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Effect of Drip Fertigation and Foliar Sprays on Morpho-Physiological Traits of Pigeonpea (*Cajanus cajan* L.)

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Abstract **– Field experiments were conducted during Kharif, 2010 (main crop) and Rabi, 2010 (ratoon crop) at Agricultural College and Research Institute (TNAU), Madurai, Tamil Nadu, India to determine the effects of** drip irrigation **and foliar sprays on morpho-physiological traits of pigeonpea. The experiment was laid out in a split plot design with three replication. The treatments consists of four main plots treatments (F_1- 50% of SRDF through drip, F_2- 75% of SRDF through drip, F_3- 100% of SRDF through drip and F_4- 150% SRDF through drip) and three sub-plots (S_1- Foliar spray of 0.5 per cent $ZnSO_4$, S_2 -Foliar spray of 100 ppm succinic acid and S_3- Foliar spray of 100 ppm humic acid) and control (surface irrigation with conventional method of fertilizer application). The following morpho-physiological parameters were studied to evaluate the effect of drip fertigation and foliar spraying treatments on plant height, stem girth, number of branches^{-1}, number of flowers^{-1}, dry matter production^{-1}, LAI, LAD, RGR and leaf chlorophyll. The results indicated that the all morpho-physiological characters were significantly influenced by combined application of 100% of SRDF through drip with foliar spraying of 0.5% of $ZnSO_4$ in both crops. Whereas in surface irrigation with conventional method of fertilizer application recorded lower morpho-physiological traits in main and ratoon crops. The increase in all morpho-physiological attributes with F_3FS_1 was mainly attributed by greater and consistent availability of soil moisture and nutrients which resulted in better crop growth and yield components of pigeonpea.**

Keywords **– Pigeonpea, Drip Fertigation, Foliar Spray, Morphological, Physiological Traits, Main Crop, Ratoon Crop.**

I. Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp.] has been considered as second most important crop after chickpea. India has virtual monopoly in pigeonpea production accounting to 90% of world's total production. In India, pigeonpea is grown in an area of 4.37 m.ha, with a production of 2.65 m.t and the average productivity is 655 kg ha^{-1}. More than 85 % area of pigeonpea is under rainfed cultivation. The demand for pulses is increasing due to increasing population. Indian Council of Medical Research recommends about 60 g/ day/ person but the average intake is only 31 g/day [1]. To meet the demand, pigeonpea productivity has to be increased. Drip fertigation is the precise application of irrigation water and fertilizer in the root zone. Fertigation is a relatively new but revolutionary concept in applying fertilizer through irrigation as it helps to achieve both fertilizer use efficiency and water-use efficiency. When fertilizer is applied through drip, it is observed that 30 per cent of the fertilizer could be saved [2]. The main cause for low seed multiplication rate is that pigeonpea is mainly grown under agro-ecological constraints compounded by paucity of nutrients and hormones. Pigeonpea seed crop requires well irrigated schedule to provide quality seeds and any method to save water will help in mitigating the harm caused by reduced water and formation of hard seeds. Water requirement is though low during the first 60-70 days, increases during flowering and pod formation. One of the possible ways to bridge the gap between demand and supply of water is to increase the pigeonpea seed yield and water saved per unit area by adopting appropriate production and management technologies. In India, medium duration pigeonpea are normally sown soon after the onset of the monsoon, in June or July; they mature around December, when they are usually cut down and removed from the field. However, if they are harvested by ratooning or by picking the pods, the plants go on to produce a second flush of pods, which matures around March [3]. Drip fertigation thus offers the scope to increase the seed yield per unit area, save time and result in quality seed production through precise application of water and fertilizers at the critical stages and prevent the vagaries caused by environmental stress. Since research in pigeonpea drip fertigation combined with foliar spray for seed crop is scanty, the present study was undertaken to study the influence of drip fertigation and foliar sprays on morphological and physiological characters of pigeonpea in main crop and ratoon crop.

II. Materials and Methods

Field location: The field trial was conducted during Kharif, 2010 and Rabi, 2010 at Central farm, Agricultural College and Research Institute (TNAU), Madurai to study effect of drip fertigation and foliar sprays on morphological and physiological parameters of pigeonpea.

Lay Out of Drip System: Laterals (12mm) from sub main were fixed at a spacing of 120cm and inline lateral emitters in fixed at 20 cm with a 16 mm tap at the head of each lateral. The drip irrigation system was well maintained by flushing and cleaning the filters. The quantity of water was calculated as follows: Volume (lit ha-1) = PE × Kp × Area (m2), PE = pan evaporation, K p= Pan Factor (0.80). Time of operation of drip system to deliver the required volume of water per plot was computed based on the formula:

Time of application =

$$\frac{\text{Volume of water required (1)}}{\text{Emitter discharge (lit ha}^{-1}\text{) x No. of emitters/plot}}$$

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Treatment details:

The field experiments were laid out in a split plot design with twelve treatments and three replications. The treatments included combination of drip fertigation and foliar spraying. Four fertigation levels *viz*., 50%, 75%, 100% and 150% of SRDF through drip along with three foliar spraying such as 0.5% $ZnSO_4$, 100 ppm succinic acid and 100 ppm humic acid to formed the treatment combinations. The treatments were: T_1- 50% of SRDF through drip + FS of 0.5% $ZnSO_4$, T_2 - 50% of SRDF through drip + FS of 100 ppm succinic acid, T_3 - 50% of SRDF through drip + FS of 100 ppm humic acid, T_4 - 75% of SRDF through drip + FS of 0.5% $ZnSO_4$, T_5 - 75% of SRDF through drip + FS of 100 ppm succinic acid , T_6 - 75% of SRDF through drip + FS of 100 ppm humic acid, T_7 - 100% of SRDF through drip + FS of 0.5% $ZnSO_4$, T_8 - 100% of SRDF through drip + FS of 100 ppm succinic acid, T_9 - 100% of SRDF through drip + FS of 100 ppm humic acid , T_{10} - 150% of SRDF through drip + FS of 0.5% $ZnSO_4$, T_{11} - 150% of SRDF through drip + FS of 100 ppm succinic acid, T_{12} - 150% of SRDF through drip + FS of 100 ppm humic acid and Control - surface irrigation with SRDF of 25:50:25 NPK kg ha^{-1}. Seeds were treated and were sown in raised bed at the spacing of 45 x 30 cm as direct spot seeding on raised beds of 90 cm width and furrows of 10 cm.

Fertigation: The SRDF dose (25:50:25 N, P_2O_5 and K_2O kg ha^{-1} respectively in two splits) was used as base for calculating the fertigation schedule. Fertigation was done once in six days starting from 15 DAS to 90 DAS in three consecutive steps *viz.,* wetting the root zone before fertigation, fertigating the field and flushing the nutrients with water.

Ratooning: After harvesting the first crop, the main stem was severed at 30 cm above ground. Drip fertigation as per the first crop schedule was applied.

Biometric Observations: In each experimental plot, five plants were selected at random and tagged for recording biometric observations. Growth components were recorded at three stages of crop growth, *viz*., 60 DAS/DAR, 90 DAS/DAR and at harvest stage.

Crop growth characters: The assessment of growth characteristics such as plant height (cm), number of branches $plant^{-1}$, stem girth $plant^{-1}$ (cm), dry weight (g $plant^{-1}$), number of flower plant $^{-1}$ was done for ten plants each selected randomly from each plot.

Physiological parameters: The physiological parameters were again observed in ten plants randomly selected per plot.

Leaf Area Index based on the leaf area.$plant^{-1}$ the LAI was calculated by using the formula

$$LAI = \frac{\text{Leaf area per plant}}{\text{Ground area occupied}}$$

Relative Growth Rate (RGR) was calculated using the formula suggested by Williams [4].

Leaf chlorophyll content of leaves was recorded as described by [5] using the chlorophyll meter (SPAD-502, Soil Plant Analysis Development section).

Statistical Analysis: The data pertaining to the experiment were subjected to statistical analysis by analysis of variance method as suggested by Gomez and Gomez [6]. Pooled analyses of the seasonal mean values were done for precise interpretation of the data. Wherever the treatment differences were found significant (F test), critical difference was worked out at five per cent probability level and the values furnished. The treatment differences that were not significant are denoted as NS.

III. Results and Discussion

Morphological characters

Drip fertigation and foliar spray treatments significantly influenced the morphological characters such as plant height, number of branches, stem girth, number of flowers, and dry matter production. Basically, plant height is a genetically controlled character. But several studies indicated that the plant height can either be increased or decreased by the application of fertigation and foliar spraying. However, in the present investigation, significant differences in plant height were noticed among the drip fertigation and foliar spray treatments. It is interesting to note that there was an increase in plant height over control in all the treatments.

Plant height (cm)

Among the treatment combinations, 100% SRDF as WSF (F3) with 0.5% of ZnSO4 resulted in higher 132.2 cm at 60 DAS and 164.3cm at harvest with 31.6 and 24.3 per cent respectively, increase over 50% of SRDF as WSF +100 ppm of humic acid in main crop (Table 1). On the other hand, ratoon crop recorded higher plant height with same treatment combinations 117.5 cm at 60 DAR 133.5 cm and at harvest 141.1 cm with 39.0% and 29.5 per cent respectively which gave an increase over 50% of SRDF as WSF + 100 ppm of humic acid (Figure 2). Similar positive influence between fertigation and foliar spray was reported by Prabhu [7] who revealed that drip fertigation of 100% RDF as water soluble fertilizer with micronutrients *viz.,* $ZnSO_4$, $FeSO_4$ as foliar spray registered the highest values for morphological characters at different phases of crop growth as compared to drip fertigation at 100% RDF alone in chilli.

Number of branches

Between the crops, main crop recorded 15.0% and 14.0 per cent higher and better yield compared to ratoon crop with combination of 100% of SRDF as WSF (F_3) with 0.5% of $ZnSO_4$ recorded maximum number of branches at 90 DAS and at harvest respectively (Figure 3). The combination of 100% of SRDF as WSF and 0.5 % of $ZnSO_4$ recorded maximum number of branches (18.3) in main crop and (15.9) in ratoon with 52.5%, 65.6 per cent higher value respectively at 90 DAS/DAR as compared to 50 % of SRDF as WSF + 100 of ppm humic acid foliar spray treatment. On the other hand, the number of branches at harvest was more in main crop (20.3) and in ratoon (17.8) an increase by 56.2% and 53.4% respectively as compared to F_1+FS_3 which recorded lower number of branches 13.0 in main and 11.6 in ratoon. Meanwhile, control plot recorded minimum number of branches in both crops. Similar results were evidenced by Benke [8] found that the 100 per cent RDF as WSF (8:8:8 NPK +

Urea) through drip irrigation system increased number of primary and secondary branches and boll per plant as compared to 100 per cent recommended solid fertilizer in cotton.

Stem girth (cm)

Stem girth is an indicator of vigorous growth consequent to proper fertilization. The stem girth at 60 DAS/DAR, 90 DAS/DAR and at harvest was influenced by drip fertigation treatment in main crop and ratoon crop. Higher stem girth was noticed in ratoon crop as compared to main crop due to the age of the crop**.** Among the fertigation treatments, application of 100 per cent of SRDF as WSF recorded higher stem girth of 8.3 cm and 4.9 cm with 6.9% and 6.5 % higher as compared to 50% of SRDF as WSF and control in ratoon and main crop respectively at 60 DAR/DAS. Similar trend was noticed at 90 DAR/DAS also with F_3 recorded higher stem girth of 9.4 cm and 7.6 cm in ratoon and in main crop respectively. On the other hand, stem girth at harvest the same trend was obtained by 100 per cent of SRDF as WSF (Figure 3). These results seemed to be in accordance with those reported by Hassan et al. [9] observed that the maximum stem girth were recorded with the application of 140 kg N ha^{-1} through drip fertigation in maize as also visualized by Fanish et al. [10] reported that drip fertigation with 100 per cent recommended dose of fertilizer (RDF) with 50 per cent P and K as water soluble fertilizer recorded significantly higher growth attributers in maize.

Number of flowers.plant^{-1}

Significant differences were noticed among the interaction effects between crops, drip fertigation and foliar spray treatments on number of flowers.plant^{-1} (Figure 2). Among the crops, main crop recorded 455 numbers which was 44.4 per cent higher and better as compared to ratoon crop (315) with the treatment combination of 100% of SRDF as WSF (F_3) + 0.5 % of $ZnSO_4$. Among the treatment combination, 100% of SRDF as WSF (F_3) + 0.5 % of $ZnSO_4$ registered maximum flowers per plant in main crop (455) than in ratoon (315) a 44.4 % and 89.7 % increase respectively over 50 % of SRDF as WSF + 100 ppm of humic acid as well as 46.7 % and 78.9 per cent higher in main crop along with ratoon compared to control plot and was in accordance with the findings of Sanju et al. [11] found that drip fertigation with 100% WSF recorded significantly higher number of flowers^{-1} and number of pods plant^{-1} (41.3) compared to other treatments in ground nut.

Dry matter production (g)

Dry matter production and its partitioning towards reproductive parts is an important yield attributing character and a basic vegetative phase is essential for the development of reproductive parts. The drip fertigation and foliar spray helps in improving the canopy structure and also increase in the productivity through the manipulation of source-sink relationship. Among the treatment combinations, combination of 100% of SRDF as WSF (F_3) + 0.5 % of $ZnSO_4$ recorded maximum dry matter production (215.4g) in main crop and (216.5g) in ratoon was higher by 38.7 % and 42.9 per cent in main and ratoon respectively as compared to F_1+FS_3. Meanwhile, the same best combinations recording 40.3% and 48.1 per cent superior in main crop and ratoon respectively as compared to control plot (Table 2). These results were corroborated with findings of Shashidhara [12] observed that the dry matter production at harvest in 100 and 75 per cent RDF applied through fertigation realized 34 and 18 per cent higher production than in 50 per cent RDF.

Physiological parameters

The importance of leaf area in determining canopy and water used by a crop is well recognized. Formation and maintenance of active leaf area is essential for continued production of photosynthate to maintain carbon and energy flow to both developing seed and plant tissues. The leaf area index, LAD, RGR and Leaf chlorophyll value differed significantly due to drip fertigation and foliar spray treatments and their interaction effect.

Leaf Area Index

However, the leaf area index was higher 2.52 in main crop and 2.10 in ratoon recording higher LAI through combination of 100% of SRDF as WSF (F_3) + 0.5 % of $ZnSO_4$ treatment with 77.5% and 90.9 % increase in main crop and ratoon respectively as compared to F_1+FS_3 treatment combinations at 60 DAS/DAR (Figure 3). On the other hand, LAI at harvest the values were higher 5.66 and 4.38 in main crop and ratoon respectively, with 5.56 and 4.21 in main and ratoon crops respectively by same best treatment combination, followed by F_3FS_2. These results are in tune with the revelations of Hebbar *et al.* [13] who reported that 100% water soluble fertilizer (WSF) through fertigation recorded significantly higher total dry matter and LAI (181.9 g per plant and 3.69, respectively) over drip irrigation in tomato. Drip fertigation led to increased physiological parameters as were reported by Chawla and Narda [14]. The importance of canopy structure in light interception, crop growth and higher LAI contributed for more carbohydrate synthesis and better yield has been pointed out by Duncan [15].

Leaf Area Duration

Leaf area duration is an important factor for growth and development of a crop (Evans, 1975, Sinclair and Dewit 1976). In the present investigation, LAD was higher by 100% of SRDF as WSF (F_3) + 0.5 % of $ZnSO_4$ treatment 134.5 in main crop and 110.2 ratoon crop with 32.4% and 41.8 % increase in main crop and ratoon respectively as compared to F_1+FS_3 treatment combinations (Table 3) agreed with the results obtained by Govindan and Grace [16] found that 150 per cent PE+ drip fertigation of 100 per cent RDF+azophosmet+humic acid resulted in better crop growth in rice as also visualized by Deng lan-sheng and Zhang cheng-lin [17] in maize.

Relative Growth Rate

There was significant difference on fertigation treatments in relative growth rate. The relative growth rate being an important parameter to quantify photosynthates accumulation in sink which in turn resulted in increased growth of pigeonpea. Among the treatments, 100% of SRDF as WSF recorded higher relative growth rate 0.050 in main crop and 0.009 in ratoon crop with 19.0% and and 50% increased as compared to control (Table 4). These findings are in conformity with the studies of

Veeraputhiran [18] attributing enhanced physiological parameters such as LAI, CGR, RGR and NAR using drip fertigation over the furrow band application of cotton.

Leaf chlorophyll

In the present study, the 100% of SRDF as WSF recorded higher leaf chlorophyll were higher in main crop SPAD values 43.8 and 43.2 in ratoon crop at 60 DAS/DAR. Similar trend was noticed at 90 DAS/DAR of pigeonpea. But control plot observed chlorophyll values were lower in both crops. Meanwhile, main crop recorded overall higher physiological parameters than ratoon. In general, control plots were observed to possess lower physiological parameters compared to all other treatments combinations under drip fertigation in both crops (Figure 3). The present study was in accordance with the findings of Sampath Kumar et al. [19] reported that drip fertigation with of 100 per cent recommended fertilizer through drip recorded significantly enhanced crop growth in cotton and also similar results were observed by Siba et al. [20] in chilli.

IV. Conclusion

From this investigation it can be concluded that, the effect of drip fertigation on morpho-phyisological traits was significant at the 100% of SRDF as WSF (F_3). This study confirms present recommendations that the best morpho-phyisological traits potential for pigeonpea is achieved by the treatment combination of 100 per cent SRDF as WSF with foliar spraying with 0.5 per cent Zinc Sulphate (F_3FS_1) and maximized the all morpho-physiological characters in both crops and substantial quantity of water saving. Between the crops, main crop was performed better over ratoon crop in terms of all morphological and physiological attributes. Thus, it clearly indicated the feasibility of introducing drip fertigation in pigeonpea seed production for higher water productivity; higher fertilizer use efficiency and sustainability in future pigeonpea seed production.

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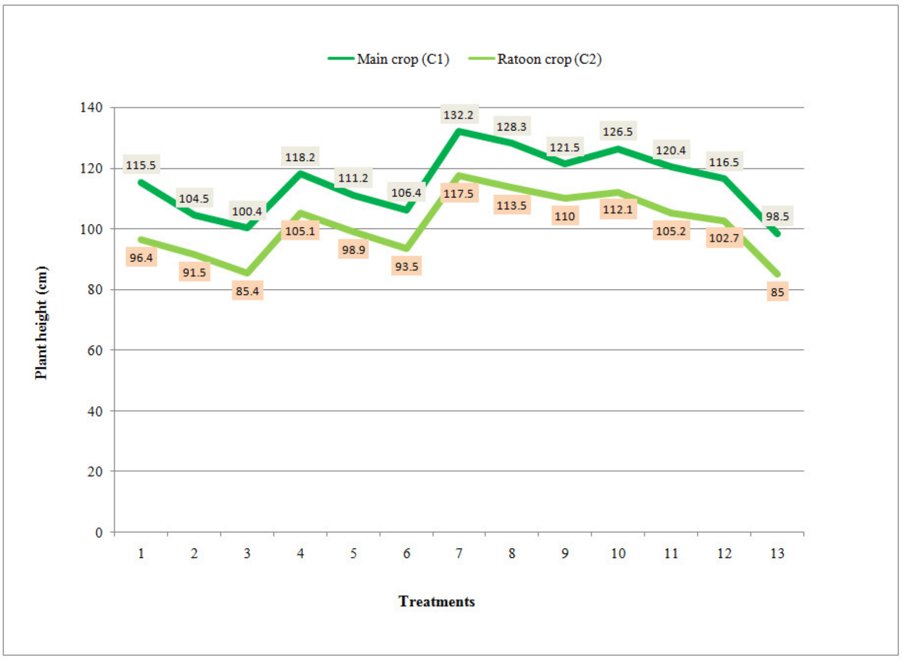

Fig.1. Effect of drip fertigation on plant height (cm) at 60DAS/DAR.

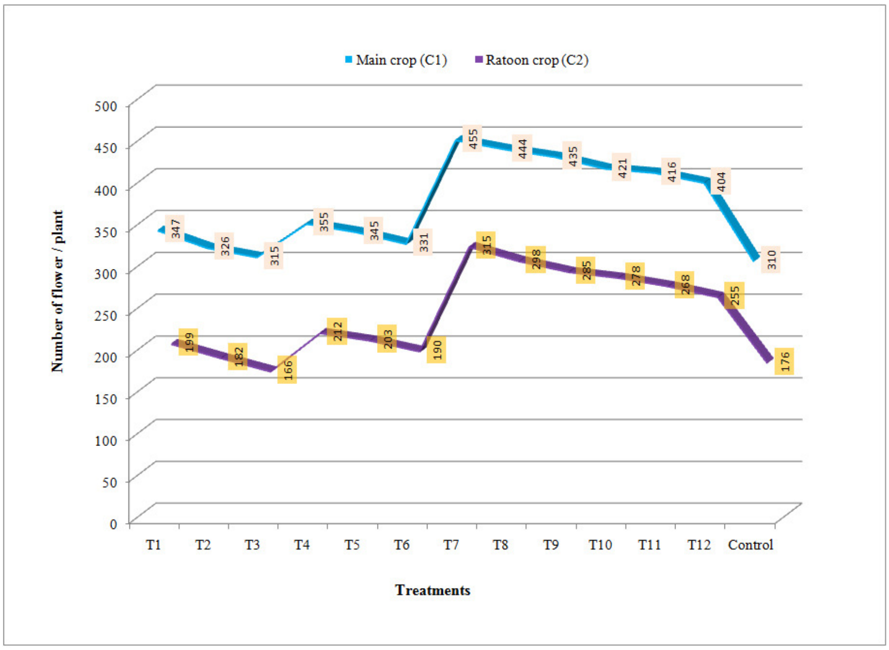

Fig.2. Effect of drip fertigation on number of flower.plant^{-1} in main and ratoon crop.

Fig.3. Morpho-physiological characters of pigeonpea under drip fertigation

Table 1: Influence of fertigation and foliar spray on plant height (cm) at harvest in pigeonpea cv. VBN 3 (Main crop, Ratoon)

F- Fertigation Treatments	Plant height (cm) at harvest											
	FS - Foliar spraying treatments											
	Main crop (C_1)				Ratoon crop (C_2)				Pooled mean			
	FS_1	FS_2	FS_3	Mean	FS_1	FS_2	FS_3	Mean	FS_1	FS_2	FS_3	Mean
F_1	148.0	136.8	132.2	139.0	120.6	114.8	108.9	114.8	134.3	125.8	120.6	126.9
F_2	150.5	143.7	138.9	144.4	131.7	122.3	117.1	123.7	141.1	133.0	128.0	134.0
F_3	164.3	160.8	153.5	159.5	141.1	137.1	132.6	136.9	152.7	148.9	143.1	148.2
F_4	159.0	152.9	148.3	153.4	136.0	131.5	125.4	131.0	147.5	142.2	136.9	142.2
Mean	155.5	148.6	143.2	149.1	132.4	126.4	121.0	126.6	143.9	137.5	132.1	137.8
	F	FS	F X FS	FS X F	F	FS	F X FS	FS X F				
SEd	0.933	0.644	1.405	1.287	0.818	0.522	1.181	1.043				
CD(P=0.05)	2.283**	1.365**	3.182*	2.729*	2.001**	1.106**	2.688**	2.212**				
Absolute Control	133.2				110.4							

Pooled	SEd	CD(P=0.05)
C	0.419	0.923**
F	1.051	2.290**
FS	0.795	1.619**
F X FS	1.670	NS
C X F	1.821	3.967**
C X FS	1.124	2.289**
C X F X FS	2.248	NS

Table 2: Influence of fertigation and foliar spray on dry matter production (g) at harvest in pigeonpea cv. VBN 3 (in Main crop and Ratoon)

F- Fertigation Treatments	Dry matter production (g) at harvest											
	FS - Foliar spraying treatments											
	Main crop (C_1)				Ratoon crop (C_2)				Pooled mean			
	FS_1	FS_2	FS_3	Mean	FS_1	FS_2	FS_3	Mean	FS_1	FS_2	FS_3	Mean
F_1	170.5	163.6	155.3	163.1	165.0	160.2	151.4	158.9	167.8	161.9	153.4	161.0
F_2	175.0	173.2	168.5	172.2	179.7	167.2	161.6	169.5	177.4	170.2	165.1	170.9
F_3	215.4	201.9	198.4	205.2	216.5	200.9	194.1	203.8	216.0	201.4	196.3	204.5
F_4	186.6	181.9	176.6	181.7	183.2	171.3	164.9	173.1	184.9	176.6	170.8	177.4
Mean	186.9	180.2	174.7	180.6	186.1	174.9	168.0	176.3	186.5	177.5	171.4	178.5
	F	FS	F X FS	FS X F	F	FS	F X FS	FS X F				
SEd	1.039	0.935	1.846	1.869	1.742	0.549	1.959	1.098				
CD(P=0.05)	2.542**	1.981**	4.105**	3.962**	4.263**	1.164**	4.660**	2.327**				
Absolute control	153.5				146.2							

Pooled	SEd	CD(P=0.05)
C	0.947	2.085**
F	1.425	3.104**
FS	0.937	1.909**
F X FS	2.091	NS
C X F	2.468	NS
C X FS	1.325	2.700**
C X F X FS	2.651	NS

Table 3: Influence of fertigation and foliar spray on leaf area duration in pigeonpea cv. VBN 3 (in Main crop and Ratoon)

F- Fertigation Treatments	LAD – leaf area duration											
	FS - Foliar spraying treatments											
	Main crop (C_1)				Ratoon crop (C_2)				Pooled mean			
	FS_1	FS_2	FS_3	Mean	FS_1	FS_2	FS_3	Mean	FS_1	FS_2	FS_3	Mean
F_1	110.4	105.0	101.6	105.7	88.5	82.5	77.7	82.9	99.5	93.8	89.7	94.3
F_2	117.6	112.6	109.5	113.2	92.9	89.7	87.5	90.0	105.2	101.2	98.5	101.6
F_3	134.5	130.8	128.5	131.3	110.2	104.3	100.1	104.9	122.4	117.5	114.3	118.1
F_4	128.8	120.6	116.5	122.0	102.4	96.6	93.5	97.5	115.6	108.6	105.0	109.7
Mean	122.8	117.3	114.0	118.0	98.5	93.3	89.7	93.8	110.7	105.3	101.9	105.9
	F	FS	F X FS	FS X F	F	FS	F X FS	FS X F				
SEd	0.356	0.365	0.693	0.729	0.412	0.369	0.730	0.738				
CD(P=0.05)	0.870**	0.773**	1.530**	1.546**	1.009**	0.782**	1.624**	1.565**				
Absolute control	101.2				77.5							

Pooled	SEd	CD(P=0.05)
C	0.408	0.899**
F	0.272	0.593**
FS	0.259	0.528**
F X FS	0.503	1.025**
C X F	0.471	1.027**
C X FS	0.366	NS
C X F X FS	0.733	1.492**

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Table 4: Influence of fertigation and foliar spray on relative growth rate (g m^{-2} d^{-1}) in pigeonpea cv. VBN 3 (in Main crop and Ratoon)

F-Fertigation Treatments	RGR – Relative Growth Rate; FS - Foliar spraying treatments: Main crop (C_1)				Ratoon crop (C_2)				Pooled mean			
	FS_1	FS_2	FS_3	Mean	FS_1	FS_2	FS_3	Mean	FS_1	FS_2	FS_3	Mean
F_1	0.046	0.044	0.044	0.045	0.007	0.007	0.007	0.007	0.026	0.025	0.025	0.026
F_2	0.048	0.047	0.047	0.047	0.007	0.007	0.007	0.007	0.027	0.027	0.027	0.027
F_3	0.050	0.050	0.049	0.050	0.009	0.009	0.008	0.009	0.030	0.030	0.029	0.029
F_4	0.050	0.048	0.046	0.048	0.008	0.007	0.007	0.008	0.029	0.028	0.027	0.028
Mean	0.049	0.047	0.047	0.047	0.008	0.008	0.007	0.008	0.028	0.027	0.027	0.028
	F	FS	F X FS	FS X F	F	FS	F X FS	FS X F				
SEd	0.00093	0.00063	0.00138	0.00126	0.00032	0.00007	0.00034	0.00014				
CD(P=0.05)	0.00226**	0.00134*	NS	NS	0.00079**	0.00014**	NS	NS				
Absolute control	0.0420				0.0063							

Pooled mean	SEd	CD(P=0.05)
C	0.0003	0.0006**
F	0.0003	0.0006**
FS	0.0002	0.0003**
F X FS	0.0004	NS
C X F	0.0005	0.0010**
C X FS	0.0002	0.0005**
C X F X FS	0.0005	NS

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- **Ph.D (Agri.) -** Drip Fertigation Studies in Pigeonpea (*Cajanus cajan* L.) Seed Production.
- **M.Sc (Agri.) -** Studies on Seed Production, Processing and Storage in Grain Amaranthus (*Amaranthus hypochondriacus* L.) cv. Suvarna.

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- Sivasubramaniam, K. and **S. Manikandan**, 2010. Effect of Mutagen and Initial Seed Vigour on Biochemical Attributes in Certain Crops. Mysore Journal of Agricultural Sciences. 44(4):729-734.
- **Manikandan, S.**, K. Sivasubramaniam and P. Srimathi, 2010. Influence of Fertilizer and Spacing on Seed Yield and quality of Grain Amaranthus. Madras Agric. J., 97 (4-6): 99-103.
- **Manikandan, S**. and K. Sivasubramaniam, 2015. Yield and Economic Analysis of Seed Production in Pigeonpea (*Cajanus cajan* L) under Drip Fertigation. Research Journal of Agricultural Sciences - An International Journal. **6**(1): 116-119.

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