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Original Research Paper

Effect of mulching on soil moisture conservation, yield, soil properties and profitability in apple (*Malus domestica*) at cold desert region in North-Western Himalayas

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ABSTRACT

In cold desert region of lower Spiti valley in Lahaul & Spiti district of Himachal Pradesh, India, apple (*Malus domestica*) is grown under adverse climatic conditions like high diurnal temperature variation, negligible rainfall (<200 mm annually), high evaporation losses during summers, low water holding capacity and timely availability of scarce irrigation water. Considering the above factors, on-farm trials were conducted for three years in lower Spiti region consisting four treatments *viz*., T_1: famers' practice (no mulching), T_2: mulching with black polythene, T_3: mulching with grey polythene and T_4: mulching with dry grass. Results revealed that on an average, the dry grass mulching in apple basin resulted in 33.1 per cent higher moisture content as compared to farmer's practice where no mulch was applied. Highest apple fruit yield (30.8 t ha^{-1}) was recorded in T_4 followed by T_3 (28.2 t ha^{-1}) and T_2 (27.8 t ha^{-1}). Dry grass mulching improved the organic carbon content of soil over initial status. Among available nutrients, nitrogen content increased over initial status in polythene mulching treatments. Available phosphorus and potassium increased in all the treatments over initial status. Higher net returns and benefit to cost ratio were obtained with dry grass mulch followed by polythene mulching.

Keywords: Mulching, profitability, soil moisture, soil properties, yield

INTRODUCTION

Among various horticultural crops grown in Himachal Pradesh, apple (*Malus domestica*) holds the most dominant position by occupying about 49 per cent of the total agricultural area and 79 per cent of the whole fruit production of the state (Negi, 2020). As apple farming has been more beneficial and employment-generating in comparison to the other crops grown in the area, a more significant proportion of the farmers have shifted to apple cultivation from traditional farming practices (Gosain, 2007). However, in recent years, there has been a gradual decline in its productivity. Among various factors responsible for higher yield, supply of nutrient and availability of moisture play vital role in the production and quality of apple.

In cold desert region of lower Spiti valley in Lahaul & Spiti district of Himachal Pradesh where rainfall is negligible (< 200 mm annually) and there is high diurnal temperature variation apple is grown under irrigated conditions where glacial melts serve as source of irrigation during summer. High evaporation losses during summers, low water holding capacity and timely availability of scarce irrigation water makes the plants prone to water stress. Under such conditions, mulching may be practiced in crop cultivation which is highly effective in checking evaporation. There are several benefits of using mulch, including soil temperature modulation, enhanced fruit quality, enhancing soil quality, improved soil and water management by reduced evaporation and soil erosion, reduced fertilizer leaching and suppression of weed growth which leads to better plants growth and yield (Nautiyal et al., 2017; Dong et al., 2017). During the decay process of organic mulch, cellulose and hemicellulose are decomposed by microorganisms, releasing nutrient elements, such as nitrogen, phosphorus and potassium into the soil (Kahlon et al., 2013). Considering the above factors, the present study was undertaken with an objective to study the effect of mulching on soil moisture conservation, yield, soil properties and profitability in apple at cold desert region in North-Western Himalayas.

MATERIALS AND METHODS

The present on-farm trial was conducted for three years at the research farm of Krishi Vigyan Kendra of Dr. Yashwant Singh Parmar University of Horticulture & Forestry, Nauni, at Tabo (32.0937° N, 78.3829° E, 3243 m above mean sea level) district Lahaul & Spiti, Himachal Pradesh, India during 2019 to 2021 in apple. Agro-climatically, the site lies in the Spiti valley representing true arid cold temperate climate of North–West Himalayas.

The experiment consisted of four treatments *viz*., T_1: famers' practice (no mulching), T_2: mulching with black polythene, T_3: mulching with grey polythene and T_4: mulching with dry grass in apple basins, laid out in randomized block design with three replications in apple trees cv. Royal Delicious aging 32 to 33 years spaced at 4 x 3 meter. The polythene sheet (black and grey) of 50 micron was used. Dry grass (3 kg per tree basin) was laid in tree basins upto 15 cm thickness. Crop was fully irrigated following flood irrigation method. The recommended package of practices as per University of Horticulture & Forestry, Nauni was followed during the cropping season. The recommended dose of N, P and K @ 700:350:700 gram per tree, respectively, was applied to all the treatments.

Soil moisture was recorded at 0-0.15 m depth on 15 days interval during the cropping season (April to October) using the gravimetric method (Black, 1965). The soil samples after harvest of apple fruit were collected from tree basins and then analyzed for soil pH (Jackson, 1973), organic carbon (Walkley & Black, 1934), available N (Subbiah & Asija, 1956), available P (Olsen et al., 1954) and available K (Black, 1965).

The economic analysis of the experiment was carried out by considering the prevailing prices of inputs used by analysis of variance (ANOVA) appropriate to the experimental design *i.e.* randomized block design (Gomez & Gomez, 1984). In order to work out the profitability of above system following equations were used:

$$\text{Gross returns } (\text{Rs.ha}^{-1}) = \text{Apple fruit yield } (\text{Kg ha}^{-1}) \text{ x Price of apple fruit } (\text{Rs kg}^{-1})$$

$$\text{Net returns } (\text{Rs.ha}^{-1}) = \text{Gross returns } (\text{Rs ha}^{-1}) - \text{ Cost of cultivation apple } (\text{Rs ha}^{-1})$$

$$\text{Benefit cost ratio} = \frac{\text{Gross returns } (\text{Rs ha}^{-1})}{\text{Cost of cultivation of apple } (\text{Rs ha}^{-1})}$$

The significance of the difference between means was evaluated at 5% level of probability using Duncan's multiple range test (Duncan, 1955) using Web Agri Online Package (WASP) online data analysis portal, CCARI (https://ccari.icar.gov.in/wasp2.0/index.php).

RESULTS AND DISCUSSION

Soil moisture

Mulching with dry grass and polythene sheet significantly affected the moisture retention in soil. Data presented in Table 1 showed average soil moisture during cropping season was significantly highest (23.0%) in T_4 where mulching with dry grass was applied followed by 20.2 per cent in T_3 (mulching with grey polythene) and 20.0 per cent in T_2 (mulching with black polythene) which were statistically at par with each other, however, farmers' practice (T_1) recorded lowest soil moisture where no mulching was done. Mulching increased the soil water content presumably as a result of reduced evaporation (Cheng et al., 2015). Furthermore, the collection and infiltration pathway was likely to have led to more efficient delivery of rainwater to the roots (Xiaomin et al., 2017). The significantly lower soil moisture in control plots (farmers practice) might be attributed to the loss of water through evaporation. Higher soil

Table 1 : Effect of different treatments on average soil moisture during cropping season

Treatment	Average soil moisture (%)			
	2019	2020	2021	Pooled
T_1: Famers' practice (no mulching)	15.8b*	18.3c	17.7c	17.3c
T_2: Mulching with black polythene	18.7a	20.5b	20.7b	20.0b
T_3: Mulching with grey polythene	19.0a	20.3b	21.4ab	20.2b
T_4: Mulching with dry grass	21.4a	24.8a	22.8a	23.0a
$LSD_{0.05}$	2.80	1.98	2.05	2.15

*values in a column with the same lowercase letter are not significantly different at 0.05 level

Table 2 : Effect of different treatments on apple fruit yield

Treatment	Apple fruit yield (t ha^{-1})			
	2019	2020	2021	Pooled
T_1: Famers' practice (no mulching)	33.3c*	16.7c	25.7c	25.2c
T_2: Mulching with black polythene	36.1bc	19.4ab	27.8b	27.8b
T_3: Mulching with grey polythene	37.5b	18.6b	28.5b	28.2b
T_4: Mulching with dry grass	41.7a	20.6a	30.3a	30.8a
$LSD_{0.05}$	3.70	1.68	1.74	1.79

*values in a column with the same lowercase letter are not significantly different at 0.05 level

moisture was observed in dry grass mulch treatment over polythene mulching either black or grey polythene which may be due to flood irrigation system where tree basins were flooded with water for few minutes resulting into less water percolation through polythene sheets. Similar results were reported by Mkhabela et al. (2019).

Fruit yield

Yearly and pooled data of three years (Table 2) revealed that highest fruit yield was recorded in T_4 where mulching with dry grass was done and it was significantly superior to rest of the treatments followed by T_3 (mulching with grey polythene) and T_2 (mulching with black polythene) which were statistically at par with each other. Farmers' practice, where no mulching was done recorded lowest yield. The higher apple fruit yield under polythene and organic mulching might be attributed to better availability of moisture during the dry period, higher nutrient availability and lesser weed infestation, whereas in no mulch treatment less soil moisture retention and nutrient losses resulted in low fruit yield (Nautiyal et al., 2017; Kour, 2020). Also, organic mulches act as a nutrient reserve to the soil which upon mineralization adds up to the soil fertility in turn resulting in higher crop yields (Kalita et al., 2022).

Soil properties

On the perusal of data in Table 3 revealed that mulching has no significant effect on pH of the soil. Soil organic carbon was significantly affected by different mulching treatments (Table 3). Data revealed that during the first year (2019) mulching has no significant effect on soil organic carbon. During second year (2020) and third year (2021) of experiment highest organic carbon content of 12.4 & 13.0 g kg^{-1}, respectively, was observed in T_4 where dry grass mulch was applied and it was significantly superior to rest of the treatments. Overall, the soil organic carbon content increased in all the treatments over initial content after completion of experiment in 2021. The soil organic carbon under dry grass mulch was significantly higher than that of the polythene mulch and control, mainly because the soil organic C was enhanced due to accumulation of carbonaceous material to the soil upon decomposition of dry grass (Guan et al., 2014; Kalita et al., 2022).

Table 3 : Effect of different treatments on soil pH and organic carbon content in soil after apple harvest

Treatment	pH			Organic carbon (g kg^{-1})		
	2019	2020	2021	2019	2020	2021
T_1- Famers' practice (no mulching)	7.53	7.52	7.50	11.5	11.7b*	11.8b
T_2- Mulching with black polythene	7.52	7.51	7.48	11.6	11.8b	12.1b
T_3- Mulching with grey polythene	7.53	7.50	7.49	11.6	11.7b	12.0b
T_4- Mulching with dry grass	7.52	7.49	7.46	11.8	12.4a	13.0a
$LSD_{0.05}$	NS	NS	NS	NS	0.50	0.40
Initial status (2019)	7.53				11.50	

*values in a column with the same lowercase letter are not significantly different at 0.05 level

Effect of different treatments on available nitrogen, phosphorus and potassium content in soil is presented in Table 4. During the first year, there was no significant effect of mulching on available nitrogen, phosphorus and potassium content of soil. Highest value of available nitrogen was recorded in T_2 where black polythene mulch was applied followed by T_3 (mulching with grey polythene) and T_4 (mulching with dry grass) in 2020 and 2021. Treatments T_2 and T_3 were statistically at par with each other and significantly superior to rest of the treatments during 2020. During 2021, treatments T_2, T_3 and T_4 were statically at par with each other. Lowest content of nitrogen in soil was observed in treatment T_1 where no mulch was applied during all the experimental years. Highest available phosphorus content of 108.7 and 114.3 kg ha^{-1} was recorded in treatment T_1 (famers' practice) during 2020 and 2021, respectively, and it was significantly superior to rest of the treatments (Table 4). All the treatments with mulching practice were statistically at par with each other and lowest value of available phosphorus (104.0 & 107.7 kg ha^{-1}) content was observed in treatment T_4 (mulching with dry grass) during 2020 and 2021, respectively. The available phosphorus content at the end of experiment increased in all the treatments over initial status at the start of experiment. Available potassium content in soil ranged from 365.3 to 370.0 kg ha^{-1} in treatments T_1 (Famers' practice) and T_2 (mulching with black polythene), respectively, during 2020 (Table 4). During 2021, available potassium content ranged from 366.3 kg ha^{-1} in treatment T_1 (famers' practice) to 374.7 kg ha^{-1} in T_3 (mulching with grey polythene) and it increased in all the treatments over initial status.

The favourable changes in the available nutrients (nitrogen, phosphorus and potassium) due to mulching with organic material (dry grass) can be attributed to the increased biological activities in the soil, thus, resulting in the mineralization of organic matter leading to increased nutrient content (Kalita et al., 2022). Higher nitrogen and potassium content in mulching treatments over control are likely to be the result of reduced water infiltration and flow beneath the mulches, therefore reduced leaching losses (Xiaomin et al., 2017). Among mulching treatments lower available nitrogen and potassium content in dry grass mulch as compared to polythene mulching may be due to higher yield in dry grass mulching treatment which may have resulted into higher nutrient uptake from soil. Muttaleb (2018) demonstrated that available P was recorded significantly highest in black plastic in the first year which can be due to improved hydrothermal regimes, more root system proliferation and effective management of weeds that have reduced P mining. More increase of P content in control over other treatments was probably because of lower yield in this treatment resulting in lesser nutrient uptake from soil. From previous studies (Nwosisi et al., 2019; Muttaleb, 2018; Jourgholami et al., 2020) it is evident that the level of soil potassium in mulching treatments increased compared to bare soil which may be attributed to increased removal of competing weeds, enhanced hydrothermal regime and higher root biomass releases of potassium to the soil.

Profitability

The cost of different components per hectare for calculating profitability in apple is presented in

Table 4 : Effect of different treatments on available nitrogen, phosphorus and potassium in soil after apple harvest

Treatment	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	2019	2020	2021	2019	2020	2021	2019	2020	2021
T_1	164.7	167.2b*	164.3b	103.3	108.7a	114.3a	361.4	365.3c	366.3c
T_2	168.3	171.5a	174.3a	101.2	104.6b	110.3b	366.3	370.0a	372.7ab
T_3	167.4	170.8a	172.3a	101.0	105.7b	109.7b	364.5	368.2ab	374.7a
T_4	166.1	167.4b	168.3ab	100.0	104.0b	107.7b	363.0	366.7bc	369.7bc
$LSD_{0.05}$	NS	3.05	6.63	NS	2.58	3.84	NS	2.79	3.83
Initial status (2019)		172.5			98.9			362.4	

*values in a column with the same lowercase letter are not significantly different at the 0.05 level

Table 5 : Details of cost of different components per hectare for calculating profitability in apple

Particular	Quantity	Unit	Value (Rs.)		
			2019	2020	2021
Labour cost	500	Man days	190000	210000	230000
Farmyard manure	300	Quintals	75000	75000	90000
Fertilizers (urea, single super phosphate, muriate of potash)	3749	Kg	40000	40000	40000
Plant protection (insecticides & fungicides)	8-10	Litre	45000	45000	50000
Mulching sheet	3600	Meter	25000	25000	25000
Dry grass	2499	Kg	20000	20000	20000

Other variable costs (interest on working capital, managerial cost, risk margin) and fixed cost were also calculated treatment wise while computing final cost of cultivation

Table 6 : Effect of different treatments on cost of cultivation and gross returns in apple crop

Treatment	Cost of cultivation (Rs. ha^{-1})				Gross returns (Rs. ha^{-1})			
	2019	2020	2021	Pooled	2019	2020	2021	Pooled
T_1	555738c*	571617c	643069c	590141b	1999200c	1249500c	2052512c	1767071c
T_2	594258a	626015a	689528a	636600a	2164134bc	1455668ab	2219112b	1946305b
T_3	594258a	626015a	689528a	636600a	2249100b	1393193b	2279088ab	1973794b
T_4	586554b	618311b	681824b	628896a	2499000a	1543133a	2419032a	2153722a
$LSD_{0.05}$	634.7	649.7	1136.2	7930.9	220992.2	141218.1	143329.2	115147.4

values in a column with the same lowercase letter are not significantly different at 0.05 level

Table 7 : Effect of different treatments on net returns and B:C ratio in apple

Treatment	Net returns (Rs. ha^{-1})				B : C ratio			
	2019	2020	2021	Pooled	2019	2020	2021	Pooled
T_1	1443462b	677883b	1409443c	1176929c	3.60b	2.19	3.19b	2.99b
T_2	1569876b	829653b	1529584cb	1309704b	3.64b	2.33	3.22b	3.06b
T_3	1654842b	767178b	1589560b	1337193b	3.78b	2.23	3.31b	3.11b
T_4	1912446a	924822a	1737208a	1524825a	4.26a	2.50	3.55a	3.43a
$LSD_{0.05}$	220992.2	141225.2	143321.6	118481.7	0.372	NS	0.212	0.208

values in a column with the same lowercase letter are not significantly different at 0.05 level

Table 5. It is evident that mulching affected the profitability in apple crop over farmers' practice (Table 6 & 7). Highest cost of cultivation per hectare (Rs. 636600) was recorded in treatments T_2 (mulching with black polythene) and T_3 (mulching with grey polythene) followed by treatments T_4 (mulching with dry grass) (Table 6). From the pooled data for three years, it is evident that significantly highest gross return of Rs. 2153722 ha^{-1} (Table 6) and net return of Rs. 1524825 ha^{-1} (Table 7) was recoded in dry grass mulch treatment (T_4). Treatments with polythene mulching (T_3 and T_2) were statistically at par with each other. Farmers' practice recorded lowest gross and net returns. Mulching with dry grass treatment (T_4) recorded significantly highest B:C ratio of 3.43 followed by T_3 (mulching with grey polythene) and T_2 (mulching with black polythene) (Table 7). Lowest B:C ratio of 2.99 was observed in

T_4 (mulching with dry grass). The highest economic returns and B:C ratio with mulching treatments over farmers practice where no mulching was done were due to higher fruit yields in these treatments which fetch higher market prices. These results are in conformity with the findings of Ghosh & Bera (2015), Nautiyal et al. (2017) and Kour (2020).

CONCLUSION

Mulching in apple basins has significant effect on soil moisture conservation. Dry grass mulch was most effective, followed by plastic mulching in conserving soil moisture. Mulching also increased apple fruit yield significantly by checking evaporation and suppression of weed growth. Organic carbon was significantly improved by use of dry grass mulch. The use of mulching either dry grass or polythene mulch maintained high profitability and recorded high benefit: cost ratio due to high fruit yield. Thus, for conserving soil moisture, high productivity of apple and getting maximum returns dry grass mulching may be recommended for cold desert regions.

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