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Effect of foliar application of plant growth regulators on growth and yield attributing characters of green gram (*Vigna radiata* L. Wilczek)

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ABSTRACT

A field experiment was conducted during the kharif 2017 to study the response of foliar application of plant growth regulators in terms of morpho-physiological parameters, yield and yield attributing characters of green gram. The results indicated that foliar application of NAA @ 75 ppm or CCC @ 150 ppm at 15 and 45 days after sowing improved the morphological characters like plant height, root volume, number of branches plant^{-1}.The foliar spray of CCC @ 150 ppm recorded maximum dry weight in all parts of the plant at all stages. Important growth parameters viz., AGR, CGR, RGR, NAR, LAD and LAI were significantly influenced by the application of PGRs in comparison with water spray control. CCC @ 150 ppm was found superior over other treatments for the AGR, CGR, NAR, and LAI during 15-45 and 30-45 DAS. Biochemical parameters like nitrate reductase activity, total protein, total soluble sugar and seed protein was significantly influenced by the PGRs treatments. The foliar spray of NAA @ 75 ppm recorded maximum total protein and seed protein in green gram cv. GM-4. The results on various yield and yield attributes indicated that all the yield contributing characters viz., number of seed per pod, dry weight of pod plant^{-1}, filled pod plant^{-1}, 1000 seed weight, seed yield increased significantly due to foliar spray of PGRs.

Keywords: AGR; CCC; green gram, NAA, root volume and seed protein

Green gram [*Vigna radiata* L. Wilczek] is an important short duration legume crop with high nutritive values and nitrogen fixing ability. The seeds of green gram contain an average of 22% protein, 62.5% carbohydrates, 1.4% fat, 4.2% fibers, vitamins and minerals (Sehrawat *et al*., 2013). Green gram improves physical properties of soil and fixes atmospheric nitrogen (Sengupta and Tamang, 2015). Green gram is the third most important pulse crop in India after chickpea and pigeon pea. Producitivity of green gram have remained static in recent and there has been a widening gap between supply and demand. In India during 2019-20, about 31.15 lakh ha area was covered under green gram. According to State Government 3rd advance estimates, green gram production in 2019-20 is at 0.53 lakh tonnes with productivity of 798 kg ha^{-1}. In 2019-20, green gram production has decreased from 24.60 to 23.40 lakh tons (Annual Report 2019-20). Plant growth regulators (PGRs) are being used as aids to enhance yield of different crops. Naphthalene acetic acid (NAA) is the growth promoting substance, which may play a significant role to change growth characters and yield of green gram. NAA has a positive effect on growth anddry matter production. It plays key role in cell elongation, cell division, vascular tissue differentiation, root initiation, apical dominance, leaf senescence, leaf and fruit abscission, fruit setting and flowering (Raoofi *et al*., 2014). Chlorocholine Chloride (CCC) is inhibitor of gibberellins biosynthesis which isinvolved in the inhibition of cyclization of geranyl-geranyl pyrophosphate to copyallyl pyrophosphate (Rademacher and Brahm, 2010). Growth regulators which inhibit the biosynthesis of gibberellins have been shown to enable the plants to impart tolerance against abiotic stress due to water deficit (Lone *et al*., 2010).

In a given environment the physiological performance like partitioning of dry matter to the economic product will indicate some of the characters which are essentially involved in contributing to higher yield. The total protein, total soluble sugar and nitrate reductase activity of leaves areindicative of environmental effects on growth and yield of green gram varieties for diagnostic purposes as has been studied by several workers. Nevertheless the biochemical parameter and partitioning of dry matter to economic product as influenced by growth regulators has received little attention. Hence the present investigation was taken up to study the effect of naphthalene acetic acid and chlorocholin chloride on green gram *cv*. GM-4.

A field experiment was carried out at Agronomy farm, Department of Agronomy, Junagadh Agricultural University, Junagadh, Gujarat with green gram cv. GM-4 during *kharif* season of 2017. Seeds were sown in rows of 45 cm apart with a plant to plant spacing of 10 cm by adopting randomized block design in three replications. The recommended packages of practices were followed for raising a good and healthy crop. The treatments *viz*., foliar spray of NAA @ 25 ppm (T_1), NAA @ 50 ppm

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(T_2), NAA @ 75 ppm (T_3), CCC @ 25 ppm (T_4), CCC @ 100 ppm (T_5), CCC @ 150 ppm (T_6) and water spray (control, T_7) were imposed at 15 and 45 days after sowing (DAS). The morphological characters *viz*., plant height, root volume, number of branches per plant, leaf area (LA) and total dry matter production (TDMP) were recorded at 30, 45 and 60 DAS. Root volume was measured using water displacement technique as suggested by Misra and Ahmed (1987) at 30, 45 and 60 DAS and expressed in cc plant^{-1}. Root volume was measured from ground level to the 10 cm of main root volume counted.Leaf area was measured by using leaf area meter (LICOR 3000). For determination of TDMP the different plant parts were harvested and dried in hot air oven at 80°C till constant weight. Growth characteristics *viz*., Crop Growth Rate (CGR), Net Assimilation Rate (NAR), Absolute Growth Rate (AGR), Relative Growth Rate (RGR), Specific Leaf Weight (SLW) and Leaf Area Duration (LAD) were calculated by adopting the procedure described by Watson (1952), Williams (1946) and Power *et al*. (1967), respectively.The biochemical parameters *viz*., total protein and total seed proteinestimated by using 500 mg of the sample was powdered with 5 to 10 mL of buffer, centrifuged and the supernatant was used for protein estimation (Lowry, 1951), Nitrate reductase activity (NRase activity) (Nicholas *et al.*, 1976) and chlorophyll concentration using SPAD-502 (Chlorophyll meter SPAD-502. Minolta Co., Ltd., Osaka, Japan) in the leaf were also estimated at 30, 45 and 60 DAS. At harvest, data on seed yield and yield related parameters were recorded. The data were analyzed statistically using the 'F' test and least significant difference was calculated (Panse and Sukhatme, 1985).

Morphological traits

The plant height, root volume, number of branches per plant and Leaf area increased from vegetative to pod filling stage (Table 1). The foliar application of NAA @ 75 ppm (T_3) and CCC @150 ppm (T_6) recorded significantly the higher plant height, root volume, number of branches plant^{-1} and leaf area in comparison of other treatments. In general, with an increase in the concentration of plant growth regulators, the mean values for these growth parameters increased at 30, 45 and 60 days after sowing. The increase in growth by the application of NAA and CCC is attributed to an increased rate of photosynthetic activity, accelerated transport and efficiency of utilizing photosynthetic products, thus, resulting in cell elongation and rapid cell division in the growing portion of the plant (Sarker *et al.*, 2008, Phinney *et al.,* 1957 and Sargent, 1965). The maximum root volume plant^{-1} was recorded in CCC @ 150 ppm (2.96 cc) and which was at par with NAA 75 ppm (2.83 cc).As has been suggested byFouly (1973) CCC retards stem elongation and lead to increase in root volume of crop. The increase in number of branches by the application of CCC might be due to its effectiveness in suppressing the apical dominance, thereby promoting growth and axillary buds into new shoots (Gowda and Gowda, 1980). The results obtained in present study are in close conformity with the findings of Shashikumar *et al.* (2013) and Foysalkabir *et al.* (2016) in green gram. Leaf area is considered to be one of the photosynthetic determinants in crop plants and in the present study, application of NAA resulted in higher leaf area which might be attributed for active role of auxins in enhancement of cell division and cell elongation (Jeyakumar *et al.*, 2008, Shashikumar *et al.,* 2013 and Upadhyay *et al.*, 2016).

Physiological traits

The effect of different plant growth regulators on physiological traits of green gram has beenpresented in table 2 and 3. The data revealed that the application of higher concentration of plant growth regulators significantly affectedthe physiological traits of green gram such as Total Dry Matter (TDM), Biomass Duration (BMD), Absolute Growth Rate (AGR), Net Assimilation Rate (NAR), Leaf Area Duration (LAD), Leaf Area Index (LAI), Crop Growth Rate (CGR) and Relative Growth Rate (RGR). The treatment CCC @ 150 ppm (T_6) and NAA @ 75 ppm (T_3) produced significantly higher total dry weight of 13.42 g and 12.59 g, respectively. Significant increase in dry matter production by the application of NAA and CCC might be due to enhanced source to sink relationship, accumulation of photosynthates and efficient utilization of food reserves for retention of flowers and fruits (Jeyakumar *et al.*, 2008 and Ullah *et al.,* 2007). Biomass duration (BMD) indicates the maintenance of dry matter over a period of time and is essential for prolonged supply of photosynthates to the developing sinks. During 30-45 DAS and 45-60 DAS treatments, CCC @ 150 ppm (T_6) recorded the maximum biomass duration which was significantly more than the remaining treatments. The enhanced biomass duration resulting from application of growth regulators was also reported by Saishankar (2001) in green gram.The AGR showed increasing trend with application of higher concentration of NAA and CCC at different time interval. Perusal of data further indicated that NAR increased with the application of higher level of NAA and CCC. Foliar application of CCC @ 150 ppm resulted in the highest mean value of NAR during both 15-30 DAS and 30-45 DAS, respectively, while during 45-60 DAS, NAA @ 75 ppm was found to record the maximum NAR. These results are in conformation with the findings of Nawalgatti *et al.* (1991) and Baghel and Yadava (1992).

Table 1: Effect of growth regulators on growth attributes of green gram cv. GM-4

Treatments	Plant height (cm)			Root volume (cc)			No. of branches plant^{-1}			Leaf area (cm^2)		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1 NAA @ 25 ppm	32.06	40.65	49.55	1.75	2.36	2.44	1.75	5.94	8.60	198.26	217.95	243.63
T_2 NAA @ 50 ppm	33.24	42.40	51.67	1.88	2.63	2.76	2.01	6.45	9.33	221.76	271.04	304.56
T_3 NAA @ 75 ppm	36.91	47.62	59.30	1.95	2.73	2.83	2.55	7.88	9.92	261.60	346.80	414.79
T_4 CCC @ 50 ppm	30.77	38.72	47.02	1.79	2.39	2.56	1.65	6.01	8.64	196.45	222.63	242.23
T_5 CCC @ 100 ppm	29.76	36.75	44.25	1.92	2.64	2.81	1.90	6.52	9.37	212.00	256.91	285.15
T_6 CCC @ 150 ppm	27.20	34.35	40.85	2.00	2.78	2.96	2.55	7.08	10.23	268.62	399.25	442.06
T_7 Control	31.80	40.25	48.55	1.43	2.06	2.29	1.65	5.60	7.89	186.89	198.39	214.15
SEm (±)	**0.85**	**1.21**	**1.53**	**0.08**	**0.11**	**0.12**	**0.07**	**0.20**	**0.29**	**8.71**	**11.80**	**13.47**
LSD (0.05)	**2.55**	**3.62**	**4.58**	**0.24**	**0.32**	**0.36**	**0.20**	**0.62**	**0.85**	**25.83**	**34.95**	**39.89**

Table 2: Effect of growth regulators on dry matter production, biomass duration, AGR and NAR of green gram cv. GM-4

Treatments	Total dry matter production (g)			Biomass duration (g days)			Absolute growth rate (g day^{-1})			Net assimilation rate (NAR) (g dm^{-1} day^{-1})		
	30 DAS	45 DAS	60 DAS	15-30	30-45	45-60	15-30	30-45	45-60	15-30	30-45	45-60
T_1 NAA @ 25 ppm	3.25	4.64	7.40	39.88	59.19	90.34	0.078	0.094	0.183	0.0462	0.0451	0.0793
T_2 NAA @ 50 ppm	3.63	5.67	9.30	42.15	69.11	112.11	0.101	0.139	0.243	0.0570	0.0567	0.0845
T_3 NAA @ 75 ppm	4.29	7.39	12.59	47.68	87.64	149.93	0.148	0.208	0.346	0.0712	0.0687	0.0911
T_4 CCC @ 50 ppm	3.22	4.74	7.35	39.96	59.66	90.39	0.079	0.096	0.177	0.0472	0.0463	0.0757
T_5 CCC @ 100 ppm	3.47	5.47	8.66	41.21	66.83	105.94	0.092	0.135	0.212	0.0535	0.0580	0.0783
T_6 CCC @ 150 ppm	4.40	8.51	13.42	48.51	96.77	164.38	0.156	0.273	0.328	0.0746	0.0829	0.0779
T_7 Control	3.04	4.21	6.50	38.47	54.21	80.21	0.062	0.078	0.154	0.0380	0.0402	0.0744
SEm (±)	**0.14**	**0.25**	**0.42**	**1.85**	**2.91**	**4.88**	**0.006**	**0.006**	**0.013**	**0.001**	**0.001**	**0.002**
LSD (0.05)	**0.43**	**0.73**	**1.25**	**5.47**	**8.62**	**14.45**	**0.017**	**0.018**	**0.039**	**0.002**	**0.003**	**0.005**

Table 3: Effect of growth regulators on leaf area duration, leaf area index, CGR and RGR of green gram cv. GM-4

Treatments	Leaf area duration (LAD) (cm^2 day)			Leaf area index (LAI)			Crop growth rate (CGR) ($g\ m^{-1}\ day^{-1}$)			Relative growth rate (RGR) ($g\ g^{-1}\ day^{-1}$)		
	15-30	30-45	45-60	15-30	30-45	45-60	15-30	30-45	45-60	15-30	30-45	45-60
T_1 NAA @ 25 ppm	8.00	10.24	11.33	0.313	0.484	0.541	1.73	2.09	4.07	0.0299	0.0237	0.0310
T_2 NAA @ 50 ppm	8.29	11.91	14.11	0.307	0.602	0.677	2.24	3.09	5.40	0.0380	0.0297	0.0329
T_3 NAA @ 75 ppm	9.21	14.50	18.47	0.323	0.771	0.922	3.28	4.61	7.69	0.0484	0.0363	0.0355
T_4 CCC @ 50 ppm	7.94	10.26	11.46	0.311	0.495	0.538	1.75	2.14	3.93	0.0295	0.0258	0.0291
T_5 CCC @ 100 ppm	8.16	11.35	13.32	0.309	0.571	0.634	2.05	3.01	4.72	0.0350	0.0303	0.0306
T_6 CCC @ 150 ppm	9.30	15.61	20.68	0.322	0.887	0.982	3.46	6.07	7.29	0.0503	0.0439	0.0304
T_7 Control	7.90	9.54	10.18	0.319	0.441	0.476	1.39	1.72	3.41	0.0246	0.0217	0.0290
SEm (±)	**0.32**	**0.48**	**0.61**	**0.012**	**0.019**	**0.026**	**0.126**	**0.132**	**0.291**	**0.0013**	**0.0003**	**0.0005**
LSD (0.05)	**0.96**	**1.43**	**1.82**	**0.036**	**0.057**	**0.078**	**0.374**	**0.391**	**0.864**	**0.0039**	**0.0008**	**0.0013**

Table 4: Effect of growth regulators on different biochemical parameters of green gram cv. GM-4

Treatments	Nitrate reductase activity (mμ moles NO_2 formed $hr^{-1}\ g^{-1}$FW)			Chlorophyll concentration (SPAD value)			Soluble protein (mg g^{-1}FW)			Total soluble sugar (mg g^{-1}FW)		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1 NAA @ 25 ppm	196.05	104.52	41.00	43.66	38.21	32.31	19.64	20.44	22.15	37.90	26.32	15.23
T_2 NAA @ 50 ppm	247.00	132.00	48.99	46.59	40.47	34.10	20.84	22.38	24.26	38.40	26.85	15.43
T_3 NAA @ 75 ppm	262.02	141.51	43.27	50.31	42.89	35.49	21.99	23.71	25.69	39.30	27.16	16.20
T_4 CCC @ 50 ppm	175.98	89.49	26.00	43.39	38.59	31.88	19.64	20.49	21.97	38.20	26.20	15.21
T_5 CCC @ 100 ppm	183.00	111.02	32.01	46.32	39.15	32.97	20.09	21.77	23.60	38.40	26.34	15.61
T_6 CCC @ 150 ppm	193.00	120.52	36.99	49.25	43.65	34.90	21.55	23.31	25.26	40.32	29.46	16.95
T_7 Control	152.95	84.22	30.00	43.26	37.56	31.53	19.50	20.30	22.00	36.80	26.01	15.10
SEm (±)	**5.32**	**3.12**	**1.36**	**1.25**	**1.25**	**0.88**	**0.55**	**0.68**	**0.73**	**0.92**	**0.72**	**0.42**
LSD (0.05)	**15.75**	**9.26**	**4.03**	**3.70**	**3.70**	**2.61**	**1.63**	**2.01**	**2.17**	**2.72**	**2.13**	**1.24**

Table 5: Effect of growth regulators on yield and yield attributing characters of green gram cv. GM-4

Treatments	Total seed protein (%)	Number of filled pod plants^{-1}	Number of seeds pod^{-1}	Dry weight of pod (g)	1000 seed weight (g)	Seed yield (kg ha^{-1})	Harvest index (%)
T_1 NAA @ 25 ppm	20.00	18.01	10.62	9.23	38.10	738.12	21.51
T_2 NAA @ 50 ppm	21.22	21.04	11.42	9.76	39.46	759.49	21.77
T_3 NAA @ 75 ppm	22.40	24.60	12.05	11.45	40.54	789.20	23.99
T_4 CCC @ 50 ppm	20.01	19.43	11.38	9.10	37.78	689.57	21.31
T_5 CCC @ 100 ppm	20.46	22.30	11.65	9.45	37.58	710.75	22.60
T_6 CCC @ 150 ppm	21.94	23.14	12.31	10.96	38.01	782.35	24.25
T_7 Control	19.86	17.35	10.60	9.07	36.25	658.00	21.24
SEm (±)	**0.65**	**0.63**	**0.36**	**0.37**	**1.21**	**34.98**	**0.56**
LSD (0.05)	**1.93**	**1.87**	**1.05**	**1.11**	**3.58**	**103.62**	**1.66**

In the present experiment, the leaf area duration (LAD) of green gram was increased by the application of CCC and NAA which might be due to an increase in number of leaves and leaf area index per plant as was also suggested earlier by Saishankar (2001) and Shashikumar *et al.* (2013). The data further indicated that different treatment of PGRs affected the leaf area index significantly during 30-45 DAS. The increase in leaf area index by the application of CCC and NAA might be due to stimulatory effect of NAA on cell division and cell enlargement which lead to enhanced leaf area (Nawalgatti *et al.,* 1991 and Saishankar, 2001). Crop growth rate is a measure of increase in size ormass of crops over a certainperiod of time. Increase in crop growth rate is due to the increases in dry weight plant^{-1}. In general, with increase in concentration of the growth regulators, the crop growth rate increased at 30, 45 and 60 DAS. The Relative Growth Rate (RGR) also increased with in advancement in crop growth. All PGRs during three stages of crop growth resulted in an increase in relative growth rate over the control. The increase in RGR by the foliar application of plant growth regulators as compared to the control mightbe attributed to increased photosynthetic efficiency by increasing leaf thickness and retaining chlorophyll content and efficient translocation of photosynthates (Patil, 1994, Upadhyay and Ranjan, 2015).

Biochemical traits

The effect of different plant growth regulators on biochemical traits from vegetative to pod filling stage has been presented in table 4. Higher nitrate reductase activity has been related to yield of grains and grain protein content in many crops (Muthuchelian *et al.,* 1994).The data indicated that all the PGRs treatment significantly influenced the nitrate reductase activity in leaf at 30, 45 and 60 DAS. The most effective treatment was NAA @ 75 ppm (T_3) for this parameter (262.02 mµ moles NO_2 formed hr^{-1} g^{-1}).The stimulated nitrate reductase activity in growth regulator treated plants might be due to the enhancement of nitrogen or nitrate uptake by plants and the possible role of PGRs in prevention of enzyme degradation by proteolysis (Lakshmamma *et al.,* 1996, Shukla *et al.,* 2017). Foliar application of higher concentration of NAA and CCC increased the chlorophyll content in leaf of green gram which might be attributed for an increase in number of chloroplasts in palisade and spongy cells of leaves (Gowda and Gowda, 1980). At 30 DAS, among the different treatments, NAA @ 75 ppm (T_3) recorded significantly higher chlorophyll content (50.31). Soluble protein content in leaf is a measure of RuBP carboxylase, an index for photosynthetic efficiency and the enhanced levels of soluble protein might have helped for growth stimulation (Kalinch *et al.*, 1985). Most of PGRs treatments at 30 DAS resulted in a significant increase in total leaf protein over the control. Total soluble sugar was found to differ significantly from other treatments under the foliar spray of CCC @ at 30, 45 and 60 DAS. The data indicated that different treatments of PGRs affected the total soluble sugar (mg g^{-1} FW) significantly. The highest soluble sugar was produced under the treatment of CCC @ 150 ppm (T_6) (40.32 mg g^{-1}) at 30 DAS; whereas the all other treatments were found at par with the control.

Yield and yield attributing traits

The effect of plant growth regulators on seed yield and yield attributing characters has been presented in table 5. The perusal of data revealed that among the different PGRs, NAA @ 75 ppm (22.40 %) and CCC @ 150 ppm (21.94 %) remained at par with each other and was found superior to all other treatments. Such an observation was also noted by Jeyakumar *et al.* (2008), Khaswa *et al.* (2014) and Deotale *et al.* (2017). The highest number of pods plant^{-1} was recorded by the application of NAA @ 75 ppm (T_3) and it was at par with CCC @ 150 ppm. The data revealed that the foliar application of PGRs brought substantial improvement in number of filled pod plant^{-1} of green gram. The increased number of pods plant^{-1} might be due to reduction in flower and fruit drop which resulted in retention of a greater number of sinks (Resmi and

Gopalkrishnan, 2004). The maximum number of seeds pod^{-1} (12.31) was recorded with the treatment of CCC @ 150 ppm. The increase in per cent filled seeds along with seed yield was probably due to inhibition of basipetal movement of auxin and utilization for development of disc and seed (Garai and Datta, 2003, Radhamani *et al*., 2003). The foliar application of higher concentration of NAA and CCC significantly affected the dry weight of pod. The treatment NAA @ 75 ppm (11.45 g) was statistically higher over the other treatments, which was followed by the treatment of CCC @ 150 ppm (10.96 g). The increase in weight of pods by the application of NAA might be attributed to the greater mobilization of metabolites from source (leaves) to sink (pods). The increased weight of pods by the application of CCC might be due to greater accumulation of carbohydrates owing to photosynthesis (Sharma and Lashkari, 2009). The data revealed that the maximum 1000 seed weight (40.54 g) was recorded by foliar application of NAA @ 75 ppm (T_3).

The foliar application of plant growth regulators was able to divert more flow of assimilates towards the developing seeds and resulted in the increase in seed size over the untreated plants (Kalita *et al.*, 1995). Maximum seed yield (789.20 kg ha^{-1}) was recorded by the application of NAA @ 75 ppm followed by CCC @ 150 ppm (782.82 kg ha^{-1}). The increase in yield by the application of CCC might be due to reduced plant height and increased branching resulting in diversion of food material for the improvement of flowering and fruiting (Kuraishi and Muri, 1963). Application of CCC @ 150 ppm (T_6) recorded significantly highest harvest index (24.25 %) and remained at par with treatment NAA 75 ppm (23.99 %). Similar results were obtained by Kalita *et al.* (1995), Ullah *et al.* (2007) and Rajesh *et al.* (2014).

The results in the present experiment indicated that the growth regulators, their concentration and time of application played an effective role on morpho-physiological, biochemical, yield and yield attributing characters of green gram. From the results it was found that higher concentration of plant growth regulators recorded enhanced growth of plant and improvement in biochemical parameters. It might be due to the increased rate of cell division, cell elongation and dry matters partitioning in the plant.

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