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CROP PRODUCTIVITY RESPONSE TO RAINFALL VARIABILITY IN *KHARIF* SEASON IN ARID WESTERN RAJASTHAN

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ABSTRACT

Major crops contributing to food grain production in the arid western Rajasthan are generally cultivated under rainfed situations, also known as *kharif* season. In this study an attempt was made to quantify the response of rainfall variability on major rainfed crops in this region. Analysis of daily rainfall data during monsoon seasons (Jun–Sept) over past 13 years showed a range of seasonal rainfall from 86 mm to 480 mm. Crop productivity data of major rainfed crops of the region e.g. pearl millet representing cereals, cluster bean and moth bean as pulses and sesame as oilseeds revealed positive correlation between productivity and monsoon rainfall or intra-monsoon rainfall (Jul-Aug). Linear trends between the productivity and rainfall during the monsoon season and intra- monsoon period was established for each selected crop. Best trend was observed for cluster bean (R^2 = 0.85) and the worst for sesame (R^2 =0.63) while the total monsoon rainfall was considered. However, when only the intra-monsoon rainfall was considered, best trend was observed for moth bean (R^2 =0.72) and the lowest for pearl millet (R^2= 0.61). From this study, it was observed that cluster bean yield is more sensitive to total monsoon rainfall than other crops of the region, whereas, moth bean yield was found most sensitive to intra-monsoon rainfall.

KEY WORDS
Crop productivity
Rainfall variability
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INTRODUCTION

Arid lands worldwide cover about 40% of the earth's land surface and are inhabited by more than 2 billion people (Thomas, 1995) and about 90% areas of such lands occur in developing countries. Despite having a combination of biophysical, geopolitical, social and economic stresses, these regions provide much of world's grain and livestock. However, food security and water availability in this region is quite unstable due to high variability of rainfall characteristics. In India, about 70% (228.3 million ha) of country's total land area (327.9 million ha) is classified as dry lands which are again divided into arid, semi-arid and dry sub-humid zones. All these regions have the problem of soil fertility and erratic rains which limits the crop production (Prasad *et al.*, 2014). Crop production, as a consequence is the difficult proposition and largely depend upon intensity and distribution of rainfall which is otherwise known as rainfed farming. About 85 million hectares of land area is under rainfed farming which constitutes about 58% of the total arable land in the country. It contributes 40% of the total food grain production from arid and semi-arid regions of the country (Chattopadhyay, 2011).

Western part of Rajasthan is primarily rainfed covering country's 13.27 per cent of available land. Annual average rainfall varies between 100 mm in the extreme west in Jaisalmer to about 500 mm in the east near Aravalli hill ranges. In much of the districts, even protective or lifesaving irrigation is often difficult. During a severe drought year (2002), the isohyet patterns fluctuate in large way (Fig.1). Among the 12 districts in western Rajasthan, the severity of problems for dryland farming in Ganganagar and Hanumangarh is quite less because of the development of irrigation facilities through Indira Gandhi Nahar Project (IGNP). Rest part of western Rajasthan is yet to gain such advantages. In the eastern part, ground water is mostly used for irrigation purpose e.g. in Sikar, Jhunjhunun, western part of Churu, some part of Jalor and Nagaur. The water level fluctuates between 40 m and 60 m below ground level (CAZRI, 2012). Farmers in rest of the area in western Rajasthan largely depend on monsoon rainfall which is very low and erratic. With the availability of such scarce rain water farmers grow pearl millet (*Pennisetun glaucum*), clusterbean (*Cyamopsis tetragonaloba*), moth bean (*Vigna acontifolia*) and sesame (*Sesamum indicum*). Previous studies have showed that a good harvest is possible during the above-normal *kharif* years whereas during sub-normal years only fodders or short duration *kharif*pulses could be grown (Pratap Narayan and Kar, 2005). The flowering stage of pulses crops extremely vulnerable to rainfall and photoperiod (Mandal and Roy, 2012). As per IMD, a normal rainfall condition is arrived when percentage departure of actual rainfall is within ± 10 % of the Long Period Average, while "Above Normal" represents a rainfall of more than 10% of the Long Period Average. In the arid part of Rajasthan, rainy season starts from first week of July and extends up to first week of September for a period of about 2 and half months only (Singh and Kumar, 2012). The average annual rainfall in the region is 343.7 mm with 16 rainy days. More than 90 per cent of annual rainfall occurs during short period from early July to middle of September. Gagne (2013) reported that Barmer district of Rajasthan experienced 7 years of rainfall deficits as well as instances of excessive rainfall during 1999-2009. At the same time, annual potential evapotranspiration over the arid zone varies from 2000 mm to 2500 mm (Sikka,1997) . The deficiency of rainfall is a common feature and the averages are made up of occasional large excesses. Thus, most of the rain falls in the form of few heavy showers otherwise, in general, the weather remains dry (Singh and Kumar, 2012). Jerie and Ndabaningi (2011) and Mehta *et al*. (2002) reported positive correlation of season rainfall with pearlmillet, groundnut, sorghum and tobacco. Total amount and distribution of seasonal rainfall, difference in temperature and soil conditions are the main factors affecting yield and yield attributes of sesame in arid and semi-arid regions (Nath and Chakarbatry, 2001). Pawar *et al*. (2015) reported that cropping pattern based on weekly rainfall analysis for effectively utilize soil moisture in arid and semi arid. Stern and Coe (1982) found variability in rainfall amount which influenced crop productivity. Larsson (1996) reported relationship of mean annual rainfall with yields of sorghum, millet and sesame. Rao (2009) reported that the high inter annual variability in rainfall is the single factor influencing crop yields in arid conditions. However, there is a need to understand the impact of monsoon / intra-monsoon rainfall variations on the crop yield. The present work tries to establish the relationship between productivity of major rainfed crops of arid region in Rajasthan and rainfall variations during the *kharif* period.

MATERIALS AND METHODS

Rainfall characteristics

Seasonal rainfall variability of twelve districts (Sikar, Pali, Nagaur, Jodhpur, Jhunjhunu, Jalore, Jaisalmer, Ganganagar, Churu, Bikaner, Barmer and Hanumangarh) of arid western Rajasthan during the period (2000-2012) was computed from available daily rainfall data recorded at rain-gauge stations of the district. The data were downloaded from the web www.waterresources.rajasthan.gov.in, and were further scrutinized and checked for their use in the study. Daily data of weather stations was pooled with average data and district level interpretation for arid western Rajasthan. The monsoon (1^{st} June to 30^{th} September) and intra-monsoon (1^{st} July to 31^{st} August) rainfall value was used for trend analysis and its relationship with crop productivity. The mean, standard deviation and coefficient of variation of seasonal rainfall were calculated. A rainfall distribution map of the region was prepared for the drought year of 2002 when most of the stations received meagre rainfall. We used rainfall attributes of those stations and used GIS methodology to draw isohyets. For this purpose, point data (rainfall) were digitized to create spatial database. This data was converted into a TIN format which represents vector based elevation layer. Contours were extracted from the TIN using TIN-Contour. The simulated contours showed a spatial range of rainfall from 50 mm to 350 mm.

Crop production and yield data

The yield data of major *kharif* crops e.g. pearl millet, clusterbean, moth and sesame during 2000-2012 were obtained from published statistical abstract of Government of Rajasthan (http://www.krishi.rajasthan.gov.in). The district yield data were pooled for further analysis.

Correlation between rainfall and yield of crop in western Rajasthan

Pearson correlation coefficients (Ryan *et al*., 1985) were calculated between crop yields and monsoon and intra-monsoon rainfall. Linear regression models were developed to establish the rainfall-yield relationship of selected crops for the region. For statistical analysis of the computed data, SPSS statistical package was used. The yield was estimated considering situations like normal monsoon and $\pm 20\%$ rainfall.

RESULTS AND DISCUSSION

Monsoon and intra monsoon rainfall variability

Generally, in western Rajasthan, onset of monsoon is confined to first week of July. However, there have been variations in the onset dates even by 15 days to 3 weeksduring 2000-2012 (Table 1). Rainfall records of Indian arid zone shows that sowing rain can be delayed as late as first week of August and as early as 2^{nd} week of June (Rao, 2009). In the same time, high variation in rainfall amount and its distribution was also observed in monsoon and intra monsoon (Table 1). Long term analysis of monsoon rainfall in western Rajasthan shows a range of 180-480 mm (Rao, 2009). However, analysis for the 2000-2012 indicates a higher / lower range. The variation in intra-monsoon rainfall (mean of July and August rainfall) ranged from 27.8 mm to 305 mm. This result indicates high variability in rainfall and in its distribution within the rainy season. Trend analysis of monsoon rainfall for the crop growing season from 2000 to 2012 (Fig 1) showed increasing trend for monsoon rain as well as inter-monsoon rainfall trend. The isolate distribution during a severe drought situation indicates how major part of Jaisalmer, Bikaner, Barmer, Jodhpur, Ganganagar received a deficit rainfall ($<$50 mm and 50-100 mm). The range was 50 mm to 300 mm of rainfall in more than 90 % area.

Analysis of Table 1 would also indicate how there were considerable deviation found in the occurrence and distribution of rainfall during the drought years. The table also indicates occurrence of one severe drought (2002), three normal droughts, six normal seasons and three above normal seasons during the same period. Let us analyse the crop yields during the same situation. During the deficit condition (-17 % in 2005), the yield of crops fluctuated significantly; pearl millet (44.4 %), sesame (39.4%), moth bean (32.6%) and clusterbean (15.2%) while with good rainfall condition (+16% in 2012), the observed yield were increasing for pearl millet (22.6%), clusterbean (37.4%), moth bean (50.1 %) but decreasing for sesame (-6.4%). It is generally known that sesame is a moderately drought resistant crop and requires higher water with a range of 360 to 550 mm (Rao and Roy, 2012 and Larsson, 1996). Larsson 1996 also found that sesame is capable of growing in areas receiving an average annual rainfall of only 640 mm. This would mean that sesame can sustain low rainfall situations.

Table 1: Onset of monsoon, rainfall and crop yield with deviation during 2000-2011

Year	Onset ofmon soon	Monsoon rainfall		Intra -monsoon rainfall		Pearl millet		Cluster bean		Moth bean		Sesame	
		Amount (mm)	Deviation (%)	Amount (mm)	Deviation (%)	Yield (kg/ha)	Deviation (%)	Yield (kg/ha)	Deviation (%)	Yield (kg/ha)	Deviation (%)	Yield (kg/ha)	Deviation (%)
2000	2 July	205.7	-30.3	179.4	-60.0	302.0	-54.2	139.4	-60.5	119.5	-52.9	180.7	-32.9
2001	4 July	320.3	8.6	248.5	-24.2	699.5	6.1	382.6	8.3	222.3	-12.4	349.2	29.8
2002	31July	86.4	-70.7	27.8	-138.7	172.0	-73.9	79.0	-77.6	38.6	-84.8	39.6	-85.3
2003	6July	364.5	23.5	305.0	5.1	993.5	50.7	573.0	62.2	489.0	92.7	449.1	66.9
2004	5 July	169.6	-42.5	117.9	-91.9	445.8	-32.4	205.2	-41.9	144.3	-43.1	319.0	18.5
2005	29 June	245.0	-17.0	108.4	-96.8	366.3	-44.4	299.6	-15.2	171.0	-32.6	163.2	-39.4
2006	20 July	333.6	13.1	258.0	-19.3	613.1	-7.0	317.0	-10.3	235.2	-7.3	290.1	7.8
2007	28 June	309.3	4.8	181.4	-59.0	948.7	43.9	415.0	17.5	319.6	26.0	347.9	29.3
2008	15June	308.7	4.6	185.6	-56.8	818.2	24.1	340.0	-3.7	286.2	12.8	258.7	-3.9
2009	1 July	160.3	-45.7	114.8	-93.5	244.2	-62.9	72.6	-79.4	57.6	-77.3	112.5	-58.2
2010	5th July	480.4	62.8	293.9	-0.6	974.2	47.8	602.7	70.6	442.3	74.3	381.0	41.6
2011	8th July	394.8	33.8	237.5	-29.9	1182.4	79.4	680.4	92.6	392.3	54.6	355.7	32.2

Table 2: Relationship of crop productivity with monsoon rainfall (June-September) and intra-monsoon rainfall (July-August) in western Rajasthan during 2000-2012

Crop	Relationship with monsoon rainfall (June-September)	R^2	Relationship with intra-monsoon (July-August)	R^2
Pearl millet	$Y=2.679X-107.9$	0.78	$Y=3.111X+59.14$	0.61
Cluster bean	$Y=1.675X-126.1$	0.85	$Y=1.912X-15.42$	0.64
Moth	$Y=1.223X-96.2$	0.83	$Y=1.500X-35.64$	0.72
Sesame	$Y=0.858X+23.52$	0.63	$Y=1.174X+42.67$	0.68

Y = Crop productivity (kg/ha) and X = rainfall (mm)

Table 3: Estimated crop yield under rainfall scenario

Rainfall scenario	Rainfall (mm)	Pearl millet (kg ha^{-1})	Clusterbean(kg ha^{-1})	Moth bean(kg ha^{-1})	Sesame(kg ha^{-1})
Long term average rainfall of western Rajasthan	295.1	682.7	368.2	264.6	276.7
20% Excess rainfall	354.1	840.8	467.1	336.8	327.4
20% Deficit rainfall	236.1	524.6	269.3	192.4	226.1

Note: Deficit (-19 to19 %), Excess (>19%)

Figure 1: Districts of western Rajasthan and Rainfall pattern during a severe drought year-2002

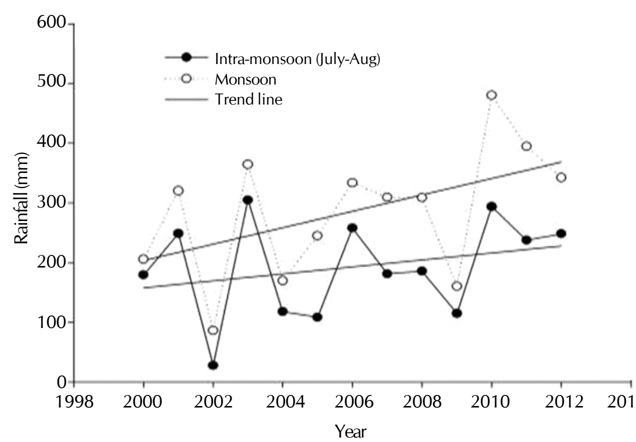

Figure 2: Monsoon and intra monsoon rainfall variability of western Rajasthan

Crop productivity response to monsoon and intra-monsoon rainfall

In general, analysis of relationship showed positive correlation with all crops (pearlmillet and sesame) (Table.2). However, clusterbean yield showed highly positive correlation with monsoon rainfall ($R^2=0.85$) (Fig.3). In case of intra-monsoon rainfall, the correlation was maximum ($R^2=0.722$) for moth. Moth bean matures in 65-70 days (Singh *et al.*, 2000 and Kumar and Rodge, 2012), therefore, higher correlation is understandably good. In contrast, clusterbean is a higher duration crop and it is found to mature in 85-100 days (Rao *et al.*, 2000). Considering ET rates, it is found to be higher for

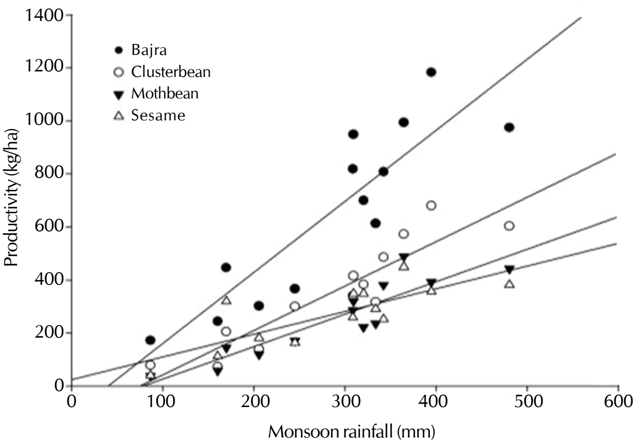

Figure 3: Relationship between monsoon rainfall and crop productivity in western Rajasthan

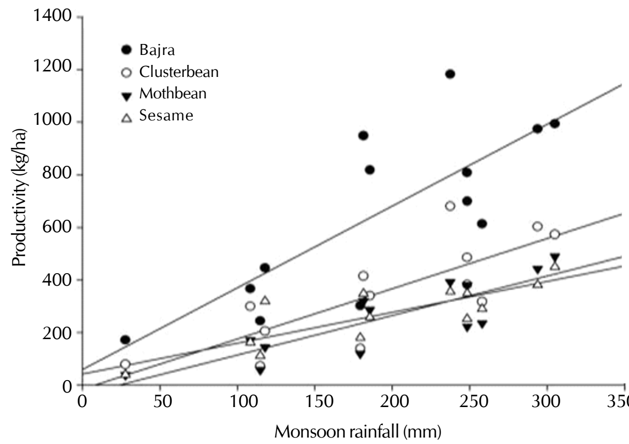

Figure 4: Relationship between intra-monsoon rainfall (July-Aug) and crop productivity in western Rajasthan

cluster bean (5.3 to 5.8 mm day^{-1}) in comparison to moth (4.8 mm day^{-1}) during flowering and pod formation. Therefore, over the season, the water requirement is expected to be higher for clusterbean which has been observed in the correlation interpretation. It has also been reported to be 332 mm for clusterbean and 203 mm for moth (Rao et al., 2000 and Singh et al., 2000).

Prediction of crop productivity based on rainfall situations (normal, excess and deficit)

Under normal rainfall conditions (295.1 mm for monsoon period of western Rajasthan), crop yields for pearlmillet, cluster bean, moth and sesame, were estimated as 682.1 kg ha^{-1}, 368.2 kg ha^{-1}, 264.6 kg ha^{-1}and 276.7 kg ha^{-1}respectively (Table 3). This crop yield estimate is based on correlation equations between monsoon rainfall and crop productivity (Table 2). It was observed that fewer than 20 % excess to normal rainfall yields of above crops showed positive response and increased by 23.1 %, 26.8 %, 27.2 % and 18.3 % respectively. Similarly the vice versa relationship was observed under 20% deficit rainfall conditions. The highest yield (27.2%) increase in moth bean as compared to pearl millet, clusterbean and sesame was highly correlated ($R^2 = 0.722$) with intra-monsoon rainfall amount (Table 2, Fig. 4)The western Rajasthan with an arid environment experience high variability in rainfall amount and distribution, and its onset and ceasession. In this study, we observed that crop productivity during *kharif* season responds to both monsoon and intra-monsoon rainfall variability. The impact of monsoon rainfall variability was found to be higher with clusterbean while moth bean was more influenced by intra-monsoon rain.

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