The Pharma Innovation Journal 2021; 10(7): 461-465

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(7): 461-465

www.thepharmajournal.com
Received: 12-05-2021
Accepted: 21-06-2021

ML Jadav
AICRP for Dryland Agriculture Indore, Madhya Pradesh, India

DV Bhagat
AICRP for Dryland Agriculture Indore, Madhya Pradesh, India

OP Girothia
AICRP for Dryland Agriculture Indore, Madhya Pradesh, India

SK Choudhary
AICRP for Dryland Agriculture Indore, Madhya Pradesh, India

Narendra Kumawat
AICRP for Dryland Agriculture Indore, Madhya Pradesh, India

Corresponding Author:
ML Jadav
AICRP for Dryland Agriculture Indore, Madhya Pradesh, India

Rainwater harvesting to mitigate climate change effects on the cropping sequences in *Malwa* region of Madhya Pradesh

ML Jadav, DV Bhagat, OP Girothia, SK Choudhary and Narendra Kumawat

Abstract
A study was carried out for two consecutive years (2018-19 and 2019-20) at All India Coordinated Research Project for Dryland Agriculture Indore of Madhya Pradesh. Four cropping systems *viz.* Soybean – Chickpea, Maize– Chickpea, Maize– Sweet corn (Green cob) and Soybean- Onion were sown for the trial. Rabi crops were irrigated through the water stored in farm pond (rainwater harvesting structure). The study reported that during 2018-19, Soybean and maize yield was 1630 kg/ha and 4333 kg/ha respectively whereas in 2019-20 it was 919 kg/ha and 652 kg/ha respectively. Productivity of *Kharif* crops in second year severely affected due to excess and continue rain fall during crop growth period. Annual rainfall for the years were 756.7mm and 1565.4mm respectively whereas normal annual rainfall is 984mm Water use efficiency of soybean and Maize were 2.62 kg/ha-mm and 7.87 kg/ha-mm respectively during *kharif* of year 2018-19, whereas next year, WUE of soybean and Maize were 0.64 kg/ha-mm and 0.45kg/ha-mm respectively. On the basis of pooled data of economics of different system, it is clear that Soybean – Onion found the more remunerative as it recorded total net returns Rs. 189161/- per hectare with B: C ratio 4.16 whereas, the lowest was recorded with Soybean – Chickpea (Rs. 64551/- with B: C ratio 2.8). Yield, WUE and economics of the crops clearly indicate that climate change severely affects the *kharif* crops but rainwater stored in farm pond can mitigate it in *rabi* crops.

Keywords: B:C ratio, climate change, farm pond, rainwater harvesting, yield, water use efficiency

Introduction

The Madhya Pradesh is predominantly rain fed farming state, as only 6.07 m ha area is irrigated. Malwa agro climatic zone comprises 8 entire districts and part of Dhar (Dhar, Badnawar, Sardarpur Tehsil) and Jhabua (Petlawad Tehsil) districts of Madhya Pradesh (Ranjeet *et al*., 2018) [17]. Soybean had played a pivotal role in socio-economic transformation of majority of small and marginal farming community of central India (Dupare *et al*., 2019). Dupare *et al.* (2020) [3, 4] studied among soybean farmers of *Malwa* and *Nimar* region and found that more than 40 per cent farmers also perceived that the yield losses due to climatic adversities were even up to 50 per cent during the last two decades in spite of following management practices. Due to climate change, water related problems are increasing throughout the world in both developing and developed countries (Duguna and Januszkiewicz, 2019) [2]. It is predicted that change in climate will affect soil moisture, ground water and frequency of flood or drought (Kisakye *et al*., 2018) [11]. Constructions of rainwater harvesting structures have been the strategy to stop migration of the people (Pandey *et al*., 2003) [13]. Maize is the third largest produced and consumed food crop, after rice and wheat in India. Sweet corn consume as green cobs and maize seed as staple food (Ranjit kumar *et al.*, 2014) [18]. Madhya Pradesh is the largest producer of chickpea followed by Maharashtra, Rajasthan, Uttar Pradesh, Andhra Pradesh and Karnataka (Singh and Singh, 2018) [22].

There is need to harvest each drop of water and use efficiently and effectively in climate change (Chouhan *et al.*, 2020) [1]. Scarce water resources is one of the crucial factors that contributes to the decline in agricultural productivity (Zhang *et al*., 2012) [24]. Fereres and Soriano (2007) [5] emphasized on the current challenge in agriculture is to produce more yields by utilizing less water.

Rainwater harvesting, the small-scale collection and storage of runoff for irrigated agriculture, is recognized as a sustainable strategy for ensuring food security, especially in monsoonal landscapes in the developing world (Kimberly *et al*., 2016) [10]. Within a context of scarce water resources for agriculture, rainwater harvesting constitutes apromising alternative (Juan *et al*., 2019) [9]. Rainwater harvesting technologies are a critical factor for productivity of agricultural crops (Schlenker and Lobe, 2010) [20]. The hydrological and geological status of any watershed having *Vertisols* are the major factors for deciding the type and size of water harvesting tank. Due to the intermittent nature of run-off events, it is necessary to store the maximum possible amount of rainwater during the rainy season so that it may be used at a later date (Qadir *et al*., 2007 and Oweis *et al*. 2003) [16, 12]. If the soil is underlained by fragmented basaltic murram with high percolation rate, the lining of such excavated farm pond is very essential. Presently, HDPE (High Density Polyethylene) films of 500 µm or cross layer-reinforced silpaulin with 300–350 g/m^2 are commonly used (Rao *et al*., 2017) [19]. Rainwater harvesting measures could play a key role in further mitigation strategies against the global warming. Singh *et al*. (2009) [21] also reported that rainwater management can minimize the risk due to changing climatic conditions associated with farming. As the runoff potential of black soils of Malwa region is very high due to its inherent properties, it is decided to harvest the runoff at suitable locations in farm pond to its subsequent utilization in *rabi* season. The water availability in farm pond will thus ensure the provision of irrigation under changing climatic conditions. Therefore, to assess farm pond technology for mitigation of climate change effect on different cropping sequences in rainfed condition, this study was conducted during 2018-19 and 2019-20 in Malwa region under AICRPDA (All India Coordinated Research Project for Dryland Agriculture) at Indore, Madhya Pradesh.

Materials and Methods

The study was conducted at research station (22^{0}42’02.0” N and 75^{0}54’20.5”E) of All India Coordinated Research Project for Dryland Agriculture at College of Agriculture, Indore (M.P.). During 2018-19 and 2019-20, Rainwater harvested in farm pond and become the only source for irrigation during *rabi*. Four cropping systems *viz*. Soybean – Chickpea, Maize–Chickpea, Maize– Sweet corn (Green cob) and Soybean-Onion were sown for the trial. In a block of 50m X 50m, crops were grown for trial purpose. During both the years no any supplemental irrigation provided during *kharif*. Soybean (JS 20-34) and maize (Composit Jawahar-216) were planted during rainy season. These two *kharif* crops were harvested and in the same area three *rabi* crops, namely chickpea (RVG 203), sweet corn (East-west) and onion (AFLR) were planted at different time by utilizing harvested rain water from the farm pond. These crops were provided irrigation time to time till their harvesting as per scheduling. This study was carried out to compare the yield and economics of the different cropping system with the provision of farm pond. The irrigation provided during *rabi* seasons is reported in the table 2. The data showed that water applied in chickpea, sweat corn and onion was 11.9cm, 75.8cm and 74cm respectively during 2018-19. Irrigation water depth during *rabi* of 2019-20 for same crop was 5.88cm, 36.8cm and 40.6cm respectively. Meteorological data recorded at Agro meteorological observatory located at the research station.

Results and Discussion

Four cropping systems were evaluated in terms of crop yield, WUE, net return and B: C ratio by using stored rainwater in farm pond during *rabi*. Normally onset of monsoon for this area is 12th June with variability of 5 days but the data clearly indicate that 20th and 19th of June were the actual onset for year 2018-19 and 2019-20 respectively. Annual rainfall for the years were 756.7mm and 1565.4mm respectively whereas normal annual rainfall is 984mm. recorded (Table 1) clearly showed that the rainfall pattern were deviate from the normal values as depicted in the Fig.1. It was obvious from the figure that during 2019-20, the rains were recorded between 25 SMW to 41 SMW with six peaks that are in 26 (135.4 mm), 27 (197.6 mm), 32 (125.7 mm), 35 (138.0 mm), 37 (198.0 mm) and 40 (114.0 mm). Total wet period was 25 SMW to 41 SMW (1549.8 mm in 66 rainy days) which were higher than normal, except 28 SMW (July 9th to 15th). In year 2018-19, the rains were recorded between 25 SMW to 38 SMW with three peaks that are in 26 (64.4mm), 28 (145.0mm), 34 (77.4 mm) and 38 (184.1 mm). Above data resulted that climate change is occuring and it negatively affacts the production and productivity of the kharif crops.

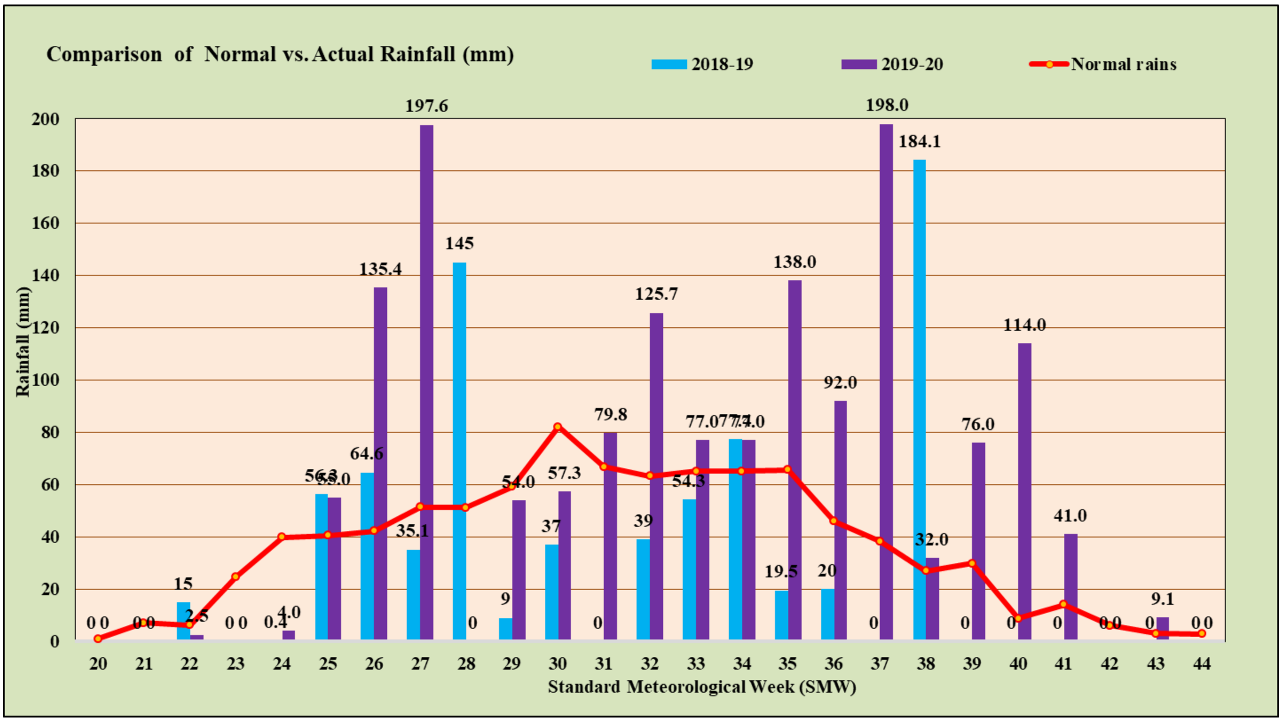

Fig 1: Comparison of Normal vs. Actual Rainfall

Table 1: Monthly agro-meteorological parameters for 2018-19 and 2019-20 at Indore

Month	Rainfall (mm)		Temperature (^{0}C)				Ave. R.H. (%)		No. of rainy days	
			Ave. Max.		Ave. Min.					
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
April 2019	0	0	41.2	41.2	23.1	22.4	58.5	61.7	0	0
May	0	0	43.9	41.1	28.5	26.9	60.3	55.8	0	0
June	136.3	136.9	38.7	39.5	26.2	27.1	68.6	64	9	9
July	226.1	395.2	31.5	29.5	22.9	23.5	74.3	79.6	11	15
August	190.2	441.2	27.9	26.9	23.0	22.5	79.7	81	11	17
September	204.1	428	30.4	27.6	21.3	22.1	76.6	83.8	8	21
October	0	164.1	34.5	29.4	17.9	19.5	70.8	79.4	0	8
November	0	0	33.7	31	13.4	16.8	72.5	76.7	0	0
December	0	0	27.6	26.8	9.0	11.7	76.8	74	0	0
January 2020	0	0	26.1	26.5	9.0	9.8	75.0	90.6	0	0
February	0	0	30.3	29.4	12.3	10.9	73.4	79.3	0	0
March	0	0	34.8	31.4	15.5	15.3	69.0	81.2	0	0
	756.7	1565.4								

Table 2: Details of Irrigation provided from farm pond during Rabi

Crop	Area Irrigated (m^2)		No. of Irrigation		Depth of Irrigation (cm)		Quantity of water supplied (m^3)		WUE (kg/ha-mm)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Soybean									2.62	0.64
Maize									7.87	0.45
Chickpea	841	612	1	1	11.9	5.88	100.8	36	9.86	23.20
Sweet corn	812	1173	8	6	75.8	36.80	615.6	394.16	7.20	19.78
Onion	255	1275	6	7	74.0	40.64	189.0	497.38	17.43	72.92

The results presented in Table 3 reported that during 2018-19, Soybean and maize yield was 1630 kg/ha and 4333 kg/ha respectively during *kharif*. The yield of chickpea (1173 kg/ha), sweet corn (5459 kg/ha) and onion (12897 kg/ha) were recorded during *rabi*. During 2019-20, productivity of *Kharif* crops is severely affected due to excess and continue rain fall during crop growth period (1549.8 mm in 66 rainy days). Same findings mention in report of ICAR- IISR 2019. Soybean and maize yield was 919 kg/ha and 652 kg/ha respectively (Table 3). The yield of chickpea (1364 kg/ha), sweet corn (7280 kg/ha) and onion (29635 kg/ha) were satisfactory because irrigation from stored water. Gupta *et al*. (2020) [7] reported that average onion bulb yield in Malwa region is 219.55 q/ha.

Table 3: Yield (kg ha^{-1}), Return and B: C ratio of different farming system

Cropping Sequence	Crops	Yield (kg ha^{-1})			Net Returns (Rs.ha^{-1})			B: C ratio		
		2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Soybean-	Soybean (K)	1630	919	1274	37037	16763	26900	2.85	1.84	2.345

Chickpea	Chickpea (R)	1173	1364	1268	33939	41364	37651	3.61	3.07	3.34
Total					70976	58127	64551	3.15	2.45	2.8
Maize –	Maize (K)	4333	652	2492	66667	(-) 6968	29849	4.33	(-) 0.65	1.84
Chickpea	Chickpea (R)	1173	1364	1268	33939	41364	37651	3.61	3.07	3.34
Total					100606	34396	67501	4.05	2.16	3.105
Maize-	Maize (K)	4333	652	2492	66667	(-) 6968	29849	4.33	(-) 0.65	1.84
Sweet corn	Sweet corn	5459	7280	6369	84184	95600	89892	4.37	2.91	3.64
Total					150851	88632	119741	4.35	2.27	3.31
Soybean-	Soybean (K)	1630	919	1274	37037	16763	26900	2.85	1.84	2.345
Onion	Onion (R)	12897	29635	21266	78175	246348	162261	4.13	5.93	5.03
Total					115212	263111	189161	3.56	4.76	4.16

Water use efficiency of soybean and Maize were 2.62 kg/ha-mm and 7.87 kg/ha-mm respectively during *kharif* of year 2018-19. Yu *et al*. (2004) [23] also found that WUE of maize was about two and a half times more than that of soybean in the same weather conditions. Next year, WUE of soybean and Maize were 0.64 kg/ha-mm and 0.45kg/ha-mm respectively. First year about half of second year rainfall received during crop growth period of *kharif* crops. Rainfall pattern was too much different during both the years and affect the yield and WUE (Table 2 and 3). Patidar *et al*. (2020) [14] also reported that Increase in rainfall resulted in decrease in maize yield. The WUE of *rabi* crops also reported in the table 2. The data showed that WUE of chickpea, sweat corn and onion was 9.86 kg/ha-mm, 7.20 kg/ha-mm and 17.43 kg/ha-mm, respectively during 2018-19. WUE during *rabi* of 2019-20 for same crop was 23.20 kg/ha-mm, 19.78 kg/ha-mm, and 72.92 kg/ha-mm respectively. Number of irrigation and water applied during second year were less than first year. During 2019-20 the rainfall before sowing of *rabi* crops increase the soil moisture, hence irrigation water applied is less and consequently more the WUE.

Result (2018-19) showed that among the different models, Maize– Sweet corn (Green cob) found the more remunerative as it recorded total net returns Rs.150851/- per hectare with B: C ratio 4.35 followed by sequentially grown Soybean –Onion (Rs. 115212/- with B: C ratio 3.56), Maize-Chickpea- (Rs.100606/- with B: C ratio 4.05). About sweet corn same findings reported by Priyanka *et al*. (2021) [15]. The lowest was recorded with soybean – chickpea (Rs. 70976/- with B: C ratio 3.15. Result also revealed that during *rabi*, sweet corn (Suger-75) for green cobs recorded highest net return Rs. 84184/- followed by onion Rs. 78175/- whereas the lowest was recorded by chickpea Rs. 33939/- per ha with higher B: C ratio of 3.61. Results in 2019-20 reported that soybean – Onion found the more remunerative as it recorded total net returns Rs. 263111/- per hectare with B: C ratio 4.76 followed by sequentially grown Maize grain – Sweet corn for green cob (Rs. 88632/- with B: C ratio 2.27), soybean – Chicpea (Rs. 58127/- with B: C ratio 2.45. The lowest was recorded with Maize grain – Chickpea (Rs. 34396/- with B: C ratio 2.16). Result revealed that during *rabi*, onion recorded highest net return Rs. 246348/- (B; C ratio 5.93) followed by sweet corn Rs.95600/- (B: C ratio 2.91) whereas, the lowest was recorded by chickpea Rs. 41363/- per ha with B: C ratio of 3.07. On the basis of pooled data (Table 3) of economics of different system, it is clear that Soybean – Onion found the more remunerative as it recorded total net returns Rs. 189161/- per hectare with B: C ratio 4.16 whereas, the lowest was recorded with Soybean – Chickpea (Rs. 64551/- with B: C ratio 2.8). These results have conformity with Gathiye and Kushwaha (2019). Yield, WUE and economics of the crops sown during both the seasons for two years clearly indicate that climate change severely affects the *kharif* crops but rainwater stored in farm pond can mitigate it in *rabi* crops. If provision of farm pond technology is associated with the cropping pattern it can compensate the loss of *kharif* crop without using ground water.

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