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Yield, water use and water use efficiency of pigeonpea [*Cajanus cajan* (L.) Millsp.] under drip fertigation system

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Abstract: Field experiments were carried out during two seasons (August-February) of 2011-12 and 2012-13 at Millet Breeding Station, Tamil Nadu Agricultural University, Coimbatore, to study the effect of drip fertigation on productivity, water use and water use efficiency of pigeonpea (*Cajanus cajan*) cv. LRG 41. The treatments included three irrigation regimes (50 %, 75 %, 100 % computed water requirement of crop) and surface irrigation along with three fertilizer levels with water soluble fertilizer (WSF) and conventional fertilizers (CF). The treatments were laid out in Randomized Block Design with three replications. The results revealed that drip irrigation at 100 % WRc with fertigation at 125 % RDF through WSF registered significantly highest grain yield of 2812 and 2586 kg ha^{-1} during 2011-12 and 2012-13, respectively. Surface irrigation with conventional method of fertilizer application recorded lower water use efficiency of 3.70 and 3.38 kg ha^{-1} mm^{-1} whereas it was reverse with drip irrigation of 100 % WRc + 125 % RDF through WSF with a WUE of 6.97 kg ha^{-1} mm^{-1} during 2011-12 and during second season (2012-13), the highest WUE of 6.72 kg ha^{-1} mm^{-1} was recorded in drip irrigation at 50 % WRc along with fertigation at 125 % RDF through WSF. The increase in grain yield with drip irrigation at 100 % WRc + fertigation with 125 % RDF through WSF was mainly attributed by greater and consistent availability of soil moisture and nutrients which resulted in better crop growth, yield components and ultimately reflected on water use efficiency and yield of pigeonpea *Cajanus cajan*.

Keywords: Drip fertigation, Water use, Water use efficiency, Yield

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millsp.] has been considered as second most important crop after chickpea (*Cicer arietinum*). 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. 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 (NNMB, 2012). 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. Effective management of irrigation water is an important issue in crop production, since irrigation is a precondition for crop growth, development and production per mm of water and productivity per unit area. Drip irrigation is a technique in which water flows through a filter into special drip pipes, with emitters located at different spacing. Water is distributed through the emitters directly into the soil near the plants through a special slow-release device. If the drip irrigation system is properly designed, installed, and managed, it may help to achieve water conservation by reducing evaporation and deep drainage. Irrigation scheduling can be managed precisely to meet crop demands, holding the promise of increased yield and quality. Adoption of drip irrigation might help in increasing area under irrigation, productivity of crops and increase the water use efficiency (Tarawalie *et al*., 2012). Drip irrigation is the direct application of water in the root zone with enhanced WUE. To meet out the requirement the only way is to increase the production and productivity for that drip irrigation is the best option. Hence, the present study was initiated to study the influence of drip fertigation on yield, water use and water use efficiency of pigeonpea [*Cajanus cajan* (L.) Millsp.] under drip fertigation in Western Agroclimatic Zones of Tamil Nadu.

MATERIALS AND METHODS

Field location: Field experiments were conducted during August - February of 2011-12 and 2012-13 at Millet Breeding Station, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore to study the effect of drip irrigation and fertigation levels on yield, water use and

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water use efficiency of pigeonpea. The experimental location is geographically situated in the Western Agro -climatic Zone of Tamil Nadu at 11°North latitude and 77◦ East longitude at an altitude of 426.7 m above MSL. The long term average annual precipitation of Coimbatore (mean of 30 years) is 720.8 mm distributed over 47 rainy days. The two monsoon rainy seasons *viz.*, South West Monsoon and North East Monsoon contribute a rainfall of 26.2 and 51.6 % respectively and the peak month of rainfall is October (186 mm). During first season (2011-12), the maximum temperature ranged from 27.3 to 33.6°C with a mean of 30.4°C and minimum temperature ranged from 15.2 to 23.1°C with a mean of 20.7°C. The total rainfall received during the cropping period was 630.1 mm. The pan evaporation ranged from 1.8 to 6.1 mm with a mean of 4.1 mm. The solar radiation ranged from 224.0 to 462.6 cal cm^{-2} day^{-1} with a mean of 364.5 cal cm^{-2} day^{-1} (Fig. 1).

During 2012-13, the second crop season, the maximum temperature ranged from 28.0 to 33.3 °C with a mean of 31.1 °C and minimum temperature ranged from 17.8 to 23.3°C with mean of 21.0°C. The total rainfall received during the cropping period was 217.2 mm. The pan evaporation ranged from 2.8 to 7.2 mm with a mean of 5.0 mm and the solar radiation ranged from 254.1 to 471.6 cal cm^{-2} day^{-1} with a mean of 372.42 cal cm^{-2} day^{-1} (Fig. 2). The soil of the experimental site was sandy clay loam in texture classified taxonomically as *Typic Ustropept.* The experimental site was texturally classified as sandy clay loam having 26.75 % moisture at field capacity, 12.50 % at permanent wilting point and 1.36 Mg m^{-3} in situ bulk density. The pH, organic carbon content and EC values were 7.55, 0.51 % and 0.78 d sm^{-1} respectively. The soil was low in available nitrogen (226 kg ha^{-1}), medium in available phosphorus (18 kg ha^{-1}) and high in available potassium (429 kg ha^{-1}).

Treatment details: The experiments were laid out in a Randomized Block Design with fourteen treatments and three replications. The treatments included combination of water and nutrients levels. Three irrigation regimes *viz*., 50 %, 75 %, 100 % computed water requirement of the crop (WRc) along with surface irrigation and three fertilizer levels (with conventional fertilizers and water soluble fertilizers) formed the treatment combinations. The treatments were: T_1- 50 % WRc + 75 % recommended dose of fertilizers (RDF) through water soluble fertilizers (WSF),T_2- 75 % WRc + 75 % RDF (WSF), T_3- 100 % WRc + 75 % RDF (WSF), T_4- 50 % WRc + 100 % RDF i.e., 25:50:25 NPK kg ha^{-1} (WSF), T_5-75 % WRc + 100 % RDF (WSF), T_6- 100 % WRc + 100 % RDF (WSF),T_7- 50 % WRc + 125 % RDF (WSF), T_8- 75 % WRc + 125 % RDF (WSF), T_9- 100 % WRc + 125 % RDF (WSF), T_{10}- 50 % WRc + 100 % RDF through conventional fertilizers (CF), T_{11}- 75 % WRc + 100 % RDF (CF), T_{12}- 100 % WRc + 100 % RDF (CF) ,T_{13}- 100 % WRc (Drip) + 100 % RDF (conventional fertilizers as basal) and T_{14}- Surface Irrigation + 100 % RDF through conventional fertilizers (N, P_2O_5 and K_2O applied as basal).

The recommended dose of fertilizer is 25:50:25 N, P_2O_5 and K_2O respectively was supplied through conventional and water soluble fertilizers. The fertigation schedules are given in the Table 1 and 2. For this experiment the variety used LRG 41 was, obtained from Agricultural Research Station, Lam centre, Andhra Pradesh. Seeds were sown with spacing 150 x 60 cm (150 cm between lateral and 60 cm in between the emitter). Drip irrigation was scheduled once in seven days by calculating computed water requirement of crop (WRc). Surface irrigation was given based on IW/CPE ratio of 0.6. Water use efficiency (WUE), the amount of yield was worked out by using the following formula and expressed as kg ha^{-1} mm^{-1}.

$$\text{WUE} = \frac{\text{Yield (kg ha}^{-1})}{\text{Total water used (mm)}}$$

The data collected on various aspects related to the study were subjected to statistical analysis by Analysis of Variance (ANOVA) method as suggested by Gomez and Gomez (1984). Whenever the treatment differences were found significant, Critical Difference (CD) was worked out at 5 % probability level and the values were furnished. The treatment differences found non significant are denoted as 'NS'

RESULTS AND DISCUSSION

Grain yield: Grain yield per hectare was significantly influenced by drip irrigation and fertigation treatments (Table 3). Drip irrigated pigeonpea (*Cajanus cajan* L. Millsp.) with WSF recorded significantly higher grain yield in both the years of study compared to surface method of irrigation. Among the drip irrigation and fertigation levels, pigeonpea crop receiving drip irrigation at 100 % WRc with fertigation at 125 % RDF through WSF registered significantly highest grain yield of 2812 and 2586 kg ha^{-1} during 2011-12 and 2012-13, respectively with 45 to 47 % increase over surface irrigation method with recommended dose of fertilizers through conventional method of fertilizer application (1908 and 1794 kg ha^{-1}). Better crop growth at higher nutrient levels might have influenced the yield attributes favourably. The increase in yield might be due to better proportion of air-soil-water which was maintained throughout the life period of crop in drip irrigation as compared to surface irrigation as reported by Kadam and Karthikeyan (2006).

The grain yield of pigeonpea realized under drip irrigation at 100 % WRc along with fertigation at 125 % RDF (WSF) was comparable with drip irrigation at 100 % WRc and fertigation at 100 % RDF through WSF (2643 and 2498 kg ha^{-1} during 2011-12 and 2012-13, respectively). The yield increase under drip

Table 1. Fertigation schedule for long duration pigeonpea cv. LRG 41 at 100 % RDF through water soluble fertilizers.

Stage	Duration (Days)	Number of applications (splits)	Application time	Nutrient supplied (%)			Quantity of nutrients fertilizer grade (kg)		
				N	P_2O_5	K_2O	Urea	MAP	SOP
Seedling	1-30	3	10, 17 and 24 DAS	20	40	0	2.32	32.78	0
Vegetative	31-90	9	31, 38, 45, 52, 59, 66, 73, 80 and 87 DAS	30	30	25	9.87	24.58	12.5
Flowering	91-120	4	94, 101, 108 and 115 DAS	30	30	40	9.87	24.58	20
Pod development	121-140	3	122, 129 and 136 DAS	20	0	35	10.85	0	17.5
			Total	**100**	**100**	**100**	**32.91**	**81.94**	**50**

Table 2. Fertigation schedule for long duration pigeonpea cv. LRG 41 at 100 % RDF through conventional fertilizers.

Stage	Duration (Days)	Number of applications (splits)	Application time	Nutrient supplied (%)		Quantity of nutrients fertilizer grade (kg)	
				N	K	Urea	MOP
Seedling	1-30	3	10, 17 and 24 DAS	20	0	10.85	0
Vegetative	31-90	9	31, 38, 45, 52, 59, 66, 73, 80 and 87 DAS	30	25	16.28	10.38
Flowering	91-120	4	94, 101, 108 and 115 DAS	30	40	16.28	16.60
Pod development	121-140	3	122, 129 and 136 DAS	20	35	10.85	14.53
			Total	**100**	**100**	**54.30**	**41.50**

Table 3. Effect of drip irrigation regimes and fertigation levels on grain yield of pigeonpea.

Treatments	Grain yield (kg ha^{-1})		% yield increase over SI	
	2011-12	2012-13	2011-12	2012-13
T_1 - 50 % WRc + Drip fertigation at 75 % RDF (WSF)	2028	1993	6.3	11.1
T_2 - 75 % WRc + Drip fertigation at 75 % RDF (WSF)	2197	2096	15.1	16.8
T_3 - 100 % WRc + Drip fertigation at 75 % RDF (WSF)	2205	2130	15.6	18.7
T_4 - 50 % WRc + Drip fertigation at 100 % RDF (WSF)	2231	2129	16.9	18.7
T_5 - 75 % WRc + Drip fertigation at 100 % RDF (WSF)	2447	2283	28.2	27.3
T_6 - 100 % WRc + Drip fertigation at 100 % RDF (WSF)	2643	2498	38.5	39.2
T_7 - 50 % WRc + Drip fertigation at 125 % RDF (WSF)	2306	2173	20.9	21.1
T_8 - 75 % WRc + Drip fertigation at 125 % RDF (WSF)	2520	2311	32.1	28.8
T_9 - 100 % WRc + Drip fertigation at 125 % RDF (WSF)	2812	2586	47.4	44.1
T_{10} - 50 % WRc + Drip fertigation at 100 % RDF (CF*)	1920	1816	0.6	1.2
T_{11} - 75 % WRc + Drip fertigation at 100 % RDF (CF*)	1983	1873	3.9	4.4
T_{12} - 100 % WRc + Drip fertigation at 100 % RDF (CF*)	2160	1978	13.2	10.3
T_{13} - Drip irrigation at 100 % WRc + 100 % RDF (CF- all basal)	2070	1844	8.5	2.8
T_{14} - Surface irrigation +100 % RDF (CF- all basal)	1908	1794	-	-
SEd	138.7	120.0	-	-
CD(P=0.05)	285.3	246.7	-	-

*P as basal; N and K through drip fertigation; WRc - Computed water requirement of crop; RDF – recommended dose of fertilizers (25:50:25 NPK kg ha^{-1}); CF- Conventional fertilizers: SI- Surface irrigation

irrigation at 100 % WRc along with fertigation at 100 % RDF (WSF) was 39 to 44 % over surface irrigation with conventional method of fertilizer application. Drip irrigation at 100 % WRc and drip fertigation with either 100% RDF or 125 % RDF through WSF registered significantly higher grain yield during both the years of study than drip irrigation at 100 % WRc with recommended dose of conventional fertilizer applied basally. Across drip irrigation regimes, drip fertigated pigeonpea at 100 % RDF through conventional fertilizer produced comparable yields with that at 75 % RDF through WSF.

Table 3. Effect of drip irrigation regimes and fertigation levels on grain yield of pigeonpea

Treatments	**Water applied (mm)**		**Effective rainfall (mm)**		**Total water used (mm)**		**WUE (kg ha^{-1} mm^{-1})**	
	2011-12	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
T_1 - 50 % WRc + Drip fertigation at 75 % RDF (WSF)	172.0	227.1	159.4	96.4	331.4	323.5	6.12	6.16
T_2 - 75 % WRc + Drip fertigation at 75 % RDF (WSF)	208.0	290.6	159.4	96.4	367.4	387.1	5.98	5.42
T_3 - 100 % WRc + Drip fertigation at 75 % RDF (WSF)	244.0	352.2	159.4	96.4	403.4	450.6	5.47	4.73
T_4 - 50 % WRc + Drip fertigation at 100 % RDF (WSF)	172.0	227.1	159.4	96.4	331.4	323.5	6.73	6.58
T_5 - 75 % WRc + Drip fertigation at 100 % RDF (WSF)	208.0	290.6	159.4	96.4	367.4	387.1	6.66	5.90
T_6 - 100 % WRc + Drip fertigation at 100 % RDF (WSF)	244.0	352.2	159.4	96.4	403.4	450.6	6.55	5.54
T_7 - 50 % WRc + Drip fertigation at 125 % RDF (WSF)	172.0	227.1	159.4	96.4	331.4	323.5	6.96	6.72
T_8 - 75 % WRc + Drip fertigation at 125 % RDF (WSF)	208.0	290.6	159.4	96.4	367.4	387.1	6.86	5.97
T_9 - 100 % WRc + Drip fertigation at 125 % RDF (WSF)	244.0	352.2	159.4	96.4	403.4	450.6	6.97	5.74
T_{10} - 50 % WRc + Drip fertigation at 100 % RDF (CF*)	172.0	227.1	159.4	96.4	331.4	323.5	5.79	5.61
T_{11} - 75 % WRc + Drip fertigation at 100 % RDF (CF*)	208.0	290.6	159.4	96.4	367.4	387.1	5.40	4.84
T_{12} - 100 % WRc + Drip fertigation at 100 % RDF (CF*)	244.0	352.2	159.4	96.4	403.4	450.6	5.35	4.39
T_{13} - Drip irrigation at 100 % WRc + 100 % RDF (CF- all basal)	244.0	352.2	159.4	96.4	403.4	450.6	5.13	4.09
T_{14} - Surface irrigation +100 % RDF (CF- all basal)	300.0	400.0	215.1	130.6	515.1	530.6	3.70	3.38

*P as basal; N and K through drip fertigation; WRc – Computed water requirement of crop; RDF – recommended dose of fertilizers (25:50:25 NPK kg ha^{-1}); CF- Conventional fertilizers: SI- Surface irrigation

Water used: Improvement in water use in agriculture is essential because of the declining irrigation sources, energy costs make irrigation more expensive to crop production. The irrigation water was applied during 2011-12 was 172, 208 and 244 mm at 50%, 75 % and 100% respectively (Table 2). During 2012-13, irrigation was applied at 50 %, 75 % and 100 % WRc was 227.1, 291.6 and 352.2 mm, respectively. The rainfall recorded during the cropping period was 670, 217 mm during first and second season respectively.

The Effective Rainfall (ER) was higher (215.1 and 130.6 mm) in surface irrigation when compared to drip irrigation (159.4, 96.4 mm) during 2011-12 and 2012-13 respectively. Total water used was higher for surface irrigation 515.1 and 530.6 mm during 2011-12 and 2012-13 respectively compared to drip irrigation.

Irrespective of the treatments, higher soil moisture use and the seasonal consumptive water use by the crop was due to higher amount of effective rainfall during first crop season and in the next year due to lower amount of effective rainfall comparatively higher amount of water was applied through drip to increase the total water used. Increase in irrigation water though increased the water use by the crop, it did not increase the grain yield proportionately which may have reduced the water use efficiency.

Water use efficiency: The data on water use efficiency of pigeonpea under drip irrigation are

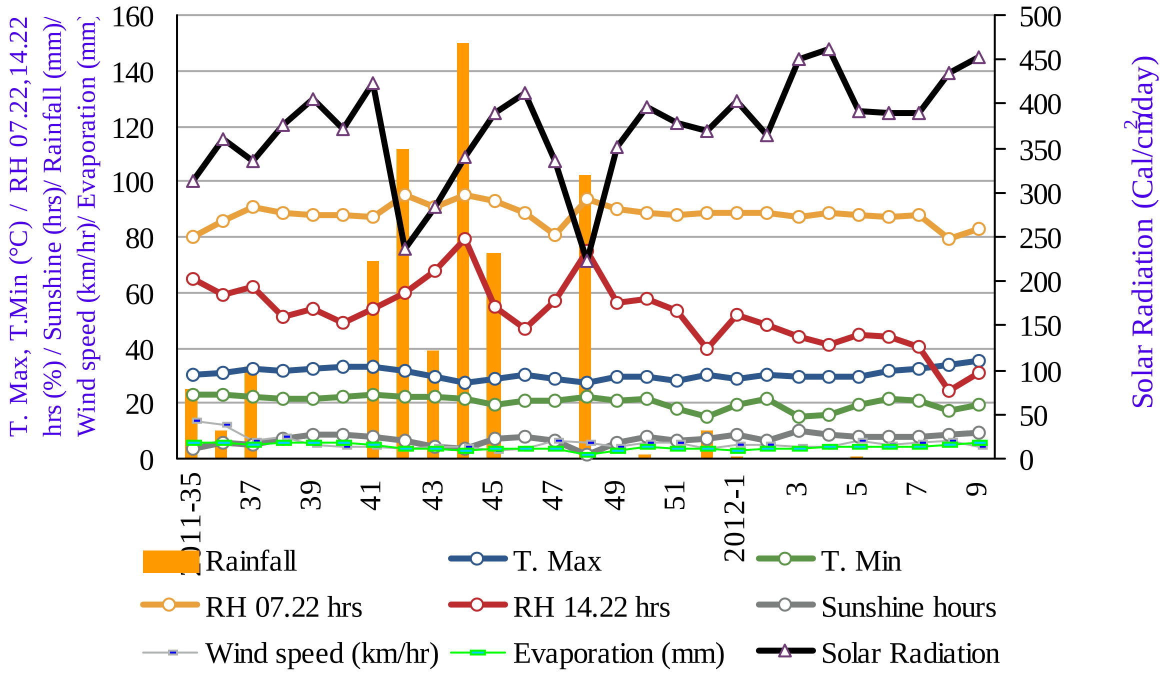

Fig 1. *Weekly meteorological data prevailed during first season, 2011-12 at TNAU, Coimbatore.*

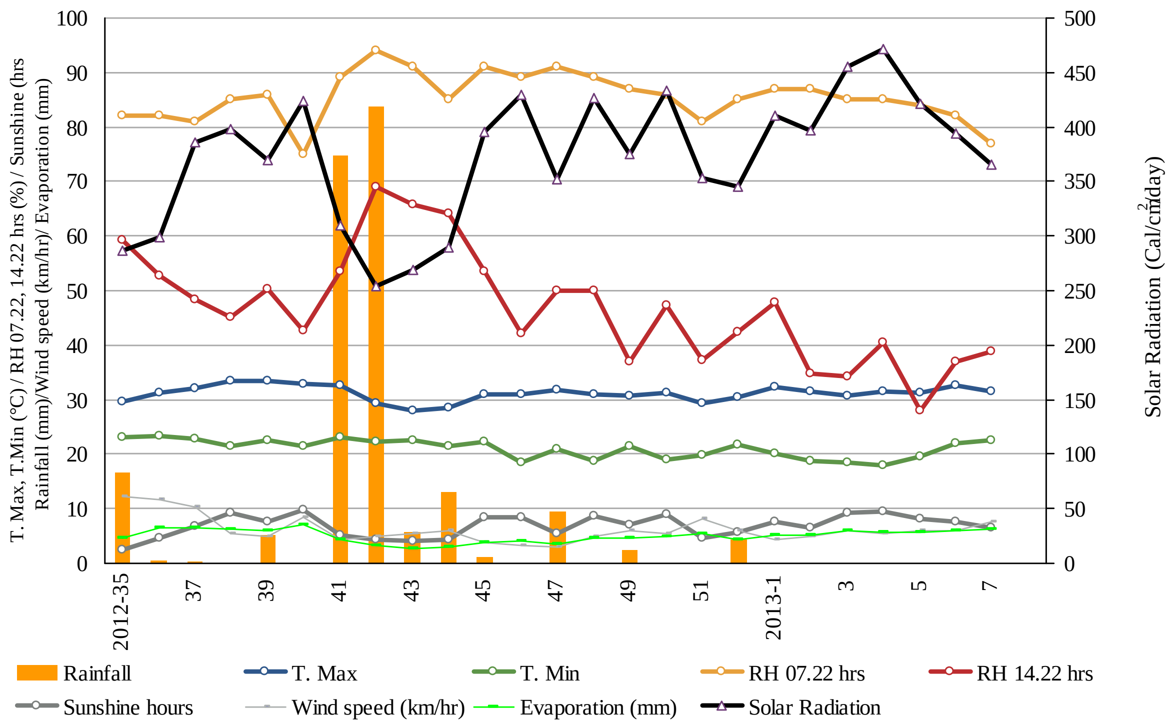

Fig 2. *Weekly meteorological data prevailed during first season, 2012-13 at TNAU, Coimbatore.*

furnished in Table 4. Water use efficiency is a important tool to assess the productivity of crop per unit water utilized. It was computed by the yield obtained by the crop and the total water used. Surface irrigation with conventional method of fertilizer application recorded lower water use efficiency of 3.70 and 3.38 kgha^{-1} mm^{-1} whereas it was reverse with drip irrigation of 100 % WRc + 125 % RDF through WSF with a WUE of 6.97 kg ha^{-1} mm^{-1} during 2011-12 and during second season (2012-13), the highest WUE of 6.72 kg ha^{-1} mm^{-1} was recorded in drip irrigation at 50 % WRc along with fertigation at 125 % RDF through WSF. This might be due to effective utilization of applied water.

WUE varied due to irrigation regimes as well as fertilizer levels. Similar result was obtained by Sunder

Singh (2001) in baby corn. The increase in WUE in all drip irrigated treatments over surface irrigation was mainly due to considerable saving of irrigation water, greater increase in yield of crops and higher nutrient use efficiency. This was in concordance with Suhas Bobade *et al.* (2002) and Ramah (2008).

Conclusion

From this investigation it can be concluded that, drip irrigation at 100 % WRc along with fertigation at 125 % RDF through WSF recorded the higher yield. While under limited water situation application of 75 % WRc itself recoded the superior yield and water use efficiency. The results showed that increase in soil moisture regime could increase WUE up certain level, but it tended to decline. Thereafter, mainly due to considerable saving of irrigation water, there was a greater increase in yield of pigeonpea and higher nutrient use efficiency.

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