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Impact of rain water harvesting and mulching on growth and yield of apple *(Malus domestica)* under rainfed condition

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ABSTRACT

Field demonstration trials were conducted for two consecutive years (2011 and 2012) to study the influence of rain water harvesting and mulching on rainfed apple production. Results clearly indicated that maximum mean plant height (3.08 m), canopy spread (4.15 m x 3.96 m), fruit yield (120.36 kg tree^{-1}) and productivity efficiency (0.46 kg^{-1}cm^2 TCSA) were recorded in full moon water harvesting system + plastic mulch. Significantly highest mean TCSA (265.32 cm^2) was recorded in Trench + plastic mulch. Maximum fruit weight (186.3 g) was recorded in half moon + plastic mulch in demonstration plot-I. Whereas, in demonstration plot II, the maximum mean plant height (3.70 m) was recorded in trench system + plastic mulch. However, highest mean TCSA (104.02 cm^2), canopy spread (2.96 m x 3.23 m), fruit yield (91.91 kg tree^{-1}) and productivity efficiency (0.89 kg^{-1}cm^2 TCSA) were recorded in full moon water harvesting system+ plastic mulch. Highest fruit weight (171.7 g) was recorded in half moon + plastic mulch in apple.

1. INTRODUCTION

Apple (*Malus domestica* Borkh) is one of the important temperate fruit crops of India. The area under apple has reached to 2.73 lakh ha with annual production of 25.63 lakh tones from a meagre area 0.44 lakh hectare with a production of 1.85 lakh tonnes during 1960-61 (Anonymous, 2011). Although India has made healthy progress in terms of area expansion and production of apple, but productivity remains a matter of concern. The average productivity of apple in India ranges between 4-11.5 t ha^{-1} (NHB-2010) which is far less than international standards (40 t ha^{-1}). The low productivity is attributed to region specific technological interventions especially water management. The production and productivity may increase many fold if scientific production technologies adopted in the region. The soil of this region is sandy clay loam with poor drainage and receives average annual rainfall of about 750 mm out of which only 20-25% of total rain fall is received during the critical stages of fruit growth and development (May, June, July and August). The erratic precipitation and constant droughts induced mainly due to climatic disturbance in the recent past have further aggravated the production potential of apple in this region. Moisture conservation *in situ* is becoming increasingly important due to recent droughts with predictions about greater moisture stress deficits in future by climate change (Lal *et al.,* 2011 and Math and Patil, 2013). For improving the productivity of rainfed apple under changing climatic scenario, the conservation and utilization of rain water is of utmost importance which requires efficient water harvesting and conservation techniques. The rain water harvesting techniques like full moon, half moon, cup and plate and trench system combined with different type of mulches (Plastic and organic mulch) has been found to be helpful in moisture conservation during critical stages of fruit growth and development under rainfed condition (Kumar *et al.,* 2012). In the dry regions, water harvesting is considered among the excellent methods for productivity enhancement (Ghosh,1982; Oweis and Hachum, 2003; Oweis and Hachum, 2006). Conservation measures for better growth and productivity were earlier advocated in ber (Sharma *et al*., 1982), sweet lime (Ghosh, 1985), sweet orange (Arora and Mohan, 1985) and cashew nut (Badhe and Magar, 2004). Mulching plays an important role in soil moisture conservation, improving soil structure, regulation of soil temperature and reduces weed growth in litchi (Ganga *et al*., 2012), straw berry (Gupta and Acharya, 1994), apple (Tang *et al*., 1984; and Lal *et al*., 2003)), plum

(Sharma and Kathiravan, 2009) and almond (Verma *et al.*, 2001). However, no systematic work has been done on rain water harvesting and *in situ* moisture conservation aspect in apple under rain fed of Kashmir valley. An experiment was conducted in order to identify suitable rain water harvesting technology in combination with mulching for rainfed apple production under temperate agro-ecological region of Jammu and Kashmir.

2. MATERIALS AND METHODS

The experiment was conducted at farmer's fields of village-Kachhuwari, District- Budgam, of Jammu & Kashmir, India during 2011 and 2012 to study the effect of rain water harvesting and mulching techniques for apple production under rainfed condition. The variety which has been selected was Golden Delicious. The demonstration plots were selected in Kachhuwari village of Budgam district of J&K situated at a latitude of 33°53'N , longitude of 74°39'E and altitude of 2118 m a msl. The soil of this experimental field was sandy clay loam (63.1% sand, 11.7% silt and 25.2% clay; 7.26 soil pH, 436.08 kg N ha^{-1} and 196.0 kg K ha^{-1}) with poor drainage. There were 10 treatment combinations (T_1-half moon, T_2-half moon + organic mulch, T_3-half moon + plastic mulch, T_4-full moon, T_5-full moon + organic mulch, T_6-full moon + plastic mulch T_7-trench, T_8-trench + organic mulch, T_9-trench + plastic mulch, and T_{10}-control) have been laid out in randomised block design with three replication.

In half moon water harvesting system, semi circular bunds were created at downstream side of the plant. The shape and design of the structure was semi circular bunds having 30 cm width and 30 cm high at a radius of 2.5 m away from the tree trunk and 5% outward slope for rain water collection. In full moon water harvesting system, circular bunds were created around the periphery of the plant. The shape and design of the structure was circular bunds having 30 cm width and 30 cm high at the radius of 2.5 m away from the tree trunk and 5% inward slope for rain water collection. There were earthing up around the tree trunk in the radius of 30-40 cm to avoid water stagnation around tree trunk. In trench water harvesting system, trench was created upstream side one meter away from the tree trunk. The shape and design of the structure was 30 cm width and 30 cm deep and 1.5 m length of trench created for collection of rain water from the catchment area. The plants were given uniform cultural treatment during the course of investigations. The rain water harvesting systems were created in apple field during 2011 and tree basins were covered with mulch as per the treatment. Black plastic much was UV resistant and cut in circular/semicircular/ rectangular shape and slightly bigger than the size of the catchment area and lay in catchment area as per the treatment. The plastic sheets near the tree trunk and at the periphery of tree basin was placed beneath the soil to prevent being blown with wind. The polythene sheets were silted with 8-10 holes at equal distance to permit the rain water to enter into the soil. The locally available dry grass was collected and spread on soil surface in a layer in tree basin. The tree height was measured with the help of a long pole marked in meters and spread was measured in two directions *i.e.* East-West and North-South and average spread was calculated and expressed in meters. Tree trunk girth was recorded before the execution and at the end of experiment during both the years of study. A ring was made with red paint at a height of 15 cm above the ground level in each selected tree to record the trunk girth from same point each year. The trunk cross-sectional area of tree was calculated by using formula TCSA= $Girth^2/4\pi$ *(West wood et al., 1970).* Fruit was harvested at maturity and yield per tree was estimated in kilogram. The productivity efficiency was calculated by formula:

$$\text{Productivity efficiency } (Kg^{-1}cm^2\ TCSA) = \frac{\text{Fruit yield (kg)}}{\text{Trunk cross sectional area } (cm^2)}$$

The data were analyzed statistically as per the standard procedure given by Gomez and Gomez (1984) for interpretation of results and drawing conclusions.

3. RESULTS AND DISCUSSION

Vegetative Growth

A perusal of data presented in Table 1 revealed that plant height, trunk cross-sectional area of tree and canopy spread as influenced by rain water harvesting and mulching in apple. Maximum mean plant height (3.08 m) and canopy spread (4.15 m x 3.96 m) were recorded in full moon water harvesting system+ plastic mulch. Significantly highest mean trunk cross sectional area (265.32 cm^2) of tree was recorded in trench water harvesting system+ plastic mulch and statistically *at par* with full moon + plastic mulch, full moon + organic mulch, half moon + plastic mulch and trench + plastic mulch respectively, and minimum was in control (No mulch and no water harvesting system). Non significant variations were found in respect of plant height among the different treatments over control in demonstration plot-I.

Similarly, in demonstration plot-II, the plant growth parameters such as plant height, trunk cross-sectional area of tree and canopy spread also influenced by rain water harvesting and mulching in apple under rainfed condition (Table 3). Non-significant variations were found among the treatment as far as height is concerned. The maximum mean plant height (3.7 m) was recorded in trench water harvesting system + plastic mulch and minimum was in control plots (3.41 m). Significantly maximum mean trunk cross sectional area of tree (104.02 cm^2) and canopy spread (2.96 m x 3.20 m) were recorded in full moon water harvesting system+ plastic mulch, which are 28.51% higher in TCSA and 16.08 and 18.95% in canopy spread over control treatment.

Table: 1
Effect of rain water harvesting and mulching on vegetative growth of apple (Demonstration trial-I)

Treatment	Plant height (m)			TCSA* (cm^2)			Canopy spread (m)					
							East - West		North - South		Mean	
	2011	2012	Mean	2011	2012	Mean	2011	2012	2011	2012	E-W	N-S
Half moon (HM)	2.55	2.65	2.60	225.12	249.18	237.15	2.74	3.14	3.16	3.36	2.94	3.26
HM + Organic mulch (OM)	2.75	2.96	2.86	227.32	258.68	243.0	3.24	3.62	3.66	3.84	3.43	3.75
HM+ Plastic mulch (PM)	2.90	3.06	2.98	245.12	266.05	255.59	3.38	3.86	3.74	3.78	3.62	3.76
Full moon (FM)	2.62	2.85	2.74	236.23	250.01	243.12	3.45	3.71	3.37	3.59	3.58	3.48
Full moon +OM	2.85	3.05	2.95	245.25	267.80	256.53	3.71	3.74	3.53	3.80	3.73	3.67
FM+PM	2.99	3.16	3.08	252.12	276.38	264.25	4.04	4.25	3.80	4.11	4.15	3.96
Trench	2.65	2.92	2.79	221.14	237.15	229.15	3.02	3.45	3.28	3.63	3.24	3.46
Trench + OM	2.86	2.97	2.92	238.24	262.75	250.50	3.45	3.89	3.59	3.77	3.67	3.68
Trench + PM	2.95	3.08	3.02	250.28	280.36	265.32	3.72	3.78	3.60	4.10	3.75	3.85
Control	2.52	2.59	2.56	224.12	235.33	229.73	2.48	2.64	2.68	2.36	2.56	2.52
LSD *(P=0.05)*	NS	NS	NS	25.23	26.34	18.12	0.58	0.56	0.54	0.74	0.68	0.67

* TCSA-Trunk Cross Sectional Area

Table: 2
Effect of rain water harvesting and mulching on yield and its contributing characters of apple (Demonstration trial-I)

Treatment	Fruit weight (g)			Fruit yield (Kg $tree^{-1}$)			Productivity efficiency ($kg^{-1}cm^2$ TCSA)		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Half moon (HM)	160.2	175.7	167.9	70.12	85.60	77.86	0.31	0.34	0.33
HM + Organic mulch (OM)	172.8	180 .6	176.7	82.63	113.40	98.02	0.36	0.44	0.40
HM+ Plastic mulch (PM)	185.2	187.4	186.3	98.98	126.05	112.52	0.40	0.47	0.44
Full moon (FM)	165.3	167.4	166.4	93.14	115.85	104.5	0.39	0.46	0.43
Full moon +OM	175.3	178.9	177.1	98.70	125.80	112.25	0.40	0.47	0.44
FM+PM	183.1	186.3	184.7	105.78	134.95	120.36	0.42	0.49	0.46
Trench	162.1	166.9	164.5	66.23	89.45	77.84	0.30	0.38	0.34
Trench + OM	165.4	170.5	167.9	97.64	123.80	110.72	0.41	0.47	0.44
Trench + PM	170.3	172.1	171.2	101.84	125.75	113.80	0.41	0.45	0.43
Control	145.2	148.2	146.7	54.78	69.20	61.99	0.24	0.29	0.27
LSD (P=0.05)	24.9	25.1	18.4	25.45	28.56	26.14	0.08	0.11	0.09

* TCSA-Trunk Cross Sectional Area

Table: 3
Effect of rain water harvesting and mulching on vegetative growth of apple (Demonstration trial-II)

Treatment	Plant height (m)			TCSA* (cm^2)			Canopy spread (m)					
							East-West		North-South		Mean	
	2011	2012	Mean	2011	2012	Mean	2011	2012	2011	2012	E-W	N-S
Half moon (HM)	3.30	3.64	3.47	75.12	89.53	82.33	2.24	2.75	2.98	3.13	2.50	3.06
HM + Organic mulch (OM)	3.35	3.63	3.49	81.56	93.18	87.37	2.54	2.78	2.76	3.18	2.66	2.97
HM + Plastic mulch (PM)	3.46	3.88	3.67	93.47	108.01	100.74	2.76	3.05	3.06	3.25	2.91	3.16
Full moon (FM)	3.34	3.75	3.55	79.12	89.96	84.54	2.78	2.82	2.52	3.10	2.80	2.81
Full moon +OM	3.42	3.79	3.61	85.45	98.12	91.79	2.62	2.95	2.94	3.11	2.79	3.03
FM+PM	3.45	3.84	3.65	94.21	113.83	104.02	2.72	3.19	3.12	3.27	2.96	3.20
Trench	3.25	3.65	3.45	81.23	95.57	88.40	2.71	2.85	2.35	2.67	2.78	2.51
Trench + OM	3.45	3.75	3.60	85.42	99.07	92.25	2.79	2.89	2.63	3.05	2.84	2.84
Trench + PM	3.48	3.91	3.70	89.25	103.96	96.61	2.68	2.96	2.90	3.20	2.82	3.05
Control	3.22	3.60	3.41	73.24	88.64	80.94	2.45	2.64	2.59	2.78	2.55	2.69
LSD *(P=0.05)*	NS	NS	NS	NS	18.24	11.25	NS	0.27	0.26	0.23	0.21	0.25

*TCSA- Trunk Cross Sectional Area

The plant height in both the demonstration plots (I and II) was better under sloppy land conditions. This might be due to more availability of soil moisture under gentle sloppy land conditions. Whereas, TCSA and canopy spread was better performance of full moon water harvesting system + plastic mulch might be due to uniform availability and distribution of soil moisture around the active root zone and translocated to aerial part of the tree and thereby increased the vegetative growth of the tree. Similar findings were reported by Dwivedi *et al.* (2011) while working on apple.

Fruit Yield and Productivity Efficiency

The rain water harvesting and mulching influenced the fruit weight, yield and productivity efficiency in apple under *rainfed* condition (Table 2). Significantly highest mean fruit weight (186.3 g) was recorded in half moon water harvesting system + plastic mulch and minimum was in control plots (146.7g). Similar fruit weight increasing trends were also recorded in demonstration plot-II (Table 4). Maximum mean fruit weight (171.7 g) was recorded in half moon water harvesting system+ plastic mulch and significantly superior over half moon, half moon + organic mulch, full moon, trench and trench + organic mulch treatments. It was 30.86% higher over control treatment. This might be due to more food diverted for development of less number of fruit per tree. Increase in carbohydrate levels leads to the increase in reproductive growth *i.e.* fruit weight (Khan, 1998).

The highest fruit yield (120.36 kg $tree^{-1}$) and productivity efficiency (0.46 $kg^{-1}cm^2$ TCSA) were recorded in full moon water harvesting system + plastic mulch followed by trench + plastic mulch and minimum was in control plot (61.99 kg $tree^{-1}$ and 0.27 $kg^{-1}cm^2$ TCSA) in demonstration plot-I (Table 2). In demonstration plot-II, the fruit yield and productivity efficiency also influenced by water harvesting system and mulching in apple (Table 4). The mean maximum fruit yield (91.91 kg $tree^{-1}$) and productivity efficiency (0.89 $kg^{-1}cm^2$ TCSA) were recorded in full moon water harvesting system + plastic mulch treatment. The higher fruit yield was recorded in full moon water harvesting + mulching and significantly superior over half moon, half moon + organic mulch, full moon, trench, trench + organic mulch treatment. It was statistically *at par* with half moon + plastic mulch, full moon + organic mulch and trench + plastic mulch treatments.

More number of fruits might be increased the fruit yield per tree and productivity efficiency in apple. The full moon water harvesting system + plastic mulch conserved more moisture due to efficient weed control and fact that water after evaporation condenses on the bottom side of the polythene sheet and drop down again on the soil surface. Raina (1992) have also reported higher moisture content under black polythene mulch. These results are in accordance with the findings of Lal *et al.*, 2003.

Table: 4
Effect of rain water harvesting and mulching on yield and its contributing characters of apple (Demonstration trial-

Treatment	Fruit wt. (g)			Fruit yield (kg/tree^{-1})			Productivity efficiency (kg^{-1}cm^{2} TCSA)		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Half moon (HM)	135.1	137.4	136.3	58.45	76.73	67.59	0.77	0.86	0.82
HM + Organic mulch (OM)	146.2	153.3	149.8	61.23	80.93	70.08	0.75	0.87	0.81
HM + Plastic mulch (PM)	168.2	175.2	171.7	75.24	95.42	85.33	0.80	0.88	0.84
Full moon (FM)	145.1	147.6	146.4	58.24	77.68	67.96	0.74	0.86	0.80
Full moon +OM	152.1	164.5	158.3	69.21	86.12	77.67	0.81	0.88	0.85
FM+PM	158.2	166.5	162.4	82.45	101.36	91.91	0.88	0.89	0.89
Trench	132.1	135.6	133.8	58.23	75.68	66.96	0.72	0.79	0.76
Trench + OM	145.5	149.3	147.4	60.24	79.75	69.99	0.71	0.80	0.76
Trench + PM	156.1	162.9	159.5	70.21	86.45	78.33	0.79	0.83	0.81
Control	130.2	132.2	131.2	45.12	58.15	51.64	0.62	0.66	0.64
CD at 5%	25.1	26.2	19.5	22.42	22.75	20.12	0.12	0.11	0.13

*TCSA- Trunk Cross Sectional Area

4. CONCLUSIONS

The present study clearly suggest that rain water harvesting system like full moon, half moon and trench in combination with plastic mulch or organic mulch improves growth and fruit yield under rainfed conditions by enhancing the availability of soil moisture during critical stages of fruit growth and development. It is a cost effective and economically viable technology for resource poor farmers of hill states.

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