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Effect of rain water harvesting and mulch material on soil moisture regimes, fertility status and yield of almond under rainfed conditions of north western Himalayas

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ABSTRACT

A field experiment was conducted to study the effect of rain water harvesting and mulching techniques for rainfed almond production during 2008-09 and 2009-10 at Srinagar, Jammu and Kashmir. Five water harvesting systems (half-moon, full-moon, trench, cup and plate and control) and three mulching (plastic, organic and control) were evaluated in factorial randomized block design. The experimental results clearly indicated that maximum plant height (4.4 m), trunk cross sectional area (193 cm^2), canopy volume (28.2 m^3), nut wt. (1.68 g), yield (3.35 kg/tree), soil moisture content (14%) and soil fertility (0.66% soil organic carbon 516 kg N, 26.3 kg P and 304 kg K ha^{-1}) were recorded in full-moon water harvesting system. Productivity efficiency (18.18 g cm^{-2} TCSA) was higher in trench water harvesting system. Among mulches, plastic mulch performed better in respect to TCSA (166 cm^2), yield (3.02 kg/tree), productivity efficiency (18.19 g cm^{-2} TCSA) and soil moisture content (14.8, 14.2, 13.2, 12.7 and 12.3%). Whereas, organic mulch registered the highest soil fertility status. Interaction effect of water harvesting and mulching indicated that growth, yield, productivity efficiency and soil moisture status were recorded in full-moon water harvesting + plastic mulch in almond 'Non Pareil' under rainfed conditions of Kashmir valley.

Key words: Almond, mulching, soil moisture, soil fertility, water harvesting.

INTRODUCTION

Almond (*Prunus amygdalus* Batsch) is one of the important nut crops of temperate region of India and is mainly grown in rainfed areas of Kashmir valley. The total cultivated area is about 21,000 ha with an annual production of 9,000 t and productivity is very low (0.43 t/ha) as compared with other countries (Anon, 1). In Kashmir valley, moisture stress during summers is one of the major constraints for economic yield of almond. To overcome this, an attempt was made to enhance the productivity of rainfed almond orchards through different water harvesting and moisture conservation techniques where irrigation facilities are not available and supplemental irrigation is also uneconomical. The study was conducted to assess the impact of soil moisture conservation practices on productivity and suitability of conservation practices on rainfed karewaland of Kashmir valley. Keeping in view the constraints for low productivity of almond in the Kashmir valley primarily the weather and soil. The soils are silty loams with poor drainage. Average annual rainfall is about 675 mm with only 25-30% falling during nut growth and kernel filling stage (May to July). Thus, water harvesting and conservation techniques have the potential to increase productivity and return to producers (Ghosh and Bauri, 7; Badhe and Magar, 3; Kumar *et al*., 9). Mulching orchard tree rows with organic materials has been proven to offer various benefits including improved weed control, enhanced tree growth and fruit yields, soil improvement, and higher water use efficiency (Forge *et al*., 6; Sanchez *et al.*, 13; Yao *et al.*, 18). Various mulch materials are known to conserve soil moisture during dry period in apple (Dwivedi *et al*., 5; Kumar *et al.*, 10; Pandey *et al*., 12), cherry (Szwedo and Maszezyk, 16), plum (Sharma and Kathiravan,14) and strawberry (Ali and Gaur, 2). However, very limited work has been done on rain water harvesting and mulching in almond under rainfed conditions of the Kashmir valley. To increase the growth and yield of almond trees in various combinations of water harvesting (full-moon, half-moon, trench, cup and plate) and mulches (organic and plastic) were studied to improve water and nutrition supply to the almond trees under rainfed conditions.

MATERIALS AND METHODS

The experiment was conducted at the Central Institute of Temperate Horticulture, Srinagar, Jammu and Kashmir (lat. 34° N, long. 74° E and elev. 1,640 m) in 2008-09 and 2009-10. Tree of 'Non Pareil' planted at 4 m × 4 m in 2002 were used for study. Mean rainfall data of the experimental site, mean maximum and minimum temperature are presented in Figs. 1 & 2.

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The soil of the experimental site was a silty loam with poor drainage. Treatment in factorial combinations of water harvesting (half-moon, full-moon, cup and plate, trench and no water harvesting) and mulching (organic, plastic and no mulch) was laid out in randomised block design, with three replications.

The water harvesting system such as 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 raised bund 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 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 storage of runoff water. In trench system, trench was created at upstream 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. In 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 has described by Kumar *et al*. (9).

The plants were given uniform cultural treatment (Recommended package of practices) during course of investigation. The NPK doses 140 g N, 30 g P and 175 g K/tree/year in 2009 and 180 g N, 40 g P and 225 g K/tree/year in 2010 were applied to all the trees in experimental block. In each

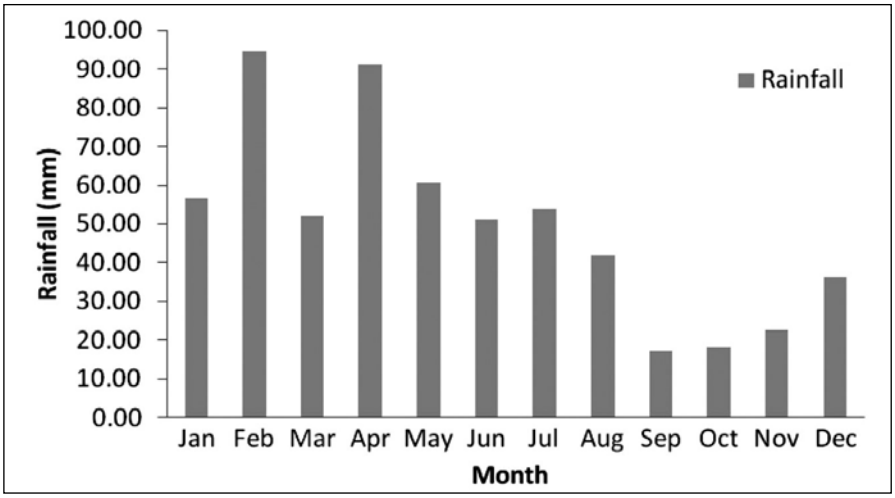

Fig. 1. Mean rainfall data (2009 & 2010) at Srinagar, J&K.

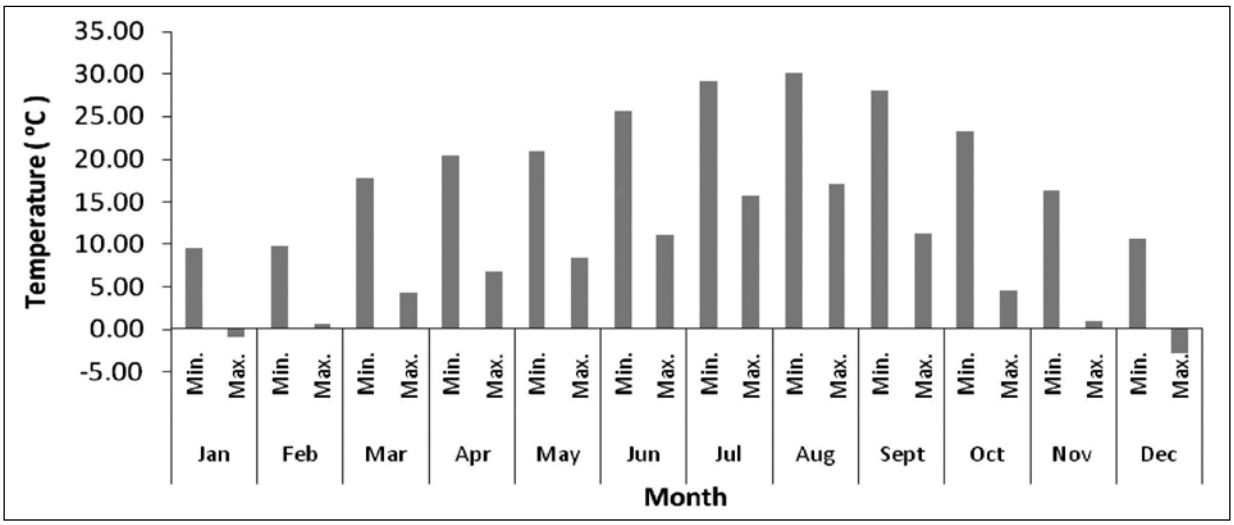

Fig. 2. Mean maximum and minimum temperatures at Srinagar, J&K.

experimental tree, recommended dose of farm yard manure and chemical fertilizers were applied during January- February for both years. 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 in the soil. The locally available dry grass (*Cynodon*, *Cyprus* and *Setaria*) as 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.

Canopy volume (CV) was estimated for each individual tree using a geometrical model referred to as the "contour method"(CV = [(1⁄4) π a b h) / (m(x) + m(y) + 1]. The dimensions a and b are measurements of the width of the tree at the base of the canopy, perpendicular and parallel to the tree row orientation, respectively. The height of the canopy (h) was measured from the lowest branch to the apex. The functions m(x) and m(y) were derived to accommodate the contour of the tree (Wright et *al*., 20). CV measurements were made after harvest in October. 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 (TCSA) of tree was calculated by using formula TCSA = Girth ^{2}/4 л. Fruit was harvested at maturity, hulled, dried and nut weight in gram and yield per tree was recorded in kilogram. The productivity efficiency was calculated by the formula;

$$\text{Productivity efficiency (g/cm}^2\text{ TCSA)} = \frac{\text{Nut yield (g/tree}^1\text{)}}{\text{TCSA (cm}^2\text{)}}$$

Soil samples were collected from 0-30 cm depth in November each year, shade dried, ground sieved through a 2 mm sieve and analysed for pH, soil organic carbon, nitrogen, phosphorus and potassium (Page *et al*., 11). Soil moisture status has studied at 0-30 cm depth at monthly intervals (15th April, 15th May, 15th June, 15th July and 15th August) each year by the thermo-gravimetric method (Black, 4). Pooled two year values of different parameters were analysed statistically using analysis of variance (Gomez and Gomez, 8). To determine the significance of the difference between the means of pairs of treatments, least significance differences (LSD) were computed at the $p \leq 0.05$ probability level.

RESULTS AND DISCUSSION

All the plant growth parameters (*e.g.* plant height, TCSA, canopy volume, nut weight, yield and productivity efficiency) as influenced by different water harvesting techniques and mulching in almond under rainfed condition are presented in Table 1. Maximum plant height was recorded in full-moon water harvesting technique and the differences were non-significant amongst the treatment. However, significantly mean maximum TCSA, canopy volume, nut weight and yield were recorded in full-moon water harvesting system, which is 66.37% TCSA, 68.86% canopy volume, 25.67% nut weight and 88.20% nut yield per tree were higher over control (no water harvesting system). Different kind of mulches also influenced the growth and yield of almond. Mean maximum TCSA, canopy volume, nut weight and yield were recorded in plastic mulch followed by organic mulch and minimum in control plots (no mulch). Increased plant growth and nut yield in full moon water harvesting system might be due to uniform availability and proper distribution of soil water around the active root zone of tree which must have increased the uptake and translocation of water and nutrients by root to aerial part of the plant. Similar observations were recorded by Kumar *et al*. (9) while working on almond under rainfed conditions. The plastic mulch improve the plant growth and yield might be due to better retention of soil moisture in plastic mulch leading better growth and yield under rainfed conditions. Similar findings were reported by Sharma and Kathirvan (14), while working on plum. The mean productivity efficiency was highest in trench system (18.18 g cm^{-2} TCSA) closely followed by half-moon system (18.11 g cm^{-2} TCSA) and full-moon (17.35 g cm^{-2} TCSA) system and minimum was in control (15.34 g cm^{-2} TCSA). Different kind of mulch material also influenced the productivity efficiency in almond. Mean highest productivity efficiency was recorded in plastic mulch treated plots (18.19 g cm^{-2} TCSA), which was significantly superior over control.

Interaction effect of water harvesting and mulching in almond also influenced the growth and yield of almond. Highest plant height (4.7 m) and soil fertility status (pH 6.8, 0.74% soil organic carbon, 545 kg/ha N, 30.6 kg/ha P and 316 kg/ha K) were recorded in full moon water harvesting system + organic mulch. Whereas, highest TCSA (203 cm^2), canopy volume (32.7 m^3), nut weight (1.83 g) and nut yield (3.93 kg tree^{-1}) and productivity efficiency (19.35 g cm^{-2} TCSA) were recorded in full-moon water harvesting system + plastic mulch in almond under rainfed conditions.

The soil moisture status at monthly intervals (0-30 cm depth) as influenced by different water harvesting and mulching techniques in almond under rainfed conditions. Soil moisture content declined continuously in all treatments during the growing seasons, probably due to the extraction of water from

Table 1. Effect of water harvesting techniques and mulching on growth and nut yield of almond.

Treatment	Plant height (m)	TCSA (cm^2)	Canopy vol. (m^3)	Nut wt. (g)	Nut yield (kg/ tree)	PE** (g/cm^2 TCSA)
Water harvesting						
Half-moon	4.2	180	22.3	1.66	3.26	18.11
Trench	3.9	143	18.4	1.65	2.60	18.18
Cup and Plate	3.4	137	16.8	1.54	2.29	16.71
Full-moon	4.4	193	28.2	1.68	3.35	17.35
No water harvesting (control)	3.4	116	16.7	1.51	1.78	15.34
LSD (P ≤ 0.05)	NS*	35	2.6	0.11	0.65	1.12
Mulching						
Plastic	3.8	166	22.8	1.67	3.02	18.19
Organic	4.0	157	20.8	1.60	2.67	17.01
No mulch (Control)	3.7	138	17.2	1.57	2.27	16.45
LSD (P ≤0.05)	NS	18	2.4	0.07	0.35	1.02
Interaction						
Half-moon (HM)	4.1	162	19.8	1.53	2.57	15.86
HM + organic mulch	4.3	182	22.5	1.69	3.46	19.01
HM + plastic mulch	4.2	195	24.6	1.77	3.74	19.18
Trench	3.7	124	14.9	1.71	2.34	18.87
Trench + organic mulch	4.1	148	19.9	1.65	2.53	17.09
Trench + plastic mulch	3.8	158	20.4	1.60	2.92	18.48
Cup & plate (C&P)	3.3	118	15.2	1.45	1.93	16.35
C&P + organic mulch	3.5	144	17.1	1.53	2.32	16.11
C&P + plastic mulch	3.4	149	18.1	1.56	2.61	17.52
Full-moon (FM)	4.2	182	23.6	1.60	2.85	15.65
FM + organic mulch	4.7	194	28.2	1.56	3.26	16.80
FM+ plastic mulch	4.4	203	32.7	1.83	3.93	19.35
Control	3.3	106	13.6	1.49	1.48	15.84
Control + organic mulch	3.5	118	17.2	1.56	1.77	15.0
Control + plastic mulch	3.4	124	19.2	1.59	1.89	15.24
$LSD_{(P\leq0.05)}$	0.7	42	4.2	0.13	0.84	1.84

**PE = Productivity efficiency, *NS = Non significant

the soil profile by almond tree (Table 2). But increasing trend of soil moisture retention at periodical intervals were recorded in full-moon water harvesting system which is 19.5% in April, 20.3% in May, 28.7% in June, 25.7% in July and 36.2% in August higher soil water content over control treatment. Different kind of mulches also influenced the soil water content during nut growth and kernel filling in almond. Plastic mulch retained 8.82% in April, 9.23% in May, 10.92% in June, 10.43% in July and 13.88% in August retained higher soil moisture content over control treatment. The highest soil water contents were recorded in full moon water harvesting system might be due to uniform availability and proper distribution of soil water around the active root zone of almond tree. Similar observations were recorded by Kumar *et al*. (9), while working on almond under rainfed conditions. The plastic mulch treated plants retained higher soil water might be due to that water evaporates from the soil surface under plastic mulch film condenses on lower surface of the film and fall back as droplets thus conserving the soil moisture for several days. Sharma and Kathiravan (14) have also reported higher moisture content under black polythene mulch. The

Table 2. Soil moisture status under water harvesting and mulching techniques in almond.

Treatment	April	May	June	July	August
Water harvesting					
Half-moon	14.9	14.5	13.1	12.8	12.3
Trench	13.9	13.3	12.2	11.8	11.5
Cup and Plate	13.6	13.1	12.4	12.0	11.4
Full-moon	15.3	14.8	13.9	13.2	12.8
No water harvesting (Control)	12.8	12.3	10.8	10.5	9.4
LSD (P ≤ 0.05)	1.2	1.1	1.3	1.2	1.4
Mulching					
Plastic	14.8	14.2	13.2	12.7	12.3
Organic	14.0	13.5	12.4	11.9	11.4
No mulch (Control)	13.6	13.0	11.9	11.5	10.8
LSD (P ≤ 0.05)	0.7	0.6	0.6	0.6	0.7
Interaction					
Half-moon (HM)	14.3	13.9	12.5	12.2	11.6
HM + organic mulch	15.1	14.6	13.2	12.7	12.3
HM + plastic mulch	15.4	15.0	13.7	13.5	13.1
Trench	13.5	12.8	11.5	11.3	11.0
Trench + organic mulch	13.8	13.2	11.8	11.5	11.2
Trench + plastic mulch	14.5	13.8	13.2	12.6	12.2
Cup & Plate (C&P)	13.2	12.7	11.6	11.3	10.8
C&P + organic mulch	13.5	12.9	12.3	11.9	11.1
C&P + plastic mulch	14.2	13.8	13.3	12.8	12.3
Full-moon (FM)	14.5	14.1	13.4	12.7	12.1
FM + organic mulch	15.0	14.5	13.9	13.2	12.8
FM + plastic mulch	16.4	15.8	14.5	13.9	13.4
Control	12.3	11.7	10.4	10.1	8.5
Control + organic mulch	12.8	12.4	10.9	10.5	9.4
Control + plastic mulch	13.3	12.8	11.3	10.9	10.4
$LSD_{(P\leq0.05)}$	1.5	1.6	1.5	1.4	1.7

interaction effect of water harvesting and mulching influenced the soil water status in almond. Highest soil moisture contents (16.4% in April, 15.8% May, 14.5% in June, 13.9% in July and 13.4% in August) were recorded in full moon water harvesting system + plastic mulching. The higher soil moisture content in full moon water harvesting system + plastic mulch might be due to more retention of soil moisture due to uniform and proper distribution of moisture in soil profile combined with plastic mulch. Findings are in accordance with Kumar *et al*. (11), and Srivastava *et al*. (15) in almond.

Pooled analysis of two years data on fertility status of soil showed that there was a significant change in soil fertility status under the different treatment (Table 3). At a soil depth 0-30 cm, the pH was almost acidic to neutral in all the water harvesting treatments. The soil organic carbon ranged from 0.50 to 0.66 under different treatments. Maximum soil organic carbon was recorded in full-moon water harvesting system which is 32% higher over control treatment. The nitrogen, phosphorus and potassium status of soils increased significantly under different water harvesting treatment which is 25.24% N, 26.41% P and 8.18% K higher over control treatment. Different kinds of mulch material also influenced the soil fertility status of almond. The soil pH (6.6), soil organic carbon (0.65%), nitrogen (495 kg/ha),

Table 3. Soil fertility status under water harvesting and mulching technique in almond.

Treatment	pH	Organic carbon (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Water harvesting					
Half-moon	6.5	0.60	491	24.8	299
Trench	6.2	0.59	448	23.8	297
Cup and Plate	6.2	0.56	442	23.2	293
Full-moon	6.5	0.66	516	26.3	304
No water harvesting (Control)	5.8	0.50	412	21.7	281
LSD ($P \leq 0.05$)	0.3	0.07	42	NS	12
Mulching					
Plastic	6.3	0.57	462	23.9	293
Organic	6.6	0.65	495	26.8	305
No mulch (Control)	5.9	0.52	427	21.2	286
LSD ($P \leq 0.05$)	0.3	0.06	33	NS	11
Interaction					
Half-moon (HM)	5.8	0.50	457	22.3	292
HM + organic mulch	7.0	0.69	520	28.1	307
HM + plastic mulch	6.7	0.60	495	24.1	298
Trench	5.6	0.54	429	21.3	290
Trench + organic mulch	6.6	0.62	464	26.6	305
Trench + plastic mulch	6.3	0.60	432	23.4	295
Cup & Plate (C&P)	5.8	0.51	395	21.2	283
C&P + organic mulch	6.6	0.65	486	25.3	304
C&P + plastic mulch	6.2	0.53	462	23.1	292
Full-moon (FM)	6.3	0.62	473	22.1	295
FM + organic mulch	6.8	0.74	545	30.6	316
FM + plastic mulch	6.4	0.63	529	26.1	302
Control	5.4	0.45	382	18.9	268
Control + organic mulch	6.2	0.55	461	23.5	295
Control + plastic mulch	5.9	0.50	392	22.8	279
LSD ($P \leq 0.05$)	0.5	0.12	54	6.2	23

phosphorus (26.8 kg/ha) and potassium (305 kg/ha) were recorded in organic mulch treated plots. The full-moon water harvesting system increase the soil fertility status might be due to proper and uniform distribution of soil water and nutrients around the tree at surface soil profile. As far as organic much is concerned, the maximum build-up of soil organic carbon, nitrogen, phosphorus and potassium might be due to decomposition of organic matter in to the soil. Mulching of orchard tree with organic materials offer various kind of benefits including soil improvement and higher water use efficiency (Forge *et al*., 6; Sanchez *et al*., 13; Yao *et al*., 18). The interaction effect of water harvesting and mulching system influenced the soil fertility status in almond. Highest soil organic carbon (0.74%), nitrogen (545 kg/ha), phosphorus (30.6 kg/ha) and potassium (316 kg/ha) were recorded in full moon water harvesting system + organic mulch in almond. This might be due to decomposition of organic mulch under ideal soil moisture conditions in almond under rainfed conditions.

Correlations drawn between different dependent and independent variables of plant growth and yield in almond reveal that parameters of growth and yield were interrelated (Table 4). Positive and significant

Table 4. Correlation coefficients among different growth and yield traits in almond.

Trait	Plant height (m)	TCSA (cm^2)	Canopy vol. (m^3)	Nut wt. (g)	Nut yield (kg/tree)	PE (g/cm^2 TCSA)
Height	1.00	0.894**	0.862**	0.564*	0.832**	0.437
TCSA		1.00	0.906**	0.609*	0.956**	0.535*
CV			1.00	0.651**	0.860**	NS
Nut wt				1.00	0.750**	0.777**
Nut yield					1.00	0.749**
PE						1.00

PE = Production efficiency

correlation was observed between plant height and TCSA, plant height and canopy volume, plant height and nut yield, plant height and productivity efficiency. Similar relationship was also recorded in soil fertility status of almond field. The positive and linear relationship was observed between pH and soil organic carbon, pH and nitrogen, pH and phosphorus and pH and potassium (Table 5).

Table 5. Correlation coefficient among different soil fertility status in almond.

Particulars	pH	SOC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
pH	1.00	0.899**	0.834**	0.875**	0.880**
SOC		1.00	0.865**	0.900**	0.929**
N			1.00	0.845**	0.907**
P				1.00	0.910**
K					1.00

*,** Correlation is significant at 0.05 and 0.01 level (2-tailed).

This study suggest that full-moon, half-moon and trench water harvesting technique along with plastic mulch/ organic mulch improve the almond yield by conserving more moisture during nut growth and kernel filling under rainfed conditions of north west Himalayan regions of India.

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