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Effect of Nutrient Management and Micro-Irrigation Techniques on *kharif* Pigeonpea (*Cajanus cajan*. L) under Transplanted Conditions on Growth, Yield and Economics

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The Study was carried out on Pigeonpea (*Cajanus cajan*) with drip cum fertigation in transplanted Pigeonpeain Vertisols (Black-cotton soils) at Agricultural Research Station, Tandur, Vikarabad District, Telangana state, India. The experiment was conducted in Split-plot design with three replications comprised of Irrigation levels (four I_1: 0.6, I_2: 0.8: I_3:1.0 and I_4:1.2 IW/CPE ratio as main plots based on Pan Evaporation and Fertility levels three (F1: 75 % RDF, F2: 100 % RDF and F3: 125% RDF) as sub-plots. The test variety was Asha ICPL 87119.Under drip cum fertigation system of Transplanted Pigeonpea (variety ICPL 87119) irrigation with 120% of daily pan evaporation recorded significantly highest seed yield (3014 kg/ha) which was supported by the Harvest index (24.4), number of pods per plant (1020), Leaf area index LAI (4.37), radiation use efficiency (0.26 g/MJ) and water use efficiency (4.33). Highest seed yields with 125% RDF through fertigation was because of higher photosynthetic activity which resulted in better development of pods (1006) 100 seed weight (10.2) and finally the water use efficiency (7.80 kg/ha/mm) In this context, micro irrigation could play a key role in higher productivity and increased water use efficiency (WUE) besides fulfilling sustainability mandates with economy in use.

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is one of the major grain legume crops of the tropics and sub-tropics endowed with several unique characteristics. It plays a major role in the house hold economy of farmers by providing protein rich food, firewood and income to the resource poor small/marginal farmers in tropics and subtropics and has long been recognized for its attributes of high leaf fall and consequent contribution to the carbon and nitrogen economy of the soil (Rego and Rao, 2000). It finds an important position in the cropping pattern adopted by small farmers in a number of developing countries. Pigeonpea is an important drought tolerant legume grown in wide range of Agro-ecological situations. The plant possesses valuable properties as restorative of nitrogen to the soil and adds lots of organic matter to the soil and thus finds a promising place in crop rotation and crop mixtures. Being a leguminous plant, it is capable of fixing atmospheric nitrogen and there by restore nitrogen in the soil. The deep rooting system helps in extracting the nutrients and moisture from the deeper soil layers. Pigeonpea occupies 6.5 per cent of the world's total pulse area and contributes 5.7 per cent to the total pulse production. India is the largest producer of pigeonpea accounting to about 64per cent of total world production. Among the total pulses, pigeonpea a protein rich staple food, accounts for 14.5 per cent in area and 15.5 per cent in productivity. In India it ranks second in area and 91% of the world Pigeonpea is produced in India. It is mainly grown in states of Maharashtra, Uttar Pradesh, Madhya Pradesh, Gujarat, Andhra Pradesh, Telangana, Karnataka and Tamil Nadu and these states constitute 90 per cent of the area.Transplanting technique is a novel and revolutionary agronomic approach to boost Redgram yields. Transplanting technique in Pigeonpea provides ample scope in enhancing the yields and net returns of Pigeonpea farmers under limited water availability conditions in Telangana state especially in ground water dependent areas. Normally during years of low rainfall, the reproductive phase of the crop coincides with moisture stress conditions and associated terminal drought situations. Any measure of advancing the planting time reduces the risk from terminal drought stress. But, late onset of monsoons, which are being experienced more frequently, doesn't allow for timely sowing. Time of sowing determines the time available for vegetative growth before the onset of flowering which is mainly influenced by the photoperiod. Sowing time determines the plant height, number of branches, flowering and pod bearing habits. Thus time of sowing has predominant influence on both vegetative and reproductive process of Pigeonpea. In such situations, raising the nursery in advance (in the month of mid of May) and transplanting the 30-45 days old redgram seedlings is the best method to mitigate terminal drought stress during poor rainfall years due to enhanced rooting architecture. Preliminary studies carried out at Agricultural Research station, Tandur under rainfed conditions revealed almost four fold increase (1760 kg/ha) in productivity compared to that of average productivity over the conventional system in the state (450 kg/ha). Deshmukh (2010) also reported multifold advantages of transplanting method in Redgram over conventional sowing method. It saved input cost in the form of less seed rate, less plant protection etc. The transplanting technique increased 2-3 fold yield (15.5 to 34.8 q/ha) due to profuse branching and flowering. Further, the crop can perform even better under irrigated conditions. As transplanting technique provides more opportunity time for vegetative growth than in the conventional planting system of sowing, it may respond positively to the application of external inputs i.e. plant nutrients and irrigation. 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 that30 per cent of the fertilizer could be saved (Sivanappan and Ranghaswami, 2005).Hence, it is worthwhile to standardize the Agro-techniques to enhance the productivity of Pigeonpea crop. At this juncture, standardization of nutrient and water management techniques would be of great help.

Materials and Methods

The field experiment was conducted on deep black cotton soils at Agricultural Research Station, Tandur, Vikarabad (Dist.), Telangana state of Professor Jayashankar Telangana state Agricultural University for three consecutive

Kharif seasons 2013-14, 2014-15 and 2015-16. The soil of the experimental site was having P^H 8.10, with low available nitrogen (187.20 $kgha^{-1}$), medium in available P (16.80 $kgha^{-1}$) and high in available K (330.20 kg ha^{-1}) in all the years. The trial was laid out in split-plot design with three replications comprised of Irrigation levels (four I_1: 0.6, I_2: 0.8:I_3:1.0and I_4:1.2 IW/CPE ratio as main plots based on Pan Evaporation and Fertility levels (three F1: 75 % RDF, F2: 100 % RDF and F3: 125% RDF) as sub-plots. The test variety was Asha ICPL 87119.The irrigation and fertilizers were applied with drip-Fertigation system. Irrigation control valve was provided to each plot. The drip system was established with dripper lines of 16mm diameter laid along the crop rows at 1.5m spacing with emitters spaced at 0.4m having a flow rate of 2L per hour. Flow meters were used to measure flow rates to each individual treatment according to designated pan evaporation replenishment factor. The Recommended dose of fertilizers (20kg N, 50 kgP_2O_5 kg/ha and 10 K_2O kg/ha) was applied through Fertigation (water soluble fertilizers MAP, Urea and KNO_3) at weekly intervals upto 100 days after transplanting starting at 20 days after planting.

The gross plot size was 13m x 12m and the seedlings were transplanted at 30 days old at 150x 90cm @ 2-3 seedlings per hill. After establishment one healthy seedling was left and the remaining two seedlings were removed by cutter just above the soil without disturbing the root system of the hill. Crop was managed as per the treatment. Leaf area and intercepted radiation was measured with LP-80 canopy analyzer from time to time. The experimental data were analysed statistically by following Fischer's method of analysis of variance as per procedure suggested by Gomez and Gomez (1984). F–test was significant at P=0.05 and the results have been compared among treatments based on critical difference.

The gross returns are worked out based on the prevailing market rate of Pigeonpea seed (Rs. 80 per kg). The benefit cost ratio was worked out for different treatments by dividing the net returns by the corresponding cost of cultivation of the treatments.

The RDF dose (20:50:10 NPK kg ha^{-1}) was used as base for calculating the fertigation schedule. Fertigation was done once in seven days starting from 20 DAT in three consecutive steps viz., wetting the root zone before Fertigation, fertigating the field and flushing the nutrients with water. Irrigation frequency is one of the most important factors in drip irrigation scheduling. Due to differences in soil moisture and wetting pattern, crop yields may be different, when the same quantity of water was applied under different frequencies. Tumbare and Bhoite (2002) concluded that weekly fertigation through drip irrigation in14 equal splits starting from the first week of transplanting was beneficial for green chilli grown in a sandy clay loam soil. Water use efficiency is the yield of marketable crop produced per unit of water used in evapotranspiration. In the absence of new irrigation projects, bringing more area under irrigation would mostly rely on the efficient use of water.

Water use efficiency (WUE) is the amount of yield that can be produced from given quantity of water. It was worked out by using the following formula and expressed as kg ha^{-1} mm^{-1}.

WUE =Yield (kg ha^{-1}) / Total water used (mm)

Results and Discussion

Growth parameters

Pooled analysis of the growth parameters (Plant height, primary branches, Secondary branches, stem girth, LAI) during maturity stage were significantly influenced by irrigation levels and Fertigation treatments but their interaction effects were not significant during all the years of study (Table 1). The tallest plant stature with highest number of primary and secondary branches and with maximum leaf area index were recorded by I_4 which was significantly higher than the $I_2$and I_1. When compared to $I_1$$I_2$and I_3, I_4 received adequate water for its growth and other physiological activities hence recorded maximum growth parameters leading to higher yield attributes and yield. The stem girth of pigeonpea was significantly influenced by drip irrigation regimes and fertigation levels during all the years of study over surface method of irrigation. Irrigation with 120% of daily pan evaporation recorded significantly higher stem girth of 15.9 cm at harvest, while the 125% recommended dose of fertilizer registered highest stem girth of 10.5 cm at harvest. The normal sown pigeonpea crop recorded with lesser stem girth (6.1 cm) was observed at all stages with surface method of irrigation and conventional method of fertilizer application in all the years of study.

Seed yield

Under drip cum fertigation system of Transplanted Pigeonpea (variety ICPL 87119) irrigation with 120% of daily pan evaporation recorded significantly highest seed yield (3014 kg/ha) which was supported by the Harvest index (24.4), number of pods per plant (1020), Leaf area index LAI (4.37), radiation use efficiency (0.26 g/MJ) and water use efficiency (4.33). In this context, microirrigation could play a key role in higher productivity and increased water use efficiency (WUE) besides fulfilling sustainability mandates with economy in use. Adoption of micro irrigation helps in raising the irrigated area, crop productivity and WUE (Sivanappan, 1985). The results obtained from the experiment with four different irrigations based on IW/CPE ratios of120, 100, 80 and 60 per cent in Pigeonpea indicated that under conditions of unlimited water, I_4 treatment seemed to be the best as it recorded 3014 kg/ha yield, which was 75% higher than the I_1 (Table 2). The benefit cost ratio ranged from 2.54 to 4.56, while the water use efficiency ranged from 3.09 to 4.33 due to drip irrigation from $I_1$to I_4. The same treatment I_4 recorded highest net returns (Rs.1,39,297-00 per hectare) and Benefit cost ratio (4.56). Seed yield of I_4 is fbI_3, I_2 and I_1 as indicated in Table No.1 and the results concurrent with the reports of Sunil Kumar and Jadhav 2007.

Of the three fertility levels 125% recommended dose of water soluble fertilizers (MAP, Urea and KNO3) registered highest seed yield (2461 kg/ha), but was on par with 100% recommended dose of water soluble fertilizers (MAP, Urea and KNO3)(2401 kg/ha). Highest seed yields recorded under Transplanted situation with 125% recommended dose through fertigation was because of higher photosynthetic activity (positive influence on radiation use efficiency 0.27 g/MJ), effective translocation of photosynthates from source to sink (harvest index 24.5) which resulted in better development of pods (1006) 100 seed weight (10.2) and finally the water use efficiency (7.80 kg/ha/mm) which might have final positive effect on yield and Net returns (Rs.1,08,001 per ha) and Benefit cost ratio (3.67). The results coincided with the findings of Telgate *et al.*, (2004). Higher yields are also due to profuse growth leading to better primary branching (16.3), secondary branching (10.3) LAI (4.32), stem girth (14.3 cm).

Economics

One of the main objectives of fertigation is to reduce the cost of cultivation and to increase the economic product as high as possible.

Table.1 Effect of drip-fertigation on growth of Transplanted Redgram during *Kharif* (2013-14, 2014-15 and 2015-16 pooled analysis)

Treatments	Plant height (cm)	Primary branches	Secondary branches	Stem girth (cm)	LAI	RUE (g/MJ)
A) Main plots – 4 Spacings						
I_1 -60 % of daily pan Evaporation	198	12.0	5.2	12.0	2.20	**0.23**
I_2-80 % of daily pan Evaporation	205	14.0	6.3	13.3	3.81	**0.25**
I_3- 100 % of daily pan Evaporation	212	17.0	8.5	14.0	4.19	**0.26**
I_4- 120 % of daily pan Evaporation	218	20.2	9.0	15.9	4.37	**0.26**
Sem$\pm$	4.48	1.32	0.35	0.18		
C.D. (p=0.05)	NS	2.91	1.78	1.16		
B) Sub-plots – 3 Fertility levels						
F_1- 75 % of RDF	199	11.4	7.9	13.4	2.97	**0.23**
F_2- 100 % of RDF	210	14.4	9.8	13.7	3.64	**0.25**
F_3- 125 % of RDF	222	16.3	10.5	14.3	4.32	**0.27**
Sem$\pm$	2.04	1.10	0.44	0.34		
C.D (p=0.05)	NS	2.81	1.08	NS		
Interaction (A X B)						
Sem$\pm$	12.35	1.27	1.2	0.63	-	-
C.D (p=0.05)	NS	NS	NS	NS	-	-
	-	-	-	-		

*RDF (Recommended dose of fertilizer): 20:50:10 N, P_2O_5 and K_2O

Table.2 Effect of drip-fertigation on yield and economics of Transplanted Redgram during *Kharif* (2013-14, 2014-15 and 2015-16 pooled analysis)

Treatments	**Seed yield (Kg/ha)**	**Number of pods**	**Harvest index**	**100 seed weight (gm)**	**Net returns (Rs)**	**BC ratio**	**WUE (kg/ha mm)**
A) Main plots – 4 Spacings							
I_1 -60 % of daily pan Evaporation	1727	733	22.4	**9.7**	69191	2.54	**3.09**
I_2-80 % of daily pan Evaporation	2092	840	23.3	**9.9**	87729	3.09	**4.12**
I_3- 100 % of daily pan Evaporation	2585	974	23.8	**10.26**	115969	3.93	**4.23**
I_4- 120 % of daily pan Evaporation	3014	1020	24.4	**10.34**	139297	4.56	**4.33**
Sem±	53.66	35.2	0.3	**0.06**	3117	0.11	**-**
C.D. (p=0.05)	355	NS	1.97	**0.37**	20658	0.69	**-**
B) Sub-plots – – 3 Fertility levels							
F_1- 75 % of RDF	2186	791	22.4	**9.7**	95223	3.39	**7.2**
F_2- 100 % of RDF	2401	878	23.5	**10.1**	105916	3.64	**7.5**
F_3- 125 % of RDF	2461	1006	24.5	**10.2**	108001	3.67	**7.8**
Sem±	63.34	50.35	0.29	**0.08**	3551	0.12	**-**
C.D (p=0.05)	261	151.0	0.87	**0.34**	10646	NS	**-**
Interaction (A X B)							
Sem±	162.1	100.7	0.89	**0.18**	9385	0.32	**-**
C.D (p=0.05)	NS	NS	NS	**NS**	NS	NS	**-**
		-					

*RDF (Recommended dose of fertilizer): 20:50:10 N, P_2O_5 and K_2O

Therefore getting maximum benefits from each unit of water and nutrient applied to crop are important. A technically feasible level of fertigation with straight and water soluble fertilizer through drip would be economically viable for its successful adoption. The benefit cost ratio ranged from 2.54 to 4.56 due to drip irrigation from $I_1$to I_4. Drip irrigation with 120% of daily pan evaporation recorded maximum net returns (Rs. 1,39,297 ha^{-1}) and benefit cost ratio (4.56) as compared to low level of drip irrigation at 60% of daily pan evaporation. Water-soluble fertilizers were found to be better source for fertigation than the normal fertilizers as they resulted in less clogging (Venkateshamurthy, 1997).Of the three fertility levels 125% RDF recorded maximum net returns (Rs, 1,08,001 ha^{-1}) and benefit cost ratio (3.67) as compared to 75% RDF.

In conclusion, pooled results of the trial indicated that it is better to go for irrigation by drip irrigation system with 120% of daily pan evaporation to Pigeonpea under transplanted conditions. Of the fertility levels 100% RDF recorded highest Pigeonpea yield with Fertigation.

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