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Effect of residual soil moisture on yields and monetary return of rain fed cropping sequences under *vertisols* in *Malwa* region of Madhya Pradesh

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Abstract
Field experiments were conducted during 2019-20 and 2020-21 at the AICRP for Dryland Agriculture, College of Agriculture (RVSKVV), Indore, Madhya Pradesh, India to find out the effect of residual soil moisture on rain fed cropping sequences in *vertisols*. Nine cropping sequences including soybean/maize/ black gram-based cropping systems, *viz.*, soybean-chickpea, soybean-chickpea (*kabuli*) soybean-safflower, maize-chickpea, maize-chickpea (*kabuli*), maize-safflower, black gram-chickpea, black gram-chickpea (*kabuli*) and black gram-safflower were tested in randomized block design with 5 replications. The soil moisture content (%) were determined by gravimetric method from two depths *viz.*, topsoil (0-15 cm) and subsoil (15-30 cm) at 20, 40, 60, 80 DAS and at harvest. Results revealed that significantly highest SEY (3504 kg/ha), total net returns (Rs. 104142/ha) and B:C ratio (3.89) were recorded by the sequence of soybean - chickpea followed by black gram-chickpea (SEY 2945 kg/ha, total net return Rs. 81815/ha and B:C ratio of 3.27). Whereas, the lowest SEY (1138 kg/ha), total net return of Rs. 9510/ha and B: C ratio of 1.26 were noticed under the sequence of maize-safflower. During initial period of crop growth, soil moisture content was higher in the upper depth but at later stages soil moisture content was found higher in lower depth of the soil. It can be concluded that residual soil moisture availability can affects the yield and economics of *Rabi* crops after *kharif* season under rain fed conditions.

Keywords: Crop sequences, rain fed, SEY, soil moisture, yield, vertisols

Introduction
In agriculture, availability soil moisture determines the success of crop production because the growth and productivity of crops highly depends on the sufficient moisture (Awulachew *et al*., 2007) [2]. Residual soil moisture can play important role in *Rabi* crops. Kar and Kumar (2009) [9] reported that after rainy season (*kharif*) where irrigation water is not available, residual moisture become imperative for second crop (*Rabi*). In rain fed areas rainfall is the gamble for crop production. The aberrant nature of rainfall is often faced may be due to delay or untimely onset and or withdrawal or associated drought spell at any stage in the crop season. The medium to deep *vertisols* in *Malwa* region are capable of sustaining sequential cropping with the short duration crops for a period about 220 days under the normal monsoon season. If heavy rainfall occurred, *kharif* crops badly affected but *Rabi* crop production can compensate it, because of residual moisture content in rain fed condition. Lack of adequate seed-zone moisture is a major problem in the timely sowing of *Rabi* crop after *kharif* in rain fed areas (Sharma and Acharya, 2000) [16].

In India, rain fed farming accounts for 52 per cent in terms of net cultivated area, about half the total population of the country and two-thirds of livestock strength (Anonymous, 2020) [1]. Low and erratic rainfall, degraded soils, and poor infrastructure are among the principal constraints in the rain fed areas of India. Thus, intensive cropping of *vertisols* requires a careful management of soil temperature and moisture regimes (Srinivasarao *et al*., 2012) [20]. Soybean [*Glycine max* (L.) Merill] based cropping systems are important for sustaining agricultural production and also maintain soil fertility with an ecological balance (Khandkar *et al*., 2019) [8]. Rain fed cropping is practiced on 1.13 billion ha globally (Biradar *et al*., 2009) [3], and meets about 60 per cent of the food and nutritional needs of the world's population. Soybean grown both as an oil seeds and grain legume, fixes atmospheric nitrogen in soil and makes it available to partially fulfill the nitrogen requirement of succeeding crop (Kumawat *et al*., 2021 and Rahangdale *et al*., 2022) [21].

The traditional cropping systems in *kharif* are soybean, cotton, maize, etc. and intercropping systems are soybean + maize/pigeon pea/etc. Length of growing period is 90-120 days. Generally, soybean is grown as a monsoon season crop under rainfed situation mainly under *Vertisols* and associated soils. It has resulted increased cropping intensity and profitability (Rahangdale *et al*., 2021) [21]. In *Malwa* and *Nimar* valley region, its cultivation is largely practiced in rainy season followed by gram/wheat on conserved soil moisture. Under irrigated conditions, soybean is largely grown in soybean-wheat cropping system, while soybean-chickpea cropping system is prevalent under rain fed conditions. Soybean-chickpea system is also prevalent as a next important cropping sequence mainly in those areas, where rainfall is not adequate or irrigation water is scarce. Long-term regular practice of soybean-chickpea and soybean-wheat system in the growing region is posing severe problems before the growers such as complexity in weed management, deterioration of soil-properties, delayed sowing of wheat and low market value of produce owing low productivity as well as poor economic viability of this cropping system. Under such circumstances, the diversification of crops under soybean based cropping system appears to be a possible way for improving the productivity and profitability per unit area per year without jeopardizing the soil health. Jadav *et al.* (2021) [6] reported that excess rainfall during recent years severely affects the *kharif* crops production, but if provision of rain water harvesting is associated with the cropping sequences, economic loss of *kharif* crops can be compensate by enhancing *rabi* crop productivity. This study was conducted to evaluate the effect of residual soil moisture on yield and monetary return in rainfed cropping sequences.

Materials and methods

Field experiment with nine different soybean/maize/ blackgram-based cropping sequences, *viz*., soybean-chickpea, soybean-chickpea (*kabuli*), soybean-safflower, maize-chickpea, maize-chickpea (*kabuli*), maize-safflower, black gram-chickpea, black gram-chickpea (*kabuli*) and black gram-safflower were performed during 2019-20 and 2020-21. Soybean/maize/black gram were grown during *kharif* (15th June to 15th September) and chickpea/safflower/mustard during *Rabi* (1st October to 31st March) at the AICRP for Dryland Agriculture, College of Agriculture (RVSKVV), Indore, Madhya Pradesh, India. Varieties of different crops mention in Table1.This station is situated in the central highlands (*Malwa*) of semi-arid eco- region at 76^{0}54' E longitudes and 22^{0}43' N latitudes at an altitude of 567 m above MSL. The climate of the area is hot dry semi-arid with an average annual rainfall ranging from 825-1100 mm. The length of growing period is 90-120 days for this region.

The total annual rainfall was recorded above the normal during years. The experimental soils of the area are medium, deep and shallow black soils with low organic carbon content (0.41%), low available N (152 kg/ha), medium available P_2O_5 (13.5 kg/ha) and high available K_2O (422 kg/ha). All the crops in the cropping sequence were grown in a gross area of 1080m^2, with recommended package and practices.

After harvesting, data pertaining to by produce and economic yield of each crop were converted into per hectare. To compare the performance of different cropping sequences, economic yield of all the crops was converted into soybean equivalent yield (SEY) based on the prevailing market price. The *Rabi viz*. chickpea, chickpea *Kabuli* and safflower were sown after harvest of *kharif* (soybean, maize and black gram). Crop was shown in first fortnight of November in residual moisture. Statistical analysis of the data was carried out using standard analysis of variance (Gomez and Gomez, 1984) [5].

The soil samples were collected from two depths viz. topsoil (0-15 cm) and 30 cm depth soil at 20, 40, 60, 80 DAS and at harvest from each of the plots. A soil auger was used to collect the soil of 30 cm depth. The circular shaped box made of aluminum was used to take weight and dry the soil sample in the oven for moisture content determination. Hot air oven was used to dry the collected soil samples. An electronic weighing balance was used to measure the mass of the dry and wet soil samples. The determination of moisture content done by oven drying method is termed as gravimetric method. In this method the soil sample was dried for 24 hours at 105°C temperature. After that the soil sample becomes bone dried. Then the dry moisture content is measured by the moisture evaporated with respected to the bone dry mass of the soil sample.

The equation for expressing moisture content of soil can be given as:

$$MC = (Ww / Ws) \times 100\%$$

Where,
MC = Moisture content of soil sample (%)
Ww = weight of the water removed from soil sample by oven drying (g)
Ws = weight of the soil sample (g)

The soil moisture profiles in the plots for the crop duration period of the different *Rabi* crops were monitored. The water requirement of the crops were fulfilled by the residual moisture content without any supplemental irrigation.

Result and Discussion

Nine crop sequences with soybean- chickpea/ chickpea (*kabuli*) / safflower, maize- chickpea/ chickpea (*kabuli*)/ safflower and black gram-chickpea/chickpea (*kabuli*)/ safflower were grown under rain fed condition. Yield and economics of different crops as well as soybean equivalent, net return and B:C presented in Table1.

Productivity of *kharif* and *Rabi* crops

Obtained data of two years showed that during *kharif* soybean (JS 20-34) was recorded highest seed yield (986 kg/ha) followed by maize (695 kg/ha) and black gram (417 kg/ha). This year crop yield was very low due to excess and continue rainfall during crop growth period (1549.8 mm in 66 rainy days).

Among the soybean based cropping sequences, in *Rabi* season the highest seed yield was recorded in soybean-chickpea sequence (2250 kg/ha) followed by soybean-chickpea (*kabuli*) (1330 kg/ha), while the lowest seed yield was recorded in soybean-safflower sequences (688 kg/ha) (Table 1). Further data shows that among the maize based sequence, the highest yield was obtained in maize-chickpea (2188 kg/ha) sequence followed by maize-chickpea (*kabuli*) (1063 kg/ha) and lowest in maize-safflower sequence (625 kg/ha). Similarly, the black gram based sequence, the maximum seed yield was noticed with black gram-chickpea sequence (2063 kg/ha) followed by

black gram-chickpea (*kabuli*) (1063 kg/ha) and lowest in black gram-safflower sequence (750 kg/ha). During *Rabi* chickpea was produced highest seed yield of 2250, 2188 and 2063 kg/ha grown after soybean, maize and black gram, respectively. Higher yield of pulse after rainy season was also reported by Pratibha *et al*. (1996) [13] under rain fed situation. Similar results were also reported by Shrikant *et al*. (2013) [17] and Prajapat *et al*. (2014) [11] and Singh *et al*. (2018).

Whereas, the higher seed yield of safflower (750 kg/ha) was obtained grown after black gram followed by 688 and 625 kg/ha after soybean and maize. This might have deteriorated the biological activities of soil and ultimately reduced the yield in the succeeding season after fallow. Similar findings were also made by Gathiye and Kushwaha (2019) [2] and Kumar *et al*. (2022) [9].

Soybean equivalent yield and economics

The yield data of sequentially grown crops were recorded and statistically analyzed in term of soybean equivalent yield (SEY) to calculate system productivity. The data presented in Table 1 revealed that significantly higher SEY (3504 kg/ha) was recorded by the sequence soybean -chickpea with highest total net return of Rs. 104142/ha with B: C ratio of 3.89 followed by black gram-chickpea (SEY 2945 kg/ha total net return Rs. 81815/ha and B:C ratio of 3.27). Whereas, lowest SEY (1138 kg/ha), total net return (Rs. 9510/ha) and B:C ratio (1.26) were found under maize-safflower sequence. Similar findings were also reported by Prajapat *et al*. (2015) [12] and Singh *et al*. (2019).

Residual soil moisture at different depth and duration

Soil moisture content was measured for all *Rabi* crops of sequences i.e. soybean-chickpea, soybean-chickpea (*kabuli*), soybean-safflower, maize-chickpea, maize-chickpea (*kabuli*), maize-safflower, black gram-chickpea, black gram-chickpea (*kabuli*) and black gram-safflower (Fig.1 and 2). It was observed that variations of soil moisture contents in surface (0-15 cm) were more compared to the soil moisture level changes at 30 cm depth (Table 2 and Fig. 1 and 2). This can be attributed to the fact that after the harvest of the first crop the evaporation losses from the topsoil were more than the loss from the subsoil. The percolation and seepage of soil water from the topsoil to the subsoil also has a tendency to maintain the subsoil moisture content at a near steady level. In the soil depth of 0-15 cm, soil moisture content initially higher (about 20%) at the time of sowing of *Rabi* crops. It was sufficient germination of seeds. As time go on towards harvesting soil continuously decreasing up to 10%. In the soil depth of 15-30 cm, Soil moisture content initially higher (about 25%) at the time of sowing of *Rabi* crops. It was sufficient germination of seeds. As time go on towards harvesting soil continuously decreasing up to 12%. During initial period of crop growth soil moisture is higher in upper layer but at later stage soil moisture found higher in lower layer of the soil. Evaporation of soil water from surface is higher in initial period because lower foliar area and less consumptive use. Drastic loss in moisture recorded in each crop because of different root zone depth and respective foliar content. Availability of sufficient soil moisture is the key for better productivity. Yield (kg/ha) variation of *Rabi* crops i.e. chickpea (2250, 2188 and 2063 kg/ha), chickpea (kabuli) (1313, 1063 and 1063 kg/ha) and safflower (688, 625 and 750 kg/ha) grown after *kharif* crops clearly indicated that residual soil moisture play an important role in improving the productivity of *Rabi* crops.

Table 1: Mean data of yield, soybean equivalent yield (SEY), net return and total net return (Rs. ha) and B: C ratio of different crop sequences

Crop sequence	Yield (kg/ha)		Cost of cultivation (Rs./ha)	Return (Rs./ha)		B: C ratio	SEY (kg/ha)	Total Return of sequence (Rs./ha)		Total B: C ratio
	Seed	Straw		Gross	Net			Gross	Net	
Soybean -	986	1403	20000	39448	19448	1.97	-	-	-	
Chickpea	2250	3375	16000	101250	85250	6.33	3504	140142	104142	3.89
Chickpea (Kabuli)	1313	3688	16000	59063	43063	3.69	2449	97955	61955	2.72
Safflower	688	2125	16000	34375	18375	2.15	1832	73267	37267	2.04
Maize -	695	2222	20000	13890	(-)6110	(-)0.69	-	-	-	-
Chickpea	2188	3438	16000	98438	82438	6.15	2817	112698	76698	3.13
Chickpea (Kabuli)	1063	3125	16000	47813	31813	2.99	1552	62073	26073	1.72
Safflower	625	1750	16000	31250	15250	1.95	1138	45510	9510	1.26
Black gram -	417	833	20000	25002	5002	1.25	-	-	-	-
Chickpea	2063	2938	16000	92813	76813	5.80	2945	117815	81815	3.27
Chickpea (Kabuli)	1063	2875	16000	47813	31813	2.99	1820	72815	36815	2.02
Safflower	750	2375	16000	37500	21500	2.34	1563	62502	26502	1.74
S.E (m) (±)	-	-	-	-	-	-	427	-	-	-
C D at 5 %	-	-	-	-	-	-	1237	-	-	-

Market Rate (Rs/kg): Soybean-35/-, Maize-20/-, Black gram-60/-, Chickpea- 40/-, Safflower-50/-

Table 2: Periodical soil moisture content (%) during Rabi of different cropping sequences

Crop sequence	Soil depth (cm)	Soil moisture content (%) days after sowing				At harvest
		20	40	60	80	
Soybean-chickpea	0-15	21.25	13.03	12.55	12.04	10.91
	15-30	23.06	15.24	15.22	14.31	12.88
Soybean- chickpea (*kabuli*)	0-15	21.67	14.40	13.31	11.42	10.44
	15-30	24.46	18.36	14.92	13.70	11.85
Soybean- safflower	0-15	20.08	16.43	13.17	11.35	10.79
	15-30	21.35	19.46	15.06	13.53	11.91
Maize-chickpea	0-15	17.16	14.45	13.97	11.88	10.52

	15-30	20.36	16.10	15.23	13.70	11.07
Maize- chickpea (*kabuli*)	0-15	18.39	14.37	13.97	12.44	10.01
	15-30	22.21	17.81	15.45	13.70	11.48
Maize-safflower	0-15	22.71	15.00	14.26	12.71	10.53
	15-30	23.53	18.47	16.28	13.89	11.52
Blackgram-chickpea	0-15	19.36	14.32	13.76	12.03	10.25
	15-30	22.28	17.24	16.29	14.28	11.32
Blackgram - chickpea (*kabuli*)	0-15	19.44	14.84	13.76	11.42	10.25
	15-30	22.35	16.87	14.82	13.55	11.18
Blackgram -safflower	0-15	21.32	15.20	13.32	11.63	10.63
	15-30	25.33	16.22	14.21	12.46	11.10

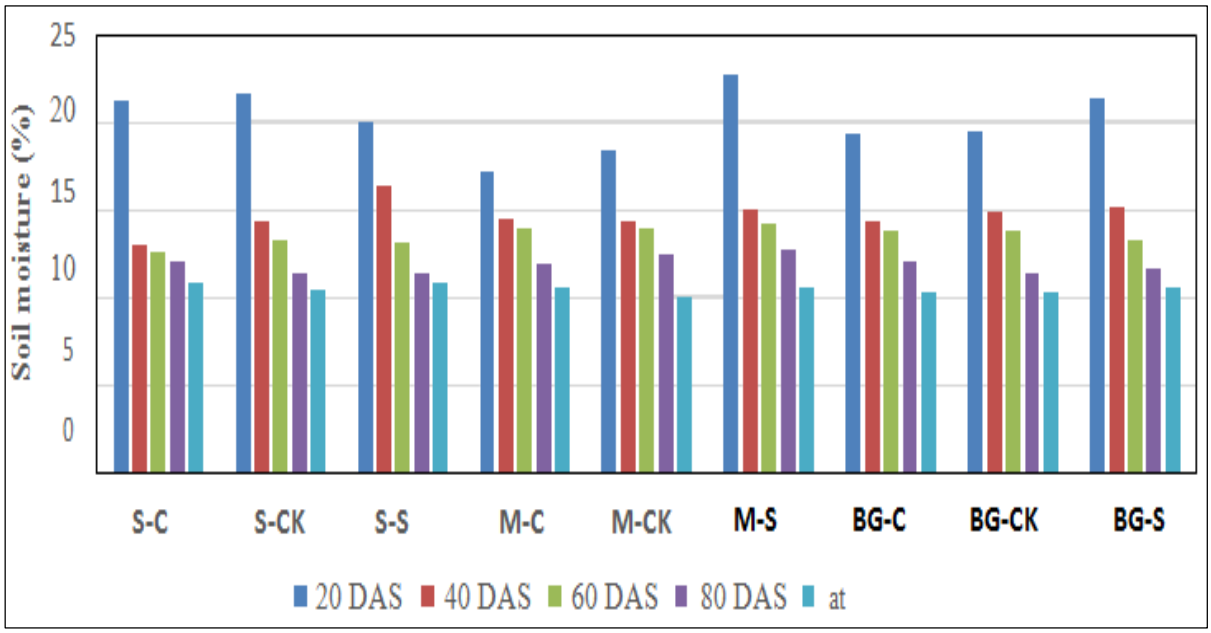

Fig 1: Soil moisture content at 0 to 15 cm depth as influenced by different cropping sequences

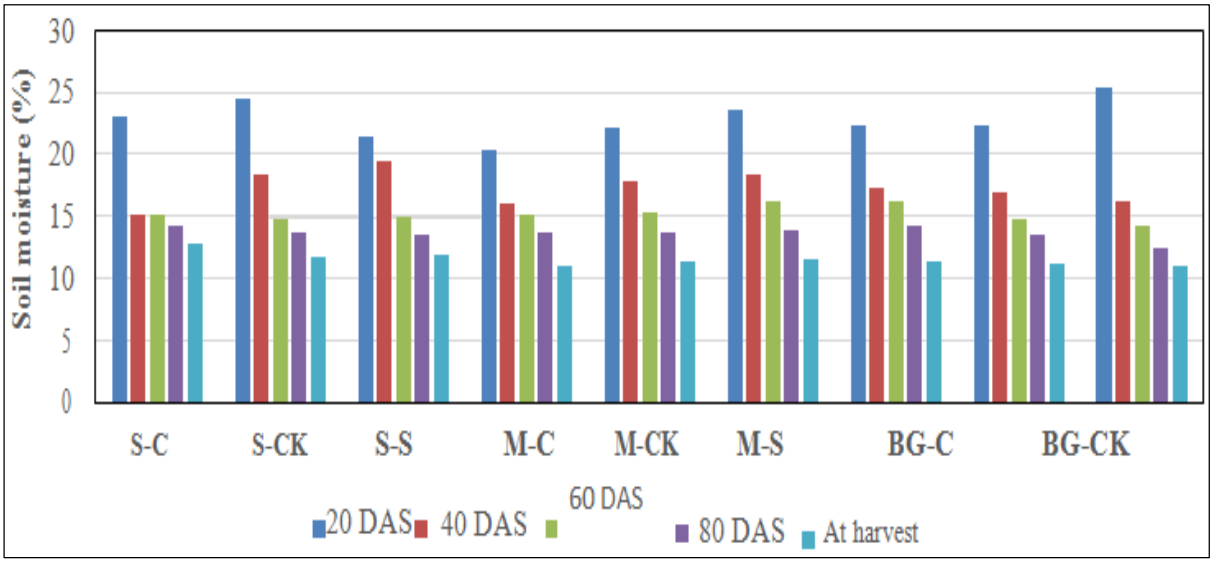

Fig 2: Soil moisture content at 0 to 15 cm depth as influenced by different cropping sequences

Conclusion

Based on above findings, it can be concluded that the residual soil moisture plays an important role for crop production in *Rabi* season. Rainfall pattern and cropping sequence of *kharif* season is the deciding factor for residual soil moisture availability which ultimately affects the production and productivity of the cropping system.

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