. Seed Management of rainfed agriculture. Land and use planning and watershed management in rainfed agriculture (ed.) Balusamy M, Chinnamuthu CR, Velayutham A. Centre of advanced studies, department of agronomy, Tamilnadu Agricultural University, Coimbatore. 2001; 140.
8. Basra SM, Farooq M, Tabassam R, Ahmad N. Physiological and biochemical aspects of pre-sowing seed treatments in fine rice (Oryza sativa L.). Seed Science and Technology. 2005;33(3):623-8.
9. Bradford KJ. Manipulation of seed water relations via osmotic priming to improve germination under stress. HortScience. 1986;21(5):1105-12.
10. 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.
11. Wawrzyniak M, Szwengiel A, STELMACH-MARDACH M, Hołubowicz R. effects of chlorocholine chloride (CCC) on Plant Height and Inulin Content in Jerusalem Artichoke (*Helianthus tuberosus* L.). bulletin of the university of agricultural sciences & veterinary medicine cluj-napoca. Horticulture. 2016;73(2).
12. Horwitz W. Official methods of analysis of the Association of Official Analytical Chemists. The Association; 1925.
13. Arnao MB, Cano A, Acosta M. The hydrophilic and lipophilic contribution to total antioxidant activity. Food chemistry. 2001;73(2):239-44.
14. Jeyakumar P, Thangaraj M. Effect of mepiquat chloride on certain physiological and yield characteristics of groundnut (*Arachis hypog*aea L.). Journal of Agronomy and Crop Science. 1996;176(3): 159-64.
15. Lone NA. Studies on effect of cycocel and ethrel sprays in association with nitrogen on growth and metabolism of mustard under non_irrigated conditions.
16. Faldu TA, Kataria GK, Singh CK, Savaliya HB. Effect of plant growth regulators on dry matter production and yield attributes of groundnut (*Arachis hypogaea* L.) cv. GJG-9. IJCS. 2018;6(3):2852-5.
17. Khaswan SL, Dubey RK, Tiwari RC, Dubey SK, Chaudhary RK. Total chlorophyll, growth and productivity of soybean [*Glycine Max* (L) Merril] under different levels and sources of phosphorus and plant growth regulators in south Rajasthan, India. Legume Research-An International Journal. 2016;39(2):228-32.
18. Saini C, Jain NK, Mathukia RK. Effect of sulphur and plant-growth regulators on growth, yield and economics of summer groundnut (*Arachis hypogaea*). Indian Journal of Agronomy. 2016;61(1):115-8.
19. Nagarjun P, Radder GD. Studies of induction of seed dormancy in bunch type groundnut. 1983:24-31.
20. Paterson DR, Wittwer SH, Weller LE, Sell HM. The effect of preharvest foliar sprays of maleic hydrazide on sprout inhibition and storage quality of potatoes. Plant physiology. 1952;27(1):135.
21. Karkar C, Mandavia MK, Mandavia C. Influence of salicylic acid and brassinolide on quality and yield of groundnut kernels. Indian Journal of Agricultural Biochemistry. 2007;20(1):1-5.
22. Kumar A, Ramesh R, Ramprasad E. Effect of plant growth regulators on morphological, physiological and biochemical parameters of soybean

(*Glycine max* L. Merrill). Biotechnology and bioforensics: new trends. 2015:61-71.
23. Nigania S, Sharma Y, Kumar B. Role of humic acid and salicylic acid on quality parameters and K/Na ratio of groundnut (*Arachis hypogaea* L.) under salt and water stress. IJCS. 2017;5(6):278-83.
24. Manu SM, Halagalimath SP, Chandranath HT, Biradar, BD. Effect of plant growth regulators and nutrient levels on productivity and nutrient uptake of soybean (*Glycine max* L.). Indian Journal of Agronomy. 2021;66(1):25-29.
25. Rao RCR. Effect of growth regulators on growth and yield of irrigated groundnut (*Arachis hyporgaea* L.) at various plant densities. M.Sc. (Agri.) Thesis, submitted to the Andhra Pradesh Agricultural University, Tirupati Campus, Tirupati; 1980.
26. Reddy SC, Patil SV. Effect of growth retardants on the vegetative and physiological characters of groundnut (*Arachis hypogaea* L.). 1982;242-244.
27. Bramhankar VW, Shende VD, Deshmukh HS, Chahande RV. Effect of plant growth regulators to enhance the yield contributing character of soybean [*Glycine max* (L.) Merill]. Journal of Pharmacognosy and Phytochemistry. 2018;7(5):1791-3.

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