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Influence of drip fertigation and sowing season on plant growth, physiological characters and yield of pigeonpea (*Cajanus cajan* L.)

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Field experiments were carried out during two seasons *Kharif,* 2010 (March to June) and *Summer,* 2011 (January - May) at Agricultural College and Research Institute, Madurai, Tamil Nadu, India to study the influence of drip fertigation and sowing season on growth, physiological attributes and seed yield of pigeonpea (*Cajanus cajan* L.) cv. VBN3. The treatments included four fertigation levels (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 foliar spays (S_1- foliar spray of 0.5% $ZnSO_4$, 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 experiment was laid out in split plot design with three replications. Drip fertigation was given once in six days as per the treatment schedule and drip irrigation was given once in three days. The results revealed that drip fertigation with 100% SRDF through water soluble fertilizers + foliar feeding with 0.5% $ZnSO_4$ (F_3FS_1) and lowest with 50% SRDF as WSF through drip registered higher crop growth, physiological characters and seed yield in both season. Between the seasons, *Kharif* crop recorded 15.2% higher seed yield over *Summer as* compared to normal soil application of fertilizers. The increased in seed yield with 100% SRDF as WSF + foliar feeding with 0.5% $ZnSO_4$ was mainly due to greater and consistent availability of nutrients, growth hormones and soil moisture which leads to better crop growth, physiological characters and seed yield components and eventually reflected on the seed yield.

Key words: Pigeonpea, drip fertigation, season, growth characters, seed yield.

INTRODUCTION

Pigeon pea (*Cajanus cajan* (L.) Millsp. is a multipurpose legume with a long tradition of cultivation in India. With 22% protein, which is almost three times that of cereals, pigeonpea supplies a major share of protein requirement of the predominantly vegetarian population in the country. The biological value improves greatly, when wheat or rice

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is combined with pigeonpea because of the complementary relationship of the essential amino acids. It is particularly rich in lysine, riboflavin, thiamine, niacin and iron.

Pigeonpea is cultivated in more than 25 tropical and sub-tropical countries, either as a sole crop or intermixed with cereals or with legumes. Being a legume, pigeonpea enriches soil through symbiotic nitrogen fixation. The crop is cultivated on marginal land by resource-poor farmers, who commonly grow traditional medium and long duration varieties. 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 to 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.

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% of the fertilizer could be saved (Sivanappan and Ranghaswami, 2005). 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. The environment interaction plays a very important role in desired seed production.

At present, the knowledge regarding the effect of environmental factors on seed production is meagre. The rise in atmospheric temperature causes detrimental effects on growth, yield, and quality of the pigeonpea crop by affecting its phenology, physiology, and yield components (Sheehy et al., 2005). A growing season is a period during which a crop experiences favourable weather condition for its optimum growth, development and yield.

As information on suitable season of seed production will be highly useful to the seed growers of pigeonpea under drip fertigation system. Hence, the objective of present study was conducted to evaluate the performance of the crop in two seasons *viz.,* Kharif, 2010 and Summer, 2011 to fix the optimum dose of drip fertigation and foliar spray treatments for realizing higher growth, physiological characters and seed yield of pigeonpea cv. VBN 3.

MATERIALS AND METHODS

The present investigation on the influence of drip fertigation and season on the growth and seed yield of pigeonpea cv.VBN3 was carried out during two seasons *Kharif,* 2010 (March to June) and *Summer,* 2011 (January - May) at Agricultural College and Research Institute, Madurai located at 9º 54' N Latitude 78° 54' E Longitude and at Altitude of 147 MSL. The soil of the study area was clayey with a pH of 7.4, available N, P, K status of 180, 10 and 312 N P K kg ha^{-1} respectively. The organic carbon content was 0.48% and electric conductivity 0.42 dSm^{-1}. Seeds were treated and were sown in raised bed at the spacing of 45 × 30 cm as direct spot seeding on raised beds of 90 cm width and furrows of 10 cm. Adopting the drip fertigation as per the first crop fertigation schedule in the same area and all other agronomic and plant protection measures were carried out as and when required as per the crop production guide. The experiment was laid out in split plot design with three replications.

Lay out of drip system

Laterals (12 mm) from sub main were fixed at a spacing of 120 cm and inline lateral emitters in fixed at 20 cm with a 16 mm tap at the head of each lateral. First irrigation was given immediately after sowing and subsequent irrigations were scheduled once in three days based on the daily pan evaporation. The drip irrigation system was well maintained by flushing and cleaning the filters. The quantity of water was calculated as follows: Volume (L ha^{-1}) = PE × Kp × area (m^2), PE = pan evaporation, Kp = 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:

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

Field experiments were conducted with twelve treatment combinations are furnished in Table 1.

Fertigation

The SRDF dose was used as base for calculating the fertigation schedule. Accordingly F_1 treatment involved 50% of SRDF as soil and the balance as WSF. Similarly for F_2 25% as soil and 75% as drip. In 100% fertigation, the SRDF was applied as WSF. The fertilizer sources for supplying NPK through drip irrigation were urea, MAP (12:61:0 kg NPK), MOP (0:0:60 kg K). Each plot consisted of one lateral for irrigating two rows of crops. The required quantity of N, P and K fertilizers as Urea, MAP and MOP as per the treatment were dissolved separately in water. Fertigation was done through fertigation tank once in six days starting from 15 to 90 DAS, which was regulated by taps, provided near the take off points of the sub main. Fertigation was carried out in three consecutive steps *viz.,* wetting the root zone before fertigation, fertigating the field and flushing the nutrients with water.

Observations

The assessment of growth characteristics was done in each experimental plot; ten plants were selected at random and tagged for recording biometric observations were recorded at 90 DAS.

Biometric observations

In each experimental plot, ten plants were selected at random and tagged for recording biometric observations were recorded at 90 DAS. The assessment of growth characteristics such as plant height (cm), number of branches plant^{-1} and the physiological parameters *viz.*, LAI (Williams, 1946), LAD and CGR (Watson, 1958) were again observed in ten plants randomly selected per plot.

Table 1. Treatment details.

T_1 (F_1FS_1)	50% of SRDF through drip + Foliar spray of 0.5% $ZnSO_4$
T_2 (F_1FS_2)	50% of SRDF through drip + Foliar spray of 100 ppm succinic acid
T_3 (F_1FS_3)	50% of SRDF through drip + Foliar spray of 100 ppm humic acid
T_4 (F_2FS_1)	75% of SRDF through drip + Foliar spray of 0.5% $ZnSO_4$
T_5 (F_2FS_2)	75% of SRDF through drip + Foliar spray of 100 ppm succinic acid
T_6 (F_2FS_3)	75% of SRDF through drip + Foliar spray of 100 ppm humic acid
T_7 (F_3FS_1)	100% of SRDF through drip + Foliar spray of 0.5% $ZnSO_4$
T_8 (F_3FS_2)	100% of SRDF through drip + Foliar spray of 100 ppm succinic acid
T_9 (F_3FS_3)	100% of SRDF through drip + Foliar spray of 100 ppm humic acid
T_{10} (F_4FS_1)	150% of SRDF through drip + Foliar spray of 0.5% $ZnSO_4$
T_{11} (F_4FS_2)	150% of SRDF through drip + Foliar spray of 100 ppm succinic acid
T_{12} (F_4FS_3)	150% of SRDF through drip + Foliar spray of 100 ppm humic acid
Control	Surface irrigation with SRDF of 25:50:25 NPK kg ha^{-1} by two splits.

SRDF, Seed recommended dose of fertilizers; F, fertigation; FS, foliar spray.

Statistical analysis

The data pertaining to the experiment were subjected to statistical analysis by analysis of variance method as suggested by Gomez and Gomez (1984). 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.

RESULTS AND DISCUSSION

Drip fertigation, foliar spray treatments and season significantly influenced the morphological characters and seed yield of pigeonpea in both seasons.

Growth characters

Drip fertigation and foliar spray treatments significantly influenced the morphological characters such as plant height and number of branches was significantly influenced by surface drip fertigation. The interaction effect of drip fertigation and foliar spray treatments in both seasons were highly significant. The plant height at 90 DAS which was higher observed with fertigation using 100% SRDF as WSF (F_3) and foliar feeding with 0.5% of $ZnSO_4$ that resulted in higher values of 157.4 and 140.7 cm at 90 DAS in *Kharif* and *summer*, respectively (Table 2).

Plant height was increased by 25.4 and 28.7% in Kharif and summer, respectively with similar treatment combinations. Whereas in plant height in Kharif 2010 was higher 12.7% over Summer 2011at 90 DAS. The number of branches produced and their survival reflects on the total number of flowers initiated, pods at harvest which ultimately determine crop fecundity and seed yield. The results clearly indicated that the combination of 100% SRDF as WSF (F_3) + foliar feeding with 0.5% of $ZnSO_4$ recorded maximum number of branches 18.3 in kharif and 14.3 in summer at 90 DAS with 50.0 AND 81.0%, respectively higher compared to 50% of SRDF as WSF in kharif and summer respectively (Figure 1).

The results also clearly indicated that the water soluble fertilizers played a significant role in increasing the plant height and number of branches. Similarly, WSF provided based on crop stage wise nutrient requirement resulted in increased plant height compared to surface irrigation with 100% of SRDF and foliar spay as also reported by Kumar and Haripriya (2010) who revealed that monthly spray of Ferrus sulphate at 0.75% + Zinc Sulphate at 0.50% are significantly maximum values on all the growth attributes like plant height, number of secondary branches, no. of leaves per plant, plant spread and leaf area in Nerium.

Physiological parameters

Leaf area index being an important tool to quantify photosynthates accumulation in sink, resulted in increased growth of pigeonpea. The same best treatment combination at 90 DAS values were higher with LAI 20.4 and 27.8%, LAD 32.4 and 43.6%, CGR 52.4 and 93.3% was higher compared to 50% SRDF as WSF + 100 ppm humic acid which was recorded during *Kharif* and *Summer*, respectively (Tables 3 to 5).

Between the season kharif season recorded all physiological parameters were higher over summer. Similar results were expressed by Veeraputhiran (2000) attributing enhanced physiological parameters such as LAI, CGR and CGR using drip fertigation over the furrow band application of cotton. The enhanced dry weight of reproductive parts by growth regulators, organics and nutrients may be due to increased translocation of

Table 2. Influence of fertigation and foliar spray on Plant height (cm) at 90 DAS in pigeonpea cv. VBN 3. (in Kharif and Summer).

F- fertigation treatments	Plant height (cm) at 90 Days after sowing FS - Foliar spraying treatments											
	Kharif 2010 (S)				Summer 2011 (S)				Pooled mean (S)			
	FS_1	FS_2	FS_3	Mean	FS_1	FS_2	FS_3	Mean	FS_1	FS_2	FS_3	Mean
F_1	140.6	129.5	125.5	131.9	119.4	115.2	109.3	114.6	130.0	122.4	117.4	123.3
F_2	143.4	136.4	131.6	137.1	128.8	121.3	116.6	122.2	136.1	128.9	124.1	129.7
F_3	157.4	153.5	146.4	152.4	140.7	136.5	132.5	136.6	149.1	145.0	139.5	144.5
F_4	151.7	145.6	141.6	146.3	135.5	129.8	125.7	130.3	143.6	137.7	133.7	138.3
Mean	148.2	141.4	136.3	141.9	131.1	125.7	121.0	125.9	139.7	133.5	128.7	133.9
	F	**FS**	**F X FS**	**FS X F**	**F**	**FS**	**F X FS**	**F**		**SEd**		**CD(P=0.05)**
SEd	0.742	0.649	1.294	1.299	0.844	0.387	1.054	0.774	S	0.388		0.854**
CD(P=0.05)	1.815**	1.376**	2.882*	2.753*	2.065**	0.820**	2.456*	1.640*	F	0.562		1.224**
									FS	0.378		0.770**
									F X FS	0.834		1.700**
Absolute control	125.5				112.3				S X F	0.973		NS
									S X FS	0.534		NS
									S X F X FS	1.069		2.177**

*DAS, Days after sowing.

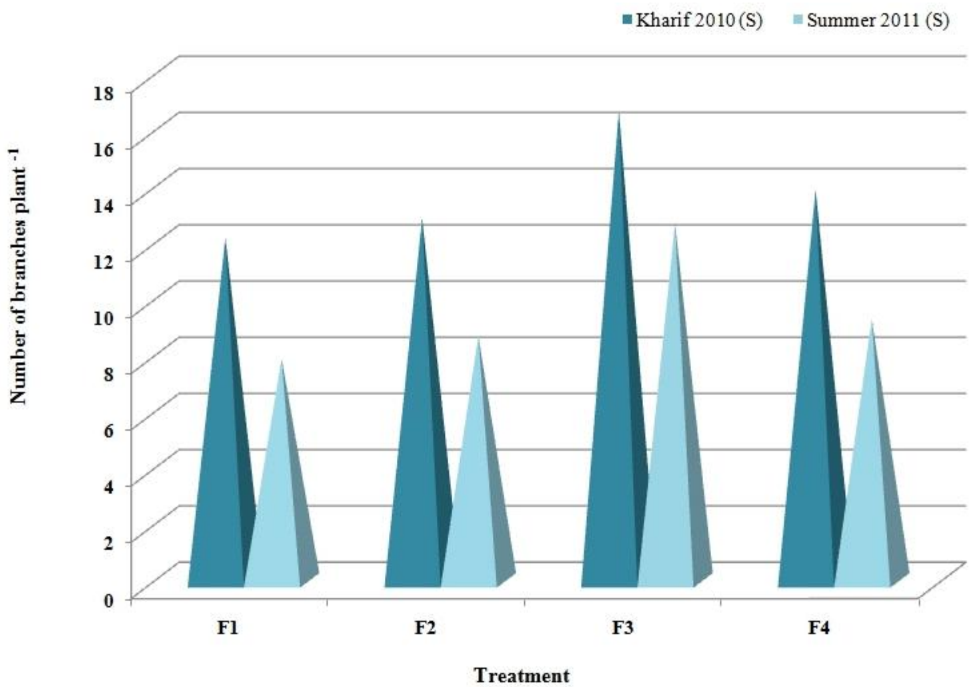

Figure 1. Influence of drip fertigation and sowing season on number of branches $plant^{-1}$ in pigeon pea.

assimilates from leaf and stem to the reproductive parts as also reported in pigeonpea due to application of zinc sulphate, succinic acid and humic acid.

Zinc plays a vital role as activator of carbohydrate and protein synthesis as well as their transport to the site of seed formation as also visulalized by Dell (2004) while comparing efficiency of plant use of foliar-fed nutrients versus soil-applied nutrients near roots and found foliar feeding provided about 95% use efficiency compared to about 10% efficiency use from soil applications thus

Table 3. Influence of fertigation and foliar spray on leaf area index at 90 DAS in pigeonpea cv. VBN 3. (in Kharif and Summer).

F- Fertigation treatments	LAI at 90 DAS											
	FS - Foliar spraying treatments											
	Kharif 2010 (S)				Summer 2011 (S)				Pooled mean (S)			
	FS_1	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**
F_1	5.63	5.46	5.35	5.48	4.72	4.44	4.24	4.47	5.18	4.95	4.80	4.97
F_2	5.81	5.66	5.65	5.71	4.93	4.75	4.62	4.77	5.37	5.20	5.14	5.24
F_3	6.44	6.35	6.25	6.35	5.42	5.30	5.17	5.30	5.93	5.83	5.71	5.82
F_4	6.22	5.89	5.81	5.98	5.24	5.02	4.78	5.01	5.73	5.46	5.30	5.49
Mean	6.03	5.84	5.76	5.88	5.08	4.88	4.70	4.89	5.55	5.36	5.23	5.38
	F	**FS**	**F X FS**	**FS X F**	**F**	**FS**	**F X FS**	**FS**		**SEd**		**CD(P=0.05)**
SEd	0.017	0.018	0.033	0.035	0.023	0.017	0.036	0.033	S	0.016		0.036**
CD(P=0.05)	0.042**	0.037**	0.074**	0.075**	0.057**	0.035**	0.081**	0.071**	F	0.014		0.031**
									FS	0.012		0.025**
									F X FS	0.024		0.050**
Absolute control	5.12				4.33				S X F	0.025		0.054**
									S X FS	0.017		0.035**
									S X F X FS	0.034		NS

*DAS, Days after sowing.

Table 4. Influence of fertigation and foliar spray on Leaf Area Duration in pigeonpea cv. VBN 3. (in Kharif and Summer).

F- Fertigation treatments	LAD – leaf area duration											
	FS - Foliar spraying treatments											
	Kharif 2010 (S)				Summer 2011 (S)				Pooled mean (S)			
	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	92.7	85.1	80.1	86.0	101.52	95.04	90.86	95.81
F_2	117.6	112.6	109.5	113.2	99.3	94.8	91.3	95.1	108.44	103.69	100.39	104.17
F_3	134.5	130.8	128.5	131.2	115.0	110.2	105.2	110.1	124.76	120.48	116.85	120.69
F_4	128.8	120.6	116.5	121.9	108.8	101.4	96.5	102.3	118.80	111.02	106.50	112.11
Mean	122.8	117.2	114.0	118.0	104.0	97.9	93.3	98.4	113.38	107.56	103.65	108.19
	F	**FS**	**F X FS**	**FS X F**	**F**	**FS**	**F X FS**	**FS**		**SEd**		**CD(P=0.05)**
SEd	0.356	0.365	0.693	0.729	0.318	0.415	0.749	0.830	S	0.333		0.734**
CD(P=0.05)	0.870**	0.773**	1.530**	1.546**	0.779**	0.880**	1.631*	1.759*	F	0.239		0.520**
									FS	0.276		0.563**
									F X FS	0.510		1.039**
Absolute control	101.2				83.3				S X F	0.413		0.901**
									S X FS	0.391		0.796**
									S X F X FS	0.781		NS

*DAS- Days after sowing.

providing a major benefit of foliar feeding where a specific plant nutrient deficiency may exist, be it a major or minor nutrient.

Yield and yield attributes

Seed yield (kg.ha^{-1}) was positively influenced by drip fertigation treatments and foliar spray treatments. Among the treatment combinations, Seed yield (kg.ha^{-1}) was higher with 100% SRDF as WSF + 0.5 % of $ZnSO_4$ recorded maximum in *Kharif* (1416 kg.ha^{-1}) and in *Summer* (1251 kg.ha^{-1}) by 40.2% and 48.0% higher seed yield compared to 50% SRDF as WSF + 100 ppm humic acid and 41.6%, 47.2% higher over the control plot during *Kharif* and *Summer*, respectively (Table 6). However,

Table 5. Influence of fertigation and foliar spray on crop growth rate g m^{-2} d^{-1} in pigeonpea cv. VBN 3 (in Kharif and Summer).

F- Fertigation treatments	Crop growth rate - CGR g m^{-2} d^{-1}											
	FS - Foliar spraying treatments											
	Kharif 2010 (S)				Summer 2011 (S)				Pooled mean (S)			
	FS_1	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**
F_1	16.5	16.3	15.3	16.0	13.2	11.5	10.4	11.7	14.83	13.91	12.88	13.87
F_2	20.2	16.8	15.9	17.6	13.6	12.3	10.6	12.2	16.90	14.54	13.28	14.91
F_3	23.6	23.0	22.6	23.1	20.1	17.4	16.6	18.0	21.84	20.20	19.61	20.55
F_4	18.6	17.6	16.5	17.6	15.5	13.9	12.1	13.8	17.05	15.77	14.27	15.70
Mean	19.7	18.4	17.6	18.6	15.6	13.8	12.4	13.9	17.65	16.11	15.01	16.26
	F	**FS**	**F X FS**	**FS X F**	**F**	**FS**	**F X FS**	**FS**		**SEd**		**CD(P=0.05)**
SEd	0.182	0.395	0.671	0.790	0.202	0.139	0.303	0.277	S	0.227		0.499**
CD(P=0.05)	0.447**	0.838**	1.438*	1.675*	0.494**	0.294**	0.687*	0.588*	F	0.136		0.297**
									FS	0.209		0.426**
									F X FS	0.368		NS
Absolute control		14.5				10.2			S X F	0.236		0.514**
									S X FS	0.296		NS
									S X F X FS	0.592		1.206**

*DAS- Days after sowing.

Table 6. Influence of fertigation and foliar spray on seed yield (kg. ha^{1}) in pigeonpea cv. VBN 3 (in Kharif and Summer).

F- Fertigation treatments	Seed yield per ha (kg)											
	FS - Foliar spraying treatments											
	Kharif 2010 (S)				Summer 2011 (S)				Pooled mean (S)			
	FS_1	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**	**FS_1**	**FS_2**	**FS_3**	**Mean**
F_1	1056	1035	1010	1034	892	873	845	870	974	954	928	952
F_2	1143	1101	1075	1106	979	941	913	944	1061	1021	994	1025
F_3	1416	1367	1344	1376	1251	1213	1180	1215	1333	1290	1262	1295
F_4	1276	1244	1215	1245	1147	1113	1052	1104	1212	1179	1133	1175
Mean	1223	1187	1161	1190	1067	1035	998	1033	1145	1111	1079	1112
	F	**FS**	**F X FS**	**FS X F**	**F**	**FS**	**F X FS**	**FS X F**		**SEd**		**CD(P=0.05)**
SEd	3.237	2.225	4.865	4.449	5.149	3.114	7.236	6.227	S	2.639		5.809**
CD(P=0.05)	7.920**	4.716**	11.019**	9.432**	12.599**	6.601**	16.539**	13.201**	F	3.041		6.626**
									FS	1.913		3.897**
									F X FS	4.360		8.881**
Absolute control		1000				850			S X F	5.267		NS
									S X FS	2.706		5.512**
									S X F X FS	5.412		11.023**

*DAS, Days after sowing.

seed yield (kg.ha^{-1}) occurred more in *Kharif* with 13.2% higher yield over *Summer* with same treatment combination. Higher number of pods plant^{-1} (415 in *Kharif* and 368 in Summer) with 12.8% higher number in *Kharif* over Summer (Figure 2). Fertigation with 100% WSF increased the seed yield significantly over furrow irrigation and drip irrigation as reported by Tayo (1990) and Somu (1995) in pigeonpea. This might be due to enhancement in growth and yield parameters as well as uptake of nutrients by this crop. Obviously, the cumulative effects of these parameters contributed to increased yield foliar application of $ZnSO_4$ (0.5%) could increase the grain yield significantly over control in rice (Manoharan et al., 2001). Foliar application of KCl, DAP, urea and KNO_3 increased the seed cotton yield due to more number of bolls per plant (Brar and Brar, 2002). Fertigation with 100% WSF increased the seed yield of tomato significantly over furrow irrigation and drip

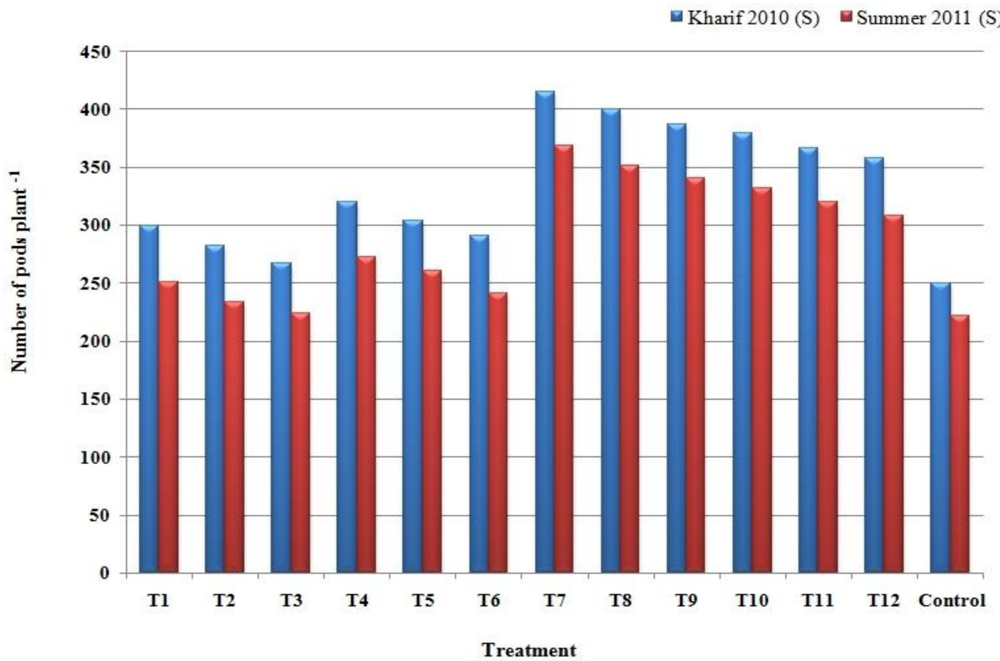

Figure 2. Influence of drip fertigation and sowing season on number of pods $plant^{-1}$ in pigeonpea.

irrigation as reported by Hebbar et al. (2004). The higher seed yield correlating with higher level of water soluble fertilizers could be attributed to translocation of more carbohydrates due to high nitrogen levels.

Potassium plays an important role in this translocation of metabolites for the development of seed. Moreover, higher production of seed yield under surface drip irrigation and fertigation might have paved the way for increased production of photosynthates, which ultimately resulted in increased production of seeds at harvest as also found by Shashidhara (2006) in chillies.

Conclusion

Seed production is better for the *Kharif* season and the treatment combination of 100% SRDF as WSF + foliar spraying of 0.5% of $ZnSO_4$ and maximized the seed yield, better crop growth, higher yield attributes and substantial quantity of water saving. 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.

Conflict of Interest

The authors have not declared any conflict of interest.

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