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Effect of Plant growth regulating compounds and nutrients on morpho-physiological characters in pigeonpea (*Cajanus cajan*)

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Abstract
A field study was conducted to investigate the impact of different growth regulating compounds and nutrients on morpho-physiological characters and yield traits in pigeonpea. The experiment was laid out in FRBD design with three replications. The treatments consisted of growth retardants *viz.*, mepiquat chloride and chlormequat chloride, each 500 ppm sprayed at vegetative stage followed by application of different PGRs (Salicylic acid @ 100 ppm, Brassinosteroid @ 0.1 ppm, NAA @ 40 ppm), Nutrients ($ZnSO_4$ @ 0.5% + Boric acid @ 0.3%, MAP @ 2%, TNAU Pulse Wonder @ 1%) and two Nutrient consortia mixture sprayed at flower initiation and 15 days thereafter. Observations on various morpho-physiological parameters and yield traits were recorded at different growth stages. The results revealed that, the combined effect of Chlormequat chloride and nutrient consortia has significantly influenced the plant height, root length, chlorophyll index, photosynthetic rate, number of flowers plant^{-1} and number of pods plant^{-1} of pigeonpea.

Keywords: Growth retardants, foliar application, source-sink relationship, photosynthetic rate, pigeonpea

Introduction
Pulses play a major role in providing a balanced protein component in the daily food diet. Among the pulses, pigeonpea (*Cajanus cajan* (L.) Mill sp.) is one of the most important pulse crop after chickpea in India and fifth most important crop in the world. The yield of pigeonpea is very low due to indeterminate growth habit, poor source-sink relationship, poor biomass production and harvest index (Chudasama and Thaker 2007) [3]. Phytohormones play an important role in inducing and enhancing various physiological activities in the plant.

Plant growth regulators which include both promoters as well as inhibitors and play an important role in increasing crop yield by increasing translocation efficiency and source sink relationship. The growth retardants used in this study Chlormequat chloride and mepiquat chloride have been reported to reduce the internodal length, minimize plant height and more effective in translocation of photo-assimilates to the production of reproductive parts compared to growth promoters (Pankaj Kumar *et al.*, 2006) [9].

Growth regulators in general, are known to influence a wide range of physiological parameters such as alteration of plant architecture, assimilation of partitioning, promotion of photosynthesis, enhancement of nitrogen metabolism, promotion of flowering, increased mobilization of assimilates to defined sinks, induction of floral synchrony and delayed leaf senescence (Sharma *et al.*, 2013; Solaimalai *et al.*, 2001) [14, 15]. Hence, the present study was taken up to evaluate and study the influence of PGR compounds in improving the growth and productivity of pigeonpea.

Materials and methods
A field experiment was carried out with indeterminate type pigeonpea CO Rg 7 under irrigated condition at Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore. The experiment was laid out in factorial randomized block design (FRBD) with three replications and treatments consisted of growth retardants *viz.*, mepiquat chloride and chlormequat chloride, each 500 ppm sprayed at vegetative stage and different PGRs (Salicylic acid @ 100 ppm, Brassinosteroid @ 0.1 ppm, NAA @ 40 ppm), Nutrients ($ZnSO_4$ @ 0.5% + Boric acid @ 0.3%, MAP @ 2%, TNAU Pulse Wonder @ 1%) and two Nutrient consortia mixture sprayed at flower initiation and 15 days thereafter. Observation on morpho-physiological characters and yield traits was taken at randomly selected five plants per

replication from each plot. The Photosynthetic rate (µmol CO_2 m^{-2} s^{-1}) was measured by using an advanced portable CO_2 gas analyzer (LI-6400 XT, Licor Inc, Nebraska, USA) and amount of chlorophyll present in leaves was qualitatively measured by non-destructive method using chlorophyll meter (SPAD-502, Minolta Co., Japan) as suggested by Gratani (1992) [6] and expressed as chlorophyll index. TNAU Pulse Wonder is combination of nutrients and growth regulators used as crop booster for yield improvement. Similarly, Nutrient consortia mixture is a combination of PGRs with nutrients in different proportions for increasing the yield of pigeonpea and in this experiment Nutrient consortia mixture was used. The data obtained from this study, was subjected to statistical analysis in FRBD as described by Gomez *et al.* (1984).

Results and Discussion

Growth attributes

The results of the study indicated that the foliar application of plant growth retardants during vegetative stage favourably altered the carbon partitioning of assimilates to main stem, branches and their growing points and increased the partitioning to reproductive organs and roots. Foliar application of growth retardants Mepiquat chloride @ 500 ppm (M_1) and Chlormequat chloride @ 500 ppm (M_2) during vegetative stage followed by application of growth regulators and nutrients (T_1-T_9) at flowering has significantly influenced the plant height and root length. Control plants (M_1) had greater mean plant height (107.76, 113.94 cm) compared to M_2 (84.39, 96.70 cm) and M_3 (94.07, 102.00 cm), irrespective of treatments (T_1-T_9) at flowering and pod filling stage (Table 1). It is evident that, specific response from growth retardants was effective in restricting the vegetative growth and promoting reproductive growth was observed. Irrespective of treatments, M_1 has recorded the highest plant height (M_1T_8 - 124.71, 136.53 cm) followed by M_3 and M_2 at flowering and pod filling stages respectively. These results are in confirmation with findings of Kulkarni *et al.* (2018)[7] and Govindan *et al.* (2000) [5] who reported that foliar application of Chlormequat chloride at different leaf stages significantly reduced the total mean shoot length compared to control. With regard to root length, M_3T_8 observed the highest root length (27.35, 29.00 cm) followed by M_2T_8 (26.66, 28.08 cm) at flowering and pod filling stage. Wang *et al.* (1995) [17] revealed that application of plant growth retardant Pix to the cotton plants at squaring decreased the partitioning of assimilates to the main stem visually reflecting in reduced plant height and increased partitioning to roots. The supply of nutrients such as iron, boron, sodium molybdenum and other compounds in nutrient consortia increased the hormonal synthesis, translocation and metabolism which improved the growth of plant. The combined application of growth regulators and nutrients explicitly improved the plant growth and development (Taiz and Zeiger, 2003) [16].

Table 1: Effect of growth regulators and nutrients on Plant height (cm) and Root length (cm) in indeterminate pigeonpea (CO Rg 7) at different growth stages

Treatments	Plant height (cm)								Root length (cm)							
	Flowering stage (75 DAS)				Pod filling stage (95 DAS)				Flowering stage (75 DAS)				Pod filling stage (95 DAS)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
T_1: Control	90.62	65.96	79.00	78.53	95.38	86.83	89.39	90.53	18.62	19.96	20.30	19.63	20.68	21.83	22.29	21.60
T_2: Salicylic acid (100 ppm)	95.92	67.64	80.47	81.34	97.99	89.21	92.03	93.08	21.52	22.94	24.77	23.08	21.79	24.01	25.83	23.88
T_3: Brassinosteroid (0.1 ppm)	100.85	72.92	84.64	86.14	104.92	91.90	95.03	97.28	19.75	21.82	22.64	21.40	24.22	26.60	26.73	25.85
T_4: NAA (40 ppm)	115.30	87.51	99.81	100.87	119.29	96.31	107.49	107.70	22.20	24.61	24.91	23.91	22.79	26.21	27.19	25.40
T_5: $ZnSO_4$ (0.5%) + H_3BO_3 (0.3%)	107.96	81.80	92.46	94.07	111.19	94.38	99.90	101.82	20.56	23.60	24.76	22.97	22.59	24.28	26.90	24.59
T_6: MAP (2%)	104.05	78.77	91.86	91.56	110.30	94.80	97.92	101.01	19.75	22.97	23.46	22.06	22.10	24.00	26.22	24.11
T_7: TNAU Pulse Wonder (1%)	112.98	89.83	102.07	101.63	123.34	95.90	102.55	107.26	22.78	24.93	25.67	24.46	24.24	26.80	27.25	26.10
T_8: Nutrient consortia-1	124.71	109.26	108.95	114.30	136.53	112.35	119.70	122.86	23.31	26.66	27.35	25.77	25.33	28.08	29.00	27.47
T_9: Nutrient consortia-2	117.44	105.84	107.38	110.22	126.51	108.59	113.98	116.36	22.74	25.54	26.48	24.92	25.01	27.39	27.75	26.72
Mean	107.76	84.39	94.07	95.41	113.94	96.70	102.00	104.21	21.25	23.67	24.48	23.13	23.19	25.47	26.57	25.08

Factors	M	T	M x T	M	T	M x T	M	T	M x T	M	T	M x T
SEd	0.73	1.27	2.19	0.70	1.21	2.10	0.15	0.26	0.44	0.18	0.32	0.55
CD (P:0.05)	1.47	2.54	4.40	1.40	2.43	4.21	0.30	0.51	0.89	0.37	0.64	1.11

*M_1-Control, M_2-Mepiquat chloride @ 500 ppm and M_3-Chlormequat chloride @ 500 ppm at Vegetative stage
*T_1 to T_9 (2 sprays: at flower initiation & 15 days thereafter)

Physiological attributes

The PGRs are known to improve the physiological efficiency of plant which forms basis for yield determination. Also augment the source-sink relationship and kindle the translocation of photo-assimilates, thereby increasing the productivity. The PGRs increased the photosynthetic rate from flowering to pod filling stage (Table 2). The highest mean photosynthetic rate was recorded in T_8-Nutrient consortia 1 (29.60, 32.76 µmol CO_2 m^{-2} s^{-1}) followed by T_9-Nutrient consortia 2 (28.15, 31.50 µmol CO_2 m^{-2} s^{-1}) while the lower value was observed in Control T_1 (22.39, 24.10 µmol CO_2 m^{-2} s^{-1}). Similarly, the application of Chlormequat chloride (500 ppm) and Mepiquat chloride (500 ppm) resulted higher chlorophyll content during reproductive stage. The data showed that Chlorophyll index was highest with the application of M_3 (49.16, 51.15) followed by M_2 (47.55, 49.37) and lowest in M_1 (45.86, 48.25). Rajesh *et al.* (2014) [10] stated that application of Chlormequat chloride (375.0 g a.i. ha^{-1}), NAA (20 ppm) and Mepiquat chloride (5% AS) resulted higher chlorophyll content during reproductive stage in green gram. Similar reports were also expressed by Ramesh and Ramprasad (2013) [12].

Table 2: Effect of growth regulators and nutrients on Photosynthetic rate (µmol CO_2 m^{-2} s^{-1}) and Chlorophyll index in indeterminate pigeonpea (CO Rg 7) at different growth stages

Treatments	Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})								Chlorophyll index							
	Flowering stage (75 DAS)				Pod filling stage (95 DAS)				Flowering stage (75 DAS)				Pod filling stage (95 DAS)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
T_1: Control	21.80	22.36	23.00	22.39	22.98	24.43	24.89	24.10	40.02	41.76	45.20	42.33	41.88	43.73	46.99	44.20
T_2: Salicylic acid (100 ppm)	23.52	25.04	26.37	24.98	26.59	28.01	28.63	27.74	47.72	48.74	47.77	48.08	49.69	49.41	50.63	49.91
T_3: Brassinosteroid (0.1 ppm)	26.65	27.02	27.74	27.14	27.92	29.20	29.63	28.91	46.65	48.12	49.04	47.94	49.62	50.10	50.53	50.08
T_4: NAA (40 ppm)	24.70	27.41	27.91	26.67	25.69	27.61	27.99	27.10	44.40	47.51	47.71	46.54	46.49	49.21	49.49	48.40
T_5: $ZnSO_4$ (0.5%) + H_3BO_3 (0.3%)	24.56	26.90	28.16	26.54	25.59	26.98	28.40	26.99	42.56	44.00	46.06	44.20	44.69	46.38	48.00	46.36
T_6: MAP (2%)	23.65	26.07	26.96	25.56	24.40	26.90	27.42	26.24	44.35	45.07	46.86	45.43	46.20	47.10	48.42	47.24
T_7: TNAU Pulse Wonder (1%)	27.28	28.03	28.87	28.06	28.04	31.00	30.35	29.80	47.58	48.53	51.87	49.33	51.34	50.60	54.25	52.06
T_8: Nutrient consortia-1	28.21	29.66	30.95	29.60	32.53	32.45	33.30	32.76	49.91	53.76	55.05	52.90	52.13	55.85	57.20	55.06
T_9: Nutrient consortia-2	26.74	28.84	28.88	28.15	31.21	31.09	32.18	31.50	49.54	50.44	52.88	50.95	52.21	51.99	54.88	53.03
Mean	25.23	26.81	27.65	26.57	27.22	28.63	29.20	28.35	45.86	47.55	49.16	47.52	48.25	49.37	51.15	49.59

Factors	M	T	M x T	M	T	M x T	M	T	M x T	M	T	M x T
SEd	0.20	0.35	0.60	0.18	0.31	0.54	0.26	0.45	0.79	0.34	0.60	1.03
CD (P:0.05)	0.40	0.69	NS	0.36	0.62	1.07	0.53	0.91	1.58	0.69	1.19	2.07

*M_1-Control, M_2-Mepiquat chloride @ 500 ppm and M_3-Chlormequat chloride @ 500 ppm at Vegetative stage
*T_1 to T_9 (2 sprays: at flower initiation & 15 days thereafter)

Yield attributes

Plant growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates thereby helping in effective flower formation, fruit and seed development, and ultimately increase productivity of the crop. The effect of plant growth regulators and nutrients on maximum number of flowers per plant was observed in M_3T_8 (304.40) followed by M_2T_8 (301.38) and lowest in M_1T_1 (225.70) (Table 3). With respect to effect of growth retardants on flowering, M_3 has the highest mean (271.50) followed by M_2 (267.37) and lowest in M_1 (261.34). In conformity with Ananthi and Gomathy (2011) [2] and Dilip Matwa *et al.* (2017) [8] who reported increased flowers per plant after application of PGRs and micro nutrients at flowering in greengram. These plant growth regulators (PGRs) in general, help to increase the number of flowers on the plant when applied at the time of flowering. The flower and pod drop may be reduced to some extent by spraying various growth regulators on foliage (Ramesh and Thirumuguran, 2001) [11].

The data on number of pods revealed that Chlormequat chloride @ 500 ppm treated plants had more number of pods (54.49) followed by Mepiquat chloride @ 500 ppm (53.27) than M_1 (51.01). Among the different plant growth regulators and nutrients, T_8 recorded the maximum mean pod number (61.98) followed by T_9 (58.14) and lowest in T_1 (43.63). With regard to treatment interactions M_3T_8 (63.06) registered the highest value followed by M_2T_8 (62.80) and the lowest value was observed in M_1T_1 (42.75). Similarly growth regulator spray significantly influenced number of pods per plant, maximum number of pods per plant with 0.1% HA + 0.1 ppm BR in greengram (Ananthi and Vanangamudi, 2013) [1]. Crop performance was poor in the control treatment thus, the yields per hectare was significantly lower than that obtained in other treatments. This result in conformity with the findings reported by Fariduddin, (2004) [4], Sengupta and Tamang (2015) [13]. In conclusion, the present investigation revealed that Plant growth regulators (PGRs) and nutrient mixture performs positively and improved flowering and yield parameters studied. The foliar application of Chlormequat chloride @ 500 ppm and Nutrient consortia treatments was found effective in increasing the yield. It is evident that chlorophyll index and net photosynthetic rate were influenced by nutrient consortia, resulting in higher yield as represented by more number of pods per plant. Thus, it could be recommended for better flowering and production of pigeon pea (*Cajanus cajan*) variety CO Rg 7.

Table 3: Effect of growth regulators and nutrients on yield compounds in indeterminate pigeonpea (CO Rg 7) at different growth stages

Treatments	Number of flowers per plant				Number of pods per plant			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
T_1: Control	225.70	238.32	244.89	236.30	42.75	44.29	43.83	43.63
T_2: Salicylic acid (100 ppm)	270.67	276.56	287.22	278.15	46.94	49.57	49.37	48.63
T_3: Brassinosteroid (0.1 ppm)	257.85	269.91	270.08	265.95	51.52	54.63	55.40	53.85
T_4: NAA (40 ppm)	255.84	259.07	263.25	259.39	50.14	56.32	56.27	54.24
T_5: $ZnSO_4$ (0.5%) + H_3BO_3 (0.3%)	253.69	256.55	258.43	256.22	47.86	46.81	48.79	47.82
T_6: MAP (2%)	238.98	242.58	252.21	244.59	48.14	50.68	53.80	50.87
T_7: TNAU Pulse Wonder (1%)	277.66	277.34	274.47	276.49	55.62	56.06	59.73	57.14
T_8: Nutrient consortia-1	291.58	301.38	304.40	299.12	60.09	62.80	63.06	61.98
T_9: Nutrient consortia-2	280.10	284.66	288.59	284.45	55.99	58.30	60.12	58.14
Mean	261.34	267.37	271.50	266.74	51.01	53.27	54.49	52.92

Factors	M	T	M x T	M	T	M x T
SEd	2.12	3.67	6.35	0.36	0.62	1.07
CD (P:0.05)	4.25	7.36	NS	0.72	1.24	2.15

*M_1-Control, M_2-Mepiquat chloride @ 500 ppm and M_3-Chlormequat chloride @ 500 ppm at Vegetative stage
*T_1 to T_9 (2 sprays: at flower initiation & 15 days thereafter)

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