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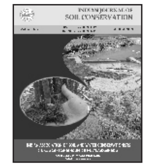

Effect of *in-situ* moisture conservation practices on selected vegetable crops in North Eastern Ghat Zone of Odisha

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ABSTRACT

The experiment was conducted at research farm of All India Coordinated Research Project for Dryland Agriculture, Phulbani, Odisha, India, during *kharif* season of 2015 and 2016 to study effect of different *in-situ* moisture conservation practices on growth, yield and water productivity of major *kharif* vegetable crops such as cauliflower, tomato and okra. The different *in-situ* moisture conservation practices adopted in this experiment were (i) broad bed furrow system (BBFS) (ii) BBFS with organic mulching (iii) ridge furrow system (RFS) (iv) RFS with organic mulching for cauliflower, tomato and okra crops. The results of the experiment revealed that RFS with organic mulching resulted in highest yield as compared to other treatments in all the three vegetable crops. Rain Water Use Efficiency (RWUE kg $ha^{-1}mm^{-1}$) was also found to be the highest in case of RFS with organic mulching in tomato crop (24.14) followed by 12.44 and 12.31 in okra and cauliflower, respectively. The RFS with mulching helps to conserve water when there was lower rainfall by holding water in ridges, and when there was higher rainfall, this helps to drain the excess water thus avoiding water logging situation.

1. INTRODUCTION

In India, rainfed agriculture occupies about 51% of country's net sown area and accounts for nearly 40% of the total food production. Production from such areas can be stabilized or even improved by reducing runoff to conserve more water, and used as supplementary irrigation. Collection of rain water directly in the field where it falls is generally termed as *in-situ* conservation. The collection can be localized in the crop land itself, usually by reshaping the soil surface. The water is stored in or close to the root zone, ensuring a high degree of utilization. There are different methods used for *in-situ* rainwater conservation (Koppad and Gouda, 2010; Memon *et al.,* 2017).

The Kandhamal district of Odisha falls in the North Eastern Ghat Zone of Odisha. Average annual rainfall in Kandhamal district is 1407 mm. The distribution of rainfall is highly erratic during *kharif* season. Limited and erratic rainfall in rainfed area creates moisture stress conditions during various critical growth stages of crop life, resulting in severe yield reduction (Behera *et al.,* 2016). In the rainfed areas of North Eastern Ghat Zone of Odisha, even when rainfall is high, most of the rainwater is lost as runoff, and very little quantity of rainwater is available for crop production. Therefore, farmers never feel comfortable to grow vegetable crops in upland situations of Kandhamal district. When farmers grow vegetable crop in their fields during *kharif* season, they solely depend on monsoon rainfall. They neither apply any irrigation technique nor any *in-situ* moisture conservation technique to save their crops against critical dry spells / droughts (Joseph and Tamilmani, 2017). Therefore, moisture conservation plays a key role for successful crop production during *kharif* season of the North Eastern Ghat Zone of Odisha. The BBFS and RFS are very useful methods for conserving soil moisture (Behera *et al.,* 2016; Bastia *et al.,* 2018).

The BBFS consists of broad bed of 100 cm width and a furrow of 30 to 50 cm width and 15 cm depth. It encourages moisture storage in soil profile and helps in safely disposing of surplus surface runoff without causing soil erosion. It also provides more soil aeration for better plant growth (Vekariya *et al.,* 2015; Gouda, 2011). The RFS is used in row crops with furrows developed between the crop rows.

The size and shape of the furrow depends on the crop grown, equipment used and spacing between crop rows. Water is applied by running small streams in furrows between the crop rows. Water infiltrates into the soil and spreads laterally to irrigate the areas between the furrows. The RFS helps to conserve water when there is lower rainfall by holding water in ridges, and when there is higher rainfall, it helps to drain the excess water thus avoiding the water logging situation (Shuhao *et al.,* 2014; Gouda, 2011; Koppad and Gouda, 2010).

Mulching is used for various reasons in agriculture, but water conservation and erosion control are the most important objectives, particularly in dryland situations (Memon *et al.,* 2017; Sarkar and Sarkar, 2018; Bhardwaj, 2013). Other reasons for use of mulching include soil temperature modification, weed control, soil conservation, and after decomposition of organic mulch, add plant nutrients, improves soil structure, increases crop quality and yield (Bakht and Khan, 2014; Tiwari *et al*., 1998; Tiwari *et al.,* 2003; Biswas *et al.,* 2015). Organic mulches are derived from plant and animal excreta such as straw, hay, peanut hulls, leaf mold, compost, sawdust, wood chips, shavings and animal manures. To achieve optimum advantage from organic mulch, the mulch should be applied immediately after germination of crop or transplanting of vegetable seedling (Kosterna, 2014). Organic mulch are efficiently reduce nitrates leaching, improve soil physical properties, prevent erosion, supply organic matter, regulate temperature and water retention, improve nitrogen balance, take part in nutrient cycle as well as increase biological activity (Muhammad *et al.*, 2009; Sarolia and Bhardwaj, 2012; Meshram *et al.,* 2018). This allows farmers to reduce application of herbicides and tillage operations which disturb soil structure (Abdul Baki *et al.,* 1996).

Keeping in view the above, a research study was conducted to determine the effect of organic mulching on yield and crop water productivity of tomato, cauliflower and okra crop under BBFS and RFS in rainfed conditions.

2. MATERIALS AND METHODS

Experimental Site

The experiment was conducted at research farm of All India Coordinated Research Project for Dryland Agriculture, Phulbani, Odisha, India, during the *kharif* season of 2015 and 2016. It is located in North Eastern Ghat Zone of Odisha (20^{0}28'N, 84^{0}14'E at an elevation of 736 m above mean sea level). The soil at the experimental site was sandy loam and slightly acidic (pH 5.3 to 6.5). The detail soil texture and physico-chemical properties in different soil layers of research farm are given in Table 1. The soil of the experimental site is having field capacity of 13.2%, wilting point of 5.6% on weight basis, and bulk density of 1.25 gc m^{-3}. The experimental site has a tropical sub-humid climate with average annual rainfall of 1407 mm, concentrated mostly in months of June to October.

Weather

Normal rainfall in the Research farm is 1407 mm, which includes 65 rainy days. The total rainfall during 2015 and 2016 were 1060.6 mm (60 rainy days) and 1248.8 mm (60 rainy days), respectively which is 24.7% and 11.2% less than the normal rainfall, respectively. The experimental site received rainfall of 778.8 mm and 1210.8 mm during *kharif* season of 2015 and 2016 in 36 and 53 rainy days, respectively. The normal date of onset of monsoon is 10th June whereas normal date of cessation of monsoon is 6th October. The date of onset of monsoon during 2015 and 2016 occurred on 12th June and 24th June, respectively whereas the date of cessation of monsoon during 2015 and 2016 occurred on 22nd September and 9th October, respectively. The occurrences of dry spells during the crop growing season during 2015 and 2016 are given in Table 2. The weekly rainfall distribution of the experimental site during 2015 and 2016 is given in Fig. 1.

Table: 2
Dry spells during the crop growing season (June to December) during 2015 and 2016

Period	Duration (days)
Dry spell during 2015	
5th - 8th July	5
13th - 21st July	9
3rd - 13th August	11
2nd - 12th September	11
22nd September - 6th October	14
Dry spell during 2016	
19th - 27th July	9
19th August - 1st September	14
18th September - 5th October	18
9th October afterwards	No rain

Table: 1
Soil texture and physico-chemical properties in different soil layers of the experimental site

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class	pH	EC (dS m^{-1})	OC (%)
0-15	68.2	14.5	17.3	Sandy loam	5.3	0.07	0.25
15-30	65.2	13.2	21.6	Sandy clay loam	5.2	0.03	0.17
30-45	63.8	11.8	24.4	Sandy clay loam	6.0	0.02	0.18
45-60	51.2	10.5	38.3	Sandy clay	6.3	0.02	0.12
60-90	48.8	10.8	40.4	Sandy clay	6.5	0.02	0.08

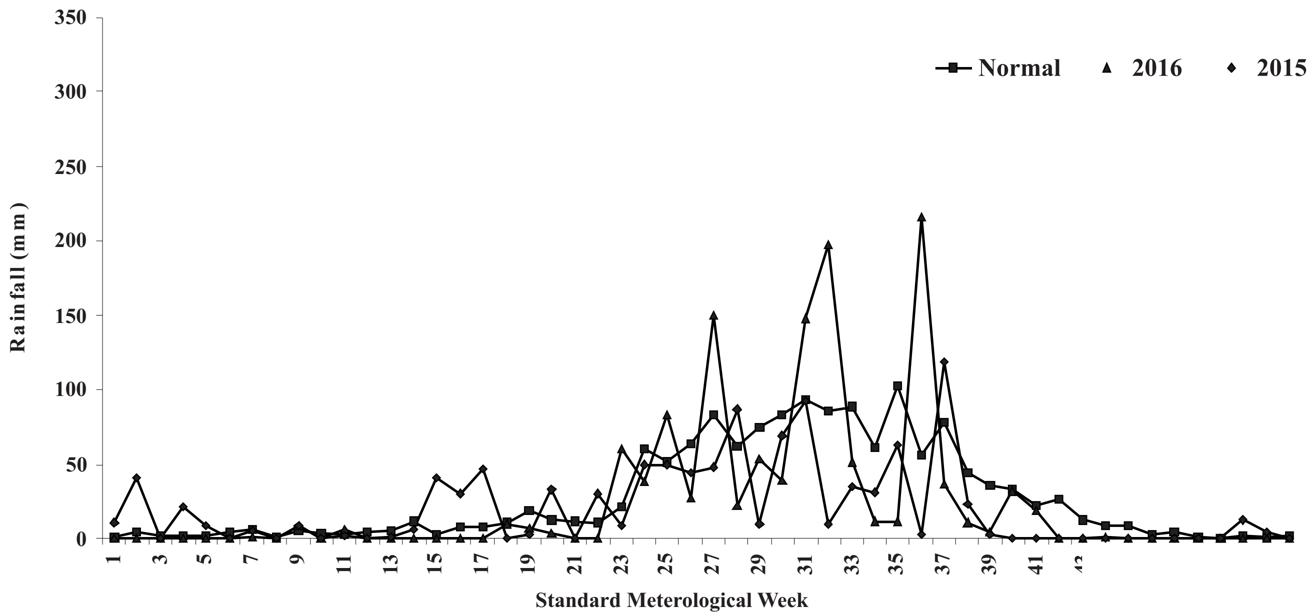

Fig. 1. Weekly rainfall distribution at the experimental site during 2015 and 2016

The mean minimum temperature was found to be lowest in the month of December while the mean maximum temperature was highest in the month of April. The mean maximum temperature remained above 30ºC from January to June and the mean minimum temperature remained below 15ºC from January to February and November to December. The mean monthly maximum relative humidity in the atmosphere varied from 65% during April to 93% during September.

Field Layout and Experimental Details

Experiment was conducted for tomato (var. Hybrid Lakhsmi), cauliflower (var. Hybrid Dawn 175) and okra (var. Hybrid Sakti) crops during *kharif* season of the year 2015 and 2016. The experiments was conducted in split plot design in which *in-situ* moisture conservation practices were taken in main plot and different vegetable crops were taken in sub plot. The different *in-situ* moisture conservation methods (i) BBFS (ii) BBFS with organic mulching (iii) RFS (iv) RFS with organic mulching were implemented in the main plot. The different vegetable crops (i) cauliflower (ii) tomato (iii) okra were cultivated in the sub plot.

The experimental area was divided into 36 plots (length 6 m and width 4.5 m) and a buffer of 1 m width was maintained between adjacent plots. There were three replications for each treatment. The seed rate of tomato, cauliflower and okra were 0.5 kg ha^{-1}, 0.5 kg ha^{-1} and 10 kg ha^{-1}, respectively. Row to row spacing and plant to plant spacing for all the vegetable crops were maintained as 60 cm and 45 cm, respectively. The broad beds of one meter width and 15 cm height with a furrow of 20 cm in between the beds were prepared before planting. Similarly, ridge and furrows were also prepared with a spacing of 45 cm between tops of ridges. Available *Sal* leaf was collected and spread as organic mulch @ 5 t ha^{-1}.

Yield Parameters and Economic Analysis

In order to evaluate the effect of different *in-situ* moisture conservation practices and organic mulching on crop responses, yield data of tomato, cauliflower and okra crop were collected during *kharif* season of 2015 and 2016. In order to assess changes in soil water status, the time changes of soil moisture at 0-30 cm was measured gravimetrically. The yield data were necessary for economic analysis and estimation of RWUE. The economics of various treatments were calculated individually for all the years considering the prevailing price of inputs and produce. The data were subjected to paired "t" test analysis for determining the significance of difference between the treatments and to draw valid conclusions. The level of significance used was $p = 0.05$.

In order to compute the profitability of different vegetable crops under *in-situ* moisture conservation methods over years, the net returns and B:C ratio were calculated (Maruthi Sankar *et al.*, 2012; Nema *et al.,* 2008). The gross returns (₹ ha^{-1}) were computed as a product of mean yield of each treatment over years and value of the crop at each location. The net returns (₹ ha^{-1}) were computed as a difference of gross returns and cost of cultivation (₹ ha^{-1}) for each treatment. The B:C ratio was derived as a ratio of gross returns and cost of cultivation for each treatment. The RWUE was calculated as a ratio of crop yield (kg ha^{-1}) and rainwater available (mm) during the crop growth period. RWUE is a measure of crop's capacity to convert rainwater into crop yield. Data were analyzed as per split plot design following Gomez and Gomez (1984). The values of tomato equivalent yield (TEY) were computed by using the formula given below (Behera *et al.,* 2012).

$$TEY = \frac{(Y_r \times P_r)}{P_m}$$

Where, Y_r is yield of replace crop (kg ha^{-1}), P_r is price of replace crop (₹ kg^{-1}) and P_m is price of tomato (₹ kg^{-1})

3. RESULTS AND DISCUSSION

The soil moisture for 0-30 cm soil profile was determined by conventional gravimetric method**.** The changes in soil moisture in soil layer 0-30 cm due to different *in-situ* moisture conservation practices for cauliflower, tomato and okra crops during 2015 and 2016 are given in Table 3 and Table 4, respectively. The results in the table revealed that during dry spells the moisture content is just above the wilting point. The moisture variation in the soil in different *in-situ* moisture conservation practices during dry spell period is more prominent than the normal rainy days periods in cauliflower, tomato and okra crop during 2015 and 2016. Soil water storage was found more in case of mulching in both broad bed furrow system and RFS as compared to the unmulched plot. The soil water storage of RFS with mulching was found to be more in case of all the vegetable crops than the other treatment during 2015 and 2016.

The conservation of soil moisture occurs through mulching due to modification of favourable micro-climatic conditions in soil. When soil surface is covered with organic mulch, it helps to prevent weed growth, reduce evaporation

Table: 3
Soil moisture variation (w/w %) as affected by different *in-situ* soil moisture conservation methods during 2015

Treatment		Date										
Crop	*In-situ* moisture conservation practices	2/8	7/8	14/8	20/8	31/8	6/9	12/9	17/9	25/9	30/9	5/10
Cauliflower	BBFS	13.8	6.8	14.4	14.2	13.3	6.7	5.8	14.1	7.2	6.1	5.9
	BBFS + M	14.0	7.2	14.6	14.5	13.7	7.8	7.0	14.3	8.3	7.2	6.9
	RFS	14.2	7.1	14.7	14.3	13.6	7.2	6.2	14.4	7.7	6.5	6.1
	RFS + M	14.4	7.5	14.9	14.8	13.9	8.1	7.3	14.5	8.6	7.5	7.2
Tomato	BBFS	13.9	6.7	14.2	13.9	13.2	6.5	6.0	13.8	7.0	6.0	6.1
	BBFS + M	14.1	7.0	14.3	14.1	13.4	7.6	7.1	14.0	8.1	7.0	7.0
	RFS	14.2	7.1	14.5	14.0	13.5	7.0	6.3	14.2	7.6	6.5	6.2
	RFS + M	14.4	7.5	14.6	14.4	13.7	7.9	7.0	14.3	8.3	7.2	7.1
Okra	BBFS	13.7	6.6	14.5	13.7	13.3	6.4	6.1	14.2	7.0	6.0	6.0
	BBFS + M	13.8	6.8	14.7	14.2	13.5	7.5	7.1	14.4	8.0	7.0	7.1
	RFS	14.1	6.9	14.8	14.1	13.6	6.9	6.5	14.5	7.5	6.4	6.4
	RFS + M	14.2	7.2	14.9	14.3	13.9	7.7	7.2	14.6	8.2	7.1	7.2

BBFS - Broad bed furrow system; M – Organic mulching; RFS – Ridge furrow system

Table: 4
Soil moisture variation (w/w %) as affected by different *in-situ* soil moisture conservation methods during 2016

Treatment		Date										
Crop	*In-situ* moisture conservation practices	1/8	7/8	15/8	22/8	1/9	8/9	15/9	22/9	30/9	5/10	15/10
Cauliflower	BBFS	14.2	14.0	7.7	6.5	5.7	13.9	13.2	7.3	5.8	7.6	5.9
	BBFS + M	14.4	14.3	8.7	7.4	6.7	14.1	13.6	8.4	6.8	8.8	7.0
	RFS	14.5	14.3	8.1	7.2	6.0	14.2	13.6	7.8	6.1	8.2	6.3
	RFS + M	14.7	14.5	8.9	8.0	7.0	14.5	13.9	8.7	7.0	9.1	7.3
Tomato	BBFS	14.0	13.6	7.5	6.5	5.9	13.9	13.2	7.1	6.0	7.5	5.8
	BBFS + M	14.1	13.9	8.4	7.6	6.8	14.0	13.5	8.2	7.1	8.6	6.8
	RFS	14.3	14.1	7.9	7.0	6.0	14.3	13.6	7.7	6.3	8.0	6.3
	RFS + M	14.4	14.3	8.8	7.9	6.9	14.5	13.8	8.4	7.2	8.9	7.0
Okra	BBFS	14.3	14.1	7.4	6.4	5.8	13.7	13.3	7.1	6.1	8.4	5.8
	BBFS + M	14.5	14.4	8.4	7.1	6.9	13.9	13.6	8.1	7.1	8.5	6.8
	RFS	14.6	14.5	7.9	6.8	6.2	14.1	13.6	7.6	6.5	8.9	6.2
	RFS + M	14.7	14.8	8.7	7.6	7.0	14.4	14.0	8.3	7.2	8.7	7.0

BBFS - Broad bed furrow system; M – Organic mulching; RFS – Ridge furrow system and increase infiltration of rain water during growing season. Chen and Katan (1980) also reported high water content (0.8 to 1.8%) in the top 5 cm of soil with mulching. Similarly, Rathore *et al.* (1998) also found that crop residues or mulch on the soil surface act as shade; serve as a vapour barrier against moisture losses from the soil, causing slow surface runoff and conserve sufficient water in the soil for better development of crops. Khurshid *et al.* (2006) and Muhammad *et al.* (2009) stated the same results that mulching improves the ecological environment of the soil, and it avoids decrease in soil water levels.

The changes in soil characteristics due to different *in-situ* moisture conservation practices for cauliflower, tomato and okra crop is given in Table 5. The effect of organic mulching on organic carbon, available nitrogen, available phosphorus in soil were found to be more prominent in case of all the crops. The concentration of available nitrogen and phosphorus was found to be higher in organic mulching plot over unmulched plot in cauliflower, tomato and okra crops. Similarly, it was found from the results that organic mulching increased the organic carbon in the soil than the unmulched plot in all the vegetable crops. It is due to increase in organic matter in soil and improvement of physical, chemical and biological properties of the soil after decomposition, which in turn increases crop yield. Similarly, Dilip Kumar *et al*. (1990) reported that organic mulches not only conserve soil moisture, but they also increase soil nutrients through addition of organic matter. Similarly, Shashidhar *et al*. (2009) reported that organic carbon content of soil was higher in organic mulching plot over unmulched plot.

The yield, economics and RWUE of cauliflower, tomato and okra crop under different *in-situ* moisture conservation practices given in Table 6. The yield of cauliflower was found to be highest in RFS with organic mulching treatment (6450 kg ha^{-1}) followed by RFS (6150 kg ha^{-1}) and BBFS with organic mulching (6020 kg ha^{-1}). Similarly, the yield of tomato and okra crop were found to highest in RFS with organic mulching treatment (12650 kg ha^{-1} and 8150 kg ha^{-1}, respectively) followed by RFS and BBFS with organic mulching. The net returns per hectare were found to be highest in RFS with organic mulching treatment in cauliflower, tomato and okra crop (₹ 109250, ₹ 195000 and ₹ 118000, respectively). Similarly, the B:C ratio was found to be highest in RFS with organic mulching treatment in cauliflower, tomato and okra crop (2.60, 3.24 and 2.51, respectively). Similarly, the RWUE (kg ha^{-1}mm^{-1}) was found to be highest in RFS with organic mulching treatment in cauliflower, tomato and okra crop (12.31, 24.14 and 12.44, respectively). As the organic carbon content of the experimental soil is less, therefore soil moisture applied in the BBFS could not reach the middle portion of broad bed. So the broad beds are not getting uniform soil moisture, and also the root of the crops. In the RFS, the root of the crops are getting the soil moisture properly and therefore resulted higher yield in all the vegetable crops. The ridge furrow method helps to conserve water when there was lower rainfall by holding water in ridges and when there was higher rainfall, this helps to drain the excess water thus avoiding water logging situation.

The yield was found to be higher in case of organic mulching treatment than the unmulched treatment because organic mulching provides a favourable environment for growth, which results in more vigorous, healthier plants that

Table: 5
Effect of different *in-situ* moisture conservation practices on soil characteristics of different vegetable crops (pooled data of 2015 and 2016)

Treatment: Crop	Treatment: *In-situ* moisture conservation practices	pH	EC (dS m^{-1})	OC (g kg^{-1})	Av. N (kg ha^{-1})	Av. P (kg ha^{-1})	Av. K (kg ha^{-1})
Initial		4.56	0.011	1.32	234	48.2	231
Cauliflower	BBFS	5.36	0.005	1.47	171	44.21	172
	BBFS + M	5.87	0.006	2.76	187	52.9	185
	RFS	5.34	0.006	1.73	240	31.06	189
	RFS + M	5.53	0.005	3.68	263	47.54	167
Tomato	BBFS	5.23	0.006	2.02	57	42.12	193
	BBFS + M	5.2	0.005	3.42	187	50.75	184
	RFS	5.7	0.007	1.55	140	39.81	161
	RFS + M	5.53	0.007	4.59	206	47.43	193
Okra	BBFS	5.06	0.006	2.7	156	37.15	197
	BBFS + M	5.68	0.006	5.89	297	48.98	198
	RFS	5.94	0.007	2.57	172	35.4	160
	RFS + M	5.77	0.007	3.49	271	46.07	168
	CD (0.05)	0.65	0.001	0.92	86	12	24
	SE (+m)	0.22	0.0003	0.33	28	4	7

BBFS - Broad bed furrow system; M – Organic mulching; RFS – Ridge furrow system

Table: 6
Yield, economics and rainwater use efficiency of crops under different *in-situ* moisture conservation practices (pooled data of 2015 and 2016)

Treatment		Yield (kg ha^{-1})	TEY (kg ha^{-1})	Cost of Cultivation (₹ ha^{-1})	Gross Income (₹ ha^{-1})	Net Income (₹ ha^{-1})	B:C ratio	RWUE (kg $ha^{-1}mm^{-1}$)
Crop	*In-situ* moisture conservation practices							
Cauliflower	BBFS	5850	7313	57000	146200	89260	2.56	11.16
	BBFS + M	6070	7588	59000	151760	92760	2.57	11.58
	RFS	6150	7688	60000	153750	93760	2.56	11.74
	RFS + M	6450	8063	62000	161250	99260	2.60	12.31
Tomato	BBFS	11250	11250	73000	225000	152000	3.08	21.47
	BBFS + M	11800	11800	75000	236000	161000	3.15	22.52
	RFS	12050	12050	76000	241000	165000	3.17	23.00
	RFS + M	12650	12650	78000	253000	175000	3.24	24.14
Okra	BBFS	5560	6950	60000	139000	79000	2.32	10.61
	BBFS + M	5830	7388	62000	145750	85760	2.35	11.13
	RFS	5920	7400	63000	148000	85000	2.35	11.30
	RFS + M	6520	8150	65000	163000	98000	2.51	12.44

BBFS - Broad bed furrow system; M – Organic mulching; RFS – Ridge furrow system; TEY – Tomato Equivalent Yield; Rain water available (mm) for Cauliflower, Tomato and Okra – 524 mm; Price (₹ kg^{-1}): Cauliflower-25.00; Tomato-20.00; Okra-25.00

may be more resistant to pest injury. Increase in soil temperature and moisture content stimulate root growth, which leads to greater plant growth and better crop yield. Sarolia and Bhardwaj, 2012 also reported that mulched plant usually grow and mature more uniformly and give better crop yield than unmulched crop. Mulching in the vegetable crops also helped in keeping fruits clean with better quality. The mulching operation favoured reduction of weed seed germination, weeds growth, and keeps the weeds in control.

The interaction effects were studied among the different *in-situ* moisture conservation method and different vegetable crops (Table 7). The yields of the vegetable crops were expressed in TEY. The results revealed significant differences in yield between RFS and RFS with organic mulching, whereas no significant differences in yield were found between BBFS and BBFS with organic mulching in case of cauliflower, tomato and okra crops. Significant differences in yield were also found between BBFS and RFS in all the vegetable crops, except cauliflower, whereas significant differences in yield were found between BBFS with organic mulching and RFS with organic mulching in all the vegetable crops. Significant differences in yield were found between the crops in all moisture conservation practices. Among the vegetables, higher TEY was found in tomato crop followed by cauliflower and okra crop in all the *in-situ* moisture conservation practices.

Table: 7
Tomato Equivalent Yield (kg ha^{-1}) of vegetable crops under different *in-situ* moisture conservation practices (pooled data 2015 and 2016)

In-situ moisture conservation practices	Crop			
	Cauliflower	Tomato	Okra	Mean
BBFS	7313	11250	6950	8504
BBFS + M	7588	11800	7388	8925
RFS	7688	12050	7400	9046
RFS + M	8063	12650	8150	9621
Mean	7663	11938	7472	

	SE (±m)	C.D. (0.05)
Crop (C)	246	760
Moisture conservation practices (M)	142	435
C x M	285	785

BBFS - Broad bed furrow system; M – Organic mulching; RFS – Ridge furrow system

4. CONCLUSIONS

The study clearly indicated that the ridge furrow system with organic mulching provided highest vegetable yield as compared to other *in-situ* moisture conservation practices in all the three vegetable crops. From economic analysis of all the vegetable crops, it was found that net income and B:C ratio of tomato crop was highest followed by okra and cauliflower crop. Similarly ridge furrow system with organic mulching resulted highest TEY as compared to other *in-situ* moisture conservation practices in all the vegetable crops. The RWUE was also found higher in case of RFS with mulching for all the three vegetable crops. The RFS with mulching helps to conserve water when there was lower rainfall by holding water in ridges, and when there was higher rainfall, this helps to drain the excess water thus avoiding water logging situation.

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