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Effect on Yield, Water use Efficiency and Economics of Pigeonpea of Mulch and Irrigation under Vindhyan Plateue of Madhya Pradesh

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ABSTRACT

The field trials were conducted during the two consecutive *kharif* seasons 2016-17 and 2017-18 with three mulching and three irrigation levels viz. 60%, 80%, 100% CPE (cumulative pan evaporation) to determine the growth and yield attributes of pigeonpea (*Cajanus cajan* L.) in Vindhyan plateau of Madhya Pradesh. The experiment was laid out in a split plot design with three replications. Mulching and irrigation levels significantly affected ($P<0.05$) the growth and yield attributes of pigeonpea. M_2 (17.51 q/ha) registered 47.98% higher seed yield than without mulch (11.83 q/ha). Irrigation treatments also affect the yield. I_2 (16.01 q/ha) registered 13.77% higher seed yield than I_1 (14.07 q/ha). Highest water use efficiency (q/ha-cm) registered with black plastic mulch (1.02) which is at par in wheat straw mulch (0.96) and lowest value recorded in without mulch (0.69). Wheat straw mulch recorded maximum B: C ratio of 1.52 which is at par with black plastic mulch (1.48). Lowest B: C ratio (1.33) recorded under without mulch treatment. Among irrigation treatments, lowest value (1.26) of it recorded with 0.6IW/CPE whereas highest B: C (1.56) registered with 0.8IW/CPE which is at par with 1.0IW/CPE (1.52).

Introduction

Pigeonpea (*Cajanus cajan* (L) MillSp.) is commonly known in India, as redgram or arhar or tur. 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 known as unique jewels of Indian farming. Pulses are an integral part of diets across the globe and 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 is the largest 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, since it is used in diverse ways as a source of food and fodder.

Pigeonpea grown worldwide in an area of 4.23 m.ha., with a production and productivity of 4.68 MTand 751 $kgha^{-1}$ respectively. More than 85% area of pigeon pea is under rain fed condition (Sanjay *et al.,* 2017). In India, it occupies an area of 3.71 m.ha. with a production and a productivity of 2.78 MT and 750 kg/ha respectively (GOI Report, 2015). Increasing population resulted in reducing per capita availability of pulses to the masses. (Annual Report 2017-18, IIPR, Kanpur).

In the global scenario, the demand for water has been on the rise from all water user sectors. Agriculture is the biggest user of water and consuming about more than 70 percent 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).

Lack of adequate water on a continuous basis is a serious obstacle to stable 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. Many researchers have reported that more than 50% of yield loss in pigeon-pea is due to drought (Roder *et al.,* 1998; Sharma *et al.,* 2012).

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).

Mulching as a moisture conservation practice has been widely practiced as a mean of improving yields in water limited environment. It also favourably modifies the soil thermal regime, retards soil erosion and improves soil health. Apart from those the plastic mulching increases the soil temperature and moisture of upper layer of soil (Rao *et al.,* 2018). Swathi *et al.,* (2018) reported that the congenial environmental conditions determine the growth and flowering behaviour of pigeon pea.

Pawar and Khanna (2018) advocated that mulching and drip can be a way to achieve the goal of more crop per drop. Pigeon pea yield increased tremendously when irrigated through drip method. Similarly, it is anticipated positive effect of mulching on yield of pigeonpea. Greater attention is now needed to manage the crop because it is in high demand at remunerative prices. There is still a scope in research to enhance productivity of the crop with the help of moisture conservation techniques. Drip and mulching are the most important resources and inputs, which have great influence on the productivity of pigeonpea (Solanki *et al.,* 2019). 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 pigeon pea 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. Hence, the present work has been taken up to the explore of water use efficiency and economics of pigeon pea through drip and mulching application.

Materials and Methods

The study area is situated in central part of Madhya Pradesh which falls under agro-climatic zone of Vindhyan plateau. It situated at 23°16'48" N-latitude, 77°21'36" E-longitude and at an altitude of 507 m above mean sea level. The field trials were conducted during the two consecutive *kharif* seasons 2016-17 and 2017-18 at farmer's field in Kulaskalan village of Sehore district of Madhya Pradesh. Area belongs to sub-tropical climate having a mean temperature range of minimum 7^0C and maximum 43^0C in winter and summer, respectively. The average annual rainfall in the district is 1027.73 mm. The topography of the experimental site was uniform and leveled and the soil is *vertisols*. TJT-501 pigeonpea variety was used for this experiment. Well treated bold seeds with *Rhizobium* culture and PSB were dibbed on ridge of RF at interval of 25 cm. The sowing was done by hand dibbling @ 2 seeds per hill at about 5.0 cm depth on RF which is 60 cm apart.. Mulching was practiced in this experiment for pigeonpea cultivation. Black plastic sheet of 25 micron and wheat straw @ 5 t/ha were used as mulch. It was laid out before establishment of the crop by cutting into pieces according to the treatment. Before spreading the plastic sheet on ridge, small circular holes were made with scissors at 25 cm apart. The sheet was spread above the lateral line. Afterwards all the sides of the mulch sheet were buried into the soil to a depth of 4-5 cm. Surface drip irrigation system was installed to irrigate pigeonpea for this field experiment. PVC pipes of 75 mm diameter were used as main and sub main lines of 63 mm diameter were fixed. LDPE pipes of 16 mm diameter were used as lateral keeping lateral spacing 60 cm and inline dripper spacing 30 mm. PVC valve of 63 mm and pressure gauge were used to control the pressure of 1.2 kg/cm^2 to get the desired discharge rate as per treatment requirement. A 7.5 HP submersible pump installed in tube well and connected to main line for irrigation water supply. Irrigation water was applied according to daily crop evapotranspiration of pigeonpea.

The experiment was laid out with twenty seven treatment combinations consisting of three mulching, three discharge rate (2lph-D_1, 4lph-D_2 and 8lph-D_3) and three irrigation levels having three replications. Three mulching treatments were without mulch (Mo), wheat straw mulch (M_1) and black plastic mulch (M_2) whereas three irrigation treatments were 60% CPE (I_1), 80% CPE (I_2) and 100% CPE (I_3).

The treatment wise water use efficiency (WUE) and B: C ratio was calculated by using following equations.

$$\boldsymbol{WUE} = \frac{Yield\ (\frac{q}{ha})}{Total\ amount\ of\ water\ applied\ (cm)} \quad ....(1)$$

$$\text{Benefit Cost Ratio} = \frac{\text{Net return (Rs/ha)}}{\text{Total cost of cultivation (Rs/ha)}} \quad .....(2)$$

The observation on growth and yield attributes were recorded using standard procedures. The recorded data were statistically analyzed by using technique of analysis of variance for the split plot design given by Gomez and Gomez (1984).

Results and Discussion

The data on results revealed that seed yield under different mulching treatments significantly affected (Table 1). 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). 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.

Water use efficiency (WUE) influenced by different mulching treatments during both the years are presented in Table 1. Highest value of it recorded under black plastic mulch (M_2) followed by wheat straw mulch (M_1) and without mulch (M_0) condition in both the years and also in pooled data. On the basis of pooled data it is clear that M_2 (1.02) registered highest WUE which is followed by M_1 (0.96) and M_0 (0.69).

Data also revealed that WUE under wheat straw mulch was found at par with black plastic mulch. It might be because of higher yield and lower evapotranspiration under different mulches. Savani *et al.,* (2017) also recorded the same trend in their findings. Different irrigation level influenced the water use efficiency during both the years. Data revealed that in 2016-17 highest (1.34) and lowest (0.90) value of it recorded with I_1 (0.6IW/CPE) and I_3 (1.0IW/CPE) respectively. In year 2017-18 also the I_1 and I_3 registered highest (1.40) and lowest (0.95) WUE respectively. Pooled data also followed the same trend. WUE decreased as discharge rate increases (from D_1 to D_2 and D_3).

This indicates that WUE decreased with increase in irrigation level. It might be because of more water applied under higher level of irrigation increased the moisture loss due to evapotranspiration. The results are in agreement with those reported by Patel (2001), Gajera and Ahlawat (2006), and Jadhav *et al.,* (2018).

Different mulching treatments significantly affect the gross return per hectare (Table 3). The pooled data showed that under black plastic mulch (M_2) significantly recorded highest gross return (Rs.99441) followed by wheat straw mulch (M_1) and without mulch (M_0). The value registered with M_1 and M_0 is Rs.93717 and Rs.68161 respectively. The gross return was found significant due to effect of different irrigation levels. The pooled data revealed that lowest value recorded with I_1 (Rs.80211) and highest with I_2 (Rs.91223) which is at par with I_3 (Rs.89886).

The significant difference recorded in net return influenced by different mulching treatments. The pooled data revealed that significantly highest net return (Rs.59392) registered under M_2 which is at par with M_1 (Rs.56536). The lowest return (Rs.38852) recorded with M_0 (Table 2). 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).

Table.1 Yield and Water use efficiency of pigeonpea under different treatment

	Yield (q/ha)			Amount of water applied (cm)			WUE (q/ha-cm)		
Treatment	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Mulch (M)									
M_o	12.46	11.20	11.83	18.58	15.70	17.14	0.67	0.71	0.69
M_1	17.46	15.55	16.51	18.58	15.70	17.14	0.94	0.99	0.96
M_2	18.48	16.54	17.51	18.58	15.70	17.14	0.99	1.05	1.02
Discharge (D)									
D_1	17.25	15.71	16.48	18.58	15.70	17.14	0.93	1.00	0.96
D_2	15.75	14.06	14.91	18.58	15.70	17.14	0.85	0.90	0.87
D_3	15.40	13.51	14.46	18.58	15.70	17.14	0.83	0.86	0.84
Irrigation (I)									
I_1	14.95	13.19	14.07	11.15	9.42	10.29	1.34	1.40	1.37
I_2	16.82	15.19	16.01	14.86	12.56	13.71	1.13	1.21	1.17
I_3	16.64	14.91	15.77	18.58	15.70	17.14	0.90	0.95	0.92
Mean	**16.14**	**14.43**	**15.28**	**17.34**	**14.66**	**16.00**	**0.95**	**1.01**	**0.98**

Table.2 Gross return (Rs/ha), Net return (Rs/ha) and Benefit Cost Ratio (B:C) of pigeonpea under different treatments

Treatment	Gross return (Rs/ha)			Net return (Rs/ha)			Benefit Cost Ratio		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Mulch (M)									
M_o	69308	67013	68161	40357	37347	38852	1.39	1.26	1.33
M_1	95672	91763	93717	58920	54151	56536	1.60	1.44	1.52
M_2	101336	97546	99441	61584	57200	59392	1.55	1.42	1.48
SEm (±)	1168	916	809	1168	916	809	0.03	0.03	0.02
CD at 5 %	3241	2544	2246	3241	2544	2246	0.09	0.07	0.06
Discharge rate (D)									
D_1	94976	93059	94018	59824	57184	58504	1.69	1.59	1.64
D_2	86678	83294	84986	51527	47419	49473	1.45	1.31	1.38
D_3	84661	79969	82315	49510	44094	46802	1.40	1.22	1.31
SEm (±)	710	845	656	710	845	656	0.02	0.02	0.02
CD at 5 %	1547	1841	1430	1547	1841	1430	0.05	0.05	0.04
Irrigation (I)									
I_1	82279	78142	80211	47294	42434	44864	1.34	1.18	1.26
I_2	92528	89917	91223	57393	54059	55726	1.62	1.49	1.56
I_3	91508	88263	89886	56173	52205	54189	1.59	1.45	1.52
SEm (±)	991	1110	562	991	1110	562	0.03	0.03	0.02
CD at 5 %	2010	2250	1141	2010	2250	1141	0.06	0.06	0.03

It is apparent from the data (Table 2) that different mulching treatments significantly influenced the B: C ratio. On the basis of pooled data it is clear that wheat straw mulch recorded maximum B: C ratio of 1.52 which is at par with black plastic mulch (1.48). Lowest B: C ratio (1.33) recorded under without mulch treatment. Data 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 0.6IW/CPE whereas highest B: C (1.56) registered with 0.8IW/CPE which is at par with 1.0IW/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.

In 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. Black plastic mulch performs best and followed by wheat straw mulch and without mulch. Economically wheat straw mulch is better option. Wheat straw mulch influenced the growth and yield attributes and finally higher B: C recorded because of soil moisture conservation and gave better result. 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 for mulching in pigeonpea crop for agro-climatic conditions of Vindhyan plateau of Madhya Pradesh.

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