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Influence of Spacing and Drip Irrigation on Yield Attributes, Productivity and Economics of Pigeonpea (*Cajanus cajan* L.)

K.T. Jadhav, A.S. Chavan*, S.K. Raskar and R.U. Lahase

ARS, Badnapur, Vasantrao naik Marathwada Krishi Vidyapeeth, Parbhani (MS), India

**Corresponding author*

ABSTRACT

Keywords

Spacing, Drip irrigation, Yield, Pigeonpea

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A field experiment was conducted at Agriculture Research Station, Badnapur on a clayey soil during *kharif* season of 2016-17 to find out the effect of with two factors viz., spacing (three levels: S_1-120 cm x 30 cm spacing, S_2-120 cm x 45 cm spacing, S_3-120 cm x 60 cm) and four irrigation levels (irrigation at 50% Epan through drip (I_1), irrigation at 75% Epan through drip (I_2), irrigation at, 100% Epan through drip (I_3), supplemental irrigation at 50% flowering through furrows (I_4) with 12 treatments combinations. Each experimental unit was repeated three times. The size of gross plot 9.60 X 3.60 m^2 and in net plot 7.20 m x 2.40 m for 90 x 30 and 30 x 60 cm, 7.20 m x 2.70 m for 90 x 45 cm spacing. Sowing was completed on 2nd July 2016. The fertilizer dose of 25:50:00 NPK kg ha^{-1} was applied after sowing. Amongst, spacing 120x45 cm spacing recorded maximum seed yield (2391 kg ha^{-1}) and net monitory returns (84565 kg ha^{-1}) than wider spacing 120 x 30 cm and 120 x 60 cm, respectively. Amongst irrigation levels, irrigation at 75% Epan through drip recorded maximum seed yield (2674 kg ha^{-1}) and NMR (96995 Rs ha^{-1}) followed by irrigation at 100% Epan through drip, irrigation at 50% Epan through drip and irrigation at 50% flowering through furrows, respectively. Highest water use efficiency was observed under irrigation at 50% flowering through furrows (32.15 kg ha^{-1} mm^{-1}) followed by irrigation at 50% Epan through drip (7.76 kg ha^{-1} mm^{-1}), irrigation at 75% Epan through drip (6.98 kg ha^{-1} mm^{-1}) and irrigation at 100% Epan through drip (4.30 kg ha^{-1} mm^{-1}).

Introduction

Pigeonpea (*Cajanus cajana* L. *Millsp.*) commonly known as red gram, tur or arhar is the fifth prominent legume crop in the world and important crop amongst pulses which ranks second after chickpea in India in terms of area and production. It is originated in South Africa in the areas of Angola and Nile river. This is a short day, often cross pollinated crop belonging to family *Leguminoceae*. It provides protein rich food, firewood and income for resource poor small farmers. In India, the area under pigeonpea in 2011-12 was 3.86 million hectares with production of 2.90 million tonnes and average productivity of 751 kg ha^{-1}. Pigeonpea is grown as a sole crop, it is relatively inefficient because of its slow initial growth rate and low harvest index therefore it is grown as intercrop, which helps in efficient utilization of available resources for enhancing the productivity and profit. In general surface irrigation methods viz., furrow irrigation and controlled flooding i.e. ridges and furrow are the most common methods of water delivery to pigeon pea. In these methods, appreciable quantity of irrigation water is lost due to conveyance, evaporation and percolation besides low application and distribution irrigation efficiencies. The use of modern irrigation system, like drip provides better crop growth and greater yields, due to efficient use of water and nutrients. Drip irrigation is slow and precise application of water and water is applied in the form of drops directly at the root zone at shorter intervals and thereby it saves water due to reduction in conveyance, percolation, evaporation losses besides improving field application and distribution irrigation efficiencies and ultimately resulting in higher water use efficiency. It was found to be an efficient agronomic management tool that allows precise control of water over the root zone environment of the crop (Bresler, 1977) and often results in consistently high yields (Firake *et al*., 2000). But till date no systematic work was attempted on drip irrigated red gram.

Due to the growing demand of red gram (*dal*) and the need to increase irrigation efficiency, drip irrigation is being investigated as a possible alternative in terms of growth and yield response to water, water use and crop coefficients at different crop growth periods, economic viability etc. when grown under water constrained situations during rabi season. For field application, farmers need information on when to irrigate (optimum time) and how much to irrigate (depth of water) at various crop developmental stages and likely response of red gram pod yield to drip irrigation scheduling to maximize water productivity and returns. The high initial investment needed for installing the drip irrigation system remains the main deterrent to its wide spread adoption. The extent to which this discouragement effect is real and the extent to which this effect can be counter balanced by the government subsidy are important policy issues requiring greater attention. Past studies for various drip irrigated crops relied heavily on the experience of one or a few farmers adopting drip irrigation (Sivanappan, 1994). Therefore, there is need to evaluate empirically the economic viability of drip irrigation impact on profitability of red gram.

Efficient application of supplemental irrigation water is extremely crucial. In the past this aspect has been neglected. Currently major water losses (>40%) and poor uniformity in water distribution are occurring due to inappropriate surface irrigation methods (Pathak *et al.,* 2009). The modern pressurized irrigation system, namely drip, sprinkler and micro-sprinkler can reduce water losses in application of irrigation coveance, percolation, evaporation etc. moreover can achieve uniform distribution irrespective of type of soil and topography of soil. In view this present investigation entitled as “Studies on response of pigeon pea (*Cajanus cajan* L. Millsp.) to drip Irrigation.

Materials and Methods

A field experiment was conducted during the period of 2016-17 at Agriculture Research Station, Badnapur situated at 19^0 52'00'' North latitude and 75^0 44'00'' East longitudes at 498 m altitude above mean sea level on clayey in texture, moderate in available nitrogen (160 kg ha^{-1}), low in available phosphorus (10 kg ha^{-1}), high in available potassium (621 kg ha^{-1}). The soil was moderately alkaline in reaction (8.13 pH). In general, weather conditions were favorable for plant growth and no severe pest and diseases noticed during experimentation. The study involved twelve treatment combinations consisting of two factors viz., spacing (three levels: S_1-120 cm x 30 cm spacing, S_2-120 cm x 45 cm spacing, S_3-120 cm x 60 cm) and irrigation levels (irrigation at 50% Epan through drip (I_1), irrigation at 75% Epan through drip (I_2), irrigation at, 100% Epan through drip (I_3), supplemental irrigation at 50% flowering through furrows (I_4) were evaluated in factorial randomized block design with three replications. The Each experimental unit was repeated three times 9.60 X 3.60 m^2 size in gross plot and in net plot 7.20 m x 2.40 m for 90 x 30 and 30 x 60 cm, 7.20 m x 2.70 m for 90 x 45 cm . Sowing was completed on 2nd July 2016. The fertilizer dose of 25:50:00 NPK kg ha^{-1} was applied after sowing. The shallow furrows were opened manually in each plot as per treatments and entire quantity of phosphorous (50 kg P_2O_2/ha) in the form of single super phosphate and 100% dose of nitrogen (25 kg N/ha) in the form of urea were manually applied uniformly before sowing of pigeonpea crop in both the years. The package of recommended practices was adopted to maintain the crop.

Results and Discussion

Effects on growth attributes

Spacing

Growth attributes viz., plant height, number of functional leaves, mean number of branches, mean total dry matter $plant^{-1}$ were significantly influenced due to spacing treatment at all growth stages except at 30 DAS. Results indicated that 120 x 60 cm spacing recorded maximum plant height, number of functional leaves, mean number of branches and total dry matter $plant^{-1}$ at all growth stages followed by 120 x 45 cm and 120 x 30 cm spacing, respectively. Gradual decrease with narrow spacing might be attributed to better moisture, nutrients, sunlight and space under wider spacing compared to narrow spacing, similar results were reported by singh *et al*.(1994) and Shaikh *et al.,* (1997).

Number of functional leaves and number of branches $plant^{-1}$ under wider spacing might have boosted better total dry matter $plant^{-1}$ under wider spacing because of increased source capacity. Dry matter $plant^{-1}$ is important to have efficient translocation of nutrients and assimilates from source to sink. Moreover, number of branches $plant^{-1}$ are very important in case of crop like pigeon pea in which sink i.e. pods are positively correlated with number of branches which ultimately improves economical yield of crop.

Irrigation levels

Amongst irrigation levels, irrigation at 75% Epan through drip showed maximum plant height, number of functional leaves, mean number of branches, mean total dry matter $plant^{-1}$followed by irrigation at 100 % Epan through drip, irrigation at 50 % Epan through drip and irrigation at 50 % flowering through furrows at harvest, However, growth attributes were comparable under irrigation at 50 % Epan through drip and irrigation at 50 % flowering through furrows at all stages which indicated significance of moisture availability at flowering stage in case of pigeon pea (Basu *et al*., 2009). Moreover, results revealed that highest irrigation level was not able to improve all growth attributes at all stages which might be due to lower efficiency of root nodules under higher irrigation levels, however, irrigation at 75% Epan through drip proved better over both its lower and higher irrigation level which indicated that optimum moisture and air are very important to have better growth attributes. Bhowmik *et al* (1983) and Kalpana and Salvi (2008) asserted significance of optimum soil moisture for pigeon pea.

Effect on yield attributes and yield

Spacing

Various yield attributes viz., number of pods plant^{-1}, weight of pods plant^{-1}, seed index were significantly influenced due to three spacings under study, except number of seeds per pod which was not influenced due to spacing effect. Wider spacing, 120 x 60 cm recorded significantly maximum number of pods plant^{-1}, seed yield plant^{-1} and seed index than 120 x 45 cm and 120 x 30 cm spacing, respectively. However, 120 x 60 cm was comparable with 120 x 45 cm in case of weight of pods plant^{-1} and seed index. Improved yield attributes under wider spacing and gradual decrease in yield attribute with decreased spacing was also reported by Saritha *et al.*, (2012) in pigeon pea. This might be attributed to improved growth attributes viz., number of functional leaves, mean number of branches, mean total dry matter plant $^{-1}$which might have helped in better translocation of nutrients towards yield attributes under wider spacing. Also increased population in narrow spacing might have higher competition for moisture, nutrients, space and sunlight which ultimately produced poor source as compared to wider spacing which ultimately negatively affected sink i.e. yield attributes. Mula *et al.*, (2011) also asserted compensatory behavior of plant densities in case of pigeon pea (Table 1).

Irrigation levels

Amongst irrigation levels, irrigation at 75% Epan through drip produced significantly maximum number of pods plant^{-1}, weight of pods plant^{-1}, seed yield plant^{-1}and seed index than rest of irrigation levels, however, it was comparable to irrigation at 100 % Epan through drip in respect to number of pods plant^{-1} and seed yield plant^{-1}. Number of seeds per pod was not significantly influenced due to irrigation levels. Superior performance of irrigation at 75% Epan through drip over irrigation at 50 % Epan through drip as well as irrigation at 100 % Epan through drip and irrigation at 50 % flowering through furrows might be attributed to optimum availability of moisture as well as aeration under irrigation at 75% Epan through drip compared to irrigation at 50 % Epan, irrigation at 100 % Epan through drip and irrigation at 50 % flowering through furrows. This indicated significance of aeration and moisture in pigeon pea for better efficiency of nodules and root activity and resulted in better growth attributes and ultimately improved yield attributes. Similar results were reported by Bhowmik *et al* (1983) and Kalpana and Salvi (2008).

Effect on net monetary returns, gross monetary returns, benefit: cost ratio

Spacing

120 x 45 cm spacing recorded significantly maximum net monetary returns, gross monetary returns, benefit: cost ratio than wider spacing 120 x 60 cm. It was comparable with 120 x 30 cm in case of net monetary returns, gross monetary returns and benefit: cost ratio. Improved economics under 120 x 45 cm spacing might be due to increased seed yield under both narrow spacings of 120 x 30 cm spacing as well as wider spacing 120 x 60 cm (Table 2).

Irrigation levels

Amongst irrigation levels, irrigation at 75% Epan through drip noted maximum net monetary returns, gross monetary returns, benefit: cost ratio than rest of the irrigation levels. Higher seed yields under irrigation at 75% Epan through drip compensated the cost incurred on installation of drip. Similar results were reported by Pramod *et al.*, (2010).

Table.1 Growth and yield attributes of pigeonpea at harvest as influenced by various treatments of spacing and drip irrigation

Treatments	Plant height (cm)	Number of branches plant^{-1}	Dry matter production (g plant^{-1})	Number of pods plant^{-1}	Weight of pod plant^{-1} (g)	Seed yield plant^{-1} (g)	Number of seed pod^{-1}
Spacings (03)							
120 x30cm	173.51	15.98	105.66	217	117	76	3.36
120 x45 cm	183.05	19.66	111.64	345	192	125	3.38
120 x60 cm	184.91	21	115.75	365	206	137	3.44
SE ±	2.60	0.97	2.01	6.77	4.71	2.67	0.030
CD at 5 %	7.64	2.87	5.90	19.86	13.83	7.85	NS
Irrigations levels (04)							
Irrigation at50% Epan through drip	178.88	17.17	109.06	303	141	110	3.38
Irrigation at75% Epan through drip	188.42	22.73	117.25	330	238	119	3.42
Irrigation at 100% Epan through drip	180.48	19.84	111.66	310	186	116	3.40
Irrigation at 50% flowering through furrows	174.17	15.77	106.08	294	122	106	3.35
SE ±	3.00	1.13	2.32	7.81	5.44	3.09	0.034
CD at 5 %	8.82	3.31	6.82	22.93	15.56	9.07	NS
Interaction							
SE ±	5.21	1.95	4.02	13.54	9.43	5.35	0.059
CD at 5 %	NS	NS	NS	NS	NS	NS	NS
General Mean	180.49	18.18	111.01	309	172	113	3.39

Table.2 Yield and economics of pigeonpea at harvest as influenced by various treatments of spacing and irrigation levels

Treatments	Yield (kg/ha)		Cost of production (Rs/ha)	Gross realization (Rs/ha)	Net realization (Rs/ha)	B:C ratio
	Grain	Stalk				
Spacings (03)						
120 x30cm	2199	3673	34986	105034	70048	2.99
120 x45 cm	2391	4077	34983	119549	84566	3.41
120 x60 cm	1998	3549	36646	99901	63255	2.72
SE ±	66.06	138.53	-	3303.19	3303.19	0.100
CD at 5 %	193.77	406.33	-	9688.52	9688.52	0.295
Irrigations levels (04)						
Irrigation at50% Epan through drip	2011	3562	36688	100531	63843	2.74
Irrigation at75% Epan through drip	2674	4527	36688	133683	96995	3.64
Irrigation at 100% Epan through drip	2239	3845	36688	111969	75281	3.05
Irrigation at 50% flowering through furrows	1929	3127	29755	86461	56706	2.90
SE ±	76.28	159.96	-	3814.19	3814.19	0.116
CD at 5 %	223.74	469.33	-	11187.35	11187.35	0.340
Interaction						
SE ±	132.12	277.07	-	6606.38	6606.38	0.201
CD at 5 %	NS	NS	-	NS	NS	NS
General Mean	2163	3765	35205	108161	72956	3.06

Table.3 Soil moisture studies and water use efficiency of pigeonpea as influenced by various treatments of spacing and irrigation levels

Treatments	Cost of production (Rs/ha)	Evaporation (mm) Duration (2nd July-30 Dec, 2017)	water applied (mm)	WUE (kg $ha^{-1}mm^{-1}$)
Spacings (03)				
120 x30cm	23.83	305.5	2199	7.19
120 x45 cm	27.33	305.5	2391	7.82
120 x60 cm	29.83	305.5	1998	6.54
SE ±	1.51	-	-	-
CD at 5 %	4.45	-	-	-
Irrigations levels (04)				
Irrigation at50% Epan through drip	24.66	259	2011	7.76
Irrigation at75% Epan through drip	30.55	383	2674	6.98
Irrigation at 100% Epan through drip	35.44	520	2239	4.30
Irrigation at 50% flowering through furrows	17.33	60	1929	32.15
SE ±	1.75	-	-	-
CD at 5 %	5.14	-	-	-
Interaction				
SE ±	3.03	-	-	-
CD at 5 %	NS	-	-	-
General Mean	27.00	305.5	2171.25	10.39

Effect on soil moisture studies

Significantly more soil moisture at all stages in wader spacing 120 x 60 cm over both closer spacing indicated decrease in soil moisture with increase in population which might be attributed to increased demand for transpiration under higher population.

In case of irrigation levels, 100 % Epan through drip showed maximum soil moisture compared to lower levels and irrigation at 50 % flowering through furrow. This might be due to more application of water under 100 % irrigation through drip. Moreover, under 50 % flowering through furrow there was gradual decrease in soil moisture from November till harvest due to no receipt of rainfall after October and this resulted in lower moisture in 50 % flowering through furrow after October 2016 (Table 3).

Effect on water use efficiency

Higher Irrigation water use efficiency under 120 x 45 cm might be attributed to increased seed yield under spacing of 120 x 45 cm compared to 120 x 30 cm and 120 x 60 cm spacing as applied water was same (305.5 mm) for all spacings under study.

In case of irrigation levels higher Irrigation water use efficiency was recorded with irrigation at 50 % flowering through furrows which might be due to very less amount of water applied under irrigation at 50 % flowering through furrows (60 mm) compared to irrigation at 50 % Epan through drip (259 mm), irrigation at 75 % Epan through drip (383 mm) and irrigation at 100 % Epan through drip (520 mm), respectively. Although irrigation at 75 % Epan through drip recorded more seed yield it could not gave more Irrigation water use efficiency due to more water applied and comparatively less increase in seed yield compared to irrigation at 50 % Epan through drip and irrigation at 50 % flowering through furrows, respectively. Thus higher seed yield was masked by higher amount of water applied under irrigation at 75 % Epan through drip and irrigation at 100 % Epan through drip, respectively for improving water use efficiency in case of pigeon pea.

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