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RESPONSE OF SUPPLEMENTAL IRRIGATION TO KHARIF CROPS BASED ON RAINFALL ANALYSIS

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ABSTRACT

A study was conducted for 3 years (2009-2012) to assess the effect of supplemental irrigation in different vegetables and maize, based on rainfall analysis. Results revealed that analysis of rainfall data established the need of supplemental irrigation in kharif maize and vegetables to stabilize and enhance productivity in the region. Application of one supplemental irrigation in maize increased maize grain yield by 52.5 and 43.8% over rainfed maize in the year 2010-11 and 2011-12, respectively. The straw yield also followed a similar trend. Mean maize grain yield increased by 48.1% with one supplemental irrigation over rainfed maize. Among different vegetables, Kachari recorded significantly higher maize grain equivalent yield with higher water use efficiency as compared to rest of the vegetables and maize. Kachari recorded 238 and 37.9 % higher mean water use efficiency as compared to sponge gourd and maize with one supplemental irrigation, respectively. Among different methods of irrigation, drip irrigation registered significantly higher maize grain equivalent yield (7287 kg ha^{-1}) and saved irrigation water by 49.2% over surface method. Drip irrigation recorded significantly higher water use efficiency as compared to surface method of irrigation. Kachari with supplemental irrigation recorded the highest net return of ₹.89509 ha^{-1} followed by ridge gourd. The higher B: C ratio achieved with supplemental irrigation in vegetables indicated that with limited irrigations one can achieve higher economic returns over rain fed maize. The results also underlined the fact that maize cultivation without any supplemental irrigation in dry land ecosystem may be risky and results in economic loss if rainfall during the crop growing period is very low as in the case of 2009-2010.

Keywords: Kharif, dry spell period, maize, kachari, supplemental irrigation, water losses

INTRODUCTION

Land and water are the two important critical natural resources. The efficient management of these natural resources is the key factor for economic growth and development of the region. The southern region of Rajasthan state comprising of 7 districts and partly Sirohi district of Rajasthan state with a geographical area of 5.08 m ha which constitute about 14.82 % of total geo-graphical area of the Rajasthan state. The region has undulating topography, scanty and uneven distribution of rainfall, scarce vegetation cover, lack of irrigation facilities and unfavorable edaphic conditions. The yield potential is low and agriculture is not economically viable with traditional management of land and water resources. This is caused by the occurrence of intermediate and terminal dry spell periods during the rainy season (Jat *et al.*, 2003 and 2005). Further, drought is the common climatic feature of the region which resulted in to low and unstable production under dryland ecosystem. Inceptisol soils occupy more than 52 % area on uplands in the region but the productivity of these soils is very low due to low fertility and moisture receptivity. The crops experience water stress even in short dry spells during rainy season and the short monsoon further aggravates the situation. Consequently, unstable yield and failure of crops are very common in the region. Under such situation, farmers are unable to take even a single successful crop during the entire year because of a long duration of maturing Kharif crop or low water requiring. Rabi oilseed crop can not be taken successfully without supplemental irrigation.

The agricultural production Scenario has been less than satisfactory in dryland areas as with a cropping intensity of 121% and much remains to be done for harnessing the land and water resources and achieving targeted yields. Though farmers are habituated with mono cropping of traditional low yielding long duration maturing maize crop yet there is ample scope for increasing the cropping intensity by growing numbers of crops, especially vegetables in Kharif season. This will be possible only by adoption of proper dryland farming technologies and the land can be brought under double cropping through proper utilization of residual soil moisture and by providing supplemental irrigation to the Kharif crops and vegetables from harvested rainwater during dry spell periods (Wani *et al.*, 2003 and Kar *et al.*, 2004). When natural contributions by rainfall or ground water are infrequently unable to satisfy full crop water requirements, a continuously optimal

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moisture regime can be obtained by supplemental irrigation, *i.e,* by a temporary and discontinues irrigation regime (Caliandro and Boari, 1996). In dry land areas where irrigation resources are too limited for ensuring a permanent optimal water regime to crops, supplemental irrigation is mainly supplied at the critical periods of the crops growth cycle to maintain moisture to improve crop production (Debarcke and Aboudrareb, 2004; Rajput *et al.*,2004; Anonymous, 2005 and Sharma *et al.,* 2010). Therefore, rainwater harvesting is necessary for sustaining production livelihood in these regions (Gontia and Sikarwar, 2005). With these views, an attempt was made to raise Kharif season crops and vegetables with supplemental irrigation during dry spell periods in order to increase the land and water productivity and profitability.

MATERIALS AND METHODS

A field experiment was conducted during the three kharif season (2009-2012) in Inceptisol soils at Dryland Farming Research Station, Arjia, Bhilwara (24^0 20' N latitude and 74^0 40 'E Longitude, and 432 m above mean sea level), Rajasthan. The soils of experimental field was clay Ioam in texture having pH 8.1, organic carbon 4.8gKg^{-1} , EC 0.25dSm-^{1}, bulk density 1.63 g/cc, the available N, P_20_5 and k_20 in soils were 245.41 and 21.3 kgha-^{1}, respectively. The field capacity and permanent wilting point of surface soil layer were 21.3 and 9.1%, respectively.

To estimate the assured amount of rainfall likely to occur in kharif season and in different weeks of the year, historical daily rainfall data (1960 to 2008) and daily weather data for the study period (2009-2012) were collected from Dryland Farming Research Station, Arjia, Bhilwara. The weekly rainfall data were analyzed for computations of assured weekly rainfall amount using incomplete gamma distribution. The procedure for fitting data to incomplete gamma distribution (IGD) is explained as follows:

The probability density function of the two parameters gamma distribution function is given by

$$f(x) = \frac{x^{\gamma-1} e}{\beta^{\gamma}\Gamma_{\gamma}} \quad \text{,for } x>0;\gamma,\ \beta > 0 \qquad \text{----- (i)}$$

$$= 0$$

fox x <0;

Where, β= Scale parameters, $\Gamma\gamma$ = Gamma function of γ

$\gamma \rightarrow \infty$, distribution approaches normal distribution

γ is large, distribution is Gaussion

$$\gamma = \frac{1}{4A}\left[1+\left\{1+\frac{4A}{3}\right\}^{1/2}\right] \qquad \text{....(ii)}$$

$$A = Ln\bar{x} - \sum Ln\frac{\bar{x}}{n},$$

$$\beta = \frac{\bar{x}}{\gamma}$$

$\bar{x}$ = Arithmetic mean (A.M.)

Ln = Natural logarithms

The probability g(x) of non zero rain less than or equal to x is given by

$$g(x) = \int_0^x \frac{x^{\gamma-1}e^{-x/\beta}}{\beta\gamma\Gamma\gamma}dx \qquad \text{....(iii)}$$

Where there are non zero rains in the series the probability p , of rain less than x can be given by

$$p_1 = p' + (1-p')g(x) \qquad \text{....(iv)}$$

Where P$^/$ = probability of zero rain obtained from rainfall data.

if there are m values of zero rains in a series of N data

$$p' = m/N \qquad \text{....(v)}$$

Probability, p_2 of rain equal or exceeding x is given by

$$p_2 = 1 - p_1 \qquad \text{....(vi)}$$

$$p_2 = 1 - p' - (1-p')g(x)$$

if q$^/$ denotes the probability of rainfall values more than zero

$$q' = 1 - p'$$

Thus, $p_2 = q' - q'g(x)$

Using the above procedure, the minimum assured rainfall amount equally or exceeding a value x can be calculated for different probability levels.

Onset of effective monsoon was computed by Morris and Zandstra (1979) method. In this method weekly rainfall was summed by forward accumulation (22 + 23 + ……….. + 52 weeks) until a certain amount of rainfall i.e. 75 mm is accumulated. If this process is repeated for a long period, then the probability of given amount of rain can be determined for each week. An amount of 75 mm accumulated rainfall at the onset of effective monsoon. Accumulation of 10 mm rainfall was chosen for end of rainy season (52+51+ …………..+41 weeks), which may be sufficient for ploughing of fields after harvesting of crops. Then the years were assigned with rank numbers i.e. 1960 – 2008 as 1 to 49. The probability of each rank was calculated by using

Weibull's formula (1939) and is expressed as:

$$P = \frac{M}{N+1} \times 100 \qquad \text{-----} \qquad (vii)$$

Where M is the rank number and N is number of years.

For forward accumulation, the rank order and the probability levels were arranged as ascending order and the corresponding week number were arranged in the same manner. Similarly, for the back accumulation, the order and the probability were arranged in descending order and the corresponding week numbers were arranged in the same way.

The probability of occurrence of two consecutive dry week were computed by Markov chain process (Robertson, 1976 and Pandarinath, 1991) considering less than 20 mm rainfall as dry week. The general formula for dry spell of n week (n consecutive weeks) is given by:

$$P\,(D,D,D, \ldots n) = P(D) \times P\,(D/D)^{n-1} \qquad \text{------} \; (viii)$$

The probability of [p (2d) 2d)] 2 consecutive dry weeks is calculated as follows :

$$P(2D) = P(D) \times P\,(D/D)_2 \qquad \text{-------}(ix)$$

Where, P (2D) = Probability of occurrence of two consecutive dry weeks,

P (D) = Probability of the week being dry (1 weeks), and

$P\,(D/D)_2$ = Probability of 2nd consecutive dry week given the preceding week being dry.

There were five main treatments of vegetables such as sponge gourd, bottle gourd, ridge gourd, kachari and vegetable cow pea and two sub treatments of irrigation methods such as surface irrigation and – drip irrigation (50% of weekly cumulative pan evaporation). These treatments were laid out in randomized block design and replicated thrice. Maize was grown with three levels of supplemental irrigation as 5 ha cm, 10 ha cm (5 ha cm + 5ha cm) and no irrigation.

The crops were grown after onset of effective monsoon. Sponge gourd cv. 'Pusha supriya', bottle gourd cv. 'Pusha megdoot', ridge gourd cv. 'Pusha nasdar', kachari cv. 'local ', vegetable cow pea cv. 'Pusha barsati' and maize cv. 'Phem-2' . The maize and vegetable cow pea were sown by single row bullock drawn seed cum fertilizer drill. Whereas, other vegetables were sown by making basin at recommended spacing manually. The recommended packages of practices were followed to raise different vegetables and maize crop. Supplemental irrigation was applied during dry spell period to the crops. Rain water is harvested in the farm pond constructed during the year 1991. It is having dimensions 14.1x14.1m top width, 5.6x5.6m bottom width and 4 m depth and 412 cum capacity with 1.99 ha catchment area. 5 ha cm water was applied in each supplemented irrigation to vegetables and maize as per treatments from the harvested rain water in farm pond through surface irrigation method. Whereas, in drip irrigation method equivalent to depth of 50% of weekly cumulative pan evaporation was applied. The available harvested rain water in farm pond during crop growing period under study has been depicted in Fig. 1. Water Productivity (WP) was calculated by dividing the seed yield with total water used in irrigation (cum). Observations on yield of different vegetables and maize were recorded at harvest.

The sampling technique for the estimation of yield was followed as per procedure. The yields of different crops were converted in to maize equivalent yield on using the following formula based on the existing market price of vegetables and maize as,

$$MEY = \frac{\sum yi * pi}{p(p)} \qquad \text{------------} \; (x)$$

Where, Yi= yield of different crops, Pi= price of respective crops and P (p) = price of maize.

The maize grain equivalents yield under vegetables was analyzed as per statistical procedure of the randomized block design in three replications (Gomez and Gomez, 1984).

For estimation of benefit generated from content concrete lined farm pond annual costs were worked out taking into consideration both fixed cost and variable costs. The investment costs on farm pond and water lifting device and drip irrigation were amortized based on their life span. Farm pond cost was amortized over a period of 20 years at 8% interest rate considering the life period of the farm pond as 20 years, on using the following equation:

$$\text{Amortized cost (Rs)} = \frac{r \times (I + r)^n \times I}{(I + r)^n - I} \qquad \text{-------------} \; (xi)$$

Where, r is the rate of interest, n is the number of years, and I is the Investment on the farm pond excavation and cement concrete lining.

The opportunity cost of the land used for constructing the pond has been valued at @ Rs 3000 ha^{-1} per annum, assuming that the net return from dryland @ Rs 3000 ha^{-1}, per annum in the study area. The annul maintenance cost of the farm pond was assumed to be 2% of the investment cost.

Variable cost of irrigation has been worked out by considering actual diesel cost, hiring charges for pump set, labour cost incurred for pumping the water and for supplemental irrigations.

RESULTS AND DISCUSSION

Weekly rainfall probability analysis

The weekly rainfall at different probability levels was computed by using Incomplete Gamma Distribution method. Results revealed that the mean weekly rainfall received at probability of 25-50% during all the 52 weeks. The onset of effective monsoon and withdrawal of monsoon was occurred in 26-27th week and 39and 40th week, respectively at probability of 10-25 %. At 50 percent probability, the minimum assured weekly rainfall varies from 13.7 to 33.5 mm during 24th to 36th week and decrease from 37th week and onwards. In monsoon (*kharif*) season, a good weekly rainfall (above 10 mm) starts in the 23rd week with 25 percent probability of exceedance level when primary tillage operation can be initiated in the region. Rainfall further increases at all probability levels from 23rd week onwards till 39th week. This indicates that preparation of seed bed for sowing of crops may be initiated during 24th week. A rainfall of 2.8 mm was received at 50 per cent probability during 40th week and the amount of rainfall further decreases at the same probability level after 40th week.

Therefore, to utilize the monsoon rain effectively, short duration maize varieties of about 90-100 days or sorghum, pulse, groundnut, sesame may be cultivated. Hence, there is ample scope for water conservation either in-situ or ex-situ for good plant establishment enhance and to stabilize the productivity. If possible, harvested rain water should be stored in the on farm reservoir to apply supplemental irrigation during dry spell periods and for pre-sowing irrigation to *rabi* crops on watershed basis. The study revealed that *rabi* crops can be raised under moisture stress conditions.

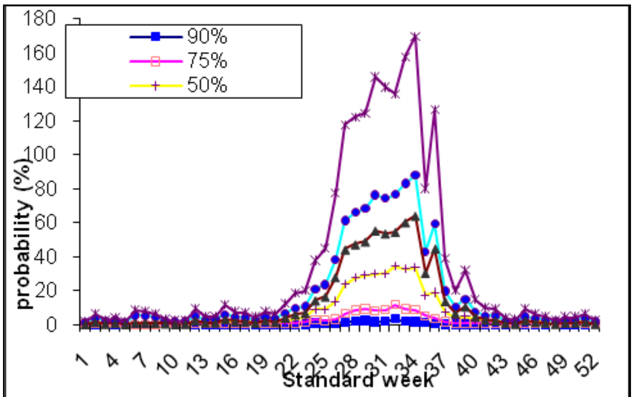

Fig. 1: Weekly rainfall at different probabilities for the study area

Characteristics of rainy season and onset of effective monsoon

The onset, withdrawal of south west monsoon and length of rainy season were determined and is presented in Table1. Results revealed that the mean date of onset of effective monsoon was found to be 27th week (2nd to 8th July) with a coefficient of variation of 6.2 per cent and south west monsoon generally withdrawal by 40th week (1st to 7th October) with a coefficient of variation of 12.9 percent. The earliest and latest probable week of OEM were found to be 22nd and 29th week, whereas, earliest and latest probable week of monsoon withdrawal were worked out to be 26th week and 51st week, respectively. The length of the rainy season ranges from 4th to 27th weeks and mean length of rainy season was observed as 12.7 weeks (89 days) with a coefficient of variation of 41.6 percent. Farmers are advised to initiate sowing of short duration, low water requiring, direct sown *kharif* (rainy season) crops started form 1st week of July and complete the sowing within 15 days to obtain full advantage of south west monsoon period. The early sowing of crops will also escape terminal drought and ensure double cropping and reduces pests, diseases and weed infestations.

Table 1: Characteristics of rainy season

Onset of effective monsoon (Weeks)				Withdrawal of effective monsoon (Weeks)				Length of rainy season (Weeks)			
Earliest	Latest	Mean	C.V.	Earliest	Latest	Mean	C.V.	Max **	Min*	Mean	C.V.
22	29	27	6.2	26	51	40	12.9	27	4	12.7	41.6

***Indicates maximum length of rainy season in weeks and, * Indicate minimum length of rainy season in week*

Probable period of occurrence of consecutive dry weeks

Dry spells may likely to occur during the crop growth period due to break in monsoon. The weekly evaporative demand of the region varies from 45 mm during the beginning of the rainy season to 3 mm during active rainy season. A week receiving rainfall about 20 mm will be able to meet 0.50 to 0.75 times the evaporative demand. During the early stages of growth, the crop water requirement will be about half of the evaporative demand and subsequently. Therefore, a week with rainfall less than 20 mm was considered as dry week (Pandarinath, 1991). However, during dry week, the crop may meet its water requirements through the moisture available in the soil. If the rainfall is less than 20 mm per week for two or more consecutive weeks, the crops are likely to be subjected to moisture stress due to lack of adequate stored soil moisture. The standard meteorological weeks during which dry spells of two or three consecutive weeks are likely to commence with probability of 10-25, 25-50 and greater than 50% are presented in Table 2.

Table 2: Probability of occurrence of consecutive dry weeks with rainfall less than 20 mm in the study area

No. of consecutive dry week	**Probability levels (%)**		
	10-25	**25-50**	**>50**
Two	28	27, 29-35	36th onwards
Three	27-32	33 – 35	36th onwards

The above facts clearly indicate the need of supplemental irrigation during dry spell periods for achieving higher crop yields and its stabilization. Dennett (1987) also emphasized the importance of rainfall analysis in terms of probability, onset and withdrawal of monsoon and occurrence of dry spell periods to assess the long-term suitability of crop cultivars and crop management strategies. Results revealed that, rainfall less than 20 mm per week for two and three consecutive weeks with 10-25 % probability falls during 28 and 27 – 32nd weeks, respectively, once the rainy season commences. Mid-season drought may likely to occur during the period 33-35 weeks due to break in monsoon condition. Terminal drought may likely to occur in 36th week onwards with more than 50% probability. Therefore, water conservation measures may be adopted for reducing ill effect of mid season and terminal droughts which leads to harvest rain water pond or *nadi* for applying life saving irrigation to crops to mitigate ill effect of drought.

Rainfall distribution during study period

Rainfall distribution during the study period is presented in Table 3. Results revealed that 46 % lesser annual rainfall (353.2 mm) was received in 2009 as compared to normal annual rainfall (657.5 mm). The mid season and terminal drought was experienced during this year at reproductive stage and grain formation stage of maize crop which adversely affected its yields. Further, rainfall distribution during this year was also much erratic as compared to other years. This may be attributed due low rainfall and 50 % lesser rainy days was received as compared to other two years whereas, 20.6 and 9.8 % higher rainfall was noted as compared to normal rainfall during the year 2010 and 2011, respectively. Year 2010 and 2011 was experienced the terminal droughts from 12th and 17th September on wards, respectively. This occurred at grain repining stage of the crops, while the year 2009 was experienced mid season and terminal droughts during the August which adversely affected growth and development stage in crop and crop yield. This indicated that stability in maize yield may be dependent on the distribution of rainfall rather than on total rainfall amount receiving during the crop growth period. Thus, three contrasting rainfall distribution patterns were recorded during the three crop years (2009 – 2011), which affected dryland farming maize crop yield in different ways.

Table 3: Rainfall distribution during the study period (2009-2012)

Year	**Rainfall during crop season (mm)**	**Monsoon season (mm)**	**Rainy days (day)**	**Annual rainfall (mm)**
2009	286.6	306.8 (15)	19	353.2 (-46)
2010	564.2	593 (31)	39	792.8 (20%)
2011	712	722 (37)	37	722
Normal	-	574	33	657.5

Yield of rain fed maize

Grain yield of rainfed maize followed the trend of the corresponding rainfall received during the crop growth period (Table 4). Among the 3 years, highest maize grain yield 4347 kg ha^{-1} of rain fed maize was recorded during the year 2010, as highest rainfall of 792.8 mm received in the crop growth period during this year, whereas no grain yield of maize was recorded during the year 2009-10 due to occurrence of sever drought. Further, rainfall received during this year is least among all the remaining two years and experienced atmospheric drought also. The results clearly indicated that under rainfed conditions, yields of maize remain unstable and yield level mainly depended up on the available rainfall during the crop growth period and its distribution. Hence, a successful crop cannot be taken without supplemental irrigation in the region. This is further confirmed by analysis of rainfall data which showed that intermediate and terminal droughts are likely to occur from 36th week on words in the region.

Table 4: Response of supplemental irrigation in maize during kharif season (2009-2012)

S. No.	Parameters	Years			
		2009	2010	2011	Mean
A.	Irrigation (5 ha cm)	-	-	-	
(i)	Maize grain yield (kg ha^{-1})	4789*	4347	4133	4240
(ii)	Maize stover yield (5cm)	9990*	9122	5056	8056
B.	10 cm irrigation (5 ha cm + 5 ha cm)	-	-	-	
(i)	Maize grain (kg ha^{-1})	5266	-	-	5266
(ii)	Maize stover (kg ha^{-1})	14027	-	-	14027
C.	Unirrgated	-	-	-	
(i)	Maize grain yield (kg ha^{-1})	-	2850	2874	2862
(ii)	Maize stover yield (kg ha^{-1})	7936	-	-	
D.	Weather parameters during crop growing period	-	-	-	
(i)	Rainfall (mm)	286.6	564.2	712.0	
(ii)	Mean max temp (^{0}C)	35.7	35.2	34.7	
(iii)	Mean evaporation (mm/day)	7.1	6.8	6.6	
E.	Mean weather parameter during crop growing period	-	-	-	
(i)	Mean rainfall (mm)	574.4	-	-	
(ii)	Mean max temp (^{0}C)	33.0	-	-	
(iii)	Mean evaporation (mm/day)	6.2	-	-	

(i) Mid season dry spell occurred from 13.08 to 29.8 2009 and terminal dry spell from 30th August onward during the year 2009,
(ii) Terminal dry spell experienced from12th September on wards during the years 2010 and dry spell experienced from 17th September on Wards, 2011

Effect of supplemental irrigation on yields

Among the crops, vegetables (Kachari and Ridge gourd) performed better than maize crop in all the three years (Table 5). Kachari recorded the significantly higher maize grain equivalent yield in all the three years.

Table 5: Response of supplemental irrigation on yield and water productivity of kharif maize and vegetable (2009-2012)

Treatments	Maize grain equivalent yield (t ha^{-1})				Water use (cm ha^{-1})				Water productivity (kg ha^{-1})			
	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean
Sponge gourd	0.00	6.36	7.77	7.064	0.00	2231.7	2769.7	2500.4 (-)	0.00	3.34	3.20	2.18
Bottle gourd	5.32	5.67667	8.12	6.371	1593.3	2271.7	2773.3	2212.8 (11.5)	3.99	2.93	3.32	3.41
Ridge gourd	7.92	8.43	7.10	7.814	1580.0	1512.5	2755.0	1949.2 (22.0)	6.01	5.60	2.92	4.85
Kachari	8.27	9.23	9.02	8.84	1191.8	1509.2	1624.2	1441.7 (42.3)	7.84	7.84	6.46	7.38
Veg. cowpea	3.93	7.65	6.27	5.951	1580.0	1615.0	1665.0	1620.0 (35.2)	3.66	6.20	4.33	4.73
S.Em ±	0.283	0.449	0.386									
CD (P=0.05)	0.595	0.943	0.810									
Surface irrigation	4.60	6.934	7.02	6.19	2040.6	2403.7	3052.7	2499	2.70	3.46	2.45	2.87
Drip irrigation	5.57	8.003	8.29	7.29	976.4	1252.3	1582.3	1270.4 (49.2)	5.90	6.91	5.64	6.15
S.Em ±	0.127	0.201	0.172									
CD (P=0.05)	0.376	0.597	0.512									
Maize (irrigated) 10 ha cm (5 ha cm + 5 ha cm)	5.27	-	-	5.27	1550	0.0	0.0	1550.0	3.40	-	-	3.40
Maize (irrigated) 5 ha cm	9.99*	4.347	4.13	4.24	725	795.0	810.0	776.7	0.00	5.72	5.56	5.35
Maize (unirrigated)	7.94*	2850	2.88	2.86	0	0	0	0	-	-	-	0.00

**Indicate the maize stover yield due to severe drought during 2009 and figures in parenthesis indicate the percent water saving*

Kachari recorded 228 per cent and 104 per cent higher maize grain equivalent yield over maize with one supplemented irrigation and rainfed maize, respectively. Grain yield of maize increased considerably under supplemental irrigation over no irrigation except during the year 2009-10. The results also revealed that supplemental irrigation has resulted in higher grain yield in maize over no irrigation but during 2009-10, only biological yield was obtained with application of one supplemental irrigation (5 ha cm). This may be attributed due to atmospheric drought. Thus, supplemental irrigation did not able to change the microclimate and did not provide better available soil moisture to crop. This is further confirmed as that mean maximum temperature and evaporation were highest during this year over mean weather parameter. Application of supplemental irrigation increased maize grain yields by 52.5 and 43.8 percent over rainfed maize in the year 2010-11 and 2011-12, respectively. The straw yield also followed a similar trend. Mean results of 2 years (2010-11 and 2011-12) revealed that yield of maize increased by 48.1 per cent with one supplemental irrigation over rainfed maize. These results are in conformity with the results obtained by Kar *et al.* (2006). Supplemental irrigation provided to maize during grain filling/ripening stage was helpful in mitigating the ill effect of moisture stress. Consequently maize grain yield increased under supplemental irrigation over no irrigation during both the years (2010-11 and 2011-12).Kannan *et al.* (2006) emphasized the need of rain water harvesting and recycling through a farm pond for providing irrigation to Kharif crops under dry spells and fulfilling the water requirement for rabi and summer crops.Among different methods of irrigation, drip irrigation recorded significantly higher maize grain equivalent yield of 7287 kgha^{-1} and saved irrigation water by 49.2 percent over surface method.

Water use efficiency and water use

In general, the WUE of all crops increased with supplemental irrigation.WUE of maize increased by 100% per cent during terminal dry spell period in 2010-11 and 2011-12 with one supplemental irrigation over rainfed maize (Table 5). During 2009-10, WUE of maize did not increase with supplemental irrigation. This may be attributed that only biological yield was recorded which was caused by sever drought/atmospheric drought conditions. Among different vegetable, Kachari influenced the significantly higher water use efficiency followed by ridge gourd. It recorded 238 and 37.9 % higher mean water use efficiency as compared to sponge gourd and maize with one supplemental irrigation, respectively. Lower WUE under supplemental irrigation might be due to proportionate more increase in evapotranspiration than increase in maize grain equivalent yield. Narayan *et al.* (1999) and Singh and Chandra (2004) also recorded higher WUE under rain fed condition which decreased under irrigation because of more water use under irrigation than proportionate increase in grain yield of Indian mustard (equivalent yield) and wheat, respectively. Drip irrigation improved significantly higher water use efficiency as compared to surface method of irrigation. It increased the WUE by 114 % over surface method of irrigation. This might be attributed due to increase in maize grain equivalent yield.

Table 6: Productivity and economics of kharif maize and vegetables as influenced by supplemental irrigation (pooled over 3years)

Treatments	**Mean maize equivalent yield (kg ha^{-1})**		**Cost of cultivation (₹ ha^{-1})**	**Gross return (₹ ha^{-1})**	**Net return (`₹ ha^{-1})**	**B: C ratio**
	Grain	**Stover**				
Vegetable						
Sponge gourd	7064	-	21110	84768	63658	4.02
Bottle gourd	6371	-	20512	76452	55940	3.73
Ridge gourd	7814	-	22310	93768	71458	4.20
Kachari	8839	-	16559	106068	89509	6.41
Vegetable cowpea	5951	4562	19749	80992	51663	4.10
Irrigation method						
Surface irrigation	6186	3093	19938	80727	60789	4.05
Drip irrigation	7287	3224	20158	94214	74056	4.67
Control(irrigation depth)						
Maize (irrigated) 10 ha cm (5 ha cm + 5 ha cm)	5266	9479	22713	83098	60385	3.65
Maize (irrigation) 5ha cm	4240	8056	16592	67798	51206	4.09
Maize (unirrigated)	2862	5438	12075	45764	33689	3.79

Economics of supplemental irrigation

The present investigation clearly indicated that higher B: C ratio in respect of kharif vegetables could be achieved except bottle gourd compared to maize under dry land eco system by providing supplemental irrigation at different critical crops growth stages or during dry spell periods (Table 6). This might be attributed due to low market price of bottle gourd. Among the different kharif vegetables, the highest net returns (₹ 89509ha^{-1}) with B: C ratio of 6.41 were also realized with Kachari while the least net ret urn with B: C ratio was noted in sponge gourd. This may be attributed due to low market price of sponge gourd as compared to other vegetable crops. Kachari with supplemental irrigation recorded the highest net return of ₹ 89509ha^{-1} followed by ridge gourd. The higher B: C ratio achieved with supplemental irrigation in vegetables indicated that with one or two irrigation cultivator can achieve higher economic returns over rain fed maize. The results also underlined the fact that maize cultivation without any supplemental irrigation in the dryland eco system may be risky and result in economic loss if rainfall during the crop growing period is very low as in the case of 2009-2010. Table 3 and Fig. 1 also strongly supported that terminal dry spell period is likely to occur from 36th week and onwards and also less rainfall (13.7mm) is expected to occur from 36th week and onwards.

Thus, it can be concluded that by providing supplemental irrigation in inter mediate and terminal dry spell periods in maize and in kharif vegetables. Kachari, ridge gourd, bottle gourd, sponge gourd and vegetable cow pea, one can achieve higher land and water productivity. In addition, the risk of crop failure in kharif during deficient rainfall years can also be minimized under dry land ecosystem. However, farmers should consider the availability of other resources like inputs, labour, investment capacity etc. at their disposal before apportioning their land in to different crops through cultivation of vegetable crops with supplemental irrigation gives higher productivity and profitability than maize crop.

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