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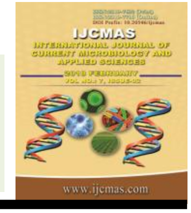

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Effect of Orchard Floor Management Practices on Nutrient Status in Apple cv. Royal Delicious

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A B S T R A C T

The present investigation entitled "Effect of orchard floor management practices on nutrient status in apple" was carried out on a 19-year-old trees in aprivate apple orchard at village Arabal, District Srinagar during the years 2015 and 2016. Forty-five trees of uniform growth and vigour were selected for experimentation. The effects of fifteen orchard floor management practices were studied on apple cv. Royal Delicious. The treatments were replicated thrice in Factorial Randomized Complete Block Design. The results revealed that nutrient content of fruits as well as leaves were appreciably influenced by different treatments and highest level of both macro and micronutrients was recorded under paddy straw mulch followed by glyphosate. Maximum soil moisture was recorded under paddy straw mulch followed by glyphosate and maximum soil temperature was recorded under bicolour polythene mulch. With respect Benefit: cost ratio was highest with paddy straw mulch followed by glyphosate which was closely followed by cowpea (green manure). It can be concluded from the study that application of paddy straw mulch followed by glyphosate resulted in acceptable level of weed control with improved nutrient status apple fruit and leaves as well as good soil health hence can be recommended in apple orchards.

Introduction

Apple (*Malus*x *domestica* Borkh.) is produced commercially in most countries in temperate regions of the world and high altitude in some tropical areas. In India, apple is the most important temperate fruit crop of the north western Himalayan region especially Jammu and Kashmir, Himachal Pradesh and Uttarakhand due to its greater potential of favourable climatic conditions. Its primary centre of origin is south-western Asia, in the Caucasus region near Gilan in Turkestan and domesticated by Greeks and Romans and few centuries BC in Middle-East and South-eastern Europe as a result of their travel and invasions. In Jammu and Kashmir, apple has been grown as early as 2000 BC. M. Ermens, formerly Head Gardeners of Public Works in Paris, who came to Kashmir during 1865 brought with him a number of fruit plants which he believed would thrive in Kashmir together with implementations of starting in experimental agriculture farm. These fruit trees were planted in ChashmaShahi, near Srinagar, J&K, in 1875 (Singh and Pal, 2013).

In India, apple occupies an area of 2,77,000 hectares with an annual production of 22,42,000 metric tonnes and productivity of 8.0 $MTha^{-1}$ (Anonymous, 2016). The total apple growing area in Jammu and Kashmir is 1,62,971 hectares with production of 17,26,834 metric tonnes and productivity of 10.60 MT ha^{-1} (Anonymous, 2017) in which the contribution of Kashmir region is 97.78 per cent of total production from 88.87 per cent of total area.

The productivity of apple in India is very low as compared to developed countries like China, Italy, Spain, USA etc. The low average yields are primarily due to improper orchard management practices. Apple orchards are generally, infested with various types of annual, biennial and perennial weeds which compete with the fruit plants for nutrients, and moisture (Majek *et al.,* 1993) and thereby directly reducing the productivity of fruit trees. Weeds also provide shelter to various pathogens by becoming an alternate orcollateral host of invaded crops by a number of fungal, bacterial and viral diseases. It has been reported that about 36-42 per cent losses may occur due to inadequate management of weeds in apple (El-Metwally and Hafez, 2007).

Although weed control in orchards is usually accomplished by various methods *viz*., manual, mechanical and chemical means, yet the conventional hand weeding is the most common method. Nevertheless, manual weed control is not only laborious but is also highly expensive. Thus of late, manual and mechanical weed control methods are gradually being replaced by other alternatives such as the use of mulches and herbicides as these are easier, cheaper and less time consuming. The ground management systems studies have shown substantially different effects on soil chemical, biological, and physical properties (Laurent *et al.,* 2008) as well as differential effects on root-zone microbial communities and tree root development (Yao *et al.,* 2005). Mulch assists in keeping the soil free from vegetation, conserves soil moisture, keeps temperature constant, increases organic matter through decomposition, releases nutrients to the soil, and improves the soil environment by enhancing microbial activity (Merwin *et al.,* 1994; Marsh *et al.,* 1996; Sanchez *et al.,* 2003). Among the types of mulch that farmers can use are living mulches, polyethylene and geotextile mulches, and dead organic mulches such as straw, bark and loose materials. Living mulch is defined as a mixed cropping system, in which one partner acts chiefly as a live soil cover for a considerable part of the life cycle of the main crop (Liedgens *et al.,* 2004). These kinds of mulches are well suited to use in fruit crops (Varadi *et al.,* 1989 and Ingels *et al.,* 1994) but even in established orchards living mulch growing along the planted row may depress crop growth (Domange, 1993 and Marks, 1993).

Clean cultivation is yet one of the common orchard floor management practice in plant basin during the growing season and leave therefore without any cultivation which increases soil erosion and cause moisture loss. Continuous, clean cultivation of the orchard floor aerates the soil and eliminates competition, but loss of organic matter, breakdown of soil structure, increased potential for erosion, and destruction of shallow tree roots will occur (Skroch and Shribbs, 1986; Hogue and Neilsen, 1987). Use of herbicides (pre and post emergence) reduce soil structure, fertility, and orchard productivity compared with “living” and straw-hay mulches (Merwin *et al.,* 1994).Conventional practices for weed management in orchards usually include annual application of residual herbicides in the inter-rows, as well as repeated use of glyphosate in the tree rows. Herbicides are considered excellent tools within a weed management strategy in many cropping systems; however, misuse of this technology can lead to problems such as residual carry-over, cropping restrictions, groundwater contamination and the development of genetically-based herbicide resistance (Booth *et al.,* 2003). Various herbicides such as atrazine, oxyflourfen, pendimethalin, simazine, glyphosate etc. have been reported to be very effective in controlling the weeds in different fruit orchards. The combination of mulches and herbicides holds promise as a method for long term control of weeds and reduce labor costs, concomitantly.

Weed management strategies for field production requires extensive knowledge of weed biology, herbicide application and calibration procedures, herbicide efficacy against target weeds and correct timing of application (Altland *et al.,* 2003), the most common reasons for ineffectiveness of herbicides are improper timing, improper rates, and wrong selection of herbicide for the prevalent weed species. The use of green manure crops particularly legumes and cover crops such as white clover as soil management practices has also been found very effective in increasing the yield of fruit trees.

In apple orchards of Kashmir valley, the common floor management practice is to perform hoeing during March and May and leave thereafter without any cultivation. In the valley, winter and spring rains are followed by drought in summer months, so it becomes necessary to conserve available soil moisture of winter and spring season for growth and development during summer months. However, information on the use of different orchard floor management practices in apple cultivation is lacking in Jammu and Kashmir state. Therefore, present study was carried out to standardize best floor management practices for adoption in the agro-climatic condition of Jammu and Kashmir with the objectives of the effect of orchard floor management practices on soil health and nutrient status.

Materials and Methods

The present investigations entitled “Effect of orchard floor management practices on apple production” was carried out in a private apple orchard at village Arabal, District Srinagar, Jammu and Kashmir during the years 2015 and 2016. The details of materials used and the methods adopted during the course of investigation are given below.

Geographical location of experimental site

Kashmir is characterized by temperate climate. Winters are severe; extending from December to March and the temperatures often go below freezing point during this period. The valley is mostly covered with snow during the winter months. The altitude of Kashmir valley ranges between 1500-2500 meters above mean sea level. The mean maximum temperatures of the valley are 24.5^{o}C and mean minimum temperature is 1.2^{o}C with a relative humidity of 43.90 per cent. The normal precipitation is 650 mm mostly received during March-May. The experimental orchard is situated at an elevation of 1611 m above mean sea level and lies at 34^{o} 09’ N latitude and 74^{o} 52’ E longitude. During the experimentation period, the maximum average temperature was 20^{o}C and 23^{o}C and minimum mean temperature was 6^{o}C and 8^{o}C during 2015 and 2016, respectively. The total precipitation of 839 mm and 427 mm was received during entire experimental periods during 2015 and 2016.

Materials

Nineteen-years-old bearing trees of apple cv. 'Royal Delicious' of uniform size and vigour receiving of uniform cultural practices were selected for the experimentation. Treatments and replications were randomly assigned with a single plot size.

Experimental details

The experiment was laid out on 19-years-old apple trees of cv. Royal Delicious spaced at 5 m × 5 m in randomized complete block design with fifteen treatments. Each treatment was replicated thrice with respect to orchard floor management practices adopted during 2015 and 2016, which are given here as under:

Field preparations

Basins of experimental trees were properly levelled before conducting the experiment.

Method and time of application

Mulches

The application of mulches and sowing of white clover and cowpea were done during last week of March. Cowpea was incorporated in the soil seven weeks after sowing.

Herbicides

The commercial formulations of oxyflourfen, atrazine, pendimethalin and glyphosate herbicides were applied as directed spray with high volume of power Knapsack sprayer. Oxyflourfen, atrazine and pendimethalin were applied as pre-emergence herbicides during the last week of March, whereas, glyphosate was applied as post-emergence herbicide during last week of June. Weeding in zero weeds was done at frequent intervals while the weeding in clean cultivation was done at 30 days intervals throughout the course of studies.

Active ingredient (a.i.)

It is a part of chemical formulation which is directly responsible for herbicidal effect.

Thus, the commercial herbicide is made up of two parts i.e. the effective part and the inert part. Since all the recommendations are made on the basis of a.i., herbicides quantity was calculated with following formula:

Weight of herbicide required
(kg ha^{-1} or lt ha^{-1}) =

$$\frac{\text{Dose of chemical required}}{\text{Active Ingredient\% in chemical product}} \times 100$$

Fruit and leaf nutrient status

Fruit samples (8 numbers in each treatment) were collected at harvest time, while leaf samples (40-50) were collected on 15 July 2015 and 2016. Both fruit and leaf samples were first washed with tap water followed by labolene wash and finally by distilled water to be dried on newspapers overnight and then transferred to oven for drying till constant weight at 60 ^oC.

Then the samples were crushed in stainless steel blender and stored in polythene bags for analysis. Leaf samples from the experimental trees were collected from the mid-point of the current season's terminal growth during mid-July. After collection of leaf samples, the fresh leaves were thoroughly washed first with tap water, and then dipped in 0.1N HCl and then in distilled water. After air drying samples were dried in an oven at 60 ^oC till constant weight was obtained (Chapman, 1964). The dried leaves were ground in steel Willey mill and then kept in butter bags for chemical analysis. The procedures adopted for analysis of different nutrients are given below:

Estimation of total nitrogen

Total nitrogen was determined by Micro-kjeldahl method by involving digestion, distillation and titration of fruit and leaf samples as described by Jackson (1973).

Digestion and preparation of fruit and leaf samples to determine other nutrients except nitrogen

To estimate nutrient elements other than nitrogen *viz*. phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, zinc and copper, fruit and leaf samples were digested separately in diacid mixture of nitric acid and perchloric acid.

The digested material was diluted in double distilled water and filtered in 100ml volumetric flask. In order to ensure complete transfer of digested material, about six washings were given with double distilled water and final volume was made to 100 ml.

Phosphorus

Phosphorus content was estimated from digested samples by the Vanadomolybdate colour reaction method with the help of the Spectrophotometer (Jackson, 1973).

Potassium

Potassium content was determined using flame photometer (Jackson, 1973).

Calcium and magnesium

Calcium and magnesium contents were determined by versenate titration method (Jackson, 1973).

Micronutrient cations

The available (DTPA-extractable) micronutrients (Zn, Cu, Fe and Mn) contents of fruit and leaves were determined in Atomic absorption spectrophotometry, as suggested by Lindsay and Norvell (1978).

Soil parameters

Soil temperature (^{o}C) at 0-15 cm

Soil temperature (^{o}C) of each experimental treatment was recorded at depth of 0-15 cm with the help of digital soil thermometer. First reading was taken on 1stApril and subsequent readings at 15 days' intervals. Final reading was recorded at the time of harvesting.

Soil moisture (%) at 0-15 cm

Soil moisture was recorded at 0-15 cm depth by oven dry method and expressed in per cent (%).

Results and Discussion

Effect of orchard floor management practices on fruit macronutrient status

The data pertaining to fruit macronutrients (N, P, K, Ca and Mg) are given in Table 1.Significantly highest fruit nitrogen content (0.450 and 0.457%) was recorded under paddy straw mulch followed by glyphosate, which was statistically at par with paddy straw mulch and cowpea. The phosphorous content in apple fruit (0.109 and 0.111%) was maximum under paddy straw mulch followed by glyphosate, which was statistically at par with paddy straw mulch and cowpea *viz*. (0.108 and 0.109%) and (0.107 and 0.109%, respectively. Minimum phosphorous content (0.103 and 0.101%) was obtained in control. The potassium content of apple fruit was significantly affected with different treatments. Maximum total potassium content (0.712 and 0.716%) was recorded under paddy straw mulch followed by glyphosate and minimum phosphorous content (0.694 and 0.693%) was observed with unweeded control. Markedly higher fruit calcium (0.173 and 0.179%) and magnesium (0.017 and 0.019%) content was recorded under paddy straw mulch followed by glyphosate. However minimum fruit calcium and magnesium content (0.124 and 0.122%) and (0.010%) was observed under unweeded control.

The use of mulch materials and herbicides reduced the competition for nutrient and moisture thus resulting in more availability of water supply and ultimately more uptake of nutrient by the tree (Raese, 1990). Present results are also in conformation with the finding of Copper(1973) who reported that mulches provide many benefit to crop production through moisture conservation, enhanced soil microbial activities and improved chemical and physical properties of the soil. Similarly, Lakatos *et al.,* (2001) reported that microbial activities play a significant part in the availability and transformation of minerals like calcium, magnesium, and will therefore influence plant nutrition availability, and also announced that mulching significantly reduced the incidence of bitter pit due to improved calcium nutrition. Szewczuk and Gudarowska (2004) also found that mulching with both organic and inorganic material, increased fruit Ca concentration.

Effect of orchard floor management practices on leaf macronutrient and micronutrient status

Leaf macronutrients

Leaf nitrogen

The data pertaining to leaf macronutrients (N, P, K, Ca and Mg) and micronutrients (Zn, Cu, Fe and Mn) status of Royal Delicious apple as influenced by various orchard floor management practices during 2015 and 2016 are presented in Tables 2 and 3, respectively. In the present studies, leaf nitrogen content (2.419 and 2.427%) was maximum under paddy straw mulch followed by glyphosate. However minimum leaf nitrogen content was recorded under control (2.347 and 2.345%). These results are in accordance with the findings of Meena *et al.*, (2015) and Negi (2015) who reported significantly higher leaf nitrogen with grass mulch followed by glyphosate. Similar results were also reported by Shylla *et al.,* (1999) in plum who reported that leaf nutrients were significantly influenced by different orchard floor management practices. The glyphosate herbicide treatment significantly increased the leaf nitrogen content, closely followed by green manuring. The use of herbicides and mulch material reduced the competition for nutrients and moisture, resulting in greater availability of nutrients. Similar results were also reported by Neilson *et al.,* (1982).

The increase in leaf N may be due to higher temperature, moisture and organic carbon content which increased the biological activities under grass mulching possibly resulted in fast mineralization and nitrogen availability and high translocation of nitrogen from soil to the leaves (Negi, 2015 and Schutt *et al.,* 2014).

Bhat and Khokhar (2009) and Sas-Paszt *et al.,* (2014) also reported that grass mulch significantly increased leaf N content. Mulches from different organic materials with variable properties have different effects on the soil food web, as well as the mineralization of the elements such as N and P as reported by Forge *et al.,* (2003). The results of the study are also in close conformity with the earlier findings of Das *et al.,* (2016) in litchi.

Leaf phosphorous and potassium

Leaf phosphorous and potassium contents showed appreciable variation among different treatments. Maximum leaf phosphorous content (0.300 and 0.303%) and potassium content (1.803 and 1.823%) was recorded with paddy straw mulch followed by glyphosate, which was statistically at par with paddy straw mulch and cowpea. However minimum phosphorous and potassium contents were observed with unweeded control. The results are in conformity with the finding of Meena (2013) and Negi (2015) who reported maximum leaf phosphorous and potassium contents under pendimethalin followed by glyphosate due to reduced weed competition. These findings are also in agreement with Shylla and Chauhan (2004) who observed highest nutrients in plum trees intercropped with French bean. Hoagland *et al.,* (2008) also noticed highest leaf phosphorus contents in cherry trees intercropped with red clover which might be due to the fact that red clover or other legumes improve soil physical conditions thereby facilitates more nutrient uptake.

Leaf calcium and magnesium

Highest leaf calcium (1.752 and 1.785%) and magnesium (0.312 and 0.318%) contents were recorded in apple trees mulched with paddy straw mulch followed by glyphosate and was statistically at par with paddy straw mulch and cowpea and lowest calcium and magnesium were recorded in unweeded control. This finding is in consonance with the observation of Kumar (1984) who reported higher Ca and Mg contents of leaves in mulching plus herbicides treated plum trees due to better availability of moisture in the soil. The results are also in conformity with Hoagland *et al.,* (2008) who noticed mobilization of calcium and magnesium by legume covers in cherry rhizosphere. Similar findings were also reported by Shylla and Chauhan (2004) in plum and Wani *et al.,* (2013) in cherry, who observed highest nutrients in trees intercropped with leguminous crops.

Leaf micronutrients

Leaf zinc

Significantly higher leaf zinc content (51.58 and 52.07 ppm) was obtained with paddy straw mulch followed by glyphosate (T_{10}), which was statistically at par with paddy straw mulch (51.28 and 52.02 ppm) and cowpea(48.96 and 49.95 ppm). Unweeded control had minimum leaf zinc content (40.84 and 40.80 ppm) which was at par with atrazine and pendimethalin during 2015 and 2016.

Leaf iron

Perusal of the data presented in Table 3 revealed that different weed control treatments exerted a significant influence on leaf iron content. During 2015 and 2016 treatment paddy straw mulch followed by glyphosate (T_{10}) recorded highest leaf iron content (222.9 and 223.4 ppm) which was statistically at par with paddy straw mulch and cowpea. However minimum leaf iron content (215.0 and 215.4 ppm) was recorded in unweeded control during both the years of study.

Leaf copper

Different orchard floor management practices significantly influence leaf copper content during both the years of study (Table 3). Maximum leaf copper content (14.05 and 14.19 ppm) was recorded with paddy straw mulch followed by glyphosate (T_{10}), which was statistically at par with paddy straw mulch, cowpea and bicolour polythene mulch. The unweeded control recorded minimum leaf copper content (11.73 and 11.71 ppm) during both the years of study.

Leaf manganese

All the orchard floor management practices showed significant effect on leaf manganese content during 2015 and 2016 (Table 3). Paddy straw mulch followed by glyphosate (T_{10}) recorded highest value of leaf manganese content (104.2 and 105.5 ppm) which was statistically at par with the paddy straw mulch (103.7 and 105.0 ppm), cowpea (103.3 and 105.0ppm) during 2015 and oxyflourfene followed by glyphosate (103.7 ppm) during 2016. Unweeded control registered lowest leaf manganese content to the tune of 98.9 and 99.0 ppm during both the years of study.

Leaf Zn, Fe, Cu and Mn contents were significantly increased with different orchard floor management practices. Maximum micronutrients content of leaves was recorded under paddy straw mulch followed by glyphosate, which was statistically at par with treatments paddy straw mulch and cowpea. All the micronutrient content in leaves increased marginally over the year. These nutrients were found in normal range as established by Shear and Faust (1980). Mulches registered highest value of foliar Cu, Fe and Mn content and were lowest in control. The use of mulch materials and herbicides reduced the competition for nutrients and moisture thus resulting in more availability of moisture and ultimately more uptake of nutrient by the tree. The integrated use of mulch materials with herbicides has additional benefit of checking moisture loss through evaporation from the soil. Mulches also add organic matter to the soil thus increasing the nutrient status in soil solution. Similar responses have been reported by Shylla *et al.*, (1999). The observations are also in close conformity with the finding of Negi (2015) who reported maximum micro nutrient contents under different mulch treatments. Yin *et al.*, (2007) reported increased foliar nutrient status with polypropylene cover relative to no cover during the 5-year trial in cherry while Merwin*et al.*, (1995) with hay in apple and Wheeler *et al.*, (1999) with grass clippings in pecan trees. There was a significant effect of ground covers on leaf Mn concentration, because soil Mn availability increases with decreasing pH (Neilsen and Neilsen, 2003 and Houge *et al.,* 2010). Sas-Paszt *et al.,* (2014) also reported increased leaf Cu, Fe, and Mn with straw mulches.

The results obtained in present investigation are also in line with the finding of Bhat and Khokhar (2009) who reported that grass mulch, though at par with pine needles mulch, grass mulch followed by atrazine and grass mulch followed by oxyfluorfen treatments, significantly increased the leaf Fe, Cu, Zn and B contents over other treatments, inducing hand weeding control which recorded minimum leaf nutrient status but the effect on Mn was found to be non-significant.

Effect of orchard floor management practices on soil moisture and temperature

Observations pertaining to soil moisture and soil temperature following the use of different orchard floor management practices were studied during 2015 and 2016.

Soil moisture

Different orchard floor management practices had a significant influence on per cent soil moisture content at 0-15 cm depth during both the years of study. Data presented in Table 4 revealed that during 2015 treatment paddy straw mulch followed by glyphosate (T_{10}) recorded highest soil moisture content (26.16%) which was statistically at par with paddy straw mulch (26.12%) followed by bicolour polythene mulch (25.19%). Among different days of observation, the maximum soil moisture content (26.24%) was recorded on 105 days after treatment.

Table.1 Effect of orchard floor management practices on fruit macronutrient status of apple cv. Royal Delicious during 2015 and 2016

Treatments		N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
		2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
T_1	Control (no weeding)	0.408	0.405	0.103	0.101	0.694	0.693	0.124	0.122	0.010	0.010
T_2	Farmer practices (Hoeing during March and May)	0.423	0.423	0.104	0.105	0.701	0.702	0.129	0.135	0.012	0.012
T_3	Zero weeds (weeding at frequent intervals)	0.430	0.436	0.105	0.108	0.703	0.705	0.139	0.149	0.014	0.013
T_4	Clean cultivation (weeding at 30 days interval)	0.427	0.434	0.105	0.107	0.703	0.704	0.142	0.147	0.013	0.013
T_5	Bicolour polythene mulch (250 µm)	0.442	0.443	0.107	0.108	0.708	0.710	0.160	0.170	0.014	0.015
T_6	Paddy straw mulch (10 cm thick)	0.448	0.455	0.108	0.109	0.710	0.713	0.170	0.177	0.016	0.018
T_7	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence)	0.411	0.414	0.104	0.105	0.700	0.701	0.128	0.136	0.011	0.011
T_8	Atrazine @ 3.0 kg ha^{-1} (pre-emergence)	0.409	0.411	0.104	0.103	0.695	0.695	0.125	0.128	0.010	0.010
T_9	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence)	0.411	0.412	0.104	0.104	0.697	0.698	0.124	0.128	0.010	0.011
T_{10}	Paddy straw mulch (10 cm thick) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	0.450	0.457	0.109	0.111	0.712	0.716	0.173	0.179	0.017	0.019
T_{11}	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	0.441	0.445	0.106	0.108	0.706	0.708	0.155	0.157	0.014	0.016
T_{12}	Atrazine @ 3.0 kg ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	0.435	0.439	0.106	0.107	0.702	0.704	0.149	0.152	0.013	0.015
T_{13}	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	0.436	0.442	0.106	0.107	0.703	0.706	0.147	0.157	0.014	0.015
T_{14}	Cowpea (green manure)	0.446	0.453	0.107	0.109	0.709	0.713	0.164	0.173	0.016	0.019
T_{15}	White clover (cover crop)	0.433	0.441	0.105	0.108	0.706	0.708	0.142	0.152	0.014	0.016
C.D.($p \leq 0.05$)		**0.013**	**0.018**	**NS**	**0.003**	**0.005**	**0.005**	**0.016**	**0.020**	**0.002**	**0.002**

Table.2 Effect of orchard floor management practices on leaf macro nutrient content (%) of apple cv. Royal Delicious during 2015 and 2016

Treatments		N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T_1	Control (no weeding)	2.347	2.345	0.267	0.267	1.735	1.738	1.533	1.530	0.280	0.280
T_2	Farmer practices (Hoeing during March and May)	2.394	2.399	0.272	0.278	1.758	1.764	1.570	1.636	0.293	0.295
T_3	Zero weeds (weeding at frequent intervals)	2.400	2.408	0.278	0.286	1.775	1.780	1.650	1.700	0.300	0.305
T_4	Clean cultivation (weeding at 30 days interval)	2.400	2.404	0.275	0.283	1.773	1.778	1.597	1.549	0.298	0.303
T_5	Bicolour polythene mulch (250 µm)	2.408	2.413	0.289	0.290	1.777	1.785	1.730	1.740	0.305	0.306
T_6	Paddy straw mulch (10 cm thick)	2.414	2.420	0.297	0.300	1.797	1.815	1.743	1.759	0.310	0.315
T_7	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence)	2.353	2.358	0.270	0.273	1.750	1.761	1.570	1.600	0.293	0.295
T_8	Atrazine @ 3.0 kg ha^{-1} (pre-emergence)	2.351	2.355	0.270	0.272	1.743	1.748	1.541	1.564	0.285	0.287
T_9	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence)	2.351	2.358	0.268	0.272	1.743	1.751	1.557	1.568	0.285	0.290
T_{10}	Paddy straw mulch (10 cm thick) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	2.419	2.427	0.300	0.303	1.803	1.823	1.757	1.785	0.312	0.318
T_{11}	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	2.405	2.413	0.279	0.283	1.770	1.793	1.705	1.733	0.302	0.309
T_{12}	Atrazine @ 3.0 kg ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	2.402	2.408	0.275	0.282	1.768	1.780	1.690	1.722	0.295	0.303
T_{13}	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	2.403	2.410	0.279	0.283	1.768	1.785	1.709	1.727	0.295	0.300
T_{14}	Cowpea (green manure)	2.413	2.420	0.284	0.295	1.789	1.811	1.733	1.753	0.308	0.315
T_{15}	White clover (cover crop)	2.408	2.416	0.284	0.291	1.779	1.800	1.730	1.747	0.306	0.308
C.D.($p \leq 0.05$)		**0.008**	**0.015**	**NS**	**0.013**	**0.026**	**0.029**	**0.025**	**0.035**	**NS**	**0.005**

Table.3 Effect of orchard floor management practices on leaf micronutrient status of apple cv. Royal Delicious during 2015 and 2016

Treatments		Zn(ppm)		Fe(ppm)		Cu (ppm)		Mn(ppm)	
		2015	2016	2015	2016	2015	2016	2015	2016
T_1	Control (no weeding)	40.84	40.80	215.0	215.4	11.73	11.71	98.9	99.0
T_2	Farmer practices (Hoeing during March and May)	44.03	44.67	216.4	217.0	12.25	12.34	101.7	102.2
T_3	Zero weeds (weeding at frequent intervals)	45.79	46.02	217.0	217.8	12.91	12.57	101.3	101.9
T_4	Clean cultivation (weeding at 30 days interval)	45.17	45.64	216.5	217.1	12.62	12.70	100.9	101.5
T_5	Bicolour polythene mulch (250 µm)	47.85	48.32	220.8	221.5	13.90	14.00	102.8	103.3
T_6	Paddy straw mulch (10 cm thick)	51.28	52.02	222.7	223.4	14.03	14.16	103.7	105.0
T_7	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence)	44.01	44.54	215.7	216.9	12.20	12.28	100.3	100.6
T_8	Atrazine @ 3.0 kg ha^{-1} (pre-emergence)	42.38	42.88	215.3	215.9	11.89	11.90	99.3	99.9
T_9	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence)	43.07	43.63	216.3	216.5	11.99	12.04	101.0	100.4
T_{10}	Paddy straw mulch (10 cm thick) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	51.58	52.07	222.9	223.4	14.05	14.19	104.2	105.5
T_{11}	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	46.71	47.31	219.4	220.0	13.66	13.74	103.1	103.7
T_{12}	Atrazine @ 3.0 kg ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	46.25	46.82	218.7	219.5	13.28	13.46	101.4	102.0
T_{13}	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	46.58	47.05	218.5	219.3	13.32	13.52	102.7	103.0
T_{14}	Cowpea (green manure)	48.96	49.95	222.0	222.7	14.01	14.11	103.3	105.0
T_{15}	White clover (cover crop)	47.79	48.09	219.9	221.6	13.58	13.95	102.3	103.3
C.D.($p \leq 0.05$)		**3.75**	**3.90**	**2.70**	**2.93**	**0.21**	**0.21**	**1.20**	**1.80**

Table.4 Effect of orchard floor management practices on soil moisture (%) at 0-15 cm depth (15 days interval) of apple cv. Royal Delicious during 2015

Treatments		Days after treatment										Mean
		15	30	45	60	75	90	105	120	135	150	
T_1	Control (no weeding)	24.20	23.13	22.90	22.50	24.37	24.80	26.37	24.03	21.90	20.83	**23.50**
T_2	Farmer practices (Hoeing during March and May)	25.33	23.13	22.70	22.50	24.50	24.80	26.33	24.00	22.13	20.87	**23.63**
T_3	Zero weeds (weeding at frequent intervals)	25.83	21.53	20.77	20.47	22.47	22.73	24.87	23.43	20.70	17.87	**22.07**
T_4	Clean cultivation (weeding at 30 days interval)	25.57	20.83	20.83	19.63	21.63	21.83	24.57	21.93	19.90	16.77	**21.35**
T_5	Bicolour polythene mulch (250 µm)	27.10	26.77	25.43	24.93	25.60	25.77	25.97	24.97	23.77	21.63	**25.19**
T_6	Paddy straw mulch (10 cm thick)	28.27	27.50	27.03	25.93	27.23	27.50	27.70	25.00	23.60	21.43	**26.12**
T_7	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence)	25.63	22.90	21.87	21.60	23.43	23.73	26.23	23.97	22.10	20.70	**23.22**
T_8	Atrazine @ 3.0 kg ha^{-1} (pre-emergence)	25.57	22.97	22.10	21.60	23.47	23.63	26.23	24.00	22.13	20.87	**23.26**
T_9	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence)	25.87	22.07	21.80	21.67	23.67	23.77	26.33	24.00	22.03	20.70	**23.19**
T_{10}	Paddy straw mulch (10 cm thick) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	28.20	27.70	27.03	25.83	27.13	27.50	27.97	25.17	23.67	21.37	**26.16**
T_{11}	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	26.40	22.57	21.83	21.33	23.20	23.43	26.17	23.57	20.90	17.97	**22.74**
T_{12}	Atrazine @ 3.0 kg ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	26.10	23.07	21.83	21.37	23.27	23.40	26.23	23.50	20.80	17.90	**22.75**
T_{13}	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	25.10	22.73	21.73	21.17	23.10	23.40	26.17	23.37	20.87	17.90	**22.55**
T_{14}	Cowpea (green manure)	27.07	21.53	21.17	21.07	23.07	23.10	25.97	23.43	20.83	17.93	**22.52**
T_{15}	White clover (cover crop)	25.67	23.17	22.77	22.57	24.57	24.67	26.43	24.17	22.20	20.93	**23.72**
	Mean	**26.13**	**23.44**	**22.79**	**22.28**	**24.05**	**24.27**	**26.24**	**23.90**	**21.84**	**19.71**	

C.D ($p \leq 0.05$)

Treatments	=	0.95
Days	=	0.68
Treatments × Days	=	1.38

Table.5 Effect of orchard floor management practices on soil moisture (%) at 0-15 cm depth (15 days interval) of apple cv. Royal Delicious during 2016

Treatments		Days after treatment										Mean
		15	30	45	60	75	90	105	120	135	150	
T_1	Control (no weeding)	25.57	23.23	21.57	21.23	22.93	24.13	24.70	23.63	22.13	20.60	**22.97**
T_2	Farmer practices (Hoeing during March and May)	24.93	23.17	21.60	21.40	22.73	24.20	24.67	23.67	22.13	20.53	**22.90**
T_3	Zero weeds (weeding at frequent intervals)	25.70	22.80	20.27	20.00	21.90	22.43	22.73	20.87	20.53	17.63	**21.49**
T_4	Clean cultivation (weeding at 30 days interval)	23.80	21.77	19.03	18.87	20.47	22.37	22.57	19.97	18.17	16.63	**20.37**
T_5	Bicolour polythene mulch (250 µm)	27.87	25.90	24.67	24.10	25.73	26.17	26.22	24.93	24.03	21.23	**25.09**
T_6	Paddy straw mulch (10 cm thick)	28.03	27.00	25.77	25.50	27.07	27.53	27.80	25.57	24.03	21.23	**25.95**
T_7	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence)	25.37	23.07	21.07	21.07	22.60	23.37	23.60	23.17	22.10	20.63	**22.61**
T_8	Atrazine @ 3.0 kg ha^{-1} (pre-emergence)	26.50	22.83	20.90	21.13	22.80	23.33	23.53	23.37	22.13	20.50	**22.70**
T_9	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence)	25.30	22.93	21.20	21.00	22.77	23.43	23.67	23.03	22.13	20.63	**22.61**
T_{10}	Paddy straw mulch (10 cm thick) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	27.90	26.93	26.93	25.77	26.93	27.27	27.53	25.87	24.07	20.87	**26.01**
T_{11}	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	26.00	22.33	21.37	20.97	22.50	23.17	23.30	21.50	20.63	17.90	**21.97**
T_{12}	Atrazine @ 3.0 kg ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	25.83	22.83	21.40	20.93	22.53	23.23	23.47	21.43	20.57	17.73	**22.00**
T_{13}	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	26.09	22.80	21.13	21.03	22.40	23.27	23.30	21.37	20.63	17.80	**21.98**
T_{14}	Cowpea (green manure)	26.10	21.23	20.87	21.17	22.77	23.53	23.63	21.57	20.73	17.80	**21.94**
T_{15}	White clover (cover crop)	25.79	23.13	23.13	23.00	24.33	24.83	24.90	23.53	22.07	20.53	**23.52**
	Mean	**26.05**	**23.46**	**22.06**	**21.81**	**23.36**	**24.15**	**24.37**	**22.90**	**21.74**	**19.48**	

C.D ($p \leq 0.05$)

Treatments = 0.95

Days = 0.89

Treatments × Days = 1.23

Table.6 Effect of orchard floor management practices on soil temperature (^{o}C) at 0-15 cm depth (15 days interval) of apple cv. Royal delicious during 2015

Treatments		Days after treatment										Mean
		15	30	45	60	75	90	105	120	135	150	
T_1	Control (no weeding)	14.7	15.9	18.9	18.0	18.5	21.9	21.5	21.5	20.8	19.8	**19.2**
T_2	Farmer practices (Hoeing during March and May)	14.7	15.4	18.8	18.3	18.7	22.5	22.3	21.7	20.3	19.5	**19.2**
T_3	Zero weeds (weeding at frequent intervals)	14.9	16.6	19.9	18.6	19.0	22.9	23.0	21.6	21.2	20.5	**19.8**
T_4	Clean cultivation (weeding at 30 days interval)	14.9	16.7	20.1	18.9	19.2	22.2	22.4	21.9	21.3	20.6	**19.8**
T_5	Bicolour polythene mulch (250 µm)	15.3	17.4	20.9	19.7	19.9	23.8	23.6	22.4	23.6	22.4	**20.9**
T_6	Paddy straw mulch (10 cm thick)	14.2	15.0	19.3	17.0	18.0	21.5	22.3	22.0	21.2	20.3	**19.1**
T_7	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence)	14.0	15.4	20.0	19.0	19.2	22.5	22.2	21.9	20.4	19.7	**19.4**
T_8	Atrazine @ 3.0 kg ha^{-1} (pre-emergence)	14.8	15.6	19.3	18.1	18.2	21.5	21.4	20.9	20.9	20.3	**19.1**
T_9	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence)	14.9	15.4	20.0	18.4	18.5	22.0	21.8	21.1	20.9	20.1	**19.3**
T_{10}	Paddy straw mulch (10 cm thick) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	14.4	15.5	19.1	17.7	18.3	21.4	21.6	21.3	21.1	20.2	**19.1**
T_{11}	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	14.8	16.2	20.1	18.9	19.1	22.1	22.1	21.6	21.2	20.3	**19.6**
T_{12}	Atrazine @ 3.0 kg ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	14.3	16.4	20.1	18.5	18.9	22.3	22.4	21.8	21.1	20.3	**19.6**
T_{13}	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	14.1	16.1	20.0	18.7	19.0	22.8	22.9	21.7	21.1	20.3	**19.7**
T_{14}	Cowpea (green manure)	14.5	15.9	20.1	18.4	19.2	22.4	22.0	21.7	20.8	19.8	**19.5**
T_{15}	White clover (cover crop)	14.8	15.6	18.9	17.8	18.8	21.9	22.5	21.8	20.4	19.2	**19.2**
	Mean	**14.6**	**15.9**	**19.7**	**18.4**	**18.8**	**22.2**	**22.3**	**21.7**	**21.1**	**20.2**	

C.D ($p \leq 0.05$)

Treatments = 0.17
Days = 0.21
Treatments × Days = 0.58

Table.7 Effect of orchard floor management practices on soil temperature (^{o}C) at 0-15 cm depth (15 days interval) of apple cv. Royal Delicious during 2016

Treatments		Days after treatment										Mean
		15	30	45	60	75	90	105	120	135	150	
T_1	Control (no weeding)	14.5	17.8	19.5	22.8	22.5	22.0	21.6	21.7	19.9	20.0	**20.2**
T_2	Farmer practices (Hoeing during March and May)	14.5	17.4	19.7	22.3	22.4	22.3	22.6	21.7	19.6	19.9	**20.2**
T_3	Zero weeds (weeding at frequent intervals)	14.7	17.6	19.9	22.6	22.7	22.8	23.1	21.7	20.6	20.4	**20.6**
T_4	Clean cultivation (weeding at 30 days interval)	14.8	17.7	19.9	22.5	22.6	22.3	22.7	22.6	20.5	20.4	**20.6**
T_5	Bicolour polythene mulch (250 µm)	15.1	18.1	21.3	23.1	23.5	23.9	24.1	23.1	23.0	22.5	**21.8**
T_6	Paddy straw mulch (10 cm thick)	14.1	17.2	19.4	22.1	22.2	22.3	22.5	21.8	20.6	20.1	**20.2**
T_7	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence)	14.7	17.6	20.0	22.4	22.6	22.2	22.5	21.9	19.9	19.7	**20.4**
T_8	Atrazine @ 3.0 kg ha^{-1} (pre-emergence)	14.9	17.5	19.9	22.6	22.6	22.0	22.1	21.9	20.5	19.9	**20.4**
T_9	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence)	14.6	17.8	19.8	22.3	22.5	21.9	22.0	21.6	20.2	20.1	**20.3**
T_{10}	Paddy straw mulch (10 cm thick) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	14.3	17.5	19.4	22.0	22.2	22.2	21.8	21.7	20.5	20.2	**20.2**
T_{11}	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	14.7	17.6	19.7	22.6	22.7	22.1	22.6	22.1	20.6	20.6	**20.5**
T_{12}	Atrazine @ 3.0 kg ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	14.6	17.5	19.8	22.7	22.7	22.4	22.8	21.8	20.5	20.1	**20.5**
T_{13}	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	14.7	17.7	19.8	22.5	22.5	22.3	22.6	22.7	20.6	20.5	**20.6**
T_{14}	Cowpea (green manure)	14.6	17.6	19.6	22.2	22.2	21.5	21.6	20.9	20.4	20.3	**20.4**
T_{15}	White clover (cover crop)	14.5	17.6	19.6	22.4	22.5	22.1	22.4	22.2	19.7	19.5	**20.3**
	Mean	**14.6**	**17.6**	**19.8**	**22.5**	**22.6**	**22.3**	**22.4**	**22.0**	**20.5**	**20.2**	

C.D ($p \leq 0.05$)

Treatments = 0.13

Days = 0.11

Treatments × Days = 0.42

Table.8 Benefit: cost ratio of different orchard floor management practices in apple cv. Royal Delicious (on hectare basis) during 2015 and 2016

Treatments		Benefit :cost ratio	
		2015	**2016**
T_1	Control	-	-
T_2	Farmer practices (Hoeing during March and May)	3.07:1	3.00:1
T_3	Zero weeds (weeding at frequent intervals)	3.90:1	3.93:1
T_4	Clean cultivation (weeding at 30 days interval)	3.97:1	3.98:1
T_5	Bicolour polythene mulch (250 µm)	4.89:1	4.92:1
T_6	Paddy straw mulch (10 cm thick)	4.98:1	5.01:1
T_7	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence)	2.72:1	2.75:1
T_8	Atrazine @ 3.0 kg ha^{-1} (pre-emergence)	2.67:1	2.68:1
T_9	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence)	2.70:1	2.72:1
T_{10}	Paddy straw mulch (10 cm thick) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	5.00:1	5.05:1
T_{11}	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	4.45:1	4.59:1
T_{12}	Atrazine @ 3.0 kg ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	4.41:1	4.49:1
T_{13}	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)	4.40:1	4.46:1
T_{14}	Cowpea (green manure)	4.95:1	4.98:1
T_{15}	White clover (cover crop)	4.80:1	4.85:1

Experimental details

Treatment Code	Treatment
T_1	Control (no weeding)
T_2	Farmer practices (Hoeing during March and May)
T_3	Zero weeds (weeding at frequent intervals)
T_4	Clean cultivation (weeding at 30 days interval)
T_5	Bicolour polythene mulch (250 µm)
T_6	Paddy straw mulch (10 cm thick)
T_7	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence)
T_8	Atrazine @ 3.0 kg ha^{-1} (pre-emergence)
T_9	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence)
T_{10}	Paddy straw mulch (10 cm thick) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)
T_{11}	Oxyflourfen @ 1.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)
T_{12}	Atrazine @ 3.0 kg ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)
T_{13}	Pendimethalin @ 2.0 l ha^{-1} (pre-emergence) followed by glyphosate @ 2.0 l ha^{-1} (post-emergence)
T_{14}	Cowpea (green manure)
T_{15}	White clover (cover crop)

The interaction effect of treatments and days after treatments indicate that paddy straw mulch (T_6) on 15 days recorded maximum soil moisture (28.27%) followed by paddy straw mulch followed by glyphosate (T_{10}) on 15 days (28.20%) and on 105 days after treatments (27.97%).

The examination of data pertaining to soil moisture content depicted in Table 5 indicated that during 2016, paddy straw mulch followed by glyphosate (T_{10}) had maximum soil moisture content (26.01%) which was statistically at par with paddy straw mulch (25.95%) and bicolour polythene mulch (25.09%). However, maximum soil moisture content (26.05%) was recorded on 15 days followed by 105 days (24.37%).The interaction effect of treatments and days after treatments indicate that the paddy straw mulch on 15 days recorded highest soil moisture content (28.03%) which was statistically at par with paddy straw mulch followed by glyphosate (T_{10}) and bicolour polythene (T_5) on 15 days, paddy straw mulch (T_6) from 75 days to 105 days and paddy straw mulch followed by glyphosate (T_{10}) from 90 days to 105 days.

Mulching with paddy straw mulch followed by glyphosate recorded highest soil moisture content, which was statistically at par with paddy straw mulch and bicolour polythene mulch on 120 days and 45 days after treatments during 2015 and 2016. These results are in conformity with the finding of Rao and Pathak (1998), Pande *et al.,* (2005) and Singh *et al.,* (2010) in aonla, Raina (1991) in apple and Sharma and Kathiravan (2009) in plum. Increased soil moisture content below the mulches in various mulches treatments might be due to reduction in soil surface evaporation, increased infiltration percolation capacity of soil and suppression in extreme fluctuation of soil temperature thus retaining the soil moisture in the soil for longer duration. These result are also in line with Greenham (1953) and Negi (2015) who stated that the general improvement in soil moisture status was likely a consequence of both improved infiltration capacity and reduced evaporation. Bhardwaj and Kumar (2012) reported that black polythene mulch acts as an insulating barrier, which checks evaporation from soil surface and conserves soil moisture. Similar findings were obtained by several researchers (Walsh *et al.,* 1996 and Chandel *et al.,* 2010) who reported comparatively higher soil moisture contents in different mulches over unmulched trees.

Raina (1991) also reported that mulches act as a cover for soil to prevent moisture loss through evaporation and transpiration by weeds aerial parts. Moisture loss was higher under clean basin management, zero weeds and herbicidal treatments, perhaps, because of bare soil surface which caused water loss due to higher evaporation during summer months. In unweeded plants, higher weed population might have extracted more moisture for their growth and development.

Soil temperature

The data presented in Table 6 indicate that different orchard floor management practices significantly influenced the soil temperature at 0-15 cm depth during both the years of study. During 2015, maximum soil temperature (20.9 ^oC) was recorded with bicolour polythene mulch (T_5) followed by zero weeds and clean cultivation (19.8 ^oC). Among different days after treatments of observation, significantly maximum soil temperature was recoreded on 105 days closely followed by 90 days. However minimum soil temperature was recorded on 15 days (14.6 ^oC). The treatments and days interaction effect in respect of soil temperature at 0-15 cm depth was also significant. Maximum soil temperature

(23.8^{o}C) was recorded under bicolour polythene mulch on 90 days which was found to be statistically at par on 105 days and 135 days (23.6 ^{o}C) under the same treatment.

Soil temperature at 0-15 cm depth during 2016 followed the similar pattern as exhibited during 2015 (Table 7). Bicolour polythene mulch (T_5) recorded significantly higher soil temperature (21.8^{o}C) followed by clean cultivation (T_4) and zero weeds (T_3).

Soil temperature also varied significantly during different days of observation and maximum mean soil temperature (22.6 ^{o}C) was recorded on 75 days and minimum mean soil temperature (14.6 ^{o}C) was recorded on 15 days. Among treatments and days after treatments interaction, maximum soil temperature (24.1^{o}C) was recorded under bicolour polythene mulch on 105 days, which was statistically at par with same treatment on 90 days (23.9 ^{o}C).

In the present investigation, higher soil temperature was recorded under bicolour polythene mulch on 75 days followed by clean cultivation, while lowest soil temperature was recorded under paddy straw mulch followed by glyphosate on 15 days after treatments. An increase in soil temperature under bicolour mulches may be attributed to the fact that these mulches absorb more radiation from sun and transmit more heat to the upper layer of soil as compared to organic mulches. Various workers (Sharma and Kathiravan, 2009 and Liu *et al.*, 2014) also found an increase in soil temperature with polythene and straw mulches. Walsh *et al.,* (1996) found higher soil temperature under cultivation as compared to straw mulch in apple. Mulches reduces the temperature fluctuation at night, condensation on the underside of the mulch absorbs the long wave radiation emitted by the soil thereby slowing cooling of the soil. The findings are in line with that of Kumar *et al.*, (1990) and Teodorescu *et al.,* (2013).

Minimum soil temperature under paddy straw mulch may also be due thick grass cover provided by the mulch, thereby preventing atmospheric heat to reach the soil surface. Greenham (1953) reported that organic mulches generally insulate the orchard soil and as a consequence lessen orchard soil temperature variability, reducing daily and annual temperature extremes. Thus, mean soil temperatures beneath mulch in summer are frequently lower under organic mulches (Gormley *et al.,* 1973). Mean monthly temperature at 10 cm depth below a 10 cm thick straw cover have frequently been 1ºC and 2°C less than those beneath bare soil in the summer months while during winter similarly measured temperature could be 1°C higher under straw mulch relative to bare soil (Weller, 1969). Similar results were also reported by Zhou *et al.*, (2014) who observed that soil water content was increased in the plots treated with organic mulch due to slow soil temperature increase in spring. Organic matter mulch treatments decreased the peak temperature of orchard soil in the summer and increased the minimum soil temperature in the fall.

Economics of production

Benefit: cost ratio under different orchard floor management practices

Data pertaining to benefit: cost ratio of each treatment are presented in Table 8. It is evident from the data that different orchard floor management practices in apple orchard observed to be maximum (5.00:1 and 5.05:1) with paddy straw mulch followed by glyphosate (T_{10}) followed by paddy straw mulch (4.98:1 and 5.01:1) whereas the minimum benefit: cost ratio (2.67:1 and 2.68:1) was observed with atrazine followed by pendimethalin (2.70:1 and 2.72:1). Treatments cowpea (T_{14}), bicolour polythene mulch (T_5) and white clover (T_{15}) had satisfactory benefit: cost ratio during 2015 and 2016.

In the present investigation maximum benefit: cost ratio (5.00:1 and 5.05:1) was recorded with paddy straw mulch followed by glyphosate, whereas the minimum benefit: cost ratio was recorded under atrazine followed by pendimethalin. Paddy straw mulch, cowpea and bicolour polythene mulch recorded satisfactory benefit: cost ratio. The increase in benefit: cost ratio may be due to higher yield of good quality fruits under these treatments. The results are in agreement with the findings of Bajwa *et al.,* (2003) in pear and Meena (2013) in peach who reported maximum profitability with grass mulch followed by glyphosate over unweeded control. Similar results were also reported by Chatha and Chanana (2007) who in peach obtained lowest profit over control with oxyflurofen and highest with metolachlor. However, Bajwa and Singh (1992) in pear also recorded maximum profitability in hexuron (herbicide) and minimum in hand weeding.

From the present study entitled "Effect of orchard floor management practices on nutrient status in Apple cv. Royal Delicious" it is concluded that application of paddy straw mulch followed by glyphosate was appreciably effective in improving growth parameters as well as leaf and soil nutrient status. On the other hand, the treatments also significantly improved the cropping which resulted in maximum nutrient status owing to higher efficiency toward elimination of weed during both the years. In general, to meet the multiple objective, paddy straw mulch (10 cm thick) followed by glyphosate (2 lha^{-1}) provided good weed control in apple orchard and its adoption is beneficial to crop and the soil to represent a good choice in orchard floor management system.

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