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Effect of moisture conservation techniques on almond (*Prunus dulcis*) productivity under rainfed conditions

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ABSTRACT

A field experiment was conducted to study the effect of moisture conservation techniques on productivity enhancement in almond (*Prunus dulcis* Mill) during 2010-11 to 2012-13 at Srinagar, Jammu and Kashmir. Treatments included five water harvesting techniques, viz. half-moon (W_1), full-moon (W_2), cup and plate (W_3), trench (W_4) and control (W_5) and three mulch materials, viz. plastic mulch (M_1), organic mulch (M_2) and control (M_3) were laid out in factorial randomized block design with three replication. The experimental results revealed that maximum mean trunk cross sectional area (266.82 cm^2), nut yield (5.37 kg/tree), productivity efficiency (19.47 g/cm^2 TCSA) and soil moisture content (13.48%) were recorded in full moon water harvesting technique. Among mulch material, plastic mulch found better in respect to TCSA (255.59 cm^2), nut yield (4.99 kg/tree), productivity efficiency (18.88 g/cm^2 TCSA) and soil moisture content (12.86%) compared to other treatments. The combined effect of water harvesting and mulching indicated that maximum TCSA (270.48 cm^2), nut yield (5.82 kg/tree), productivity efficiency (20.92 g/cm^2 TCSA) and soil moisture (13.98 %) were recorded in full moon water harvesting + plastic mulch in almond cultivar Non Pareil under rainfed conditions of north west Himalayan regions of India.

Key words: Almond, Moisture conservation techniques, Productivity, Rainfed conditions

Almond (*Prunus dulcis* Mill), a member of Rosaceae family is an important nut crop of temperate region of India, mainly grown in Kashmir valley under rainfed conditions. The total cultivated area of 7107 ha with an annual production of 6360 tonnes and productivity is 0.89 tonne/ha in Jammu and Kashmir (Anon 2016-17). Almond kernels are concentrated source of energy with a significant share of fat, protein and fibre. Commercial almond production in India is low considering the demand and economical potential. The low productivity is attributed to region specific technological interventions especially water management. In Kashmir valley, moisture stress during summers is one of the major constraints for economical yield of almond. To overcome this, an attempt was made to enhance the productivity of rainfed almond orchards through different moisture conservation techniques. The study was aimed to assess the impact of moisture conservation practices on productivity of almond under rainfed karewa conditions of Kashmir valley. Average annual rainfall during study period is about 700 mm and only 25-30 % available during critical stage, i.e. kernel development stage (May to July). The moisture conservation techniques have potential to increase productivity of fruit crops under rainfed conditions. The different conservation measures improve cashew yield as reported by Badhe and Magar (2004) and in almond by Kumar (2016) under rainfed conditions. Various mulch materials are also known to conserve soil moisture during dry spell period for productivity improvement in mango (Ghosh and Bauri 2003 and Kumar *et al*. 2008), in guava (Singh *et al*. 2015), in turmeric (Kumar *et al*. 2002), in apple (Lal *et al*. 2003, Kumar *et al.* 2013, Pandey *et al.* 2005), in plum (Sharma and Kathiravan 2009) and in strawberry (Ali and Gaur 2007). Mulching has been found beneficial in improving physical and biological health of soil (Garg *et al*. 2007) However, very limited work has been done on rain water harvesting and mulching in almond under rainfed conditions of the Kashmir valley. Keeping in view, an experiment was initiated in order to identify suitable moisture conservation techniques for improving almond productivity under rainfed conditions of north west Himalayan regions of India.

MATERIALS AND METHODS

A field experiment was conducted at the ICAR-Central Institute of Temperate Horticulture, Srinagar, Jammu and Kashmir, India. The Institute is situated at 34^0 05'N latitude, 74^0 50'E longitude and 1640 m altitude during 2010-11 to 2012-13. The almond cultivar Non Pareil planted at 4 m × 4 m spacing in 2002 were used for experimentation. The soils of the experimental site was silty loam with low fertility status. Treatments included five water harvesting

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techniques, viz. half moon (W_1), full moon (W_2), cup and plate (W_3), trench(W_4) and no water harvesting (W_5) and three type of mulches, viz. organic mulch (M_1), plastic mulch (M_2) and no mulch (M_3) were laid out in factorial Randomised Block Design with three replications. The total treatment combinations of rain water harvesting and mulching is 15 (Table 1).

The moisture conservation techniques, viz 1. Half moon structure- In this system semi circular bunds were created at downstream side of the plant. The shape and dimension of the structure was semi- circular bunds having 30 cm width and 30 cm raised bund at a radius of 1.7 m away from the tree trunk for collection of runoff water from the catchment area. 2. Full moon structure- circular bunds were created around the periphery of the tree. The shape and dimension of the structure was circular bunds having 30 cm width and 30 cm raised bund at a radius of 1.7 m away from the tree trunk for collection of runoff water from the catchments area. 3. Trench structure-trench was created at upstream side of the plant with one meter away from the tree trunk. The shape and dimension of the structure was 30 cm deep, 30 cm width and 1.5 m length of trench created for collection of runoff water from catchments area. 4. Cup and plate structure- This system was created around periphery of the tree having 30 cm width and 30 cm deep for collection and storage of runoff water from the catchments area of the tree (Kumar *et al*. 2012).

The plants of uniform thickness and size were selected for the study. However, for getting precise results, four plants/replication were taken for recording the data. UV resistant black polythene having thickness of 100 micron and locally available dry grass (35-40 kg/tree basin on dry weight basis) were used as plastic and organic mulch respectively. Both the mulches were spread over the tree basin leaving 30-45 cm distance from the trunk. However, plastic mulch silted with 8-10 hole (10 mm) at equal distance to permit rain water into the soil. Tree trunk girth was recorded before the execution and at the end of experiment during the years of study to record trunk girth, a ring was made with red paint at 15 cm above the ground level and data was recorded every year from same marked point. The trunk cross-sectional area (TCSA) of tree was calculated by using formula, i.e. Girth$^2/4\pi$ (Westwood and Roberts 1970). Fruits were harvested at commercial maturity stage hulled, dried and nut weight (g) and yield/tree (kg) was recorded and projected in tonnes/ha. The productivity efficiency (g/cm^2 TCSA) was calculated by the formula Productivity efficiency= Nut yield (g) / TCSA (cm^2). Soil moisture contents (0-30 cm depth) were recorded at monthly interval from April to August by thermo-gravimetric method described by Black (1965). Data were analysed statistically as per procedure suggested by Gomez and Gomez (1984).

Table 1 Treatment details of experiment

Treatment	Details	Treatment	Details	Treatment	Details
Half moon+OM	W_1M_1	Full moon	W_2M_3	Trench+PM	W_4M_2
Half moon+PM	W_1M_2	CP+OM	W_3M_1	Trench	W_4M_3
Half moon	W_1M_3	CP+PM	W_3M_2	Organic mulch	W_5M_1
Full moon+OM	W_2M_1	CP	W_3M_3	Plastic mulch	W_5M_2
Full monn+PM	W_2M_2	Trench+OM	W_4M_1	Control	W_5M_3

CP-Cup and plate, OM-Organic mulch, PM-Plastic mulch

RESULTS AND DISCUSSION

Trunk cross sectional area (TCSA)

TCSA as influenced by water harvesting techniques and mulching in almond under rainfed conditions. The TCSA increases over the year from 2010-11 to 2012-13 in all the treatments. The maximum TCSA (237.45 cm^2, 268.37 cm^2 and 294.66 cm^2) were recorded in full moon water harvesting system and it was 52.53%, 45.42% and 51.01% higher over the control treatment in 2010-11, 2011-12, 2012-13. Overall mean maximum TCSA (266.82 cm^2) was recorded in full moon water harvesting system and superior to other treatments and it was 49.52% higher over control treatment. Different kind of mulch material also influenced the TCSA in almond. The TCSA increases over the year under mulch treatment. Maximum TCSA was recorded in plastic mulch followed by organic mulch and minimum was in control treatment. The TCSA increased 39.46%, 34.24% and 36.97% over control plots in 2010-11, 2011-12 and 2012-13. Overall mean TCSA was higher in plastic mulch and significantly superior over control treatment and at par with organic mulch. The combined effect of water harvesting and mulching techniques showed that maximum TCSA (242.34 cm^2, 271.81 cm^2 and 279.28 cm^2) were recorded in full moon water harvesting + plastic mulch followed by half moon + plastic mulch (239.82 cm^2, 268.02 cm^2 and 293.26 cm^2) and full moon + organic mulch (238.54 cm^2, 268.18 cm^2 and 295.45 cm^2), respectively. The overall mean (270.48 cm^2) was higher in full moon water harvesting + plastic mulch and significantly superior over control treatment in almond cultivar Non Pareil (Table 2). The TCSA was higher in full moon water harvesting technique along with plastic mulch might be due to uniform availability of soil moisture around the active root zone of plant. These results were in agreement with Kumar (2016) and Lal *et al*. (2003) while working on almond and apple.

Nut yield

Nut yield as influenced by rain water harvesting and mulching in almond under rainfed condition (Fig 1 and 2). Among water harvesting system, significantly maximum nut yield (3.59 kg/tree) was recorded in full moon water harvesting technique followed by half moon (3.57 kg/tree) and minimum in control (1.68 kg/tree) in 2010-11. In 2011-12, marginal reduction in yield over previous year in all the treatments, however, maximum nut yield (2.38 kg/

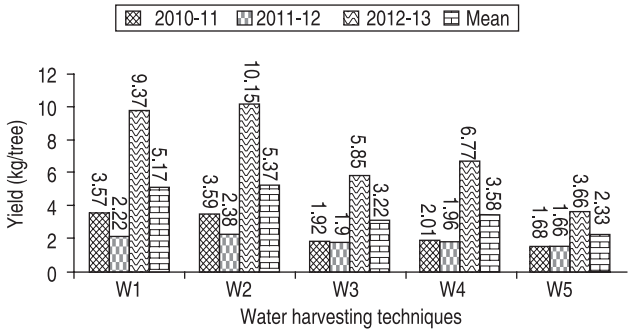

Fig 1 Effect of water harvesting techniques on nut yield of almond

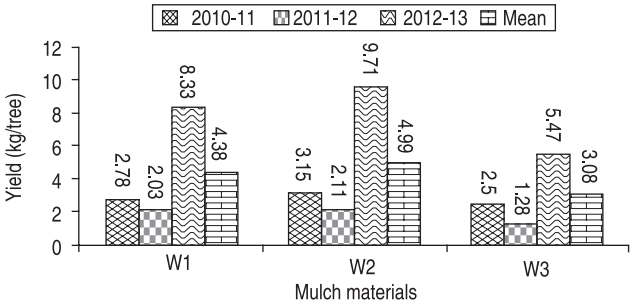

Fig 2 Effect of mulch materials on nut yield of almond

Table 2 Effect of moisture conservation techniques on TCSA in almond

Treatment	TCSA (cm^2)			
	2010-11	2011-12	2012-13	Mean
W_1M_1	236.45	266.34	290.45	264.41
W_1M_2	239.82	268.02	293.26	267.03
W_1M_3	229.75	261.75	285.75	259.08
W_2M_1	238.54	268.18	295.45	267.39
W_2M_2	242.34	271.81	297.28	270.48
W_2M_3	231.47	265.12	291.25	262.61
W_3M_1	180.45	208.37	242.12	210.31
W_3M_2	183.73	211.05	244.98	213.25
W_3M_3	176.78	205.54	237.67	206.66
W_4M_1	187.55	215.75	250.45	217.92
W_4M_2	189.05	217.91	251.69	219.55
W_4M_3	182.75	212.45	245.22	213.47
W_5M_1	156.75	185.32	196.45	179.51
W_5M_2	157.61	186.15	197.16	180.31
W_5M_3	152.65	182.15	191.75	175.52
CD (P=0.05)				
WHT	61.34	62.87	74.66	
Mulching	48.49	49.49	56.62	
Interaction	67.27	67.25	79.15	

tree) was recorded in full moon water harvesting system. Again drastic yield improvement in 2012-13, the highest nut yield (10.15 kg/tree) was recorded in full moon water harvesting system and significantly superior over control treatment and at par with half moon water harvesting system.

The variations in nut yield in different year might be due to fluctuation in rainfall pattern of the region. The overall mean nut yield (5.37 kg/tree) was recorded in full moon water harvesting followed by half moon (5.17 kg/tree) and it was 130.47% and 121.88% higher over control treatment. Different kind of mulches also influenced the nut yield in almond. There were increasing/decreasing trends over the years in all the treatment from 2010-11 to 2012-13 due to rainfall fluctuation. Maximum nut yield 3.15 kg/tree was recorded in plastic mulch in 2010-11 and similar trends were also recorded in 2011-12 and 2012-13. The overall mean nut yield (4.99 kg/tree) was recorded in plastic mulch followed by organic mulch (4.38 kg/tree) and lowest (3.08 kg/tree) in control treatment. Combined effect of water harvesting and mulching techniques also influenced the nut yield in almond (Table 3). Maximum mean nut yield (5.82 kg/tree) was recorded in full moon water harvesting + plastic mulch followed by half moon + plastic mulch (5.70 kg/tree) and full moon along with organic mulch (5.37 kg/tree), respectively in almond cultivar Non Pareil. The nut yield/ha (3.64 t/ha) was higher in full moon water harvesting technique coupled with plastic mulch and superior to other treatments. The highest nut yield in full moon water harvesting technique + plastic mulch might be due to efficient weed control and available soil moisture activate root system throughout the critical stages of nut growth and kernel development. These results are in accordance with the findings of Lal *et al*. (2003) and Kumar *et al.* (2013). Raina (1992) reported

Table 3 Effect of moisture conservation techniques on nut yield in almond

Treatment	Nut yield (kg/tree)				Yield (t/ha)
	2010-11	2011-12	2012-13	Mean	
W_1M_1	3.50	2.20	9.95	5.22	3.26
W_1M_2	4.06	2.56	10.49	5.70	3.56
W_1M_3	3.15	1.90	8.75	4.60	2.88
W_2M_1	3.52	2.35	10.25	5.37	3.35
W_2M_2	4.09	2.64	10.75	5.82	3.64
W_2M_3	3.16	2.15	9.45	4.92	3.08
W_3M_1	1.90	1.91	6.04	3.28	2.05
W_3M_2	2.11	2.07	6.39	3.52	2.20
W_3M_3	1.75	1.78	5.12	2.88	1.80
W_4M_1	1.96	1.99	6.75	3.56	2.23
W_4M_2	2.25	2.24	7.41	3.97	2.48
W_4M_3	1.82	1.80	6.15	3.26	2.04
W_5M_1	1.65	1.75	3.65	2.35	1.46
W_5M_2	1.89	1.79	4.21	2.63	1.64
W_5M_3	1.50	1.49	3.12	2.04	1.28
CD (P=0.05)					
WHT	0.68	0.38	2.17		
Mulching	0.45	0.42	1.18		
Interaction	0.94	0.75	2.56		

that mulching controls weed growth and thereby improves soil moisture in apple orchard.

Productivity efficiency

Productivity efficiency as influenced by rain water harvesting and mulching in almond under rainfed condition. Maximum productivity efficiency (15.17 g/cm^2 TCSA) was recorded in half moon water harvesting followed by full moon water harvesting (15.12 g/cm^2 TCSA) in 2010-11. In 2011-12, maximum productivity efficiency (9.33 g/cm^2 TCSA) was recorded in trench system followed by cup and plate system (9.22 g/cm^2 TCSA). In 2012-13, highest productivity efficiency (34.45 g/cm^2 TCSA) was recorded in full moon water harvesting followed by half moon (33.57 g/cm^2 TCSA). The overall mean productivity efficiency (19.47 g/cm^2 TCSA) was recorded in full moon followed by half moon (19.03 g/cm^2 TCSA) and it was 51.16% and 47.74 % higher over control treatment. Different kind of mulches also influenced the productivity efficiency in almond. Maximum productivity efficiency (14.02 g/cm^2 TCSA and 8.90 g/cm^2 TCSA) were recorded with organic mulch in 2010-11 and 2011-12. The highest productivity efficiency (34.72 g/cm^2 TCSA) was recorded in plastic mulch in 2012-13. The overall mean productivity efficiency (18.88 g/cm^2 TCSA) was recorded in plastic mulch treatment. Combined effect of water harvesting and mulching techniques influenced the productivity efficiency in almond (Table 4). The overall mean productivity efficiency (20.92 g/cm^2 TCSA) was recorded in full moon water harvesting + plastic mulch followed by half moon along with plastic mulch (20.74 g/cm^2 TCSA) and full moon + organic mulch (19.40 g/cm^2 TCSA) in almond variety Non Pareil. The productivity efficiency was higher in full moon + plastic mulch water harvesting might be due to higher TCSA as well as yield leads to higher productivity efficiency. The results are in conformity with the finding of Kumar *et al*. (2013).

Table 4 Effect of moisture conservation techniques on PE in almond

Treatment	Productivity efficiency (g/cm^{2}TCSA)			
	2010-11	2011-12	2012-13	Mean
W_1M_1	14.80	8.26	34.25	19.10
W_1M_2	16.92	9.54	35.77	20.74
W_1M_3	13.71	7.25	30.62	17.19
W_2M_1	14.75	8.76	34.69	19.40
W_2M_2	16.88	9.71	36.16	20.92
W_2M_3	13.65	8.11	32.45	18.07
W_3M_1	10.52	9.17	24.94	14.88
W_3M_2	11.48	9.81	26.08	15.79
W_3M_3	9.89	8.66	21.54	13.36
W_4M_1	10.45	9.22	26.95	15.54
W_4M_2	11.90	10.28	29.44	17.21
W_4M_3	9.95	8.47	25.08	14.50
W_5M_1	10.52	9.44	18.57	12.84
W_5M_2	11.99	9.62	21.35	14.32
W_5M_3	9.83	8.23	16.27	11.44
CD (P=0.05)				
WHT	3.29	NS	11.76	
Mulching	NS	1.70	5.94	
Interaction	5.32	1.54	14.91	

PE= Productivity efficiency

Soil moisture

Soil moisture as influenced by rain water harvesting techniques in almond under rainfed condition. There were increasing/decreasing trends over the years for soil moisture from 2010-11 to 2012-13 in different treatments. The pooled soil moisture data (five month) of consecutive three years indicated that maximum soil moisture (13.52%) was recorded in full moon water harvesting system and it was 34.52% in 2010-11; 46.28% in 2011-12 and 43.38 % higher in 2012-13 and significantly superior over control treatment. Among mulches, plastic mulch retained 31.95% in 2010-11; 42.01% in 2011-12 and 37.14% in 2012-13 more soil moisture over control plots. The overall mean value was also higher in same treatment. Combined effect of rain water harvesting and mulching techniques indicated that highest soil moisture (14.16%, 13.38%, 14.41%) were recorded in full moon water harvesting + plastic mulching in almond cultivar Non Pareil (Table 5). The higher soil moisture content in full moon water harvesting system + plastic mulch might be due to efficient moisture conservation and fact that water after evaporation condenses on the bottom

Table 5 Effect of moisture conservation techniques on soil moisture (%) in almond

Treatment	2010-11	2011-12	2012-13	Mean
W_1M_1	12.41	12.38	13.38	12.72
W_1M_2	13.47	12.83	13.84	13.38
W_1M_3	11.89	11.96	12.99	12.28
W_2M_1	13.44	12.89	13.41	13.25
W_2M_2	14.16	13.38	14.41	13.98
W_2M_3	12.95	12.62	13.63	13.07
W_3M_1	11.56	11.15	12.14	11.62
W_3M_2	11.75	11.42	12.42	11.86
W_3M_3	11.38	10.85	11.89	11.37
W_4M_1	12.07	11.62	12.62	12.10
W_4M_2	12.07	11.87	12.88	12.27
W_4M_3	11.52	11.38	12.38	11.76
W_5M_1	10.12	8.91	9.73	9.59
W_5M_2	10.45	9.14	10.02	9.87
W_5M_3	9.57	8.53	9.49	9.20
CD (P=0.05)				
WHT	0.95	1.04	1.10	
Mulching	0.71	0.84	0.92	
Interaction	1.14	1.18	1.21	

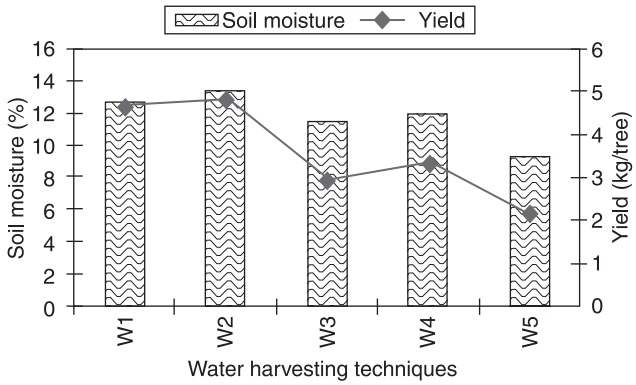

Fig 3 Effect of water harvesting techniques on soil moisture and yield in almond.

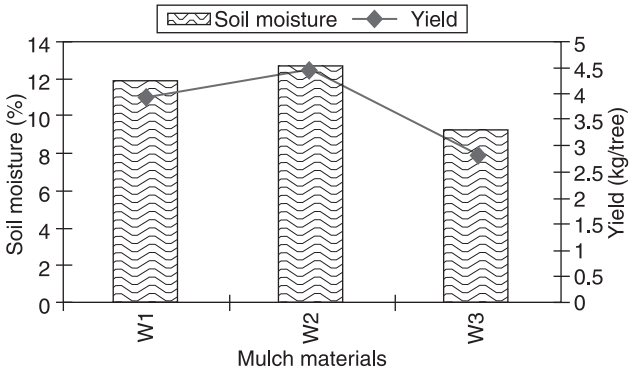

Fig 4 Effect of kind of mulches on soil moisture and yield in almond.

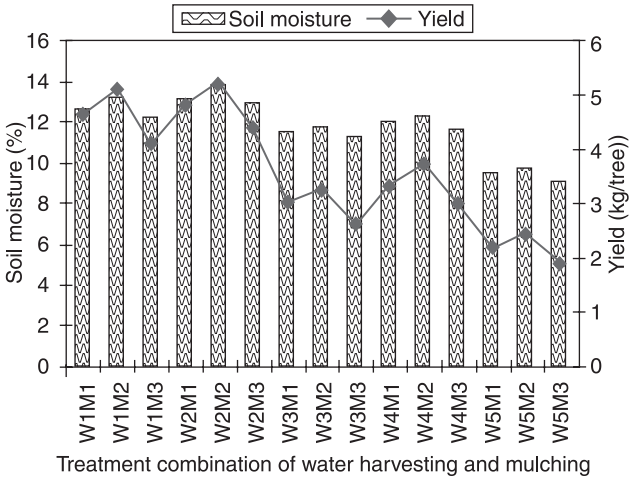

Fig 5 Effect of moisture conservation techniques on soil moisture and yield in almond.

side of the polyethylene sheet and drop down again on the soil surface hence increase soil moisture during critical stages of nut growth and kernel development. Sharma and Kathirvan (2009) also reported higher moisture content under black polyethylene mulch.

Relationship between soil moisture vs yield

Correlation was drawn between dependent and independent variables of soil moisture and yield parameters. There is positive relationship between soil moisture and yield in almond (Fig 3). The water harvesting techniques influence the yield of almond under rainfed condition. The correlation value for water harvesting techniques and yield was 0.93 and maximum yield 5.37 kg/tree with 13.48 % available soil moisture. Whereas, correlation value for kinds of mulches and yield was 0.99 and maximum yield 4.99 kg/tree with 12.86 % available soil moisture (Fig 4). The correlation value for combined effect of water harvesting and mulching techniques was 0.93 and highest yield 5.82 kg/tree with 13.98 % available soil moisture in almond variety Non Pareil (Fig 5).

In the present experiment it could be concluded that the soil moisture play an important role for improving nut yield in almond. The moisture conservation techniques like full moon, half moon and trench system combined with plastic/organic mulch found to be effective in improving nut yield of almond under rainfed conditions. The nut yield was also positively correlated with available soil moisture in Karewa conditions of Kashmir valley .

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