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Micro-catchment water harvesting and moisture conservation techniques for apple (*Malus domestica*) production under rainfed condition

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ABSTRACT

A field experiment was conducted during 2009-10 and 2010-11 on influence of micro-catchment rain water harvesting and moisture conservation techniques for apple production under rainfed condition. Result indicated maximum plant height (2.94 m), TCSA (87.07 cm^2), canopy volume (3.73 m^3), annual shoot growth (69.96 cm), fruit yield (23.44 kg/tree and 14.65 tonnes/ha) were recorded in full moon water harvesting system and minimum in control. Among mulches, plastic mulch performed better in respect to TCSA (84.26 cm^2), canopy volume (2.71 m^3), annual shoot growth (63.34 cm), fruit yield (19.36 kg/tree and 12.10 tonnes/ha) respectively. Maximum soil moisture content was estimated in full moon water harvesting system followed by half moon. Among mulches, plastic mulch conserved more moisture than organic mulch and no mulch during fruit growth and maturation stage. Interaction effect of full moon water harvesting system + plastic mulching showed significantly maximum vegetative growth, fruit yield and soil moisture content in apple.

Key words: Apple, Fruit yield, Moisture conservation, Soil moisture, Water harvesting

Apple (*Malus domestica* Borkh) is one of the important fruit crops of temperate region of the country. It is a temperate fruit tree; more than 80% of the worlds supply being produced in Europe. The high yield and good quality fruits can only be obtained when the growing inputs given at right quantity for proper growth and fruiting. In India, it is mostly grown in the state of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh etc. In J&K, it is cultivated in Srinagar, Budgam, Pulwama, Anantang, Baramulla and Kupwara districts. The trend in growth of different fruit crops indicated that there was a tremendous growth both in the area and production from 1960-61 to 2010-2011 in apple with annual production of 1.85 lakh tonnes from a meager area of 0.44 lakh hectare to 25.63 lakh tones from 2.74 lakh hectare area (NHB 2010). The average productivity is 7.12 tonnes/ha under rainfed condition for apple. The low productivity is attributed to several production factors which can be overcome by providing suitable region specific technological interventions.

The production and productivity may increase many fold if adopted proper scientific production technologies in the region. The main reason for its low productivity is due to its cultivation on rainfed karewa conditions. Owing to this constraint, the crop faces severe moisture stress during fruit development stages. Under such situation, farmers have to depend largely upon rain and *insitu* moisture conservation practices through various kinds of water harvesting system and mulching. The soil of the experimental site are sandy clay loam with poor drainage and received average annual rainfall of about 718.9 mm out of which 24.4% of total rainfall was available during the critical stage of fruits growth and development (May, June and July). For improving the productivity of rainfed apple under changing climate scenario, the conservation and utilization of rain water is of utmost important 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 kind of mulches (plastic and organic mulch) will help in moisture conservation during critical stage of fruits growth and development under rainfed condition (Kumar *et al*. 2012). In the dry/rainfed region, water harvesting is considered among the excellent methods for productivity enhancement (Arora and Mohan 1985, Oweis and Hachum 2003, Oweis and Hachum 2006 and Kumar *et al*. 2012). Some of the work done in tropical and sub-tropical fruits like in mango (Ghosh and Bauri 2003) and cashewnut (Badhe and Magar 2004) for better growth and productivity.

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Mulching play an important role in soil moisture conservation in apple (Dwevedi *et al*. 2000, Hira Lal *et al*. 2003, Neilsen *et al*. 2004 and Pande *et al.* 2005), cherry (Szwedo 2000), plum (Sharma and Kathiravan 2009) and strawberry (Ali and Gaur 2007). However, no systematic work has been done on rain water harvesting and *insitu* moisture conservation aspect in apple under rainfed condition of Kashmir valley. Hence, an experiment was conducted to identify suitable water harvesting technology for rainfed apple production in Kashmir valley condition.

MATERIALS AND METHODS

The experiment was conducted at research farm of Central Institute of Temperate Horticulture, Srinagar, Jammu & Kashmir, during 2009-10 to 2010-11 to study the effect of rain water harvesting and *in-situ* moisture conservation techniques for apple production under rainfed condition. The variety which has been selected is Red Chief: a regular bearer, high yielder and good quality fruits. The planting has been done at 4 m × 4 m spacing during 2002-03. The research farm at Srinagar is situated at a latitude of 34 05'N and longitude of 74 50'E and at an altitude of 1640 m above msl. The soil of this experimental field are sandy clay loam with poor drainage. Five water harvesting system such as full moon, half moon, trench, cup and plate and no water harvesting (control) and three mulching materials such as plastic mulch, organic mulch and no mulch (control) were used in a randomized block design (factorial) with three replication. Four plants (7-8 year old) in each treatment per replication were selected for the study.

In half moon 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 1.7 m away from the tree trunk for storage of runoff water from the catchment area. In full moon system-circular bunds were created around the periphery of the tree. The shape and design of the structure was circular bunds having 30 cm width and 30 cm high at a radius of 1.7 m away from the tree trunk for storage of runoff water. In trench system, trench was created up stream side one meter away from the tree trunk. The shape and design of the structure was 30 cm deep, 30 cm width and 1.5 m length of trench created for collection of runoff water. Cup and plate system. This system was created around periphery of the tree having 30 cm width and 30 cm deep for collection and storage of rain water from the catchment area (Kumar *et al*. 2012). The experimental farm falls under temperate region having cold condition from November to February. The plants were given uniform cultural treatment (Recommended package of practices) during course of investigation. Before the execution of experiment, the trees basins were ploughed with spade to keep them weed-free and mix the farmyard manure (FYM) and fertilizers. In each experimental tree, recommended dose of farmyard manure (35 kg/tree) and NPK (180 g, 40 g, 225 g/tree) at the age of 7^{th} year and 40 kg FYM and NPK (220 g, 45 g and 270 g) at the age of 8^{th} year were applied during January-February for both year. Black plastic mulch was UV resistant laid in catchment area as per the treatment. 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 as an organic mulch were collected and was spread at soil surface in a layer in tree basin (35-40 kg dry grass) on oven dry weight basis which was 30-45 cm away from the tree trunk as per the treatment.

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 $^2/4\ \pi$ (Westwood *et al.* 1970). The height of the trees along with spread was measured in two directions, i.e. east-west and north-south. Canopy volume was calculated by Castle's (1983) formula as given below: Canopy volume = 0.5228 × canopy height (m) × canopy diameter (m^2). Canopy volume measurements were made after harvest in October 2010 and 2011. Annual shoot growth was recorded before pruning during December. Ten uniform and healthy shoots were randomly selected all over the periphery of tree and the length of each shoot was measured at beginning and end of growing season between the point of next growth initiation to the tip of the shoot. The total shoot growth observed during entire growing season was thus recorded and expressed in centimetre. Fruit was harvested at maturity and yield per tree was estimated in kilogram. Ten fruits were randomly selected from each tree and pooled as per replication in all treatments for quality analysis. The total soluble solid (TSS) of fruit was estimated by hand refractometer (0-93 range) and present in term of ^{0}Brix. To estimate TSS, fruit pulp was crushed in a pestle and mortar and then squeezed through a muslin cloth for extraction of juice. Soil moisture contents were recorded at monthly interval from 0-30 cm depths by thermo-gravimetric method (Black 1965). Data were analyzed statistically as per Gomez and Gomez (1984) for interpretation of results and drawing conclusions.

RESULTS AND DISCUSSION

Plant growth

Vegetative growth of apple trees was influenced by rain water harvesting techniques under rainfed conditions (Table 1). Maximum average mean plant height, trunk cross sectional area, canopy volume and annual shoot growth were recorded in full moon water harvesting system followed by halfmoon system and minimum in control. The full moon water harvesting system increased the plant height (31.25 %), TCSA (33.58 %), canopy volume (75.94 %) and annual shoot growth (22.14 %) over control treatment. All the rain water harvesting

Table 1 Effect of rain water harvesting and moisture conservation techniques on vegetative growth in apple

Treatment	Plant height (m)	TCSA (cm^2)	Canopy volume (m^3)	Annual shoot growth (cm)
Water harvesting				
Half moon system	2.81	85.03	3.61	63.66
Trench system	2.48	80.76	3.27	67.95
Cup and plate system	2.66	72.32	2.92	56.01
Full moon system	2.94	87.07	3.73	69.96
No water harvesting	2.24	65.18	2.12	57.28
CD (P=0.05)	0.35	14.24	1.13	10.91
Mulching				
Organic mulch	2.71	78.86	2.62	60.59
Plastic mulch	2.64	84.26	2.71	63.34
No mulch	2.56	71.51	1.65	54.28
CD (P=0.05)	0.14	6.37	0.54	6.86
Interaction				
Half moon	2.65	75.12	3.21	58.12
Halfmoon + organic mulch	2.82	81.24	3.54	61.54
Half moon + plastic mulch	2.96	98.73	3.69	71.32
Trench system	2.28	69.18	3.02	61.25
Trench + organic mulch	2.45	76.25	3.21	66.28
Trench + plastic mulch	2.71	86.85	3.58	76.35
Cup and plate system	2.52	64.28	2.75	51.24
C&P + organic mulch	2.62	72.12	2.86	55.74
C&P + plastic mulch	2.84	80.56	3.15	61.05
Full moon	2.73	79.54	3.47	65.42
Full moon + organic mulch	2.85	88.12	3.64	68.26
Full moon + plastic mulch	3.24	93.53	3.88	77.84
Control	2.05	59.54	1.99	53.75
Control + organic mulch	2.12	63.75	2.08	58.76
Control + plastic mulch	2.55	72.25	2.29	59.33
CD (P=0.05)	0.42	16.15	0.82	12.15

systems were superior over control treatment. The better performance of full moon water harvesting system 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 tree. The results are inconformity with the findings of Srivastava *et al*. (2011) and Kumar *et al*. (2012). Among the mulches, organic mulch performed better in respect to plant height compared to control. Whereas, TCSA, canopy volume and annual shoot growth were significantly higher in plastic mulch over control. It was increased by 17.82% TCSA, 64.24 % canopy volume and 16.69 % annual shoot growth over control treatment in apple. This may be due to better moderation of soil hydrothermal regimes by black polythene mulch which consequently increased the availability of moisture for better plant growth (Sharma and Kathiravan 2009). Interaction effect of rain water harvesting system and mulching also showed significant variations with respect to vegetative growth of apple plants. Significantly higher plant height (3.24 m), TCSA (93.53 cm^2), canopy volume (3.88 m^3) and annual shoot growth (77.84 cm) were recorded in full moon water harvesting system + plastic mulch in apple.

Fruit yield and quality

Fruit yield and its contributing characters as influenced by rain water harvesting techniques in apple (Table 2). Highest average mean fruit yield and projected yield per hectare were recorded in full moon water harvesting system and significantly superior to other water harvesting system and minimum was in control plots. It was increased by 45.59% of fruit yield per tree and 45.62% yield per hectare over control treatment. The fruit yield was better in full moon water harvesting system might be due to more and uniform availability of soil moisture under full moon water harvesting system during fruit development and maturity leads to more uptake of nutrient through root to aerial part of plants. Similar

Table 2 Effect of rain water harvesting and moisture conservation techniques on fruit yield and quality in apple

Treatment	Fruit yield (kg/tree)	Yield (tonnes/ha)	TSS (°Brix)
Water harvesting			
Half moon system	20.62	12.88	11.6
Trench system	19.28	12.05	11.7
Cup and plate system	18.80	11.75	11.7
Full moon system	23.44	14.65	11.6
No water harvesting	16.10	10.06	11.7
CD (P=0.05)	3.20	1.14	NS
Mulching			
Organic mulch	18.04	11.27	11.7
Plastic mulch	19.36	12.10	11.6
No mulch	15.24	9.52	11.6
CD (P=0.05)	2.22	1.34	NS
Interaction			
Half moon	17.12	10.70	11.5
Halfmoon + organic mulch	21.45	13.41	11.6
Half moon + plastic mulch	23.29	14.55	11.6
Trench system	16.45	10.28	11.4
Trench + organic mulch	19.72	12.33	11.5
Trench + plastic mulch	21.67	13.54	11.6
Cup and plate system	15.92	9.95	11.5
C & P + organic mulch	18.24	11.40	11.6
C & P + plastic mulch	22.24	13.90	11.7
Full moon	19.56	12.23	11.4
Full moon + organic mulch	23.18	14.48	11.5
Full moon + plastic mulch	27.58	17.23	11.6
Control	14.45	9.03	11.5
Control + organic mulch	15.96	9.97	11.6
Control + plastic mulch	17.89	11.18	11.7
CD (P=0.05)	4.12	2.23	NS

Table 3 Effect of rain water harvesting and mulching techniques on soil moisture status under different treatment in apple

Treatment	Soil moisture content (%)				
	April	May	June	July	August
Water harvesting					
Half moon system	14.09	13.5	11.83	11.93	12.78
Trench system	12.63	12.04	11.37	11.03	11.97
Cup and plate system	12.45	11.92	11.03	10.84	11.55
Full moon system	14.22	13.65	12.13	12.10	12.99
No water harvesting	11.39	10.52	7.91	7.78	9.67
CD (P=0.05)	1.12	1.03	1.07	1.09	1.45
Mulching					
Organic mulch	12.70	12.26	11.25	10.93	10.87
Plastic mulch	13.62	12.84	11.93	11.65	12.23
No mulch	12.25	11.45	10.17	9.88	10.05
CD (P=0.05)	0.62	0.64	0.65	0.64	0.66
Interaction					
Half moon	12.92	12.45	10.56	10.25	11.75
Halfmoon + organic mulch	14.12	13.32	11.67	11.60	12.50
Half moon + plastic mulch	15.23	14.73	13.26	13.21	14.09
Trench system	11.45	11.05	10.25	10.12	11.05
Trench + organic mulch	12.61	11.95	11.15	10.95	11.74
Trench + plastic mulch	13.83	13.12	12.71	12.02	13.12
Cup and plate system	11.75	10.15	10.12	10.05	10.94
C&P + organic mulch	12.42	11.45	10.95	10.65	11.25
C&P + plastic mulch	13.18	12.98	12.02	11.82	12.46
Full moon	13.05	12.55	11.17	11.04	11.78
Full moon + organic mulch	14.25	13.60	11.92	11.75	12.56
Full moon + plastic mulch	15.36	14.80	13.30	13.21	14.63
Control	10.45	10.05	7.05	6.95	9.05
Control + organic mulch	11.30	10.51	7.85	7.50	9.52
Control + plastic mulch	12.42	11.01	8.83	8.79	10.44
CD (P=0.05)	2.03	2.11	2.56	2.51	2.25

result was obtained by Kumar *et al.* (2012). Non-significant variations were found in respect to total soluble solids of fruit among different water harvesting system. Different type of mulches also influenced the fruit yield in apple. Significantly higher fruit yield were recorded in plastic mulch treated plots and superior to other treatment. Plastic mulch increased the fruit yield per tree by 27.03 % and yield per hectare 27.10 % over control. Similar findings were reported by Dwevedi *et al*. (2000) and Hira Lal *et al*. (2003). Non significant variations were found in total soluble solids content of apple fruit under different kind of mulches. Interaction effect of rain water harvesting system and mulching also showed significant variations with respect to fruit yield in apple. Significantly higher fruit yield (27.58 kg/tree and 17.23 tonnes/ha) were recorded in full moon water harvesting system + plastic mulch in apple. Interaction effect in TSS content of apple fruits were non-significant.

Soil moisture content

Maximum average mean soil moisture content (14.22 in April; 13.65% in May; 12.13% in June; 12.10% in July and 12.99 % in August) were recorded in full moon water harvesting system and minimum in control plots (Table 3). The performance of different water harvesting systems were superior over control plots. The higher soil moisture content in full moon water harvesting might be due to uniform distribution of moisture in soil profile leads to higher soil moisture in full moon water harvesting system. Among mulches, plastic mulch maintained higher soil moisture content throughout the cropping season. It was increased by 11.18% in April; 12.13% in May; 17.31% in June; 17.91% in July and 21.69% in August over control treatment. Among different mulches, comparatively higher moisture content was under plastic mulch may be 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 over control. Results are inconformity with the findings of Kamal *et al*. (2006) and Kuhn *et al*. (2009). Interaction effect of rain water harvesting system and mulching techniques indicated that mean maximum soil moisture content (15.36% in April; 14.80% in May; 13.30% in June; 13.21% in July and 14.63% in August) were estimated in full moon water harvesting system + plastic mulch in apple.

Thus full moon and half moon water harvesting system alongwith plastic mulch /organic mulch performed better in respect to vegetative, fruit yield and soil moisture content of apple under rainfed conditions.

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