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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2019; 8(6): 1302-1308
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www.thepharmajournal.com
Received: 03-11-2018
Accepted: 05-12-2018

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Effect of growth regulators and spraying stages on flower drop, pod setting, seed yield and quality in pigeonpea [*Cajanus cajan* (L.) Millsp]

RG Chawhan, HS Deshmukh and RV Chahande

Abstract
The field experiment was conducted at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, to study the effect of growth regulators and spraying stages on flower drop, pod setting, seed yield and quality in pigeonpea Cv. Vipula; was conducted under field conditions. Further, the laboratory experiment was also conducted in the Seed Technology Research Unit, Mahatma Phule Krishi Vidyapeeth, Rahuri during 2015-16 and 2016-17. The field experiment consisted of 12 treatment combinations involving six growth regulators as main factor *viz*., T_1- Control, T_2- 1-Naphthaleneacetic acid (NAA) @ 0.5ml/L, T_3- Indole-3-acetic acid (IAA) @ 50 mg, T_4- Diammonium phosphate (DAP) @ 2%, T_5- Urea @ 1%, T_6- Potassium nitrate (KNO_3) @ 2% and two spraying stages as sub factor *viz*., S_1- At initiation of flowering and S_2-15 days after 1st spraying. The plants sprayed with NAA @0.5ml/l (T_2) have recorded consistently more number of pods per plant (439.28), pod yield per plant (122.04 g), pod yield per hectare (3813.83 kg), seed yield per plant (83.59 g) and seed yield per hectare (2612.03 kg) as against control (408.9, 112.33 g, 3510.39 kg, 73.80 g and 2306.33kg, respectively) followed by IAA @ 50 mg (429.04, 119.34 g, 3729.45 kg, 82.48 g and 2577.58 kg). NAA @ 0.5ml/l (T_2) has out yielded over the rest of the growth regulators by registering 11.71 per cent increased seed yield per hectare over control. Spraying at initiation of flowering (S_1) shows better performance of yield per hectare (1.82%) than the (S_2) 15 days after 1^{st} flowering. Similar effects were recorded for growth regulators sprayed at initiation of flowering stage and interaction effect.

Keywords: Pigeonpea, growth regulators, spraying stages, cv. vipula, FRBD, FCRD, growth and yield parameters, seed quality parameters, biochemical parameters, physical characterization

Introduction
Green revolution made our nation self-sufficient in case of cereals but we are still deficient in pulse production. India still imports red gram from countries like Myanmar, Australia and Africa to satisfy the pulse requirement of the country. This import has created great burden on our economy. To get rid of this bulky expenditure, we have to think about pigeonpea improvement, as a remedial measure (Singhal, 2003) [24].

Plant growth regulators (PGR'S) are considered as new generation of agro chemicals after fertilizers, pesticides and herbicides to augment seed yield and quality. The growth promoters like NAA are known to enhance the fruit set by preventing the flower drop in number of field crops, more so in pigeon pea crop. The exogenous application of growth regulators are known to stimulate flowering, pollination, fertilization, seed setting, yield and quality of seeds by controlling flower and pod shedding. Even though such studies have been conducted in different pulse crops, it is necessary to integrate such research efforts to boost up average productivity of pigeonpea crop and to realize these benefits in pigeonpea seed production.

Pulses constitute an important ingredient in predominantly vegetarian diet and are important and cheaper source of protein that nutritionally balances the proteins with cereal grains. (Hariprassanna and Bhatt, 2002) [7].

Being legume, it has symbiotic association with Rhizobium which plays an important role in fixing atmospheric nitrogen upto 20-40 kg ha^{-1} for which pigeonpea is inevitable crop of various cropping systems (Singh, 2003) [23].

Pigeonpea is important pulse crops of India and ranks second to chickpea in area and production. In India area occupied by pigeonpea is about 3.96 million ha with total production of 2.56 million tonnes but average productivity is quite low 646 kg/ha (Anonymous, 2015-16) because of several factors including its cultivation in rainfed and marginal lands, use of old and low quality seeds by the farmers which in turn gives poor germination, delayed emergence and sick seedlings that leads to poor yield.

With this background, a systemic study was conducted on improving seed quality of pigeonpea with the objectives, to study the effect of growth regulators and spraying stages on flower drop, pod setting, seed yield and quality in pigeonpea.

Materials and Methods

The present investigation entitled "Effect of growth regulators and spraying stages on flower drop, pod setting, seed yield and quality in pigeonpea [*Cajanus cajan* (L.) Millsp]." was conducted at Post Graduate Institute Farm and Seed Technology Research Unit, Mahatma Phule Krishi Vidyapeeth, Rahuri during the period from 2015-2016 and 2016-2017. The required seed material of the selected varieties were obtained from Pulses Research Unit, Mahatma Phule Krishi Vidyapeeth, Rahuri.

Geographically, Rahuri is situated at 19^0 34' N latitude and 74^0 64' E longitude with an altitude of 536 meters above Mean Sea Level.

The field experiment consisted of 12 treatment combinations involving six growth regulators as main factor *viz.*,T_1- Control, T_2- 1-Naphthaleneacetic acid (NAA) at the rate 0.5ml/L,T_3- Indole-3-acetic acid (IAA) at the rate 50 mg,T_4- Diammonium phosphate (DAP) at the rate 2%,T_5- Urea at the rate 1%,T_6-Potassium nitrate (KNO_3) at the rate 2% and two spraying stages as sub factor *viz.*, S_1- At initiation of flowering and S_2- 15 days after 1st spraying.

The data obtained from all the parameters in (field and laboratory) by using Factorial Randomized Block Design (FRBD) and Factorial Completely Randomized Design (FCRD) as per Panse and Sukhatme (1985) [13].

Plant growth and quality of seed production of field crop like pigeonpea is influenced mainly by the interplay between genotypic and environmental factors as supported by judicious application of seed crop management practices. Among the several cultural practices, optimum date of sowing will play important role for realizing the maximum possible yield of quality seeds of pigeonpea.

Plant based observations like Growth and yield parameters *viz*., Plant height at maturity (cm), Number of primary branches per plant, Number of secondary branches per plant, Days to flower initiation, Days to 50% flowering, Duration of flowering, Pod retention per plant, Days to pod initiation, Percent of flower drop per plant, Days to pod maturity, Number of pods per plant, Pod yield per plant (g), Pod yield per hectare (Kg), Seed yield per plant (g) and Seed yield per hectare (kg) were recorded of five randomly selected and tagged plants.

Afterwards, Seed Quality Parameters such as *viz*., Germination percentage (%), Seed mycoflora, Root length (cm), Shoot length (cm), Hundred seed weight (g), Seedling dry weight (mg-10 seedlings), Vigour index- I, Vigour index-II and Electrical conductivity (dSm-1) were recorded at laboratory condition.

Biochemical Parameter *viz*., Protein and Carbohydrate content estimated by NIR spectrometer (ZEUTEC) again various seedling response test like GA3 and 2, 4-D Test also estimated at laboratory.

The seeds visualized under the computerized vision system (Image Analyzer) for Physical Characterization of seeds *viz*., Seed surface area (mm), Seed length (mm), Seed width (mm), Seed roundness (mm) and Seed volume (mm3).

Results and Discussion

According to Table. No. 1 and 2, data from the results of this evaluation indicated that, Irrespective of spraying stages, foliar application of growth regulators showed non-significant differences for plant height at maturity and days to flower initiation. Application of NAA@ 0.5ml/l recorded earliness in pod initiation (90.00 days) compared to control (101.00 days). Among the different growth regulators, the experimental crop sprayed with NAA@ 0.5ml/L recorded minimum percent of flower drop per plant (73.23%) and more pod retention per plant (442.52), number of pods per plant (439.28), pod yield per plant (122.04 g), pod yield (3813.83 kg/ha) seed yield per plant (83.59g) and seed yield per hectare (2612.03 kg/ha) followed by IAA @ 50mg (74.54%, 432.81, 429.04, 119.34g, 3729.45 kg/ha, 82.48 g and 2577.58 kg/ha, respectively) as against control. On an average, NAA @ 0.5ml/l out yielded over rest of the growth regulators by registering 11.71 per cent increased seed yield per hectare over control, it also depleted in Graph 1 and 2.

These finding are in conformity in other crops like chickpea (Reddy, 2002) [18], greengram (Dixit and Elamati, 2007) [5] and blackgram (Kumar *et al.*, 2008) [8]. Similar findings were also reported by earlier workers like Patil *et al.* (2005) [15] in mungbean and Saishankar (2001) [20] in greengram. The significant increase in pod and seed yield attributes obtained with application of growth regulators may be attributed to more number of productive branches per plant, number of flowers retained per plant and pods per plant apart from decreased percent of flower drop per plant. Further, growth regulators have also influenced carbon cycle in the plant leading to higher CO2 fixation and efficient translocation of synthates from the source towards the sinks (developing seeds) (Tripathi *et al.* 2001 in chickpea) [25]. Similar results were also reported by earlier workers Upadhyay *et al.* 2002 [26] and Prabhu 2000 [16], Further, NAA has shown beneficial effect on preventing flower drop in pigeonpea which may be perhaps due to maintenance of favorable balance of endogenous hormones related to flowering and physiological traits which in turn resulted in decrease in flower drop but increase in seed yield per hectare (Upadhayay, 2002) [26] in chickpea. Patil *et al.* (2005) [15] in mungbean, Dixit and Elamathi, (2007) [5] in greengram, Muhammad Aslam *et al.* (2010) [12] in chickpea and Parmar *et al.* (2011) in greengram.

The pooled value of seed quality parameters shown in Table 3, The higher seed quality parameters *viz*., hundred seed weight (11.94 g), germination percentage (93.50%), root length (14.94 cm), shoot length (13.53 cm), seedling dry weight (84.14 mg-10seedlings), vigour index – I (2661.62) and vigour index – II (78.67) were observed by spraying with NAA @ 0.5ml/l over control. Similar beneficial effects of growth regulators on seed quality traits were also reported in pigeonpea by Deshpande, 1983 and Reddy *et al.* 1996 [17] and in blackgram by Lakshmamma and Rao, 1996 [9].

Non-significant results were obtained between the stages of spraying for plant height at maturity, number of primary branches per plant, number of secondary branches per plant, days to flower initiation, days to 50% flowering, duration of flowering, pod retention per plant, days to pod initiation, percent of flower drop per plant, days to pod maturity, pod yield per plant, pod yield per hectare, seed yield per plant and seed yield per hectare. The higher pod retention per plant (436.77), number of pod per plant (432.39), pod yield per plant (118.07 g), pod yield per hectare (3689.71 kg/ha), seed yield per plant (79.58 g) and seed yield per hectare (2486.88 kg/ha) were recorded in the spray given at initiation of flowering than spray at 15 days after 1st flowering.

The higher seed quality parameters *viz*. hundred seed weight (10.99 g), germination percentage (92.30%), root length (14.30 cm), shoot length (13.12 cm), seedling dry weight (83.46 mg-10seedlings), vigour index – I (2532.05) and vigour index – II (77.04) were found in spray at initiation of flowering than spray at 15 days after 1st flowering. The interaction effect due to growth regulators and stages of spray (T×S) were non-significant for various crop growth, flowering and reproductive parameters studied. Interaction effect due to growth regulators and spraying stages (T×S) showed significant effect on seed yield component in NAA sprayed at initiation of flowering stage. The interaction between growth regulators and spraying stages (T×S) were non-significant for all the seed quality parameters except electrical conductivity.

The pooled value of biochemical parameters shown in Table 4, The higher values of biochemical parameters *viz*., protein content (21.22%), carbohydrate content (64.23%) and GA3 test (22.05%) were observed by spraying NAA@ 50 ml/L over control. Whereas 2, 4-D test (20.26%) showed significant result in negative direction, indicating that increase in this character will result in decrease in yield. Interaction effect due to growth regulators and spraying stages (T×S) showed non-significant results for all biochemical parameters except 2,4-D test. Among the stages of spray, higher values for protein (20.80%), carbohydrate (63.97%) and GA3 test (14.57%) were recorded in spray applied at initiation of flowering compared to spray at 15 days after 1st spraying. Seedling length increase due to exogenous application of GA3. Similar results were also reported by Sambasivarao *et al.* (2002) [21] in groundnut. Significant decrease in seedling length while response to 2, 4 –D test attributed due to coleoptiles stimulation and root inhibition as reported by Ashwani Kumar *et al.* (1995) [2].

The higher values for of physical characteristics of seed *viz.* seed surface area (93.00 mm), seed length (6.70 mm), seed width (5.32 mm), seed roundness (95.07 mm) and seed volume (103.94 mm3) were observed by spraying NAA@ 50 ml/l over control for all the observation recorded with image analyzer. The interaction between growth regulators and stages of spray (T×S) was non-significant for all the observations recorded with image analyzer except seed surface area. These results indicated that the growth regulators have shown significant effect on physical characteristics of seed. These results are also supported by the findings of Geetha *et al.* (2011) [6].

Table 1: Effect of different spray at different growth stages on growth and yield parameters of pigeonpea (Cv. Vipula)

	Plant height at maturity (cm)	Number of primary branches per plant	Number of secondary branches per plant	Days to flower initiation	Days to 50% flowering	Duration of flowering	Pod retention per plant	Days to pod initiation
Treatments (T)								
T1	203.08	19.76	24.09	92.63	109.34	36.4	413.84	101.22
T2	228.92	26.12	29.66	81.88	96.86	33.52	442.52	90.48
T3	224.63	23.28	28.14	86.74	100.32	34.75	432.81	94.93
T4	213.98	22.13	27.61	91.58	107.74	36.06	428.17	99.04
T5	217.85	20.96	24.77	90.16	106.3	35.76	422.91	98.31
T6	209.1	21.84	24.8	88.03	104.71	35.08	430.84	97.04
SEm(±)	11.32	1.22	1.47	4.9	1.45	0.66	0.75	0.82
CD 5%	NS	3.49	NS	NS	4.13	1.89	2.15	2.33
Stages of spray (S)								
S1	216.98	22.11	27.02	89.03	104.73	35.07	436.77	96.52
S2	215.54	22.58	26	87.97	103.69	35.45	420.26	97.15
SEm(±)	6.53	0.71	0.85	2.83	0.84	0.38	0.43	0.47
CD 5%	NS	NS	NS	NS	NS	NS	1.24	NS
Interaction (TxS)								
T1S1	203.7	19.12	24.55	92.55	110.34	36.08	421.38	100.76
T1S2	202.45	20.4	23.63	92.7	108.33	36.73	406.3	101.68
T2S1	229.55	26.02	30.39	82.23	96.72	33.5	453.07	90.11
T2S2	228.28	26.21	28.92	81.53	96.99	33.53	431.97	90.84
T3S1	225	23.16	28.68	87.78	101.05	34.59	441.28	94.71
T3S2	224.25	23.4	27.6	85.7	99.58	34.91	424.34	95.14
T4S1	214.75	22.13	28.01	92.06	108.07	35.78	436.47	98.56
T4S2	213.2	22.13	27.2	91.1	107.4	36.34	419.86	99.51
T5S1	219.5	20.57	25.41	90.8	106.96	35.45	429.83	98.15
T5S2	216.2	21.34	24.13	89.53	105.63	36.07	415.99	98.46
T6S1	209.35	21.67	25.05	88.79	105.21	35.04	438.57	96.81
T6S2	208.85	22.01	24.54	87.27	104.2	35.11	423.11	97.28
Mean	216.26	22.35	26.51	88.5	104.21	35.26	428.51	96.83
SEm(±)	16.01	1.73	2.08	6.94	2.05	0.94	1.06	1.16
CD 5%	NS	NS	NS	NS	NS	NS	3.03	NS

Table 2: Effect of different spray at different growth stages on growth and yield parameters of pigeonpea (Cv. Vipula)

	Percent of flower drop per plant	Days to pod maturity	Number of pods per plant	Pod yield per plant (g)	Pod yield per hectare (Kg)	Seed yield per plant (g)	Seed yield per hectare (kg)
Treatments (T)							
T1	62.13	138.47	408.59	112.33	3510.39	73.8	2306.33
T2	58.85	127.35	439.28	122.04	3813.83	83.59	2612.03
T3	59.7	131.74	429.04	119.34	3729.45	82.48	2577.58
T4	61.17	137.03	424.03	116.45	3638.98	78	2437.34
T5	60.98	135.72	418.09	115.04	3595.08	74.96	2342.42
T6	60.42	133.91	426.77	117.87	3683.44	80.32	2510
SEm(±)	0.5	1.06	0.68	0.28	6.23	0.26	10.21
CD 5%	1.43	3.01	1.94	0.8	17.76	0.74	29.1

Stages of spray (S)							
S1	60.29	133.22	432.39	118.07	3689.71	79.58	2486.88
S2	60.79	134.85	416.21	116.29	3634.01	78.13	2441.69
SEm(±)	0.29	0.61	0.39	0.16	3.6	0.15	5.89
CD 5%	NS	NS	1.12	0.46	10.25	0.43	16.8
Interaction (T x S)							
T1S1	61.74	137.57	416.09	112.68	3521.09	73.66	2301.72
T1S2	62.53	139.36	401.1	111.99	3499.69	73.95	2310.94
T2S1	58.69	126.25	449.42	123.93	3872.66	85.03	2657.19
T2S2	59	128.45	429.14	120.16	3755	82.14	2566.88
T3S1	59.71	131.14	437.24	120.68	3771.25	83.03	2594.69
T3S2	59.7	132.33	420.84	118.01	3687.66	81.94	2560.47
T4S1	60.69	135.99	432.14	117.1	3659.22	79.04	2470
T4S2	61.65	138.06	415.93	115.8	3618.75	76.95	2404.69
T5S1	60.68	134.88	425.01	115.26	3601.88	75.19	2349.69
T5S2	61.29	136.57	411.18	114.83	3588.28	74.73	2335.16
T6S1	60.24	133.47	434.46	118.79	3712.19	81.54	2547.97
T6S2	60.6	134.35	419.09	116.95	3654.69	79.11	2472.03
Mean	60.54	134.03	424.3	117.18	3661.86	78.86	2464.28
SEm(±)	0.71	1.49	0.96	0.4	8.81	0.37	14.44
CD 5%	NS	NS	2.75	1.13	25.11	1.05	41.15

Table 3: Effect of different spray at different growth stages on seed quality parameters of pigeonpea (Cv. Vipula)

	Germination percentage (%)	Seed mycoflora (%)	Root length (cm)	Shoot length (cm)	Hundred seed weight (g)	Seedling dry weight (mg-10 seedlings)	Vigour index- I	Vigour index- II	Electrical conductivity (dSm-1)
Treatments (T)									
T1	72.17	25.51	13.43	12.49	10.51	82.55	2350.13	74.82	0.67
T2	75.23	23.07	14.94	13.53	11.94	84.14	2661.62	78.67	0.27
T3	74.93	23.53	14.72	13.37	11.24	83.81	2618.72	78.15	0.38
T4	73.84	24.41	14.22	13.06	10.63	83.19	2516.65	76.75	0.6
T5	72.61	24.9	13.57	12.86	10.56	83.14	2406.69	75.7	0.57
T6	74.34	24.15	14.5	13.2	10.84	83.55	2567.78	77.46	0.4
SEm(±)	0.11	0.06	0.19	0.04	0.11	0.09	60.6	0.08	0.02
CD 5%	0.3	0.18	0.53	0.11	0.31	0.24	172.3	0.23	0.07
Stages of spray (S)									
S1	73.92	23.8	14.3	13.12	10.99	83.46	2532.05	77.04	0.47
S2	73.79	24.72	14.15	13.05	10.91	83.33	2508.49	76.81	0.49
SEm(±)	0.06	0.04	0.11	0.02	0.06	0.05	34.99	0.05	0.01
CD 5%	0.18	0.1	0.31	0.06	0.18	NS	99.48	0.13	0.04
Interaction (T x S)									
T1S1	72.25	24.99	13.51	12.56	10.54	82.67	2364.75	74.98	0.65
T1S2	72.1	26.03	13.36	12.43	10.48	82.44	2335.51	74.65	0.7
T2S1	75.28	22.55	15.01	13.58	11.99	84.26	2673.78	78.82	0.28
T2S2	75.17	23.6	14.87	13.48	11.89	84.02	2649.46	78.52	0.26
T3S1	75	23.1	14.81	13.4	11.28	83.9	2631.75	78.27	0.36
T3S2	74.87	23.95	14.63	13.34	11.21	83.73	2605.69	78.02	0.4
T4S1	73.93	24.13	14.29	13.01	10.64	83.27	2520.14	76.88	0.6
T4S2	73.76	24.69	14.15	13.12	10.61	83.12	2513.16	76.61	0.61
T5S1	72.67	24.33	13.65	12.92	10.59	83.08	2419.52	75.7	0.55
T5S2	72.54	25.47	13.5	12.8	10.53	83.2	2393.87	75.71	0.59
T6S1	74.41	23.71	14.56	13.28	10.93	83.6	2582.35	77.55	0.39
T6S2	74.28	24.59	14.43	13.13	10.76	83.5	2553.21	77.36	0.41
Mean	73.85	24.26	14.23	13.09	10.95	83.4	2520.27	76.92	0.48
SEm(±)	0.15	0.09	0.26	0.05	0.15	0.12	85.7	0.11	0.03
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	0.09

Table 4: Effect of different spray at different growth stages on biochemical parameters and physical characterization of pigeonpea (Cv. Vipula)

	Protein content (%)	Carbohydrates content (%)	Response to GA3 test	Response to 2, 4-D test	Seed surface area (mm)	Seed length (mm)	Seed width (mm)	Seed roundness (mm)	Seed volume (mm3)
Treatments (T)									
T1	26.78	52.92	15.84	38.74	89.18	5.92	4.72	89.53	77.95
T2	27.43	53.27	28	26.73	93	6.7	5.32	95.07	103.94
T3	27.31	53.15	25.75	28.96	92.05	6.64	5.21	94.04	100.86
T4	26.97	53.04	19.89	33.9	89.99	6.38	4.91	91.46	88.29
T5	27	53.02	18.15	35.87	89.61	6.22	4.82	90.57	83.29
T6	27.17	53.1	23.01	32.83	90.67	6.54	5.06	92.48	94.68
SEm(±)	0.03	0.01	0.1	0.08	0.13	0.03	0.01	0.45	0.67
CD 5%	0.09	0.04	0.27	0.24	0.38	0.08	0.04	1.28	1.91
Stages of spray (S)									
S1	27.13	53.11	22.12	31.77	90.94	6.43	5.06	92.62	92.61
S2	27.09	53.05	21.43	33.9	90.56	6.37	4.95	91.76	90.39
SEm(±)	0.02	0.01	0.06	0.05	0.08	0.02	0.01	0.26	0.39
CD 5%	0.05	0.02	0.16	0.14	0.22	NS	0.02	0.74	1.1
Interaction (TxS)									
T1S1	26.8	52.95	16.08	38.1	88.83	5.98	4.78	90	78.8

T1S2	26.76	52.89	15.59	39.37	89.53	5.86	4.66	89.05	77.1
T2S1	27.44	53.27	28.22	25.67	93.73	6.72	5.36	95.58	105.72
T2S2	27.41	53.26	27.78	27.79	92.28	6.68	5.27	94.56	102.16
T3S1	27.34	53.17	26.04	27.7	92.51	6.67	5.27	94.27	101.92
T3S2	27.29	53.12	25.46	30.22	91.59	6.61	5.16	93.8	99.81
T4S1	27	53.07	20.22	33.11	89.89	6.41	4.97	91.88	89.12
T4S2	26.95	53	19.56	34.69	90.09	6.35	4.86	91.04	87.46
T5S1	27.03	53.06	18.55	34.6	89.36	6.23	4.86	91.29	84.74
T5S2	26.97	52.99	17.74	37.14	89.86	6.21	4.78	89.86	81.84
T6S1	27.2	53.14	23.59	31.46	91.35	6.56	5.12	92.73	95.36
T6S2	27.14	53.06	22.43	34.19	90	6.52	5	92.23	94
Mean	27.11	53.08	21.77	32.84	90.75	6.4	5.01	92.19	91.5
SEm(±)	0.04	0.02	0.13	0.12	0.19	0.04	0.02	0.64	0.95
CD 5%	NS	NS	NS	0.34	0.54	NS	NS	NS	NS

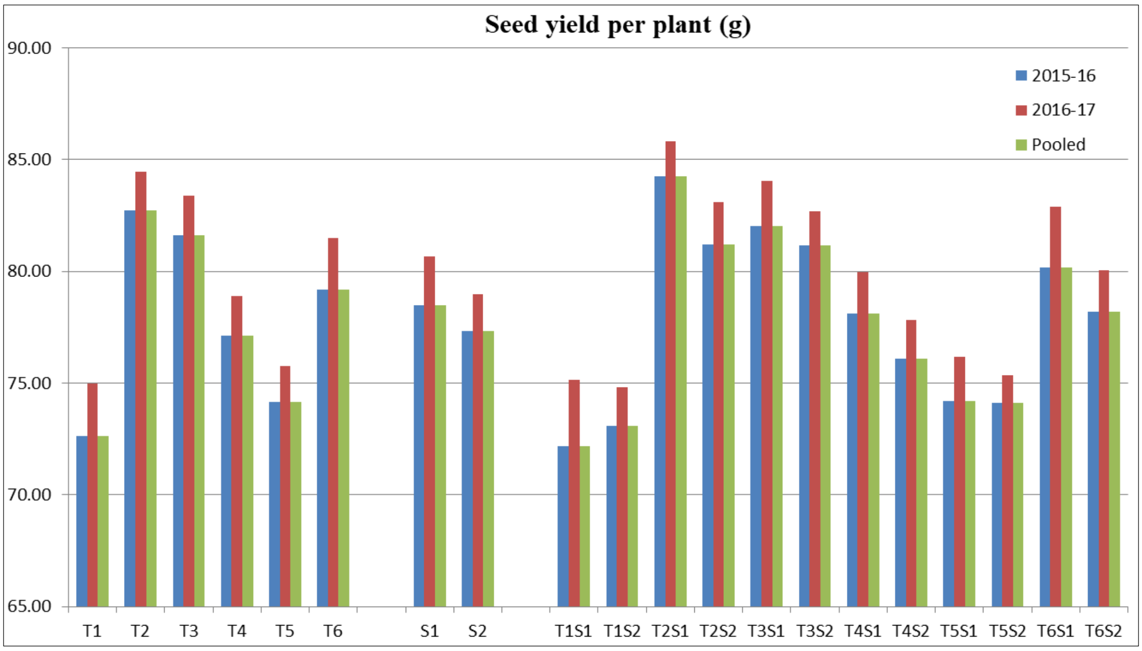

Fig 1: Effect of different spray at different growth stages and their interaction on seed yield per plant (g) of pigeonpea (Cv. Vipula)

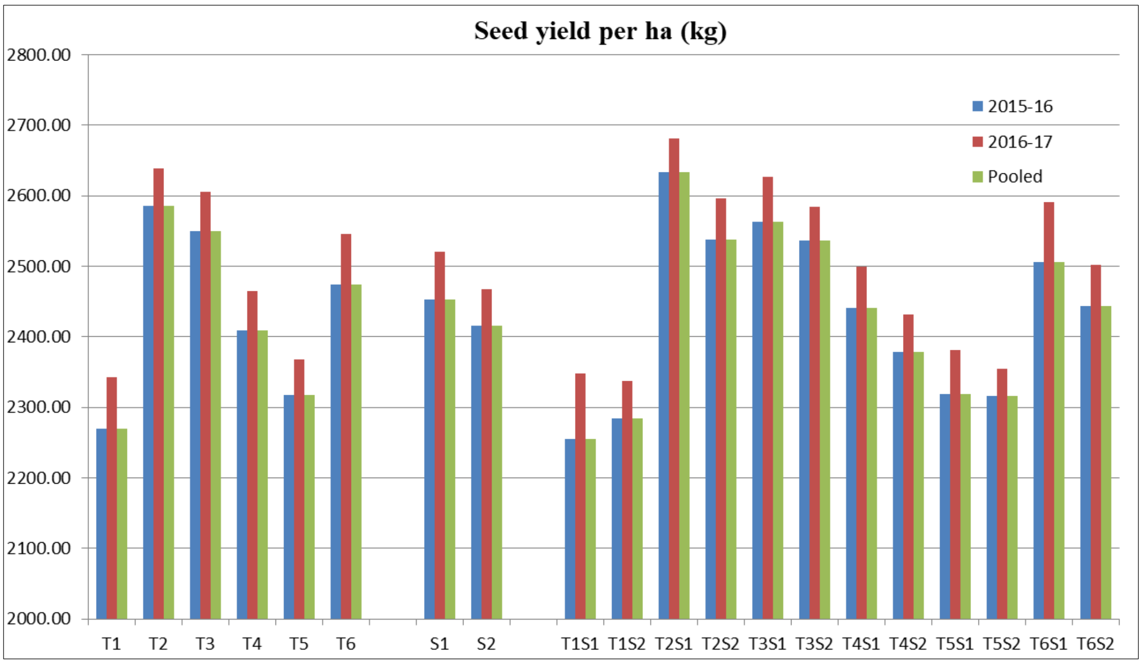

Fig 2: Effect of different spray at different growth stages and their interaction on seed yield per hectare (kg) of pigeonpea (Cv. Vipula)

Influence of Growth Regulators

Among the different growth regulators, the experimental crop sprayed with NAA@ 0.5ml/L (T2) recorded least percent of flower drop per plant, but higher pod retention per plant, number of pods per plant, pod yield per plant, pod yield per hectare and seed yield per plant and seed yield per hectare followed by IAA @ 50mg (T3) as against control (T1). Foliar application of NAA@ 0.5ml/l (T2) out yielded over the rest of the growth regulators by registering 11.71 per cent increased seed yield per hectare over control. Irrespective of spray stages, foliar application of growth regulators showed non-significant differences for crop growth parameters *viz*. plant height at maturity, number of primery branches per plant, number of primery branches per plant and days to flower initiation. The higher seed quality parameters *viz*., hundred seed weight, germination percentage, root length, shoot length, seedling dry weight, vigour index – I and vigour index – II were observed by spraying NAA@ 0.5ml/l over control.

Influence of spraying stages

Among the stages of spraying, higher pod retention per plant, number of pod per plant, pod yield per plant, pod yield per hectare, seed yield per plant and seed yield per hectare were recorded in the spray given at initiation of flowering (S1) than spray at (S2) 15 days after 1st flowering. Spraying at initiation of flowering (S1) showed higher seed yield per hectare (1.78%) than the (S2) 15 days after 1st flowering. Various growth and yield parameters, seed quality parameters, biochemical parameters and pod observation recorded under Image Analyzer showed better performance at initiation of flowering (S1) than (S2) 15 days after 1st flowering. Between the stages of spray, higher values for protein, carbohydrate and GA3 test were recorded in spray at initiation of flowering compared to spray at (S1) 15 days after 1st spraying. In this study, numerically higher growth parameters were noticed in the initiation of flowering stage may be attributed to the enhanced effect of growth regulators sprayed at the early stages of the crop growth compared to those sprayed at later growth stage. These results are in conformity with those of earlier researchers like Saishankar (2001) [20] in greengram, Kumar *et al.* (2008) [8] in blackgram and Yadav *et al.* (2008) [27] in field pea. Similar results were noticed in chickpea (Merwade 2000) [10], greengram (Saishankar 2001) [20], blackgram (Kumar *et al.* 2008) [8] and fieldpea (Yadav *et al.* 2008) [27].

The similar beneficial effect of exogenous application of growth regulators at different crop growth stages was also confirmed in blackgram (Kumar *et al.*, 2008) [8]. The increased seed quality parameters at initiation of flowering stage may be probably due to greater accumulation and assimilation of food reserves in seeds due to spraying of growth regulators at flower initiation stage (early growth stage) compared to pod initiation stage (later stage). Similar results were also in confirmation to those of (Shantappa *et al.* 2007) [22] in bitter gourd and (Kumar *et al.* 2008) [8] in blackgram. This increase in values for biochemical parameters may be attributed to the enhanced valuable biochemical composition of seed which further improve seed quality and yield. Similar results were reported by Sainis *et al.* (2009) [19] in wheat.

Interaction Effect (T×S)

The interaction effect due to growth regulators and stages of spray (T×S) was non-significant for various crop growth, flowering and reproductive parameters and observations recorded with image analyzer. The interaction between growth regulators and spraying stages (T×S) was non-significant for all the seed quality parameters except electrical conductivity. Interaction effect due to growth regulators and spraying stages (T×S) showed non-significant results for all biochemical parameters except 2, 4-D test.

These results are supported by the earlier result of growth regulators and spraying stages and similar findings were also confirmed in greengram by Saishankar (2001) [20], bittergourd by Shantappa *et al.* (2007) [22] and blackgram by Kumar *et al.* 2008 [8]. The significant increase in seed yield per hectare was related to more retention of flowers reduced, flower drop and higher number of pods per plant and other yield components as seen from the results of this study. Similar results were confirmed in greengram by Saishankar 2001 [20] and bitter gourd by Shantappa *et al.* 2007 [22]. Similar findings were reported by Sambasivarao *et al.* (2002) [21] in groundnut and Biradarpatil *et al.* (2006) [3] while working on safflower.

Conclusion

There is a need to study the influence of other growth regulators at various concentrations, methods of application at different crop stages on flower drop, seed yield and quality. There is a need to investigate and identify suitable sowing dates and varieties under different agro-climatic zones for getting higher seed yield and seed quality. The characterization based on distinct and stable seed, seedling and plant morphological markers are need to be standardized for different varieties of pigeonpea.

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