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Influence of Seed Hardening and Foliar Spraying of PGRs on Morpho-physiological Parameters in Green Gram (*Vigna radiata* L.)

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ABSTRACT

Background: Pre-sowing seed hardening and foliar spray with plant growth regulators is an easy, low cost and low risk technique and also an alternative approach recently used to mitigate the effect of abiotic stresses in agricultural production.

Methods: The mung bean *var*. GAM-5 was treated with seed hardening treatments and also for foliar spray using $CaCl_2$ 2% and 1%, CCC 500 mg/L, CCC 1000 mg/L, NAA 25 mg/L, NAA 50 mg/L. during *summer* season of 2015-16 and 2016-17. The trial was laid out in RBD with three replications and sixteen treatment combinations.

Result: The results indicated a significant improvement in morpho-physiological growth parameters, dry matter production and thereby yield potential increased due to the application of plant growth regulators and agrochemical under field conditions. Among the different treatments, seed hardening with 2% $CaCl_2$ + 1% foliar spraying at 30 DAS (T_{11}) treatment significantly improved most of morpho-physiological parameters and thereby yield in green gram followed by the seed hardening treatments of Cycocel 1000 mg/L + foliar spraying at 30 DAS (T_{13}) and seed hardening with NAA 50 mg/L + foliar spraying at 30 DAS (T_{15}).

Key words: $CaCl_2$, Cycocel, Dry matter partitioning, Foliar spray, Mung bean, NAA, Seed hardening.

INTRODUCTION

Mung bean (*Vigna radiata* L.) belongs to the family *Leguminosae* (Fabaceae) and had originated from India and Central Asia. Mung bean is one of the important pulse crops and rank third in area and production after pigeonpea and chickpea. India is the largest producer of mung bean accounting for almost 65 per cent of area and 54 per cent of production of the world. In addition to being an important source of human food and animal feed, pulses play an important role in maintaining the soil fertility in sustainable manner. It is a drought resistant crop and suitable for dry land farming and predominantly used as an intercrop with other crops. It is a very good catch crop in summer and can be grown very well in this season. Mung bean is a short duration, low input requiring crop that matures in 65 to 80 days, photo and thermo-insensitive in nature. The productivity of mung bean is low (474 kg/ha).

Efforts made to maximize yield, are largely hampered by adverse effect of abiotic stress such as salinity and drought. These effects cause a huge loss due to low yield and failure of the crop to establish in harsh conditions. Pre-sowing seed hardening treatment is an easy, low cost and low risk technique and also an alternative approach recently used to overcome the effect of abiotic stresses in agricultural production. It is found to be efficient in improving seed emergence and growth of crops. It was reported clearly that the hardening treatment enhance seeds vigour by protecting structure of the plasma membrane against injury during stress (Bewley and Black, 1982). It is a well established fact that, pre-soaking seeds with optimal concentration of phytohormones enhance their germination, dry matter accumulation and yield of some crop species under condition of environmental stress by increasing nutrient reserves through increased physiological activities and root proliferation.

Considering the constraints in the production potential of mung bean it is worthwhile to study the influence of different seed hardening and foliar spraying treatments on the production potential of mung bean. It is also of utmost importance to understand the physiological basis of plant height, number of branches, leaf area and dry matter accumulation and thereby yield variation due to seed hardening and foliar spraying of various growth regulators and chemicals. The manner in which the net dry matter is produced and distributed among the different parts of plant will determine the economic yield (Patil *et al*., 2007). The present study was therefore, undertaken to assess the pattern of plant height, leaf area and dry matter production in relation to yield in green gram.

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MATERIALS AND METHODS

The present work was carried out at Agronomy farm, Anand Agricultural University, Anand to study the influence of seed hardening and foliar spraying on morpho-physiological characters in green gram (*Vigna radiata* L.) during *summer* season of 2015-16 and 2016-17. The trial was laid out in RBD with three replications and sixteen treatment combinations including five seed hardening treatments, five foliar spraying treatments, five seed hardening treatments with foliar spraying and one absolute control treatment. Seeds of mung bean *var.* GAM- 5 were imposed with the following seed treatments.

The different solutions with different concentrations *viz.*, $CaCl_2$ 2%, Cycocel 500 mg l^{-1} and 1000 mg l^{-1} and NAA 25 mg l^{-1} and 50 mg l^{-1} were used in this experiment for seed hardening. The solutions were prepared by dissolving 10 g of $CaCl_2$ directly in the water while 250 mg and 500 mg of Cycocel and 12.50 mg and 25.00 mg of NAA in small amount of ethyl alcohol separately and after dissolved completely, made the final volume up to 500 ml by addition of water.

Seed hardening treatments were given to sufficient quantity of seeds of mung bean cv. GAM-5. For hardening, seeds were soaked in above prepared various solutions of double the volume of seed for three hours. The seeds were then removed from respective solutions and kept overnight in shade for drying to attained the seeds to its original moisture level. The seeds were ready for sowing in field on next day.

The different solutions with their different concentrations were used in this experiment for foliar spraying. Solutions of $CaCl_2$ 1%, Cycocel 500 mg l^{-1} and 1000 mg l^{-1} and NAA 25 mg l^{-1} and 50 mg l^{-1} were prepared by dissolving 100 g of $CaCl_2$ directly in the water while 5.0 g and 10.0 g of Cycocel and 250 mg and 500 mg NAA in small amount of ethyl alcohol separately and made final quantity of 10 litter of each solution by water. The spraying was carried out as per treatments during the morning time or before noon at 30 days after sowing (DAS) in respective gross plot of each replication using knapsack sprayer.

Treat. no.	Treatment details
T_1	$CaCl_2$ 2% Seed hardening (SH)
T_2	CCC 500 mg/L Seed hardening (SH)
T_3	CCC 1000 mg/L Seed hardening (SH)
T_4	NAA 25 mg/L Seed hardening (SH)
T_5	NAA 50 mg/L Seed hardening (SH)
T_6	$CaCl_2$ 1% spraying at 30 days after sowing (DAS)
T_7	CCC 500 mg/L spraying at 30 days after sowing (DAS)
T_8	CCC 1000 mg/L spraying at 30 days after sowing (DAS)
T_9	NAA 25 mg/L spraying at 30 days after sowing (DAS)
T_{10}	NAA 50 mg/L spraying at 30 days after sowing (DAS)
T_{11}	$CaCl_2$ 2% Seed hardening (SH) + 1% spraying at 30 days after sowing (DAS)
T_{12}	CCC 500 mg/L Seed hardening (SH) + spraying at 30 days after sowing (DAS)
T_{13}	CCC 1000 mg/L Seed hardening (SH) + spraying at 30 days after sowing (DAS)
T_{14}	NAA 25 mg/L Seed hardening (SH) + spraying at 30 days after sowing (DAS)
T_{15}	NAA 50 mg/L Seed hardening (SH) + spraying at 30 days after sowing (DAS)
T_{16}	Absolute control

Morphological growth parameters

Five plants from each plot were tagged randomly at seedling stage for recording various morphological observations at 30, 45, 60 DAS and at harvest. Plant height and number of branches per plant were recorded by non destructive method from each replication and treatment and the average values were calculated.

Leaf area (cm^2 $plant^{-1}$)

Leaf area per plant was taken at harvest with the help of Leaf area meter (Model- 3100) at regional research station. Five plants were randomly selected from all replications and clipped and recorded.

Total dry matter production

Sampling was done at every 15 days interval from 30 DAS until harvest regardless of growth stage. The total dry matter production was recorded by destructive method. Randomly selected five plant samples were uprooted and separated into root, leaf, stem and reproductive parts and dried in oven at 80°C until constant weight was obtained. Total dry matter was calculated by adding dry weight of different plant parts and expressed as grams per plant at different intervals 30, 45, 60 and at harvest of crop growth period.

RESULTS and DISCUSSION

Plant height (cm) at 30, 45, 60 DAS and at harvest

The data on plant height at various growth stages were analyzed statistically are represented in Table 1. Among the treatments seed hardening with 2% $CaCl_2$ (T_{11} and T_1) recorded significantly higher plant height (11.33 cm and 11.00 cm) respectively at 30 DAS in summer 2016. During 2017 as well as in pooled basis 2% $CaCl_2$ (T_{11} and T_1) recorded significantly higher plant height (12.50, 11.92 cm and 12.00, 11.50 cm) respectively at 30 DAS. These results are in accordance with the research findings of Manjunath and Dhanoji (2011). The lowest plant height was recorded (8.00, 8.83 and 8.42 cm) during 2016, 2017 and in pooled analysis respectively with untreated absolute control (T_{16}) as well as T_9 and T_{10}. However, the treatment seed hardening with 2% $CaCl_2$ (T_{11} and T_1) remained at par with other treatments *viz.*, T_2,T_3, T_5, T_{12}, T_{13}, T_{14} and T_{15} at 30 DAS.

At 45 DAS the plant height was significantly superior in the treatment $CaCl_2$ 2% seed hardening + 1% spraying at 30 DAS (T_{11}) (26.00, 28.33 and 27.17 cm). It was followed by the treatments with NAA 50 mg/L seed hardening + spraying at 30 DAS (T_{15}) (25.67, 28.00 and 26.83 cm) and NAA 25 mg/L seed hardening + spraying at 30 DAS (T_{14}) (25.00, 27.33 and 26.17 cm). The treatment CCC 1000 mg/L spraying at 30 DAS (T_8) recorded significantly lower plant height (18.33, 19.00 and 18.67 cm) during 2016, 2017 and in pooled basis, respectively. The treatments showed same trend at 60 DAS and at harvest stage for plant height.

Plant height was increased due to treatments of $CaCl_2$ and NAA, while decreased due to Cycocel at various growth stages *viz.*, 45 DAS, 60 DAS and at harvest in green gram.

Table 1: Effect of seed hardening, foliar spraying and their combined effect on Plant height (cm) at 30, 45, 60 DAS and at harvest.

Treat. no.	Treatment details	Plant height (cm)											
		30 DAS			45 DAS			60 DAS			AT harvest		
		2016	2017	pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	$CaCl_2$ 2% SH	11.00	12.00	11.50	24.00	26.00	25.00	29.33	32.33	30.83	31.00	34.83	32.92
T_2	CCC 500 mg/L SH	10.50	11.00	10.75	22.50	24.33	23.42	27.00	29.67	28.33	28.67	31.33	30.00
T_3	CCC 1000 mg/L SH	10.83	11.83	11.33	23.67	25.67	24.67	28.67	31.67	30.17	30.33	33.33	31.83
T_4	NAA 25 mg/L SH	9.83	10.67	10.25	22.00	24.00	23.00	26.67	29.33	28.00	28.33	31.00	29.67
T_5	NAA 50 mg/L SH	10.50	11.50	11.00	23.00	24.67	23.83	27.67	30.33	29.00	29.33	32.00	30.67
T_6	$CaCl_2$ 1% spraying at 30 DAS	8.17	9.00	8.58	24.67	27.00	25.83	32.00	35.00	33.50	33.67	37.00	35.33
T_7	CCC 500 mg/L spraying at 30 DAS	7.83	8.67	8.25	19.50	20.67	20.08	23.00	25.00	24.00	24.67	27.00	25.83
T_8	CCC 1000 mg/L spraying at 30 DAS	8.17	8.83	8.50	18.33	19.00	18.67	22.33	24.50	23.42	23.67	26.00	24.83
T_9	NAA 25 mg/L spraying at 30 DAS	8.00	8.83	8.42	24.00	26.33	25.17	30.33	33.00	31.67	32.00	35.00	33.50
T_{10}	NAA 50 mg/L spraying at 30 DAS	8.00	8.83	8.42	24.33	26.67	25.50	31.00	33.67	32.33	32.67	35.50	34.08
T_{11}	$CaCl_2$ 2% SH + 1% spraying at 30 DAS	11.33	12.50	11.92	26.00	28.33	27.17	35.33	38.00	36.67	37.00	40.67	38.83
T_{12}	CCC 500 mg/L SH + spraying at 30 DAS	10.33	11.33	10.83	20.83	22.00	21.42	25.33	27.33	26.33	27.00	29.33	28.17
T_{13}	CCC 1000 mg/L SH + spraying at 30 DAS	11.00	12.00	11.50	20.00	21.67	20.83	24.33	26.00	25.17	26.00	27.67	26.83
T_{14}	NAA 25 mg/L SH + spraying at 30 DAS	9.83	10.83	10.33	25.00	27.33	26.17	33.00	35.67	34.33	34.67	37.50	36.08
T_{15}	NAA 50 mg/L SH + spraying at 30 DAS	10.67	11.67	11.17	25.67	28.00	26.83	34.00	37.00	35.50	35.67	39.33	37.50
T_{16}	Absolute control	8.00	8.83	8.42	21.33	22.33	21.83	26.00	28.50	27.25	27.67	30.33	29.00
	S.Em. ±	0.84	0.83	0.53	1.33	1.66	0.96	2.21	2.34	1.44	2.28	2.47	1.51
	C.D. @ 5%	2.44	2.40	1.50	3.84	4.78	2.70	6.37	6.77	4.07	6.58	7.13	4.26
	C.V. %	15.19	13.68	14.40	10.11	11.64	10.97	13.40	13.07	13.24	13.09	12.97	13.04

*SH- Seed hardening.

The decrease in plant height with cycocel may be attributed to anti - auxin activity of Cycocel. It blocked the synthesis of IAA in the plant system. The mechanism of reduction of plant height by spraying with Cycocel also appears due to reduced cell size and cell wall thickening or reduction in the cell division activity (Ginzo *et al*., 1977). Similar results observed by Sujatha (2014) in chickpea and Kinjal (2017) in black gram.

It was observed that NAA showed a positive effect among the different treatments. The application of auxin in plant has a role in the stimulation of RNA and protein synthesis and greater enhancement in photosynthesis rate, increased in cell elongation as well as cell division and cell wall plasticity, which ultimately showed the enhancement in various growth parameters. The above finding were in agreement with the results reported by Ananthi and Mallika (2014) in green gram, Sunil Jadhav (2016) and Kinjal (2017) in black gram, Pothalkar (2007) in pigeon pea, Sujatha *et al* (2017) in chickpea.

Number of branches per plant at 30, 45, 60 DAS and at harvest

The results on number of branches per plant were analyzed statistically and represented in Table 2. Among the treatments, seed hardening with CCC 1000 mg/L (T_{13} and T_3) recorded significantly higher number of branches per plant (3.70) and absolute control (T_{16}) and T_7 recorded lowest (3.23) at 30 DAS. However, the treatments T_{11} and T_1, T_{12} and T_2 as well as T_{15} and T_5 remained at par with the treatments T_{13} and T_3 at 30 DAS in pooled analysis. On pooled basis, CCC 1000 mg/L seed hardening + spraying at 30 DAS (T_{13}) recorded significantly maximum (6.28, 8.13 and 8.67) number of branches per plant than untreated absolute control (4.94, 6.27 and 6.67) at 45 DAS, 60 DAS and at harvest, respectively.

The reduction in plant height due to growth retardants is mainly seem to have released the apical dominance and diversion of the plant metabolites from vertical growth to horizontal growth and thereby more number of branches per plant. As the apical dominance is removed usually the plant itself adjusts to encourage the growth of auxiliary buds which then converted into branches. Similar results were obtained in pigeon pea by Arjun Sharma *et al*. (2003) and Manjunath and Dhanoji (2011) and Sujatha (2014) in chickpea.

Leaf area at 30 DAS, 45 DAS, 60 DAS and at harvest (cm^2 $plant^{-1}$)

The data regarding leaf area per plant were recorded and analyzed statistically are furnished in Table 3. The data revealed that pre-sowing seed hardening with 2% $CaCl_2$ (T_{11} and T_1) recorded significantly higher leaf area per plant (194, 222, 208 cm^2 and 191, 220, 206 cm^2) while lower total leaf area per plant was observed (102, 114 and 108 cm^2) in untreated absolute control (T_{16}) at 30 DAS during summer 2016 and 2017 seasons as well as in pooled analysis, respectively. The treatments *viz*., CCC 1000 mg/L (T_{13} and T_3) (180, 210 cm^2 and 177, 209 cm^2) remained at par with the treatments 2% $CaCl_2$ (T_{11} and T_1) at 30 DAS during 2016 and 2017 seasons, respectively. The treatment $CaCl_2$ 2% seed hardening + 1% spraying at 30 DAS (T_{11}) recorded significantly highest total leaf area per plant (422, 607 and 395 cm^2) and remained at par with the treatments T_{13} (411, 594 and 387 cm^2), T_{15} (399, 583 and 374 cm^2) and T_{12} (397, 576 and 368 cm^2) at 45 DAS, 60 DAS and at harvest, respectively. The untreated absolute control (T_{16}) recorded significantly the lowest (270, 419 and 244 cm^2) leaf area per plant.

The increased in leaf area by seed hardening and foliar spraying with $CaCl_2$, Cycocel and NAA might be due to increase in cell division, cell enlargement as well as induce more extensive and denser network of veins and ribs and there by increased foliar leaf area. These results are conformity with the finding of Ginzo *et al.* (1977) in chick pea, Shinde and Jadhav (1995) in cowpea, Prabhu (2000) in blackgram, Pothalkar (2007) in pigeonpea, Prakash *et al.* (2013) in rice and Kinjal (2017) in black gram. Kalubarme and Pandey (1979) also reported that leaf area increased with an increase in time to a maximum coinciding with maximum top growth and steady decline at later stage.

Dynamics of dry matter accumulation

Both treatments and sampling time *i.e.* growth stage had a significant effect on dry matter accumulation (g $plant^{-1}$). Production of dry matter was slow during the first month after sowing, which is typical for legumes adapted to winter conditions (Zapata *et al*., 2019). In early growth phase larger portion of total dry matter was shared by the leaves than the stem. The dry matter accumulation in pods initiated after 30 DAS with reproductive parts like flowers and continued to increase upto the harvest.

In the present study, significant differences were observed in the total dry matter per plant. The data regarding total dry matter accumulation per plant were analyzed statistically and furnished in Table 4.

Total dry matter production at various growth stages

The total dry matter production per plant is aggregate of stem, leaf, root and reproductive dry matter accumulation at respective growth stages. It was increased progressively and differed significantly at all the growth stages from sowing to harvest in green gram. The results pertaining to the total dry matter (TDM) production indicated significant differences and revealed that pre-sowing seed hardening with 2% $CaCl_2$ (T_{11} and T_1) recorded highest total dry weight per plant (4.393, 5.043, 4.718 and 4.383, 5.000, 4.692 g) while lowest total dry matter production was recorded (3.450, 4.033 and 3.742 g) in untreated absolute control (T_{16}) at 30 DAS during summer 2016, 2017 seasons and in pooled analysis, respectively. The treatment with $CaCl_2$ 2% seed hardening + 1% spraying at 30 DAS (T_{11}) recorded highest total dry matter accumulation per plant (13.013, 14.537 and 13.775 g) at 45 DAS, at 60 DAS (27.057, 30.417 and 28.737 g) and at harvest (29.720, 33.420 and 31.570 g) during summer 2016,

Table 2: Effect of seed hardening, foliar spraying and their combined effect on number of branches/plant at 30, 45, 60 DAS and at harvest.

Treat. no.	Treatment details	Number of branches per plant											
		30 DAS			45 DAS			60 DAS			AT harvest		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	$CaCl_2$ 2% SH	3.60	3.60	3.60	5.33	5.44	5.39	6.67	6.93	6.80	7.07	7.27	7.17
T_2	CCC 500 mg/L SH	3.53	3.53	3.53	5.22	5.33	5.28	6.53	6.80	6.67	6.93	7.13	7.03
T_3	CCC 1000 mg/L SH	3.67	3.73	3.70	5.33	5.44	5.39	6.73	7.00	6.87	7.13	7.33	7.23
T_4	NAA 25 mg/L SH	3.40	3.40	3.40	5.00	5.11	5.06	6.33	6.60	6.47	6.73	6.87	6.80
T_5	NAA 50 mg/L SH	3.47	3.47	3.47	5.11	5.22	5.17	6.47	6.73	6.60	6.87	7.00	6.93
T_6	$CaCl_2$ 1% spraying at 30 DAS	3.27	3.33	3.30	5.67	5.78	5.72	7.27	7.60	7.43	7.67	7.87	7.77
T_7	CCC 500 mg/L spraying at 30 DAS	3.20	3.27	3.23	5.56	5.67	5.61	7.07	7.47	7.27	7.47	7.73	7.60
T_8	CCC 1000 mg/L spraying at 30 DAS	3.27	3.33	3.30	5.67	5.78	5.72	7.40	7.67	7.53	7.80	7.93	7.87
T_9	NAA 25 mg/L spraying at 30 DAS	3.27	3.33	3.30	5.44	5.44	5.44	6.87	7.13	7.00	7.27	7.40	7.33
T_{10}	NAA 50 mg/L spraying at 30 DAS	3.20	3.33	3.27	5.56	5.56	5.56	7.00	7.40	7.20	7.40	7.60	7.50
T_{11}	$CaCl_2$ 2% SH + 1% spraying at 30 DAS	3.60	3.67	3.63	6.11	6.22	6.17	7.93	8.20	8.07	8.33	8.87	8.60
T_{12}	CCC 500 mg/L SH + spraying at 30 DAS	3.53	3.53	3.53	6.00	6.11	6.06	7.80	8.07	7.93	8.20	8.47	8.33
T_{13}	CCC 1000 mg/L SH + spraying at 30 DAS	3.67	3.73	3.70	6.22	6.33	6.28	8.00	8.27	8.13	8.40	8.93	8.67
T_{14}	NAA 25 mg/L SH + spraying at 30 DAS	3.40	3.47	3.43	5.89	6.00	5.94	7.60	7.87	7.73	8.00	8.27	8.13
T_{15}	NAA 50 mg/L SH + spraying at 30 DAS	3.53	3.47	3.50	6.00	6.11	6.06	7.73	8.00	7.87	8.13	8.40	8.27
T_{16}	Absolute control	3.20	3.27	3.23	4.89	5.00	4.94	6.13	6.40	6.27	6.53	6.80	6.67
	S.Em. ±	0.13	0.15	0.09	0.29	0.36	0.21	0.43	0.44	0.28	0.44	0.51	0.30
	C.D. @ 5%	NS	NS	0.25	NS	NS	0.58	NS	NS	0.78	NS	NS	0.85
	C.V. %	6.54	7.36	6.97	8.95	10.97	10.03	10.51	10.36	10.43	10.13	11.41	10.81

*SH- Seed hardening.

Table 3: Effect of seed hardening, foliar spraying and their combined effect on leaf area/plant (cm^2/plant) at 30, 45, 60 DAS and at harvest.

Treat. no.	Treatment details	Leaf area per plant (cm^2/plant)											
		30 DAS			45 DAS			60 DAS			AT harvest		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	$CaCl_2$ 2% SH	191	220	206	292	363	328	435	531	483	262	310	286
T_2	CCC 500 mg/L SH	148	183	166	275	348	312	415	504	460	255	300	278
T_3	CCC 1000 mg/L SH	177	209	193	289	360	325	431	524	478	260	308	284
T_4	NAA 25 mg/L SH	129	159	144	255	335	295	398	489	443	240	286	263
T_5	NAA 50 mg/L SH	161	193	177	280	354	317	420	510	465	258	303	281
T_6	$CaCl_2$ 1% spraying at 30 DAS	108	124	116	330	394	362	481	589	535	304	353	329
T_7	CCC 500 mg/L spraying at 30 DAS	103	115	109	310	376	343	453	557	505	278	326	302
T_8	CCC 1000 mg/L spraying at 30 DAS	107	123	115	325	389	357	475	580	528	297	345	321
T_9	NAA 25 mg/L spraying at 30 DAS	105	118	112	298	370	334	442	533	488	270	321	296
T_{10}	NAA 50 mg/L spraying at 30 DAS	105	120	113	313	380	347	461	566	514	285	332	309
T_{11}	$CaCl_2$ 2% SH + 1% spraying at 30 DAS	194	222	208	393	451	422	555	658	607	362	428	395
T_{12}	CCC 500 mg/L SH + spraying at 30 DAS	150	185	168	365	429	397	525	626	576	341	395	368
T_{13}	CCC 1000 mg/L SH + spraying at 30 DAS	180	210	195	380	441	411	544	644	594	355	418	387
T_{14}	NAA 25 mg/L SH + spraying at 30 DAS	131	161	146	348	412	380	505	604	555	325	376	351
T_{15}	NAA 50 mg/L SH + spraying at 30 DAS	163	194	179	367	430	399	530	635	583	344	404	374
T_{16}	Absolute control	102	114	108	235	305	270	375	462	419	223	264	244
	S.Em. ±	5.97	6.72	4.48	14.53	11.57	8.40	16.78	17.10	10.82	15.16	16.81	10.24
	C.D. @ 5%	17	19	13	42	33	24	49	49	31	44	49	29
	C.V. %	7.34	7.02	7.18	7.97	5.22	6.50	6.25	5.25	5.71	9.02	8.52	8.76

*SH- Seed hardening.

Table 4: Effect of seed hardening, foliar spraying and their combined effect on Total dry matter at 30, 45, 60 DAS and at harvest (g/plant).

Treat. no.	Treatment details	Total dry matter (g/plant)											
		30 DAS			45 DAS			60 DAS			AT harvest		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	$CaCl_2$ 2% SH	4.383	5.000	4.692	10.467	12.290	11.378	22.853	26.213	24.533	25.337	29.023	27.180
T_2	CCC 500 mg/L SH	4.050	4.730	4.390	9.987	11.810	10.898	21.933	25.213	23.573	24.473	28.140	26.307
T_3	CCC 1000 mg/L SH	4.307	4.930	4.618	10.290	12.107	11.198	22.620	25.880	24.250	25.087	28.780	26.933
T_4	NAA 25 mg/L SH	3.923	4.643	4.283	9.853	11.690	10.772	21.630	24.860	23.245	24.170	27.867	26.018
T_5	NAA 50 mg/L SH	4.130	4.793	4.462	10.177	11.987	11.082	22.170	25.467	23.818	24.783	28.353	26.568
T_6	$CaCl_2$ 1% spraying at 30 DAS	3.580	4.127	3.853	11.487	13.323	12.405	24.510	27.890	26.200	26.920	30.557	28.738
T_7	CCC 500 mg/L spraying at 30 DAS	3.477	4.030	3.753	11.027	12.837	11.932	23.657	27.050	25.353	26.113	29.723	27.918
T_8	CCC 1000 mg/L spraying at 30 DAS	3.553	4.090	3.822	11.337	13.173	12.255	24.307	27.643	25.975	26.680	30.303	28.492
T_9	NAA 25 mg/L spraying at 30 DAS	3.493	4.063	3.778	10.843	12.760	11.802	23.300	26.687	24.993	25.747	29.403	27.575
T_{10}	NAA 50 mg/L spraying at 30 DAS	3.527	4.060	3.793	11.267	13.067	12.167	23.997	27.350	25.673	26.443	30.027	28.235
T_{11}	$CaCl_2$ 2% SH + 1% spraying at 30 DAS	4.393	5.043	4.718	13.013	14.537	13.775	27.057	30.417	28.737	29.720	33.420	31.570
T_{12}	CCC 500 mg/L SH + spraying at 30 DAS	4.077	4.733	4.405	12.463	14.147	13.305	26.137	29.463	27.800	28.500	32.183	30.342
T_{13}	CCC 1000 mg/L SH + spraying at 30 DAS	4.333	4.960	4.647	12.880	14.440	13.660	26.710	30.023	28.367	29.000	32.833	30.917
T_{14}	NAA 25 mg/L SH + spraying at 30 DAS	3.943	4.680	4.312	12.167	13.950	13.058	25.777	29.087	27.432	27.983	31.780	29.882
T_{15}	NAA 50 mg/L SH + spraying at 30 DAS	4.287	4.847	4.567	12.730	14.263	13.497	26.437	29.773	28.105	28.783	32.493	30.638
T_{16}	Absolute control	3.450	4.033	3.742	9.090	10.773	9.932	19.743	22.687	21.215	22.077	25.520	23.798
	S.Em. ±	0.15	0.20	0.111	0.37	0.49	0.276	0.69	0.67	0.430	0.86	0.79	0.520
	C.D. @ 5%	0.428	0.566	0.313	1.066	1.422	0.780	1.988	1.931	1.213	2.473	2.268	1.467
	C.V. %	6.53	7.46	7.10	5.71	6.59	6.24	4.98	4.25	4.60	5.63	4.53	5.05

*SH- Seed hardening.

2017 seasons and in pooled analysis, respectively (Table 4). The increase in TDM production towards maturity may be due to indeterminate growth pattern, higher rate of CO_2 fixation and RuBP carboxylase activity during crop growth. The association of TDM partitioning with grain yield was more significant at all the stages of crop growth. Thus, TDM production and partitioning is an important parameter in boosting the source-sink relationship and ultimately yield potential. Similar observations were also made by Nam *et al.* (1998), Katti *et al.* (1999), Manjunatha (2007), Sujatha (2014) in chickpea and Patil *et al.*, (2007) in groundnut. Thus, the total dry matter is composed of more with the leaf and stem dry weight and little with root dry weight during vegetative growth phase. But during reproductive growth phase, reproductive parts like pods, flowers contributes more as compared to leaf, stem and root dry weight. Murthy *et al.* (2002) corroborated the increase in dry matter in any genotype might reflect in increase in yield contributing characters and ultimately final economic yield and positive correlation of dry pod yield with dry matter accumulation.

Seed yield per plant (g plant^{-1})

The data regarding seed yield per plant and seed yield per hectare were recorded and analyzed statistically are furnished in Table 5. The treatment $CaCl_2$ 2% seed hardening + 1% spraying at 30 DAS (T_{11}) recorded significantly higher values of seed yield per plant (13.07, 14.20 and 13.63 g) and remained at par with T_{13} (12.60, 13.93 and 13.27 g), T_{15} (12.47, 13.60 and 13.03 g) and T_{12} (12.13, 13.27 and 12.70 g) during 2016, 2017 and on pooled basis, respectively. Whereas, the treatment of absolute control (T_{16}) recorded significantly lowest yield per plant (8.07, 9.40 and 8.73 g, respectively).

Seed yield per hectare (kg ha^{-1})

The significantly highest seed yield per hectare (949, 1006 and 978 kg ha^{-1}) was recorded by the treatment T_{11} which remained at par with the treatments T_{13} (922, 964 and 943 kg ha^{-1}) and T_{15} (893, 917 and 905 kg ha^{-1}). While significantly the lowest seed yield per hectare was observed in the absolute control (639, 679 and 659 kg ha^{-1}) during 2016, 2017 and in pooled analysis, respectively (Table 5).

Improvement in yield could happen in two ways *i.e.*, by adopting the existing varieties to grow better in their environment or by altering the relative proportion of different plant parts so as to increase the yield of economically important parts. The influence of plant growth regulators and seed hardening chemicals significantly increased the seed yield. The present study also revealed that increase in seed yield was significantly higher in seed hardening + spraying with $CaCl_2$ (2% seed hardening and 1% spraying) followed by Cycocel 1000 mg/L and NAA 50 mg/L. This could probably be due to beneficial effects of agrochemical and plant growth regulator treatments which help in enhancement of photosynthesis and nitrogen metabolism which are the major physiological process influencing plant growth and development. The treatments of $CaCl_2$ was significantly superior as compared to other treatments in enhancing the plant height, number of branches per plant, leaf area, dry matter production and thereby seed yield. The increase in the higher yield may be due to better carbon assimilation, better accumulation of carbohydrates and reduced

Table 5: Seed yield as influenced by seed hardening, foliar spraying and their combined effect at harvest.

Treat. no.	Treatment details	Seed yield/plant (g plant^{-1})			Seed yield/ha (kg ha^{-1})		
		2016	2017	Pooled	2016	2017	Pooled
T_1	$CaCl_2$ 2% SH	10.00	11.20	10.60	741	769	755
T_2	CCC 500 mg/L SH	9.47	10.60	10.03	697	737	717
T_3	CCC 1000 mg/L SH	9.87	11.00	10.43	721	761	741
T_4	NAA 25 mg/L SH	9.00	10.33	9.67	674	701	688
T_5	NAA 50 mg/L SH	9.60	10.87	10.23	702	752	727
T_6	$CaCl_2$ 1% spraying at 30 DAS	11.00	12.20	11.60	799	845	822
T_7	CCC 500 mg/L spraying at 30 DAS	10.47	11.60	11.03	764	800	782
T_8	CCC 1000 mg/L spraying at 30 DAS	10.80	12.07	11.43	779	831	805
T_9	NAA 25 mg/L spraying at 30 DAS	10.13	11.33	10.73	745	785	765
T_{10}	NAA 50 mg/L spraying at 30 DAS	10.53	11.80	11.17	765	825	795
T_{11}	$CaCl_2$ 2% SH + 1% spraying at 30 DAS	13.07	14.20	13.63	949	1006	978
T_{12}	CCC 500 mg/L SH + spraying at 30 DAS	12.13	13.27	12.70	860	880	870
T_{13}	CCC 1000 mg/L SH + spraying at 30 DAS	12.60	13.93	13.27	922	964	943
T_{14}	NAA 25 mg/L SH + spraying at 30 DAS	11.80	12.93	12.37	835	866	851
T_{15}	NAA 50 mg/L SH + spraying at 30 DAS	12.47	13.60	13.03	893	917	905
T_{16}	Absolute control	8.07	9.40	8.73	639	679	659
	S.Em. ±	0.59	0.56	0.36	55.36	55.94	35.29
	C.D. @ 5%	1.70	1.61	1.02	160	162	100
	C.V. %	9.51	8.10	8.77	12.29	11.82	12.05

*SH- Seed hardening.

respiration in plants. These results are in agreement with the findings of Mahabir singh and Rajodia (1989) in soybean and Pothalkar (2007) in pigeon pea.

CONCLUSION

Based on the above results, it is concluded that the yield potential in green gram can be improved by using plant growth regulators and agrochemical. The results also indicated a significant improvement in morpho-physiological growth parameters, dry matter production and thereby yield due to the application of PGR's and agrochemical. Among the different treatments, seed hardening with 2% $CaCl_2$ + 1% foliar spraying at 30 DAS treatment significantly improved the most of morpho-physiological parameters and thereby yield in green gram followed by the seed hardening treatments of Cycocel 1000 mg/L + foliar spraying at 30 DAS and seed hardening with NAA 50 mg/L + foliar spraying at 30 DAS.

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