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Pigeonpea (*Cajanus cajan* L.) Growth, Yield and Monetary Influence by Drip Irrigation and Mulch in *Vertisols* of Madhya Pradesh

Mohan Lal Jadav, Dhanesh K. Raidas[1], Narendra Kumawat,
O.P. Girothia, D.V. Bhagat, S.K. Choudhary

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ABSTRACT

Background: Farmers are facing many constraints related with pigeonpea cultivation therefore proper resources management and scientific practices can increase the production and productivity of pigeonpea. Drip and mulching can be a way to achieve the goal of *more crop per drop.*

Methods: The field experiments were conducted during *kharif* season of year 2016-17 and 2017-18. The study area is located (23°16'48'' N-latitude, 77°21'36'' E-longitude) in Madhya Pradesh. The experiment was laid out in *vertisols* with twenty seven treatment combinations consisting of three mulching, three discharge rate (2 lph-D_1, 4 lph-D_2 and 8 lph-D_3) and three irrigation levels *viz.* 60% CPE (I_1), 80% CPE (I_2) and 100% CPE (I_3). Well treated bold seeds of pigeonpea (TJT-501) were dibbed in soil on ridge-furrow land configuration.

Result: The plant height was maximum in 2 lph (175.78 cm), I_2 (176.10 cm) and number of branches, number of pods per plant, seeds per pod also followed the same trend. Maximum yield was registered with D_1 (16.48 q/ha) followed by D_2 (14.91 q/ha) and D_3 (14.46 q/ha). Irrigation level I_2 (16.01 q/ha) registered 13.77% higher seed yield than I_1 (14.07 q/ha). In case of discharge rate, B:C decreased as rate increased. Among irrigation level treatments, lowest value (1.26) of B:C recorded with 60% CPE whereas highest B:C (1.56) was registered with 80% CPE, which is at par with 100% CPE (1.52). It can be concluded that pigeonpea cultivation is not economical with mulch and 100% supply of irrigation during *kharif*. It is viable to supply irrigation as per CPE only at branching, flowering and pod development stages.

Key words: B:C ratio, CPE, Discharge rate, Drip, Mulch, Pigeonpea, *Vertisols*.

INTRODUCTION

Pigeonpea (*Cajanus cajan* L.) is commonly known as *tur* or *arhar* in India. Pigeonpea is a perennial member of the Fabaceae family and one of the major legume crop of the tropics and subtropics (Vanaja *et al*. 2010). Pulses are proved as unique jewels of Indian farming. Pulses are an integral part of Indian diets as well as worldwide. It have great potential to improve human health, conserve soils, protect the environment and contribute to global food security. The United Nations, declared 2016 as *"International Year of Pulses".* India has first position as producer, consumer and importer of the pulses in the world. Pigeonpea is particularly rich in lysine, riboflavin, thiamine, niacin and iron (Manikandan and Sivasubramaniam, 2015). Pigeonpea plays an important role in food security, balanced diet and the alleviation of poverty.

Pigeonpea is grown worldwide in an area of 4.24 mha, with a production of 4.67 MT and productivity of 750 kg/ha. Rain fed pigeon pea has more than 85% area (Sanjay *et al.,* 2017). In India, it occupies an area of 3.75 mha with a production of 2.78 MT and a productivity of 750 kg/ha (GOI Report, 2015). Annual Report 2017-18 of IIPR Kanpur showed that per capita availability of pulses are reducing as population is increasing that resulted in reduced availability to the masses. India's population is expected to touch 1.68 billion by 2030 and the pulse requirement for the year 2030 is projected at 32 MT (Sarkar *et al.,* 2020).

Vertisols is the soil known for its shrinking and swelling properties. When the moisture content decreases the soil shrinks and creates the deep cracks in the soil surface. In such soil when water applied it gets swelled. These soils have drainage problems (Shrivastava *et al*., 2018). Willey *et al.* (1981) studied the problems and technology required for higher pulse production in such soils. Season and soil critically affect the water demand and other cultural

College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Indore-452 001, Madhya Pradesh, India.
[1]College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya Sehore-466 001, Madhya Pradesh, India.

Corresponding Author: Mohan Lal Jadav, College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Indore-452 001, Madhya Pradesh, India. Email: mohanjadav@rediffmail.com

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practices of pigeonpea cultivation (Manikandan and Sivasubramanyam, 2015).

The demand for fresh water has been on the rise from all water user sectors. Agriculture is the biggest user of water and consuming about more than 70 % of water utilization. As of now irrigation sector consumes about 83% of the total water use which may reduce to about 72% by 2025 in India (MoWR, 2014). Thus, producing more with less is the only option. Emphasize must be on the need for water conservation and improvement in water use efficiency to achieve '*more crop per drop'* of water. Among the various techniques advocated for economizing water use, scheduling of irrigation based on IW/CPE ratio is considered most effective and important (Gajera and Ahlawat, 2006).

Unavailability of water on a continuous basis is a serious hurdle to maximize pigeonpea yields (Reddy and Virmani, 1980). Water stress affects the final yield due to the reduction in growth attributes *i.e.* plant height, number of pods, reduction in pod weight. Roder *et al.* 1998 and Sharma *et al.* (2012) reported that more than 50% of yield loss in pigeon-pea is due to drought. The plant's physiological processes get affected because of moisture stress in plant (Patel *et al.* 2001). Proper use of existing water resources by using suitable irrigation technologies to increase pigeonpea production per unit area is the need of the hour (Jeyjothi *et al.*, 2017). Swathi *et al.* (2018) reported that the congenial environmental conditions determine the growth and flowering behavior of pigeon pea.

Drip and mulching can be a way to achieve the goal of *more crop per drop* (Pawar and Khanna, 2018). Importance of water requirement in *kharif* crop for *Malwa* region is also advocated by Ranade *et al*. (2021). Pigeonpea yield increased tremendously when irrigated through drip method. Greater attention is now needed to manage the pigeonpea because of high remunerative price. Moisture conservation techniques can enhance production and productivity of the crop. Solanki *et al*. (2019) indicated that drip and mulching have great influence on the productivity of pigeonpea. Vision 2050 of IIPR (ICAR) also emphasized on resource conservation techniques in pulses *viz*., raised bed planting, drip irrigation and mulching to minimize water loss and enhance water productivity. Tiwari *et al*. (2012) and Gireesh *et al*. (2019) studied the yield gap, constraints and economics of pigeonpea production in Madhya Pradesh. Farmers are facing many constraints related with pigeonpea cultivation therefore proper resources management and scientific practices can increase the production and productivity of pigeonpea.

MATERIALS AND METHODS

The study area is located (23°16'48'' N-latitude, 77°21'36'' E-longitude) in Madhya Pradesh which is under Vindhyan plateau as an agro-climatic zone. The field experiments were conducted in a village of Sehore district of Vindhyan plateau during year 2016-17 and 2017-18. This area belongs to sub-tropical climate with mean temperature range of min. 7^{0}C in winter and max. 43^{o}C in summer. The experimental site soil is *vertisols* with uniform and leveled topography.

Well treated bold seeds of pigeonpea (TJT-501) were dibbed in soil on ridge-furrow land configuration. Hand dibbling @ two seeds per hill was performed at about 6 cm depth. Row to row and plant to plant distance were kept 60cm and 25cm respectively. Drip irrigation system was used to irrigate pigeonpea having main (75 mm) and sub main (63 mm) of PVC pipes. LDPE pipes of 16 mm diameter were used as lateral, keeping lateral spacing of 60 cm with inline emitters. Control valve and pressure gauge were used to regulate the pressure of 1.2 kg/cm^2 to get the desired discharge rate as per treatment requirement. A 7.5 HP submersible pump was installed in tube well and connected to main line for irrigation water supply. Lateral lock was provided to each lateral for delivering desired quantity of water as per treatment. A screen filter was fitted in the system to avoid chocking due to impurities in the water. Laterals were put along the row soon after sowing of seeds. Black plastic sheet of 25 micron and wheat straw @ 5 t/ha were used as mulch. Irrigation water was applied according to daily crop evapotranspiration of pigeonpea. Daily evaporation (mm) was recorded for the two growing seasons from USWB class 'A' pan evaporimeter situated at experimental field.

Crop evapotranspiration was calculated by using following relationship.

$$ETc = PE \times Pf \times Kc \qquad \text{........(1)}$$

Where,
ETc = Crop evapotranspiration (mm).
PE = Pan evaporation (mm).
Pf = Pan fraction (0.8).
Kc = Crop coefficient.

Amount of water to be applied per treatment was calculated as follows:

$$V = ETc \times S_l \times Sd \qquad \text{.......(2)}$$

Where,
V = Volume of irrigation water (lit/day/emitter).
ETc = Crop evapotranspiration (mm).
S_l = Spacing between laterals (m).
Sd = Spacing between drippers (m).

The experiment was laid out with twenty seven treatment combinations consisting of three mulching, three discharge rate (2 lph-D_1, 4 lph-D_2 and 8 lph-D_3) and three irrigation levels *viz.* 60% CPE (I_1), 80% CPE (I_2) and 100% CPE (I_3). The treatment wise B:C ratio were calculated by using following equations.

$$\text{Benefit cost ratio} = \frac{\text{Net returns (Rs/ha)}}{\text{Total cost of cultivation (Rs/ha)}} \qquad \text{......(3)}$$

The recorded data were statistically analyzed by using technique of analysis of variance for the split plot design given by Gomez and Gomez (1984). The critical difference

(C.D.) at 5% level of significance and standard error of mean (S.Em) was worked out for treatment comparison where the F-test revealed the significant effect.

RESULTS AND DISCUSSION

The results on the basis of pooled data showed that the crop growth and yield attributes of pigeonpea were significantly affected by different treatments. Table 1 indicated that the maximum plant height was obtained in black plastic mulch and lowest in without mulch (161.99 cm) which has significantly difference of 11.91%. The maximum plant height was recorded in I_2 (176.10 cm) which is at par in I_3 (174.16 cm). The significantly lowest height was registered in I_1 (166.22 cm). The similar result was reported by Savani *et al*., (2017) and Jadhav *et al.* (2018). The increased plant height might be due to better availability of moisture and nutrients near root zone during entire crop growth period which favoured the growth attributes. Almost similar trend was observed by Ghosh and Biswas (1984) and Solanki *et al.* (2019). The pooled data (Table 1) clearly indicate that the plant height was highest with 2 lph (D_1) and value recorded with D_2 is at par with D_3 (8 lph). Among different discharges evaluated, significantly highest was observed with D_1 (175.78 cm) followed by D_2 (171.28 cm) and D_3 (169.42 cm). The results are similar with Pragna *et al.,* (2016). It might be due to soil moisture variation in vertisols with different discharge rate. In such soil, water is absorbed very slowly and runoff can possible if water is applied with higher discharge rate (Kareem *et al*., 2013).

Increasing the rate of discharge allows more water to move in horizontal direction, while decreasing the rate allows more water to move in vertical direction (Badr *et al*., 2003) and Kumar *et al.* (2018). Lower discharge rate gave better result than upper as reported in Table 1. The irrigation treatment significantly affects the number of branches and maximum recorded in I_2 (13.10) which is at par with I_3 (11.64). The increased number of branches per plant might be due to better availability of moisture and nutrients during entire crop growth period which favoured the growth attributes. Also, drip irrigation treatment created better micro-climate as compared because of prolonged duration of watering. The above findings are in close conformity with the findings of Yadav *et al.* (2006) and Savani *et al*. (2017) who found the same trend in dry matter accumulation. Table 1 also indicated that the maximum value of growth attributes were obtained in black plastic mulch and lowest in without mulch which has significantly difference.

The pooled data (Table 2) revealed that lowest value of pods per plant recorded with I_1 (106.45) and highest with I_2 (113.19) which is at par with I_3 (111.97). These results are conformity with Jadhav *et al.* (2018). Maximum number of pods registered with D_1 (113.62) followed by D_2 (110.05) and D_3 (107.94). Goldberg *et al.* (1970) reported that water movement from drip source is a function of soil type and dripper discharge together. Soil moisture variation affects the number of pods per plant. The different discharge rate did not significantly influence test weight. The highest test weight was recorded with D_1 (9.93) followed by D_2 (9.81) and D_3 (9.78) as given in Table 2. The test weight variation due to different irrigation levels found significant. On the pooled data basis, it is clear that lowest weight was recorded with I_1 (9.61) and highest with I_2 (9.96) which is at par with I_3 (9.94). The number of seeds per pod was significantly influenced by different discharge rate. The pooled data clearly indicate that was significantly difference among these. Maximum number of seeds registered with D_1 (3.41) followed by D_2 (3.25) and D_3 (3.20). The pooled data also indicate that lowest value recorded with I_1 (3.21) and highest with I_2 (3.33) which is at par with I_3 (3.32) as illustrated in Table 2. Increasing the soil moisture storage through irrigation significantly improved yield attributes. The similar results were reported by Patel and Patel (1994) and

Table 1: Effect on growth attributes of pigeonpea at harvest under different treatments.

	Height (cm)			No. of branches per plant			Dry matter accumulation (gms/plant)		
	I yr	II yr	Pooled	I yr	II yr	Pooled	I yr	II yr	Pooled
M_o	164.95	159.03	161.99	11.69	10.15	10.92	108.21	105.09	106.65
M_1	176.82	169.59	173.20	13.84	12.03	12.94	113.97	110.70	112.33
M_2	185.91	176.67	181.29	14.75	12.86	13.81	119.97	116.09	118.03
SEm (±)	2.82	2.67	2.74	0.28	0.23	0.26	2.01	1.85	1.93
CD at 5 %	7.82	7.41	7.61	0.77	0.65	0.71	5.58	5.14	5.36
D_1	179.66	171.91	175.78	13.97	12.24	13.10	115.38	112.22	113.80
D_2	174.99	167.56	171.28	13.25	11.51	12.38	113.67	110.17	111.92
D_3	173.03	165.81	169.42	13.06	11.30	12.18	113.09	109.49	111.29
SEm (±)	1.44	1.43	1.43	0.14	0.16	0.14	0.95	0.91	0.93
CD at 5 %	3.14	3.10	3.12	0.31	0.34	0.31	2.06	1.98	2.02
I_1	169.55	162.89	166.22	12.47	10.82	11.64	110.60	107.34	108.97
I_2	180.09	172.11	176.10	14.02	12.19	13.10	115.98	112.45	114.21
I_3	178.03	170.28	174.16	13.79	12.04	12.92	115.57	112.09	113.83
SEm (±)	1.40	1.33	1.36	0.13	0.11	0.11	0.93	0.91	0.92
CD at 5 %	2.84	2.69	2.77	0.26	0.23	0.23	1.89	1.84	1.86

Table 2: Effect on yield attributes of pigeonpea under different treatments.

	No. of pods per plant			Test weight (g)			No. of seeds per pod		
	I yr	II yr	Pooled	I yr	II yr	Pooled	I yr	II yr	Pooled
M_o	103.19	94.62	98.90	9.25	9.07	9.16	3.23	3.19	3.21
M_1	118.86	107.86	113.36	10.16	10.06	10.11	3.33	3.27	3.30
M_2	125.85	112.84	119.34	10.28	10.21	10.24	3.38	3.32	3.35
SEm (±)	1.87	1.71	1.79	0.22	0.21	0.21	0.06	0.05	0.06
CD at 5 %	5.20	4.74	4.97	0.61	0.57	0.59	NS	NS	NS
D_1	119.90	107.34	113.62	9.99	9.86	9.93	3.44	3.38	3.41
D_2	115.27	104.83	110.05	9.88	9.74	9.81	3.28	3.22	3.25
D_3	112.73	103.15	107.94	9.82	9.74	9.78	3.22	3.18	3.20
SEm (±)	0.93	0.85	0.89	0.12	0.09	0.11	0.03	0.03	0.03
CD at 5 %	2.04	1.86	1.95	NS	NS	NS	0.06	0.06	0.06
I_1	111.68	101.22	106.45	9.67	9.56	9.61	3.23	3.18	3.21
I_2	118.74	107.64	113.19	10.04	9.88	9.96	3.36	3.31	3.33
I_3	117.48	106.46	111.97	9.98	9.90	9.94	3.35	3.29	3.32
SEm (±)	0.94	0.86	0.90	0.09	0.09	0.09	0.03	0.03	0.03
CD at 5 %	1.91	1.73	1.82	0.19	0.18	0.18	0.06	0.05	0.05

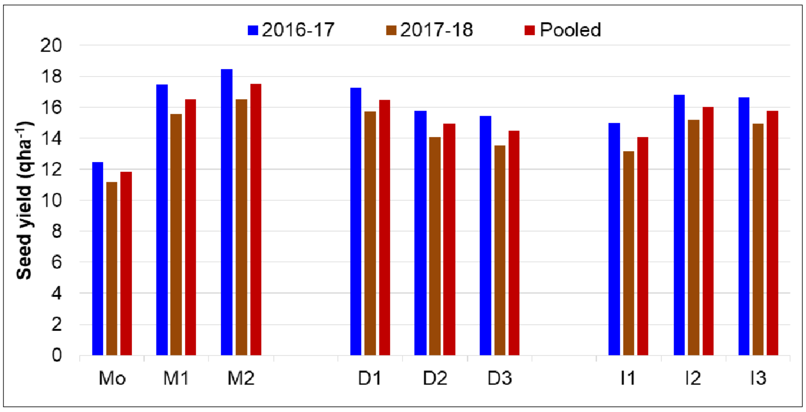

Fig 1: Seed yield (q ha^{-1}) of pigeonpea as influenced by defferent treatment.

Venugopal and Rao (1999). Table 2 also indicated that the maximum values of yield attributes were obtained in black plastic mulch and lowest in without mulch which has significantly difference.

The data on results revealed that seed yield under different mulching treatments significantly affected (Table 3 and Fig1). The pooled data revealed that significantly maximum seed yield (17.51 q/ha) registered under M_2 followed by M_1 (16.51 q/ha) and M_0 (11.83 q/ha). Savani *et al.* (2017) reported 48 % higher yield under plastic mulch than no mulch. Rao *et al.* (2018) reported that plastic mulch is far better than without mulch. Contrary result reported by Solanki *et al*. (2019) that higher yield in organic mulch than in plastic mulch. Maximum yield registered with D_1 (16.48 q/ha) followed by D_2 (14.91 q/ha) and D_3 (14.46 q/ha). Increasing the soil moisture storage through irrigation significantly improved yield attributes. The seed yield was found significant due to effect of different irrigation levels. The pooled data clear that lowest value recorded with I_1 (14.07 q/ha) and highest with I_2 (16.01 q/ha) which is at par with I_3 (15.77 q/ha). These results are conformity with Jadhav *et al.* (2018). Improvement in yield might be due to better proportion of air-soil-water which was maintained throughout the crop life in drip irrigation.

The significant difference recorded in net return influenced by different mulching treatments (Table 3). The significant variation observed in net return due to effect of different irrigation levels. The pooled data revealed that lowest return recorded with I_1 (Rs.44864) and highest with I_2 (Rs.55726) which is at par with I_3 (Rs.54189). These findings are conformity with Jadhav *et al.* (2018). Different discharge rate significantly influences the net return. On the basis of pooled data, it is clear that maximum return registered with D_1 (Rs.58504) followed by D_2 (Rs.49473) and D_3 (Rs.46802).

It is apparent from the data (Table 3 and Fig 2) on B:C ratio indicated that different irrigation level significantly influenced this monetary parameter. The pooled data indicate that lowest value (1.26) of it recorded with 60% IW/ CPE whereas highest B:C (1.56) registered with 80% IW/

Table 3: Seed yield (kg/ha) and economics of pigeonpea under different treatments.

	Seed yield (kgha^{-1})			Net return (Rsha^{-1})			B: C Ratio		
	I yr	II yr	Pooled	I yr	II yr	Pooled	I yr	II yr	Pooled
M_o	12.46	11.20	11.83	40357	37347	38852	1.39	1.26	1.33
M_1	17.46	15.55	16.51	58920	54151	56536	1.60	1.44	1.52
M_2	18.48	16.54	17.51	61584	57200	59392	1.55	1.42	1.48
SEm (±)	0.23	0.22	0.21	1168	916	809	0.03	0.03	0.02
CD at 5 %	0.63	0.61	0.58	3241	2544	2246	0.09	0.07	0.06
D_1	17.25	15.71	16.48	59824	57184	58504	1.69	1.59	1.64
D_2	15.75	14.06	14.91	51527	47419	49473	1.45	1.31	1.38
D_3	15.40	13.51	14.46	49510	44094	46802	1.40	1.22	1.31
SEm (±)	0.17	0.11	0.09	710	845	656	0.02	0.02	0.02
CD at 5 %	0.37	0.25	0.20	1547	1841	1430	0.05	0.05	0.04
I_1	14.95	13.19	14.07	47294	42434	44864	1.34	1.18	1.26
I_2	16.82	15.19	16.01	57393	54059	55726	1.62	1.49	1.56
I_3	16.64	14.91	15.77	56173	52205	54189	1.59	1.45	1.52
SEm (±)	0.20	0.12	0.12	991	1110	562	0.03	0.03	0.02
CD at 5 %	0.40	0.24	0.24	2010	2250	1141	0.06	0.06	0.03

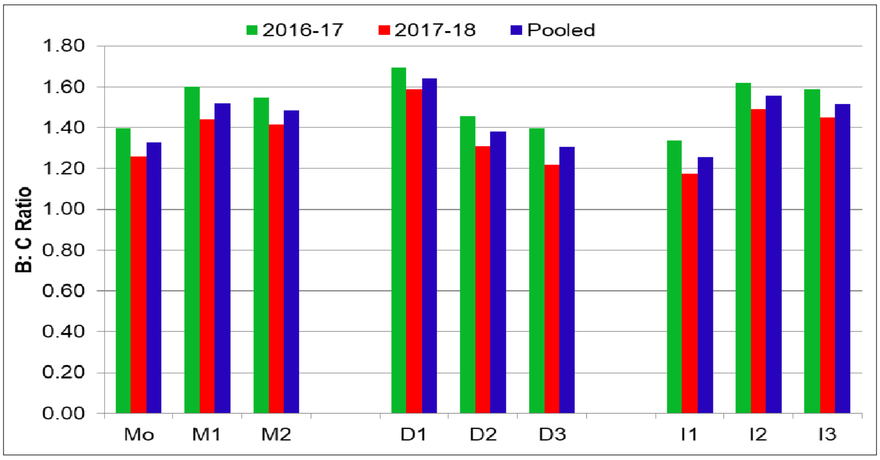

Fig 2: Benefit cost ratio (B:C) variation due to influence by different treatment.

CPE which is at par with 100% IW/CPE (1.52). Higher seed yields under irrigation (I_2) through drip compensated the cost incurred on installation of drip. Similar results were reported by Pramod *et al*., (2010) and Jadhav *et al*. (2018). These findings are in agreement with those of Mathukia *et al*. (2015). Savani *et al*. (2017) also reported that irrigation at 0.8 PEF with organic mulch gave better results due to higher cost of plastic sheet, it was not economical for mulching in pigeonpea crop. Different discharge rate significantly influences the B:C. On the basis of pooled data, it is clear that highest B:C registered with D_1 (1.64) followed by D_2 (1.38) and D_3 (1.31).

CONCLUSION

On the basis of results obtained in present study, the drip irrigation as per crop evapotranspiration demand at 80% CPE gave the best performance than lower (60%) and upper (100%) level. Mulch influenced the growth and yield attributes and finally higher B:C recorded because of soil moisture conservation and gave better result. In *vertisols*, lower discharge rate gave better results than higher rate. It can be concluded that irrigation at 0.8 PEF with organic mulch gave better results and due to higher cost of plastic sheet, it was not economical with 100% supply of irrigation during *kharif*. It is viable to supply irrigation as per CPE only at branching, flowering and pod development stages of pigeonpea crop in *vertisols* of Madhya Pradesh.

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