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Effect of Orchard Floor Management Practices on Fruit Production

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A B S T R A C T

Different scientist and researcher's work on various to investigate the effect of orchard floor management practices on apple production indifferent climatic condition of the world. This paper highlights the main finding of some relevant research work. The results and experimental work on the effect of orchard floor management practices on fruit production are briefly compiled.

Introduction

Fruits are the demanding source of food in regard of nutrition and health. The demand for fruits is very much high in the market because of their unique taste and flavor. Fruits have a great potential butorchards are generally, infested with various types of annual, biennial and perennial weeds which compete with the fruit plants for nutrients, space, moisture, light and adversely affect growth, vigour, fruit set, flower initiation, yield, fruit quality and winter hardiness (Majek *et al.*, 1993) and thereby directly reducing the productivity of fruit trees. Weeds also provide shelter to various pathogens by becoming an alternate or collateral 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).

Orchard floor management 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). 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.

Main findings of various research work on the effect of orchard floor management practices on fruit production has been reviewed below under appropriate heads.

Effect of orchard floor management practices on weed studies

DeGregorio and Ashley (1985) found that white clover living mulch provides weed control comparable to current commercial herbicide programs. Weed control by cover crops has been attributed to both an allelopathic (Barnes *et al.,* 1987) and physical influence of mulch on the soil surface (Creamer *et al.,* 1996). Teasdale (1988) reported that living mulch residue suppressed pigweed (*Amaranthus* spp.), foxtail (*Setaria* spp.), and velvetleaf (*Abutilon theophrasti* Medikus), and he also suggested that maximum weed suppression by living mulch residue occurs shortly after cover crop death. Sharma and Bhutani (1989) observed excellent weed control in peach orchard with 10 cm thick grass mulch. The presence of living mulches helps in controlling escape weeds and may prevent or slow down the invasion of new weeds (Hartwig, 1989).

A judicious combination of chemical and cultural methods of weed control would not only reduce the expenditure on herbicides but would benefit the crop by providing proper aeration and conservation of moisture (Prakash *et al.,* 1991). Herbicide-treated mulches can also reduce the phytotoxicity of herbicides to desirable species as there is little direct contact of herbicides with plants. Herbicide treated mulch is safe on most nursery crops when the herbicide is applied to the mulch at the recommended dose (Derr, 1994), increase environmental and ecological safety, and comply with current label restrictions (Mathers and Ozkan, 2001). Inclusion of pre-emergence herbicides and mechanical tillage to eliminate weeds also may reduce soil structure, fertility, and orchard productivity compared with “living” and straw-hay mulches (Merwin *et al.,* 1994). Both rye cover crop desiccated with herbicides (Bordelon and Weller, 1997) and olive pomace (Ferrara *et al.,* 2012) were effective in reducing weeds in young vineyards.

Glyphosate is an effective herbicide against perennial weeds. Repeated applications of this herbicide have been found effective against *Imperata cylindrical* and also another perennial weeds (MacDonald *et al.*, 2000).The continuous use of herbicides might lead to the development and evolution of resistant biotypes. Evolution of herbicide resistance may be considered as an example of recurrent selection in which there is a progressive and sometimes rapid shift in average fitness of populations of weeds exposed to an herbicide (Shane-Friesen *et al.*, 2000). In pre-herbicides plots with negligible surface vegetation during the summer months, herbicide residues can accumulate and soil physical conditions may deteriorate over time, eventually becoming unfavorable for root growth near the surface (Oliveira and Merwin, 2001). Previous studies demonstrated that herbicide and mulch combinations worked effectively in controlling weeds. Application of pre-emergence herbicides on mulches can reduce herbicide leaching up to 74% compared to the herbicides applied to the bare soil (Knight *et al.,* 2001).

Hutchinson and McGiffen (2000) observed that, in both seasons cowpea mulch reduced weed populations significantly at 3, 5, and 9 weeks after transplanting. At harvest, the number of weeds emerged in the cowpea mulch non weeded plots was reduced by 80 and 90% of the number in the bare ground plots in 1997 and 1998, respectively. Use of cover crop to reduce weed populations is also well documented (Herrero *et al.*, 2001). Radwan and Hussein (2001) reported that broadleaf weeds were more susceptible to mulching treatments than grassy weeds. Mulching and cultivation are also sometimes employed to control weeds (Appleton and French, 2000). Mulches provide effective weed control only if they are applied at proper thickness (Mohanty *et al.,* 2002).

When herbicides became available for use in vineyards, they provided close to perfect season-long weed control, and with pre-emergent herbicides, not even dead mulch remained. As a result, there was an alarming increase in soil erosion (Hartwig and Ammon, 2002). 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). Mathers (2003) conducted two-year studies on different mulches, discs, herbicides, and their combinations, and reported that the application of pre-emergent herbicide-treated bark nuggets resulted in increased and extended herbicide efficacy compared to the herbicides or mulches applied alone.

Faber *et al.,* (2003), while studying the effects of mulch on avocado and citrus found that weed population was least in mulched plot. They also reported that 15 cm mulch depth resulted in greatest reduction in weeds, but even the 2.5 cm depth had some effect. Abou Sayed-Ahmed *et al.,* (2005) also found that mulch treatments resulted in the most effective control of broadleaf, grassy, and perennial weeds of oranges. The weed species were suppressed differently by each green manure species, when the green manure was incorporated into the top 5 cm of soil or left on the surface, the emergence of weed seeds was significantly inhibited, depending on the species, and on the amount and depth of green manure incorporation (Severino and Christoffoleti, 2004). Cover crops growing in the alley have been found to compete for nitrogen and available water (Tesic *et al.*, 2007). If managed properly, cover crops can be beneficial for limiting erosion (Marques *et al.,* 2010) and increasing soil organic matter (Peregrina *et al.,* 2010).

Barros *et al.*(2005) reported that herbicide efficiency in controlling weeds differs according to weed species. Post-emergence herbicides have an advantage over pre-emergence herbicides in that post-emergence herbicides can be selected based on weed species that are present. Pre-emergence herbicides on the other hand are often applied without prior knowledge of weed species that are present in the soil, resulting in poor weed control and loss of revenue (Case and Mather, 2006). Weed control is important in agronomic and horticultural crops as weeds compete for resources such as water, nutrients, space, and light, resulting in reduced crop growth. Some weeds produce allelopathic chemicals to suppress the growth of other plant species surrounding them (Verma and Rao, 2006).

Shogren and David (2006) reported that straw mulches were effective in preventing weed growth around the plants while hand weeding was required for the bare soil plots where mulches appear to be a convenient and effective alternative to laborious hand weeding. Verdu and Mas (2007) indicated that in mandarin orchard black geotextile and almond husk controlled the presence of weeds as well as or better than the applications of glyphosate at least during the first year after their introduction. No significant differences were found between the mean weed cover of black geotextile (0.88%), almond husk (4.04%) and herbicide plots (2.04%). The results also showed that mulching is one weed control strategy in mandarin orchards that also provides other benefits in terms of sustainable agriculture, such as soil protection or avoiding herbicide pollution.

Samtani *et al.,* (2007) compared herbicides alone with herbicide-treated leaf pellets, rice hulls, and pine bark applied at a 0.5 cm thickness and reported that the herbicide-treated mulches resulted in equivalent or, in a few cases, improved weed control compared to herbicides alone. Chatha and Chanana (2007) observed that reduction in dry matter accumulation by weeds in all the herbicide treatments over control might be attributed to the fact that herbicides when applied, affect different physiological processes of the growing weeds and inhibit the weed seed germination and growth. Grasses were damaged most by oxyfluorfen, followed by oxadiazon; however, injury was not as severe with oxadiazon as with oxyfluorfen as observed by Cole and Cole (2007). Herbicides are the most important weed control tools for alleviating the infestation of weeds and getting higher yield as reported by Ashiq *et al.,* (2007). Herbicidal weed control seems indispensable and has proved efficient in controlling weeds (Kahramanoglu and Uygur, 2010) and hence presently about two-third, by volume, of the pesticides used worldwide in agricultural production are herbicides. New fabrics are being developed with white colour on top (to reflect light and heat) and black on bottom to suppress weeds (Makus, 2007).

Covering the soil of mandarin orchards with one layer of rice straw, cattail, and wild oat mulch, as well as the thinnest black plastic layer, had less effect against grasses, where torpedo grass emerged through the mulch (Abouziena *et al.,* 2008). Sharma and Kathiravan (2009) also studied the effect of different mulches *viz.* transparent polyethylene, black polyethylene, bicoloured polyethylene, field grass, pine needles and control on soil hydrothermal regimes and growth of plum and reported that minimum weed growth was observed under black polyethylene and bicoloured polyethylene.

Samedani *et al.*(2008) revealed that amitrol + ammonium thiocyanate + glyphosate at 2.9, 3.6 and 4.3 kg a.i. ha^{-1} and new glyphosate at 0.54 kg a.i. ha^{-1} could be suggested as suitable option for post-emergence control of broadleaved and grass weeds in orchards. Glyphosate is the systemic herbicide that is commonly used to control a broad spectrum of weeds in crops and pastures worldwide (Zabaloy *et al.,* 2008). Mulch plus lower than recommended herbicide rates suppressed weed growth for more than five months in the field (Ferguson *et al.,* 2008). Abouziena *et al.*(2008) investigated that the soil mulching with three layers of rice straw, cultivation, glyphosate, and 80-mm plastic mulch treatments caused a significant reduction in weed density and weed biomass.

Annual grass weeds such as green foxtail (*Setaria viridis*) and downy brome (*Bromus tectorum*) did increase rapidly during the course of the trial. Overall, the white clover treatments provided good weed control (Granatstein and Mullinix, 2008), and suppression of grass and broadleaf weeds was similar. Bartoli and Dousset (2011) found that both clover and fescue cover crop treatments led to increased soil organic matter and water stabile aggregation as compared to bare soil and straw mulch treatments in a 10-year study of vineyard soil. Fredrikson *et al.,* (2011) found a strong reduction in weeds in mulched vine rows using cover crop residue as the mulch source.

Kaur and Kaundal (2009) observed that weed density was lower in pre-emergence application of black polythene mulch and post emergence glyphosate @ 1.6 l ha^{-1}, finally resulting in very low weed density and least weed dry weight; sod culture and manual weeding both showed significantly lesser weed dry weight than control in plum. Dry grass mulch alone and in combination with post-emergence herbicide (paraquat 1.5 l ha^{-1}) was found to be most effective in controlling weed in kiwifruit (Chandel *et al.,* 2010).

Atucha *et al.*(2011) observed that the year-round elimination of surface vegetation with residual soil active herbicides may be unnecessary or even detrimental for orchard productivity, soil fertility in established orchards and post-emergence herbicides that reduce weed competition primarily during the summer months may offer an optimal combination of weed suppression and soil conservation. Kaith and Bhardwaj (2011) investigated that the use of glyphosate @ 0.5% was significantly most desirable and had prolonged effect on weed population. Rankova and Zhivondov (2012) observed that herbicide combination of oxyfluorofen and glyphosate achieved high herbicide efficiency against the weed species forming the weed association in the row strip of the plantation. The use of oxyfluorofen and glyphosate did not entail any risk of contaminating the environmental components with pesticide residues. That is a good reason to apply the herbicides oxyfluorofen and glyphosate for ecologically sound weed control in young peach orchards. Superiority of pendimethalin @ 1.0 kg ha^{-1} in controlling weeds in pea + maize intercropping system on raised seedbed has been reported by Singh *et al.,* (2012). Pendimethalin @ 1.00 kg ha^{-1} was the effective treatment for satisfactory weed control and higher productivity and profitability in French bean cultivation (Kumar *et al.,* 2014). Sidhu *et al.*(2014) also reported that all herbicides reduced the growth of weeds compared to those observed in control.

Shankar *et al.*(2014) reported that all the weed management practices caused significant reduction in weed density under monocots and during both the years and the plot receiving four hand weeding registered the highest weed control efficiency in both years on grasses, broad leaved weeds and sedges, respectively followed by black polythene mulch which showed the effective control of weeds and lowest in alone application of herbicides and hand weeding. Lisek (2014) revealed that integrated weed control based on rational use of herbicides and alternative method suppressed weed competition in fruit trees. Synthetic herbicides were most effective way of controlling weeds within fruit crops but synthetic herbicides need to be used carefully so that problems with their use can be minimized. Mulching stops growth of weeds on row trees without herbicides in apple (Teodorescu *et al.,* 2013).

Kalaichelvi*et al.*(2015) observed that weed control efficiency was higher with pre-emergence application of oxyfluorfen at 0.25 kg ha^{-1} followed by hand weeding on 20 days after sowing and pendimethalin at 0.75 kg ha^{-1} followed by a hand weeding on 20 days after sowing at different intervals of 10, 25, 40 and 60 days after sowing. Superimposition of pendimethalin + hand weeding improved the effectiveness in reducing total weed dry weight (Tehria *et al.,* 2015). Komal and Yadav(2015) also reported that the weed free check (two hand weeding at 20 and 40 days after sowing) was most effective to control weeds and recorded lowest weed density, weed dry matter and weed index and highest weed control efficiency. Yadav *et al.,* (2015) reported that the major weed flora consisted of *Cyperus rotundus, Echinochloa crusgalli, Commelina benghalensis, Phyllanthus niruri* and *Digera arvensis* were effectively controlled by pendimethalin + imazethapyr as compared to alone application of pendimethalin as preemergence and imazethapyr as post emergence were equally effective as two hand weedings.

Effect of orchard floor management practices on growth and vigour

Thakur *et al.*(1993) in Red Delicious apple observed that annual extension growth was highest in black polythene treatment followed by red clover, white clover and clean cultivation. Straw mulch and herbicides had the best apple tree-growth and fruit yield; tilled plots were intermediate, and grass or legume-sod plots were lowest (Merwin *et al.,* 1994). Darbellay (1997) studied effect of different soil management practices on young apple planting and revealed that organic mulches had positive effect on tree growth as compared to polythene mulch. Although mulch research indicates short term benefits to tree vigour, but long term growth can also be increased as indicated in 20 years study by Toenjes (1941) in which trees grew larger with the sod-mulch system compared to cultivation cover crop soil management in apple.

Kumar *et al.,* (1999) conducted a field experiment during 1987-95 at Bajaura (H.P.) to study the effect of five orchard soil management practices viz. herbicide (simazine) plus mulching with hay, herbicide, mulching with hay, mulching with white netted polythene and clean cultivation on growth, yield and fruit quality of Starking Delicious apple grafted on M.7 rootstock. They found the greatest trunk girth (55.8 cm) and shoot length (46.6 cm) with herbicide plus mulching with hay followed by herbicide alone while lowest trunk girth and shoot length were recorded under clean cultivation.

Dwivedi *et al.,* (2000) studied the effect of different mulching material on establishment and growth of apple seedling and showed that incremental height was encouraged by mulching and weed growth was suppressed. Smith (2000) found that tree height and diameter of pecan trees were positively related to mulch area and a 2 m wide mulch application, 30 cm deep, in combination with 4 m wide weed free strip, resulted in the greatest tree growth. Hutchinson and McGiffen (2000) reported that, the cowpea mulch promoted plant growth. Thakur *et al.*(2000) reported that different mulching material like grass, lantana and plastic helped plant to perform better at water deficits from 25, 50 and 75%. The plant height, leaf area, leaf area index, flower number and fruit yield were significantly maintained at higher level in mulched plants than unmulched ones up to 75% water deficit.

Tworkoski and Glenn (2001) reported that grass competition reduced growth and pruning weights. Singh *et al.,* (2004) observed maximum annual shoot growth (159 cm) in plum trees under hay mulch as compared to 120.4 cm recorded in control. Hipps *et al.,* (2004) conducted a trial with different ground cover management systems viz. contact and residual herbicides, polypropylene woven (plastic) and straw mulches. They revealed that trees growing in the straw mulch had the greatest shoot growth and those in the contact herbicide treated soil had the least shoot growth in apple.

Pande *et al.,* (2005) conducted a field experiment on apple cv. Red Delicious to study the effect of mulches and found that dry grass mulch and black polythene mulch recorded the maximum shoot extension growth followed by dry leaf and pine needle mulches. Singh *et al.,* (2005) carried out an experiment on apple cv. Red Delicious to study the response of mulches and antitranspirants on moisture conservation under rainfed conditions of Kashmir valley and found maximum plant growth under mulch treatment as compared to other treatments. Joolka *et al.,* (2008) carried out a field experiment on twelve-year-old Royal Delicious apple trees grafted on seedling rootstock and found maximum shoot extension growth (46 cm) in the trees under atrazine @ 4 kg ha^{-1} plus dry grass mulch and minimum under control.

Increased soil moisture due to cover crop treatments can decrease soil mechanical resistance (To and Kay, 2005), and this decrease can lead to increased root density due to ease of root elongation (Becel *et al.,* 2012). While working on the effect of different mulches and herbicides on growth, yield and quality of strawberry (*Fragaria x ananassa* Dutch.) cv. Chandler, Sharma and Khokhar (2006) observed that black polyethylene significantly increased the plant height compared to control and other mulches. The legumes generally led to increased trunk size and fruit yield in apple compared to the control, but leaf nitrogen still declined over time (Sanchez *et al.,* 2006). It was observed that the regeneration was more and rapid in glufocinate ammonium treatments but in glyphosate treatments the regeneration in the form of new shoots was very low and slow. By the end of the season considerable regeneration was also observed in glyphosate treated plots (Bhatia *et al.,* 2006).

Yin *et al.*(2007) suggested that increased soil moisture content and soil temperature were both likely attributed to the greater tree growth and fruit yield with the covered trees than non-covered trees. Incorporation of green manure into soil as a possible nutrient source especially nitrogen was chief promoter of growth and improved growth (Bair *et al.,* 2008). Kim *et al.,* (2008) studied the effect of pre harvest reflective mulch on growth and fruit quality of plum (*Prunus domestica* L.) and observed that mean shoot length declined under the mulched treatments compared to the control, with a greater effect with earlier imposition of mulching. Sharma and Kathiravan (2009) reported that different orchard floor management treatments significantly influenced annual shoot growth in plum under rain-fed conditions of Himachal Pradesh. Further, trunk cross sectional area was found increased with weed free environment as compared to weed pressured environment (Belding *et al.,* 2004).

Stafne *et al.*(2009) observed that in peach the trunk cross sectional area and average pruning weight were lowest in the weedy control treatment and did not differ among other treatments, but average tree height in weedy control was lower than trees in glyphosate, and suggested that glyphosate or 4 inches' deep mulch were the best treatments for tree growth. Merwin and Brown (2009) in a study on apple where trees those were planted with four groundcover management systems observed greater tree growth and higher yields in post-emergence herbicide treatments than other treatments during most years from 1992 to 2003. Pre-emergence herbicide treatment trees had more total roots and new roots than all other treatments, whereas grass plots had fewer total roots than others. Kher *et al.,* (2010), while studying the influence of planting time and mulching material on growth of strawberry cv. Chandler reported significantly maximum leaf area under black polyethylene mulch followed by transparent polyethylene mulch over paddy straw. A trial of seven cover crop combinations, including winter annuals, legumes, and perennial grasses, resulted in no differences in root density between cover cropped and clean cultivated alleys in two Oregon vineyards (Sweet and Schreiner, 2010).

Bal and Singh (2011) in ber reported that mulching treatments increased tree volume but the maximum leaf area and tree volume was recorded under black polythene + gramoxone @ 1 l ha^{-1} which was closely followed by black polythene + glyphosate @ 1 l ha^{-1} and black polythene. Vegetation-free strips minimize direct competition between orchard trees and orchard floor vegetation for water and nutrients thus result in more tree growth (MarcRowley, 2012). Dubey *et al.*(2015) investigated that all live mulch options enhanced vegetative growth of aonla trees in order of sunhemp > cowpea > weeds over unmulched control having no distinct residue input benefit. However, variations in tree height between weed mulch and sunhemp mulch and variations in tree crown spread between cowpea mulch and sunhemp mulch were statistically at par. Bhat (2015) observed that the annual extension growth, plant girth, plant height and plant spread were significantly influenced by intercropping with pea followed by red clover and French bean and had higher annual extension growth, plant girth, plant height and plant spread in sweet cherry trees with clean cultivation (control).

Effect of orchard floor management practices on fruit yield

Bredell (1973) studied the effect of plastic mulching in a Valencia citrus orchard and concluded that tree yields were positively stimulated, mainly due to soil moisture conservation. Herbicide control of all orchard-floor vegetation often results in the greatest fruit yield (Hogue and Neilsen, 1987). Borthakur and Bhattacharya (1992) observed improved fruit yield in guava under mulched tree. Merwin and Stiles (1994) found increased fruit yield in apple trees when straw mulch was applied, compared to tilled and herbicide treatments. Kalita and Bhattacharyya (1995) reported that controlling weeds in lemon (*Citrus limon* Burm.f.) orchards improved flowering, fruiting, and fruit yield. Marsh *et al.,* (1996) evaluated mulching strategy with apples in New Zealand and saw greater fruit yield with the mulch.

Continuous use of organic mulches is helpful in improving the soil physico-chemical properties, microbial flora and soil aeration, which ultimately resulted into better yield of aonla plant (Rao and Pathak, 1998). Shukla *et al.,* (2000) recorded higher fruit yield with mulching as compared to control. Covering beds with black polyethylene hastened flowering by approximately one month and increased total yields by 20% (Pramanick *et al.,* 2000). Neilsen *et al.,* (2003) while studying the effect of mulches and biosolids on fruit yield of fertigated high density apple found that cumulative yield efficiency of trees treated with black plastic mulch was higher than check trees.

Fruit yield in 18-year-old tart cherry (*Prunus cerasus*) trees in Michigan was not reduced by any of the three living mulch systems compared to the herbicide-strip control (Sanchez *et al.,* 2003). Edson *et al.,* (2003) found that supplemental straw mulch (10,000 kg ha^{-1} year^{-1} dry weight) significantly reduced increased tart cherry yield.

Mulching with pine bark and nonwoven polypropylene had higher yields than trees treated with herbicide fallow in Jonagold apple (Szewczuk and Gudarowska, 2004). Szewczuk and Gudarowska (2005) revealed that using plastic mulch improved the cropping of the trees in the first two years of yielding in nectarine. The total yield for 8 years was higher in the case of the trees mulched with polypropylene fabric, but they did not found any significant difference. Similar result was also reported by Pande *et al.*(2005) who reported that the final fruit retention and subsequent yields were highest from the tree receiving the dry grass mulch, while the minimum fruit yield and maximum fruit drop were observed under clean cultivation. In a two-year study on the effect of different mulches and herbicides on fruit yield of strawberry (*Fragaria* × *ananassa* Duch.) cv. Chandler, Sharma and Khokhar (2006) found that black polyethylene mulch resulted in significantly increased yield (62.19 and 77.16 q ha^{-1}) in comparison to other treatments (bicoloured polyethylene mulch, grass mulch, pine needles and weedicide @ 2.0 kg ha^{-1}) during both the years of study. Das *et al.,* (2007) studied the effect of different mulching materials on strawberry plants and found that black polyethylene produced maximum fruit yield in comparison to paddy straw.

Bair *et al.*(2008) in their study put forth that higher residual effect of green manuring might have increased the soil organic matter content and available nutrients, which in turn, favourably affected fruit yield in the subsequent year. Kumar *et al.,* (2008) during a five-year study with ‘Lal Sundari’ mango (*Magnifera indica* L.) found higher yields under dry grass mulching. Castaneda *et al.,* (2009) recorded maximum fruit yield (386.66 g plant^{-1}) in strawberry cv. Camarosa under black plastic polyethylene mulch and the minimum yield of 40.28 g per plant under white polythene film mulch. Sharma and Kathiravan (2009) during a two-year study with plum cv. Santa Rosa recorded significantly higher fruit yields over unmulched and highest mean fruit yield of 80.62 quintal ha^{-1} was produced under black polythene mulch. Kaur and Kaundal (2009) studied the efficacy of herbicides, mulching and sod cover on control of weeds in plum orchard and reported that maximum fruit yield was observed in black polyethylene mulch followed by glyphosphate @ 1.6 l ha^{-1}.

Androetii *et al.,* (2009) during a two year study with nectarine using reflective mulch observed increased fruit yield during both the years as compared to control. Kher *et al.,* (2010) reported significantly higher fruit yield in strawberry cv. Chandler under black polyethylene mulch followed by transparent polyethylene as compared to paddy straw mulch. Smith (2011) demonstrated substantial fruit yield reductions associated with floor vegetation of young pecan orchards in the humid southeastern United States. Atucha *et al.,* (2011) examined effects of four apple orchard floor management practices *viz.* vegetation-free with the use of pre-emergent herbicides, vegetation-free with the use of post-emergent herbicides, a sod cover crop, and hardwood bark mulch. They observed that as the trees matured, the effect of the cover crop became less remarkable and there was no significant effect of orchard floor management treatment on fruit yield. Kumar and Shukla (2011) reported that under storey forage crop combinations did not influence the fruit yields of established ber and aonla tree species due to differential rooting behaviour of crops.In strawberry, Kumar *et al.,* (2012) reported significantly maximum fruit yield under transparent polyethylene mulch followed by black polyethylene mulch. The minimum yield was obtained under control.

Application of pine dust mulch to different apple cultivars in the tree row stripes increased mean fruit yield by 19.1-26.3% depending on the cultivar and least yield was recorded in control (Solomakhin *et al.,* 2012). In peach cv. 'Earli Grande', Thakur *et al.*(2012) recorded highest fruit yield with straw mulch. Mulch treatments had higher numbers of clusters per shoot when compared to non-mulched treatments in a vineyard. The fruitfulness of buds was determined the previous year while the buds were still developing (Morgan, 2013). Bennet *et al.,* (2005) found a strong relationship between fruitfulness and carbohydrate reserves in a study utilizing severe defoliation treatments in Chardonnay. Live sunhemp mulch recorded significantly higher litter yield per tree and per hectare but variations were statistically at par with live weed mulch and cowpea mulch. This shows that leguminous residues of sunhemp (narrow C:N ratio) significantly enhanced litter production on mineralization and led to nutrient and moisture benefits to aonla trees (Dubey *et al.,* 2015).

Hussain *et al.,* (2017) recorded maximum annual shoot extension growth (49.3 cm and 50.2 cm) was recorded under paddy straw mulch followed by glyphosate, which was at par with cowpea, white clover, paddy straw mulch. and bicolour polythene mulch. The increase in annual shoot extension growth due to paddy straw mulch was associated to suppression of weed growth and increased the availability of moisture minimum losses due to evaporation from soil surface, addition of extra organic matter and nutrient to soil.

Effect of orchard floor management practices on fruit quality

Comparison of sod, mulch, cultivation and herbicide floor management practices for grape production in non-irrigated vine yards was studied by Pool *et al.,* (1990). The study revealed that mulch and trashy cultivation vines had lower soluble solids concentration of the 'Seyal Blanc' grapevine. Thakur *et al.*(1993) recorded highest titratable acidity in Red Delicious apple trees with clean cultivation followed by white and red clover intercropping system when effect of soil management on bearing and fruit quality of apple was studied. Gupta and Acharya (1993) while studying the effect of mulch induced hydrothermal regime on yield and quality of strawberry found that berry size was significantly higher under black polyethylene followed by pine needle mulch. A legume living mulch (full orchard floor) provided 120 kg N ha^{-1} over two years in an apple trial, and equalled compost for tree leaf nitrogen. However, it also delayed fruit maturity and reduced firmness and colour (Marsh *et al.,* 1996). The critical weed-free period is the length of time that a crop must be maintained free of weeds to minimize quality reduction (Monks and Schultheis, 1998).

Yakushiji *et al.,* (1996) investigated the effect of water stress induced to enhance sugar accumulation in Satsuma mandarin (*Citrus unshiu* Marc.) fruit, soil was covered with double-layered plastic sheets that prevented rainfall from permeating the soil, but allowed water from soil to evaporate. Concentrations of sucrose, fructose, and glucose increased in fruit sap under water stress, and the acidity in the fruit juice increased. Furthermore, the total sugars content per fruit of water stressed trees was significantly higher than in fruit of well-watered trees. Kumar *et al.*(1999) obtained highest fruit length (7.20 cm), fruit breadth (7.48 cm) and fruit weight (260.4 g) under herbicide plus mulching with hay followed by mulching with hay, while these parameters were lowest under clean cultivation treatment. However, clean cultivation resulted in the highest total soluble solids (15.1 °Brix). Maximum total soluble solids (TSS) were observed in the strawberry fruits harvested from black polyethylene and minimum in fruits from control plants (Hassan *et al.,* 2000). Layne *et al.,* (2002) used metalized, high-density polyethylene reflective film on 'Imperial Gala' apples 4 weeks before the first commercial harvest date. They reported a 27% increase in the percentage of red surface compared with the control, without affecting fruit size.

Mathieu and Aure (2000) conducted a study on effect of plastic reflective mulches on fruit quality of apple. They recorded improved fruit size due to increased photosynthetic activity of the tree in Gala variety in addition to one-week advanced ripening when the mulch was applied after flowering. However, when mulch was applied few days before harvesting it improved the colour of apple fruits. ShuXin *et al.,* (2012) revealed that reflective film mulching in plum had set fruit picking seven days and three days ahead, respectively, compared with ordinary light film mulching and the bare ground. Improvement in fruit sugar, soluble solids and protein and vitamin C contents in the fruits followed the order as: reflective film mulching > ordinary light film > the bare ground in plum. Akasaka and Imai (2002) studied the effect of reflective sheet mulches in peach in comparison to non-mulched treatments. It was observed that the soluble solids content of the fruit juice increased by 8-13% and fruit weight increased by 7-12% per year under reflective mulches. Further the rate of pit splitting also decreased by 10-25%, the concentration of sucrose in the fruit juice increased by 23% but, glucose and fructose concentrations were not affected. They concluded that treatment with reflective sheet mulching during the maturation period increased the fruit quality of peach.

Mohanty *et al.,* (2002) reported that no significant difference in total soluble solids of mandarin fruits was observed among mulch treatments (black plastic mulch, soybean straw, local grasses, and paddy straw), but acidity was least with a black polyethylene sheet and was highest with unweeded treatment. Fruit length and width of apricot were significantly influenced by drip irrigation plus plastic mulch treatment than without plastic mulch treatment (Singh *et al.,* 2002). Highest TSS (18.3%) in mango under black polyethylene mulch followed by paddy straw and lowest TSS in untreated fruits was reported by Ghosh and Bauri (2003). Gaikwad *et al.,* (2004) recorded significantly higher average fruit volume in Nagpur mandarin fruits under grass mulch followed by polyethylene mulch over control. Shylla and Chauhan (2004) reported highest total soluble solid in fruits of plum trees under glyphosate herbicide treatment followed by intercropping with French bean. Pande *et al.,* (2005) while studying the effect of various mulches on quality attributes of apple cv. Red Delicious found that application of organic mulches resulted in relatively low TSS (13.7^{o}Brix) content than black polyethylene mulch which recorded a TSS content of 14.2 ^{o}Brix.

Sharma and Khokhar (2006) in a two year study on the effect of different mulches and herbicides on quality of strawberry (*Fragaria*

× *ananassa* Duch.) cv. Chandler reported that maximum fruit size (length × breadth) and decreased the titratable acidity were found under black polyethylene significantly followed by bicoloured polythene while as highest acidity was observed under atrazine (0.5 kg ha^{-1}) treatment. MacRae *et al.,* (2007) also reported that maintaining the orchard floor weed-free for 12 weeks after peach tree bloom resulted in the greatest fruit size (individual fruit weight and diameter) and fruit number. Kim *et al.,* (2008) studied the effect of pre harvest reflective mulch on fruit quality of plum (*Prunus domestica* L.) and observed that firmness of pericarp and flesh were 1.75 kgf (Kilogram-force) and 0.52 kgf (Kilogram-force) at 4 weeks before harvest. Androetii *et al.,* (2009) studied the effect of reflective mulch on nectarine orchard and reported that reflective mulches did not cause any detectable effect on the flesh firmness during first year whereas during second year flesh firmness was significantly higher as compared to control.

Kaur and Kaundal (2009) studied the efficacy of herbicides, mulching and sod cover on control of weeds in plum orchard and reported that black polyethylene mulch was most effective treatment in reducing the acid content of plum fruits followed by different doses of glyphosate and diuron which, were equally effective in lowering the acid content of plum fruits. Castaneda *et al.*(2009) while studying the utilization of different mulching types in strawberry production found that black polyethylene film mulch increased the fruit size as compared to white polyethylene mulch. While studying the effect of different mulching material in strawberry, Kher *et al.,* (2010) reported significantly higher fruit volume under black polyethylene over control. Reflective mulch was found to increases total soluble solids and sugar content, but decreased in fruit firmness and acid content of the peach fruit (Jun and Hong Qing, 2009 and XiangMing *et al.,* 2012). Similarly, Pliakoni and Nanos (2010) also found that reflective mulches increased fruit quality by increasing total soluble content, better skin colour and better firmness in peach and nectarine as compared to control, but decreased in storability of the fruits.

Agrawal *et al.,* (2010) observed that, the quality parameters like total soluble solids (6.94%), acidity (0.96%), juice (47.83%), moisture (96.76%) and dry matter (9.87%), were maximum in coloured polythene mulch treatment and the same characters were lowest in control treatment i.e. no mulch. Bal and Singh (2011) while studying the effect of mulching material in ber observed maximum TSS (12.16%) with black polyethylene + gramaxone @ 1 l ha^{-1}. They also reported that TSS under paddy straw and sarkanda was higher as compared to control.

For sugars content in apple fruits, Iordanescu *et al.*(2011) observed that in plants where *Trifolium repens* was used as green manure had higher values (11.42%) while the lowest values were obtained with grass cover crops. Similarly, the content of vitamin C in 2009 was the same as in 2008 in cover crops on the interval mixture and in cover crops on the interval, mixed grass, and mulching on the tree row. Fan *et al.,* (2012) while studying the effect of mulching systems *viz.* matted row system, plastic mulch, plastic mulch with row cover on fruit quality and phytochemical composition of newly developed strawberry lines, found that plastic mulch with row cover increased fruit firmness while in matted row system and plastic mulch it was lowest and were statistically at par with each other. Kumar *et al.,* (2012) recorded significantly maximum TSS in strawberry under transparent polyethylene mulch followed by black polyethylene. They further reported higher TSS under organic mulches. Total sugars were slightly higher in plums from

trees treated with plastic mulching film as reported by Melgarejo *et al.,* (2012).
Chemical properties comprising total soluble solids, titratable acidity and total sugar were influenced by different orchard floor management practices. Hussain *et al.,* (2017) recorded maximum total soluble solids, total sugar and minimum titratable acidity with bicolour polythene mulch followed by paddy straw mulch followed by glyphosate. Bicolour polythene mulch was reflective in nature due to which, it might have improved the photosynthetic activities of the plants and accumulated more photosynthates which leads to increase in total soluble solids content in fruits. Reflective mulches also change the micro-climatic condition of the tree by increasing the temperature which results in advanced ripening and more accumulation of total sugars.

Effect of orchard floor management practices on leaf and fruit nutrient status

Gormley *et al.*(1982) studied effect of soil management on the mineral composition of Golden Delicious and Cox's Orange Pippin apple trees. The study revealed that leaf magnesium was found to be increased in Golden Delicious and Cox's Orange Pippin apple trees in association with sod cover and minimum under clean cultivation treatment. Cover crop material high in nitrogen will break down quickly and become mineralized into ammonium and nitrate, the latter being principle grapevine available form of nitrogen (Perez and Kliewer, 1982). Neilson *et al.*(1984) recorded increased leaf calcium in young Golden Delicious apple tree when found associated with orchard sod cover as compared to grass. Sharma (1985) recorded higher leaf phosphorous and potassium content with mulching plus simazine and mulching plus glyphosate in apricot orchard soil, compared to control. Neilson and Hogue (1985) studied the effect of orchard soil management on leaf nutrient concentration of young dwarf 'Red Delicious' apple trees and observed increased leaf Mg and N under all ground cover suppression treatments.

Pool *et al.,* (1990) showed greatly increased petiole potassium in vines mulched with straw, although magnesium was severely decreased in these vines. Goff *et al.*(1991) observed that leaf concentration of magnesium of young pecan trees in association with different orchard floor management practices like weedy unmoved, weed control by herbicides and weed control by disking was suppressed with weed competition. Merwin *et al.*(1995) observed that apple leaf N, K, Cu and Zn concentrations were greater with herbicide, hay mulch and polypropylene than cultivation. Eissa and Helail (1997) found that rice straw mulching in Balady lime (*Citrus aurantifolia*) improved leaf content of phosphorus, potassium, magnesium, iron, and zinc.

Hartley and Rahman (1998) studied the effect of organic mulches *viz*. sawdust and barley straw in an apple orchard and reported that mulches had little effect on the nutrient status of apple leaves or fruits. Shylla *et al.,* (1999) while studying the effect of orchard floor management practices on leaf nutrient status of plum observed that mulching with hay resulted in higher leaf nitrogen compared to clean cultivation, but lower than herbicidal treatment. Further, with respect to leaf phosphorous content, all the orchard floor management practices were statistically at par. However, hay mulch treatment recorded highest phosphorous content closely followed by herbicide and black polyethylene mulch treatment. They also reported that hay mulch treatment recorded higher leaf K, Ca and Mg content as compared to other soil management practices.

Jin Myeon *et al.,* (2000) revealed that in comparison of four orchard management systems in apple trees, leaf nitrogen concentration was highest in heat insulating woven synthetic textile and black polyethylene film plots, but leaf phosphorous, calcium and magnesium concentrations were highest in grass covered plots. Mengel and Kirkby (2001) explained that the mineral concentration depends on the leaf status; young leaf tissues usually have lower water content and higher N, P and K concentrations, meanwhile older tissues are rich in Ca, Mn, Fe and B. Wright *et al.,* (2003) found no effect of orchard floor vegetation in a young citrus (*Citrus limon* L., *Citrus sinensis* L.) orchard on leaf nutrient concentration.

Neilsen *et al.,* (2003) while studying the effect of mulches and biosolids on leaf nutrition of fertigated higher density apple found higher leaf nitrogen and phosphorous content under shredded paper mulch alone or with biosolids as compared to check. Also, higher leaf potassium content was recorded under alfalfa hay mulch and inconsistent effects of mulch treatments on leaf Ca concentration relative to check trees were observed.

Krohn and Ferree (2005) studied the effect of ground cover on cluster attributes, and petiole macronutrient of 'Seyval Blanc' grapevine and recorded highest petiole calcium and magnesium in herbicide treatment followed by late spring weeding. Kim *et al.,* (2008) studied the effect of reflective mulch on growth and fruit quality of plum (*Prunus domestica* L.) and observed that total nitrogen content of leaves increased with mulching but phosphorus and calcium concentrations were lower as compared to control. Seasonally, nitrogen is taken up by roots with highest rate of uptake occurring soon after bloom. After harvest, uptake slows and nitrogen is transported from leaves for storage in the trunk and roots (Schreiner *et al.,* 2006). Yin *et al.,* (2007) reported reduced leaf P, Ca and Mg concentration with the covered trees. However, the effect of polypropylene ground cover on leaf Mn concentration was statistically insignificant. A significant increase in leaf Zn and Cu increment was detected. Nielsen *et al.,* (2003) also reported lower leaf Ca and Mg concentration with fabric ground covered apple trees.

Granatstein and Mullinix (2008) showed that alfalfa and clover mulch and a clover cover crop growing as a living mulch increased apple leaf nitrogen in Washington apple orchards. In a related mineralization experiment in mowed white clover living mulch, measured up to 60 kg ha^{-1} N release over 3 weeks that would be available to the trees. The high N treatments (*Trifolium repens* L.) led to clear responses in leaf N in the trees within several weeks after application and lasted for three crops. Highest leaf P, K and Ca contents were recorded in cherry trees intercropped with red clover and lowest was recorded in cherry trees with maize (Bhat, 2015). Sirrine *et al.,* (2008) observed that ground cover management system significantly influenced leaf nutrient status, nutrient uptake and reserve nitrogen in ground and permanent tissues from previous growth cycles in tart cherry. Besides this, in late summer and autumn trees move nitrogen and other nutrients from annual tissues to perennial tissues.

Bhat and Khokhar (2009) while studying the effect of orchard floor management practices on nutrient status in apricot orchard found that grass mulch, though at par with pine needles mulch, grass mulch + atrazine and grass mulch + oxyfluorfen treatments, significantly increased the leaf N, P, K, Mg, Fe, Cu, Zn and B contents over other treatments, inducing hand weeding control which recorded minimum leaf nutrient status but the effect on Ca and Mn was found to be non-significant. There were no significant differences among orchard floor management treatments on nitrogen concentration in pecan leaf samples (Potter *et al.,* 2012). Singh and Bal (2013) recorded highest leaf nitrogen content in jujube plants with black polythene and glyphosate at 1 l ha^{-1} (2.49%). However maximum leaf phosphorus and potassium content was recorded with paddy straw mulch.

The organic treatments promoted higher phosphorus and potassium concentrations in apple leaves and fruit than the integrated production treatments. Leaf and fruit nitrogen levels were normal in both the organic and integrated production treatments (Wooldridge, 2013). Nagy *et al.*(2013) laid out a field trial on five-year-old Sweet Lady and Royal Glory peach cultivars on a sandy loam soil. Four in-row ground management systems were evaluated and they observed that leaf nitrogen, potassium and calcium concentrations increased with mulch but leaf magnesium and zinc decreased with the orchard floor management treatments. Leaf manganese and copper content were slightly affected by the treatments and the changes were not significant. Overall, results suggested that leaf nutrient concentrations responded differentially to different mulches. The superior combination of bio-organic input resulted in considerably greater amounts of leaf macro-and micronutrients *viz*. nitrogen, phosphorous, potassium, iron, copper, zinc, and manganese, which was responsible for better nutrient profile for sustainable kiwi fruit production (Khachi *et al.,* 2015).

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 as observed by Hussain *et al.,* (2018).

Effect of orchard floor management practices on soil hydrothermal condition

Temperature and moisture

Weller (1969) observed low soil temperature with mulching plus herbicides even under extreme solar radiation in a fruit orchard. Van der Westhuizen (1980) found higher soil moisture with polythene mulch in a dry farmed vineyard in South Africa. Mulches offer many potential benefits such as protection of desirable plants from extreme temperatures (Harris, 1983), soil moisture conservation by reducing evaporation and also improvement of water infiltration (Faber *et al.,* 2001) and maintenance of optimum soil temperatures (Montague and Kjelgren, 2004). In a study, mulches reduced maximum soil temperatures by 2.3 to 3.3 ^{o}C and increased minimum temperatures by 1.1 to 2.2 ^{o}C (Skroch *et al.,* 1992). Mulches are effective suppressors of water evaporation (Scholl and Schwemmer, 1982).

Mulch reduces diurnal temperature flux by reducing the solar energy reaching the soil surface during the day and insulating against radiant heat loss at night (Thompson and Grime, 1983). Adeoye (1984) recorded high moisture content up to a depth of 60 cm in grass-mulched soil together with good infiltration and reduced evaporation. Chen (1985) also reported high water content in the top 5 cm of soil with polythene mulch. Kumar (1984) and Sharma (1985) also reported a lower soil temperature throughout the season under mulch + herbicide treatment as compared to other management practices like clean cultivation, herbicidal application and unweeded control in plum and apricot orchards. Herbicidal treatment of orchard soil with strong chemical resulted in lower soil moisture deficit than grassed soil (Haynes, 1980). Bhelia (1988) reported that increased plant dry weight for mulched plants was due to the capabilities of mulch to maintain soil moisture as well as increased efficiency in water uptake by plants. Chen and Yin (1989) reported that the plastic mulching increased soil temperature by 0.9 to 4.3 ºC at the seedling stage, 1.6 to 2.3 ºC at the bud initiation stage and 0.8 to 1.9 ºC at the flowering stage.

Pritchard *et al.,* (1990) observed that cover crops as an orchard floor management option resulted in greater water infiltration rates in the soil compared with a clean orchard floor immature and mature almond (*Prunus communis* Mill.) trees in California. Higher soil moisture retention with herbicide application in apple orchard was reported by Raina (1991). Soil water availability, water infiltration, saturated hydraulic conductivity, and soil temperatures were improved by organic mulching (Merwin *et al.,* 1994). Walsh *et al.,* (1996) observed higher soil water content and temperature under polypropylene and straw compared to herbicide or cover crops in apple trees. Rathore *et al.,* (1998) reported more water conservation in the soil profile during the early growth period with straw mulch.

Mulches provide several advantages over a bare-ground orchard floor because they conserve soil moisture which may also lessen cold injury during droughty conditions (Smith, 2000). Sutagundi (2000) reported that straw mulch resulted in better soil water conservation. The pan evaporation and moisture deficit (PE/MD) ratio was observed to be maximum as 44.97% in case of red mulch plot over control which may be due to the fact that the retardation of evapo-transpiration was better with mulch as reported by Agrawal *et al.*(2010). Hatfield *et al.*, (2001) reported a 34-50 per cent reduction in soil water evaporation as a result of crop residue mulching. Faber *et al.,* (2001) observed a pronounced effect of mulch on soil moisture by reduced evaporative loss.

Soil temperature determines size, shape, quality of root and hastens uptake and translocation of water and nutrient (Dong *et al.*, 2001). Fabric may have a negative effect on water infiltration (Neilsen *et al.,* 2003). Mulches impart manifold beneficial effect, like extreme fluctuation of soil temperature, reduced water loss through evaporation, resulting more stored soil moisture (Shirgure *et al.,* 2003). Application of plastic as mulch material in horticulture is increasing day by days and play an important role to conserve soil moisture (Panigrahi *et al.,* 2008) and maintain soil temperature. Polythene mulching has proved its effectiveness in conserving the soil moisture in citrus (Shirgure *et al.,* 2005).

Increased soil moisture result in increasing nutrient availability (Keller, 2005) both by improving the soil conditions for mineralization as well as improving solute movement through soil to roots. Downer and Faber (2005) reported that the mulchtreatments increased soil moisture retention as compared to unmulched treatments. Mulches maintained lower surface temperature than unmulched soils. MacRae *et al.,* (2007) reported that interference from weeds with peach trees would reduce the availability of water. Soil moisture content at sampling was greater under mulch than in all other orchard management treatments **(**Laurent, 2008).

Mulches insulate the soil against temperature extremes, and prevent soil erosion (Stefanelli *et al.,* 2009). Muhammad *et al.,* (2009) reported that mulching increases soil water contents. Mulches prevent loss of water from the soil by evaporation (Yaun *et al.,* 2009). In orchards, reduced soil temperatures in summer and minimized diurnal soil temperature variation with mulches was observed by Fourie and Freitag (2010). Singh *et al.,* (2010) reported that paddy straw mulch significantly increased the soil moisture status at various soil depths. Paddy straw mulch followed by maize straw and grasses had given favorable results with regards to soil moisture. Hot summer temperatures and dry soil conditions create high evapotranspiration rates which can lower rhizosphere water reserves (Taiz and Zeiger, 2010). In such conditions, mulches provide efficient conservation of irrigation and rainwater, thereby reducing future irrigation requirements in some situations and making the best use of applied irrigation water (Granatstein and Mullinix, 2008).

Jordan *et al.,* (2010), while studying the effects of wheat-straw mulch on soil physical properties revealed that available water was increased by 18% when wheat-straw mulch was applied at rates between 5 and 15 Mg/ha, whereas it doesn't show any differences when applied at the rate of less than 5mg/ha from the control. Mulumba and Lal (2008) obtained similar results with wheat-straw mulch, and concluded that plant-available water increased as mulch application rates increased. However, their data showed greater benefit at lower application rates, such that even at low rates, mulching significantly increased plant-available water.

Mulching at 10 cm thickness, conserved soil water compared to when no mulch was used(Van Donk *et al.,* 2011). Similarly, the soil temperatures were highest at the shallower soil depths in the unmulched plots. Mulching reduces soil temperature in summer and raises it in winter, which prevents the extremes of temperatures during summer. They also conserve the soil moisture due to reduced evaporation and results in cooling of soil (Kumar and Lal, 2012). They further reported that the effect of mulching on the temperature regime of the soil varies according to the capacity of the mulching material to reflect and transmit solar energy. White mulches decreased soil temperature while clear plastic mulches increased soil temperature.

Potter *et al.,* (2012) suggested that the trees with vegetation in the outer area had greater water potential (less stress) than the trees without vegetation in the outer area, which may see benefits by allowing some vegetation cover in orchards at the end of the summer season. Singh (2013) observed that red colour plastic film with size of 1.5 m × 1.5 m conserved maximum soil moisture which was 19.75, 15.27 and 14.38% in the month of July, September and November, respectively and was significantly higher than other treatments.

Mulches changed the minimum temperature in the top 50 mm by 1°C, and as much as 5°C for maximum temperature during summer (Lotze and Kotze, 2014). The plastic-film mulch improved soil hydrothermal conditions (Hai *et al.,* 2015) and (Wang *et al.,* 2016) and these improved soil hydrothermal conditions and nutrient availability comprise the basic mechanisms for the increase in plant productivity under plastic-film mulch.

Hussain *et al.,* (2018) observed that mulch 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. 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.

Effect of orchard floor management practices on soil chemical parameters

Some workers have reported that application of herbicides increased soil pH (Atkinson and White, 1977 and Robinson, 1982). But on the contrary, Miller and Glenn (1985) observed that use of herbicides over similar period of time have found small reduction in soil pH. The integration of cover crops into a cropping system by relay cropping, over seeding, inter-seeding, and double cropping may serve to provide and conserve nitrogen for crops, reduce soil erosion, reduce weed pressure, and increase soil organic matter content (Hartwig and Hoffman, 1975). Shylla *et al.*(1998) none of the orchard floor-management practices significantly affected the soil pH, however electrical conductivity and organic carbon were highest under mulching with hay treatment which was significantly different from all other orchard floor-management practices in plum.

Introduction of organic matter to orchard soils improve soil quality (Reganold *et al.,* 2001). More stable soil organic matter compounds will be produced through the decomposition process that will last years (Wolf and Wagner, 1999). Positive impacts on measurable chemical soil properties such as cation exchange capacity, throughout introduction of organic matter have been observed by various workers (Sanchez *et al.,* 2003 and Rice *et al.,* 2007). Cover crops improve soil structure, tilth, and water-holding capacity and reduce the chance of environmental pollution from nitrogen fertilizers (Danso *et al.,* 1991). It was observed that paddy straw; maize straw, grasses and *subabul* loppings decomposed almost after rainy season and added lot of humus to the soil (Borthakur and Bhattacharya, 1992).

Persson and Kirchmann (1994) reported that the total soil organic matter content changes slowly after mulching. Earlier studies have shown that the inclusion of a green manure crop improve soil organic matter status and led to an increase in soil respiratory activity (Chander *et al.,* 1997). Micronutrient cations (Zn, Cu, Mn and Fe) were found to be significantly correlated with organic carbon (Jalali *et al.,* 1989). Soil chemical properties undergo a series of modifications with the addition of compost (Cuevas *et al.,* 2000). Such changes include organic matter build up, increased pH and increased soil aeration. Soil pH is one of most important soil chemical attributes. It influences plant growth directly, through regulating physiological activities in seed germination and root growth, and indirectly, through its effects on ion mobility, precipitation and dissolution equilibrium, microbial activity and nutrient availability of soil (Bloom, 2000).

Hartwig and Ammon (2002) reported that the living ground covers mulch stop nutrient loss in surface runoff and tie up excess nitrate, nutrients, and residual pesticides to prevent leaching into the groundwater. Application of green manures mulches have shown to significantly increase the activity of urease, dehydrogenase, amidase and phosphatase over control (Sriramachandrasekharan, 2002). Turley *et al.*(2003) reported that the effect of straw mulch on soil organic matter content were smaller and conflicting. The increase in biomass accumulation of ground mulch cultivation (*Sesbania* and *Vigna radiata*) can be due to its fast and determinate growth habit leading to enhanced organic carbon content of soil and nutrient availability, as reported earlier by Dwivedi *et al.,* (2005). Itwas observed that soil electrical conductivity was influenced by mulching (Osunbitan *et al.,* 2004). Chaudhry *et al.,* (2004) reported that by using mulch the electrical conductivity of soil decreases by 53% as compared to unmulched treatments.

Lejon *et al.,* (2007) found that one application of straw mulch to vineyard alleys had legacy effects and increased soil organic matter 27 years later. Soil suitability is necessary for sustaining plant growth. The biological activity and soil suitability is function of soil chemical properties like electrical conductivity which depends on the quality and quantity of soil organic matter (Lukman and Lal, 2008). Shashidhar *et al.,* (2009) also found no measurable increase in organic carbon content with paddy straw. Soil organic carbon was highest in paddy straw while lowest in control (Singh *et al.,* 2010). Carrera *et al.,* (2007) reported that most mulching materials do not strongly affect soil pH. Also there was also no effect of mulching and N-fertilization on electrical conductivity of soil. Zamir *et al.*(2013) reported that the increase in soil pH was more where mulch was applied with tillage than control treatments. Among the different soil ground mulching cultivations, *S. aculeate* recorded highest organic carbon after its incorporation into the soil, which was statistically at par with cowpea (Pooniya *et al.,* 2012).

Mulches are used in many crop systems for adding organic matter (Guerra and Steenwerth, 2012). Wang *et al.,* (2017) demonstrated that continuous plastic-film mulch decreased soil pH. The decrease in soil pH was linked with an increase in soil nitrate concentrations due to the stimulated nitrogen mineralization as a result of increased soil temperature and moisture under plastic-film mulch.

Soil nutrient status

Mulching appears to increase soil phosphorous and exchangeable cations (Tukey and Schoff, 1963). Deist *et al.,* (1973) studied the role of clover in the movement of phosphate and calcium in soil and recorded increased level of available soil phosphorous under clover like red and white clovers, while lowest available soil phosphorous was recorded under clean cultivation. In contrast, cultivated soils are more likely to experience leaching of K, Ca. and Mg compared to soil under grass (Komosa, 1990).

Haystead and Marriott (1978) concluded that significant nitrogen transfer occurred only when legume crop or cover crop reached maturity or when stressed through shading or defoliation. The determining factor in total nitrogen contribution of a cover crop is the amount of dry matter produced by cover crop (Holderbaum *et al.,* 1990). Atkinson (1986) recorded highest available soil phosphorus with red clover followed by white clover as compared to the clean cultivation while studying the nutrient requirement of fruit trees. Decomposable materials used as mulch were straw and composted manure. Soil NO_3-N levels under unincorporated straw cover were higher compared to cultivation and vegetative ground cover (Shribbs and Skroch, 1986). In a review on orchard floor management, Hogue and Neilsen (1987) concluded that organic mulches in the tree row were superior to permanent vegetation or herbicide strips due to increased availability of phosphorous and potassium.

Living mulch increased the availability of nitrogen to succeeding crops, (Frye *et al.,* 1988). Levels of mineral nitrogen and phosphorous in soil under polyethylene geotextile plastic may be higher than levels under straw and grass cover due to elevated soil temperatures which would stimulate microbial mineralization of nutrients from organic matter (Lytton, 1990). Neilsen and Hogue (1992) found that ground cover reduced soil extractable phosphorous relative to early season vegetation control, but increased Ca and Mg relative to black plastic mulch in non-fertilized treatments with apple.

Grass cover has increased available forms of soil P, K, and Ca by decreasing leaching losses (Haynes, 1983), and increasing recycling of nutrients to the soil following mowing.

An apple crop was estimated to remove 58 kg N ha^{-1} in the fruit and from leaching loss (Goh and Ridgen, 1995), while a clover cover crop provided significant nitrogen in its biomass, illustrating the potential for organic orchards to supply a significant portion of their nitrogen needs internally. Cowpea is capable of fixing large quantities of atmospheric nitrogen (Anonymous, 1996). Biological nitrogen fixation has rarely been measured in cover crops of organic apple orchards, however, Goh and Ridgen (1997) measured nitrogen fixation rates of 33-94 kg N ha^{-1} $year^{-1}$ in ryegrass (*Lolium* spp.) and red clover (*Trifolium* spp.) cover crops. Rao and Pathak (1996) reported that highest available potassium (247.20 kg ha^{-1}) content in soil was registered under paddy straw mulch and lowest in black polythene (228.20 kg ha^{-1}) and control (232.80 kg ha^{-1}) in aonla cv. Francis. The higher available potassium content in tree basin is directly associated with rapid decomposition of organic mulches. Borthakur and Bhattacharya (1992) reported similar response with organic mulch in guava. The results were similar with the finding of Shylla *et al.,* (1998) who in plum cv. Santa Rosa reported higher amount (281.1 ppm) of available potassium in soil under hay mulch. However lower amount (237.6 ppm) was recorded under soyabean intercropping.

Stortzer (1996) recorded highest available soil phosphorus with straw mulch followed by clovers while studying the effect of various orchard soil management practices on the availability of potassium and phosphoric acid in the soil. Plant roots proliferated in response to increased soil nutrient concentration (Zhang and Forde, 1998) and are favored in mulched treatment. Long term effect of seven orchard soil management practices *viz*. mulching with black polythene, sod culture with red clover, white clover, lucerne and lolium, mulching with hay and clean cultivation on mineral nutrition of apple cultivar Red Delicious was studied by Thakur *et al.,* (1997) and observed that soil nitrogen was highest with with white clover, however the lowest available soil N, P and K contents were observed with clean cultivation.

In areas where excess nitrogen is already a problem, use of ground covers may provide a sink to tie up some of this excess nitrogen and hold it until the next growing season, when a crop that can make use of it might be planted (Hooda *et al.,* 1998). Nayyar and Chhibha (2000) reported that incorporation of cowpea as green manuring crops could ameliorate iron and manganese deficiency. Sanchez *et al.*(2001) observed that the most remarkable benefit of using legumes as ground cover is their ability to live in a mutually beneficial relationship with nitrogen-fixing bacteria, it takes significant amount of fixed nitrogen, resulting an increase of the active nitrogen pool when their residue enters the soil. Cover crops growing in the alley take up nitrogen and other nutrients from the soil. This uptake is reduced in legumes due to nitrogen fixation of symbiotic bacteria, but depending on soil nitrogen availability, legume soil nitrogen uptake can be substantial (Voisin *et al.,* 2002).

Sanchez *et al.*(2003) assumed that increase in mineralized nitrogen would generally be related to greater bacterial and fungal activity and possible plant health impacts by the use of cover crop species *viz.* white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.), alfalfa (*Medicago sativa* L.) as orchard management practices. Soil nitrogen content was higher during most growing seasons in the mulch and pre-herbicide treatments, compared with grass and post-herbicide treatments (Merwin, 2004). Yao *et al.*, (2005) attributed the greater nitrogen retention in mulch plots to its high C:N ratio (98:1) and microbial cycling and retention of the nitrogen mineralized from decomposing mulch residues.

Leguminous green manuring crop fixes atmospheric nitrogen in soil in available organic form (Virdi *et al.*, 2005). Cowpea is a quick growing cover crop that produces 2,500-4,500 lb acre^{-1} year^{-1} of dry matter, while providing 100-150 lb^{-1} of nitrogen to the subsequent crop (Clark, 2007). In a simulated mulch experiment, Findeling *et al.*, (2007) found that nitrate levels increased over nine weeks in soil matrix below a mulch layer, and this increase was higher when mulch was used with greater nitrogen concentration. Yin *et al.*(2007) observed that soil available NO_3, P, K, Ca, Mg, S, B, Zn, Mn, and Cu contents in 0 to 30 cm in August did not differ significantly between the cover and no cover treatments in any year of study except one, when soil nitrogen and potassium levels were lower with polypropylene cover. Although phosphorus is present in much smaller amounts than nitrogen and potassium in plant tissues, phosphorus is the key plant nutrient involved in energy transfer in the plant chemical reactions (Prasad, 2007).

Research in apple (Granatstein and Mullinix, 2008) has shown increased soil nutrient availability from mulch decomposition. Maintenance of a living cover understory increased soil nitrogen concentration (Hoagland *et al.*, 2008). Application of bio-organics resulted in the increase in the growth of vine ascribed to increased nitrogen uptake and increased release of growth factors (auxins, gibberellins and cytokinins) in root zone (Singh *et al.*, 2010). For mulch trees, lower nitrogen values in some sections of above and below ground tree biomass may also have reflected tracer dilution by a greater total nitrogen pool in mulch soil and trees compared with other ground management systems (Teravest *et al.*, 2010).

As costs for nitrogenous fertilizers become increasingly expensive, organic and conventional apple producers recognize the potential to integrate leguminous plants in orchard agro-ecosystem to contribute to nitrogen nutrition. Mullinix and Granatstein (2011) evaluated white clover as an under tree living mulch and observed that white clover clearly impacted soil nitrate and similarly clover co-location with tree roots enabled nitrogen contribution from both tops and roots. Jat *et al.*, .(2012) observed that cowpea resulted in significantly higher soil available nitrogen which was due to the fact that cowpea produced higher fresh and dry matter accumulation in shoot as well as in root and added more decomposable residues into soil resulting in more organic matter and N in soil. Incorporation of the sown legumes returned 93-177 kg N, 16-20 kg P_2O_5 and 98-153 kg K_2O per ha to soil (Talgre *et al.*, 2012). Increase in available soil phosphorous under grass mulches was also observed by Negi (2015).

Yogesh and Hiremath (2014) recorded significantly higher phosphorous accumulation (17.90 kg ha^{-1}) with cowpea. Total nitrogen under white clover and crown vetch was 50% greater than with no mulch. White clover significantly improved the soil invertase, urease, and alkaline phosphatase activity levels (Qian *et al.*, 2015). Bedse *et al.*, (2015) observed significantly higher nitrogen content in soil with cowpea which was 193.03, 189.40 and 191.22 kg ha^{-1} during both the years as well as in pooled basis, respectively.

Effect of orchard floor management practices on soil microbial population

Azotobacter was found to be positively correlated with plant growth and yield since it tended to promote nitrogen fixation and biosynthesis of plant growth regulators like indole acetic acid and gibberellic acid and hence positively influenced growth and production of fruit trees (Venkateswarlu and Rao, 1983). Yaron *et al.,* (1985) observed that soil that contains high organic matter exhibited elevated microbial activity. However, these soils had the capacity to adsorb applied herbicide more tightly, therefore, decreasing its concentration in soil solution, and thus protect the herbicide from biodegradation; ultimately prolonged its persistence in soil. Fungi played a more important role in surface decomposition than for incorporated residue due to their increased access to residue carbon and soil nitrogen (Holland and Coleman, 1987). Herbicides and their degradation products generally get accumulated in the top soil to a depth of approximately 15 cm, the zone of maximum activity of soil flora and fauna, and may upset the equilibrium of soil microflora (Schuster and Schroder, 1990).

DeVay (1995) observed that mulching of soil with plastic film increases populations of beneficial bacteria and fungi. Soil microorganisms are involved in critical ecosystem processes such as organic matter decomposition, soil aggregation and humus formation, nutrient cycling and retention, and various symbioses and parasitic relationships with plants (Paul and Clark, 1996). Positive and significant correlations of *azotobacter* count with soil pH, organic carbon, and available nitrogen might be due to higher nitrogen level owing atmospheric N_2 - fixing property of this microflora (Tiwary *et al.,* 1999). The dynamic increase of micro-organisms in rhizosphere of fruit crops intercropped with legume cultivation can be explained by favorable quantitative and qualitative composition of organic compounds provided in the form of root exudates and crop residues (Lehmann *et al.,* 2000). Increasing concentration of herbicides not only affect the target organisms (weeds) but also the microbial communities present in soils, and reduce organic matter degradation, nitrogen cycle and methane oxidation (Hutsch, 2001). The higher soil bacterial populations in mulch treatment especially as compared to the pre-herbicide treatment suggest that available resources for micro-organisms i.e. total amount of organic matter inputs increased bacterial populations and activity in these soils. Soil microbial community composition and populations are affected by a range of edaphic factors, plant species, soil management practices, and climate (Marschner *et al.,* 2001). Groundcover management systems for perennial crops must support and enable soil biota to carry out key below ground nutrient retention and decomposition related processes required for long term soil fertility and crop production (Wardle *et al.,* 2001). It is well known that soil micro-organisms are often carbon limited, and that variation in plant biomass inputs across soil treatments influences soil biota.

Busse *et al.,* (2001) reported toxic effect of glyphosate on soil bacteria and fungi. Tu *et al.,* (2001) reported that herbicides have varying effects on soil microbial populations depending on herbicide concentrations and microbial species present. Both glyphosate and paraquat have been reported to cause activation in soil urease and invertase soil enzymes (Sannino and Gianfreda, 2001), while diquat and paraquat increased fungal populations (Mewatankarn and Sivasithamparam, 1987).

Dehydrogenases exist as an integral of intact cells and represent oxidative activities of soil microbes by transferring hydrogen or electrons from substrates to acceptors and may be used as a measurement of overall microbial activity and mineralizes capacity in soil and are suitable to assess broad spectrum biological activity in short period (Nannipieri *et al.,* 2002). Soil microorganisms also have a crucial role in cycling of nitrogen, sulfur, and phosphorus and decomposition of organic residues (Nielsen and Winding, 2002). Bacteria involved in nitrogen fixation (*Azotobacter*) were highly sensitive to herbicide (Nada and Mitar, 2002) and were reduced in herbicide treated soil. Araujo *et al.,* (2003) reported an increase in heterotrophic bacteria of a soil with history of glyphosate application. In contrast, Ratcliff *et al.,* (2006) reported transient increase in fungal propagules and effect on culturable bacteria after glyphosate addition (50 mg kg^{-1}). An unintended consequence of the application of herbicides is that it may lead to significant changes in the populations of soil micro-organisms and their activities thereby influenced the microbial ecological balance in the soil (Saeki and Toyota, 2004).

Balasubramanian and Sankaran (2004) reported that the herbicides application at initial stage suppress the soil micro flora which recovered later on in different soil. As a weed killer, glyphosate targets a single enzyme called 5-enolpyruvylshikimate-3-phosphate synthase, which plays important role in the shikimic acid pathway responsible for biosynthesis of aromatic amino acids which is widely present in microorganisms, including bacteria and fungi (CaJacob *et al.,* 2004). The presence of 5-enolpyruvylshikimate-3-phosphate synthase proteins in bacteria and fungi, therefore, made the microorganisms vulnerable to glyphosate.

Yao *et al.,* (2005) observed that soil phosphorous and calcium availability, soil cation exchange capacity, soil pH and organic matter content were significantly greater in mulch treatment. They also observed that mulch, grass and post herbicide treatments had more soil bacterial colony forming units than the pre herbicide treatment, but colony forming unit counts were similar among the first three treatments. In contrast, the grass treatment had higher colony forming unit counts for soil fungi compared to the other ground management treatments. Increased microbial activity and high microbial populations may also sequester plant nutrients in microbial biomass (Wolf and Wagner, 1999). Cupples *et al.,* (2005) reported drop in soil bacterial population because of rapid mortality of bacteria due to herbicide. Dehydrogenase is thought to be an indicator of overall microbial activity, because it occurs intracellularly in all living microbial cells and is linked with microbial oxydoreduction processes (Stepniewska and Wolinska, 2005). Living plant roots produce exudate containing soluble organic compounds such as sugars, amino acids and organic acids and these relatively labile substances can contribute from 0.1 to 2.8 t C ha^{-1} to the soil microbial community (Rees *et al.,* 2005).

Kuklinsky-Sobral *et al.,* (2005) suggested that the application of the glyphosate herbicide at pre-planting may interfere with the endophytic bacterial community’s equilibrium, which is composed of different species with the capacity for plant growth promotion and biological control that may be affected. Ramesh and Nadanassababady (2005) reported that soil microbial population (bacteria, fungi and actinomycetes) was not affected by the herbicides *viz*., atrazine, used and their time of application tried for weed control in maize.

Ayansina and Oso (2006) reported that high concentrations of herbicides treatments resulted in much lower microbial counts when compared to soils treated with recommended doses. As microorganisms are scavengers in soil and possess physiological variability, they degrade a great variety of chemical substances including the incorporated herbicides in soil (Das and Debnath, 2006). Microorganisms are sensitive to particular herbicide, its application will interfere with vital metabolic activities of microbes (Oliveira and Pampulha, 2006) thus affect the availability of nutrients in the soil (Nautiyal, 2006).

Veverka *et al.,* (2007) reported that fungi are sensitive to urea and could inhibit the growth of saprophytic, and pathogenic fungi. Pampulha *et al.,* (2007) reported significant inhibition in growth of actinomycetes, and *Streptomyces* spp. within six days after application of the herbicide to soil microcosms. Soil microbial communities (like bacteria, fungi and actinomycetes) play critical role in litter decomposition and nutrient cycling, which in turn, affect soil fertility and plant growth (Pandey *et al.*, 2007). An assessment of the soil microfauna in June predicted enhanced N mineralization under the clover (Granatstein and Mullinix, 2008). This was generally associated with increased populations of bacterivorous nematodes and, to a lesser extent, with protozoa. Control plots had the lowest numbers of these organisms and of mycophagus nematodes.

Glyphosate as an organophosphonate can be used as a source of phosphorous, carbon or nitrogen by either Gram positive or Gram negative bacteria (Zabaloy *et al.*, 2008). Some researches highlighted the positive effect of glyphosate on the soil microflora (Sumalan *et al.,* 2008). Actinobacteria are reported to be relatively resistant to herbicides and get affected at high concentration only as reported by Sondhia (2008). Colony forming unit counts for bacteria and fungi were about twice as high in orchard soil from grass lane and mulch plots than in all other ground management system treatments, but *Pseudomonas* counts did not differ among the treatments **(**Laurent *et al.,* 2008). Sumalan *et al.,* (2010) showed that the soil bacteria population after 10 days of glyphosate application was significantly higher than three days of its application (about 2.3 times). Amendments or mulches with wide C: N ratios generally faster increased fungal biomass which itself has a wider C/N ratio than bacterial biomass (Strickland and Rousk, 2010). Significant decrease in phosphate solubilizing bacteria (*Enterobacter asburiae*) was reported by Ahmad and Khan (2010) due to glyphosate herbicides.

Fontaine *et al.,* (2011) suggested that micro-organisms use the energy from the fresh material to decompose soil organic matter in order to release organic nitrogen when inorganic nitrogen is limited. Partoazar *et al.*(2011) recorded trends in bacteria population and observed that in a soil with a long historical use of glyphosate, hetrotrophic bacteria population was significantly increased. Also, by increasing bacteria population, the possibility of glyphosate existence as nutrient source is enhanced. It is likely that the glyphosate provided nutrients for bacterial growth, as evidenced by the significant increase in bacterial population. Sebiomo *et al.,* (2011) reported that soils treated with prime extra had the lowest dehydrogenase activity of 16.09 μg (g^{1} min^{-1}) after the sixth week of treatment, while soils treated with glyphosate had the highest dehydrogenase activity of 20.16 μg (g^{-1} min^{-1}) when compared to atrazine and paraquat, which indicated significant response of soil microbial activity to herbicide treatment and increased adaptation of the microbial community to the stress caused by increase in concentration of the herbicides over weeks of treatment. Different plastic mulches enhanced rhizosphere microbial population (Singh, 2013).

Zain *et al.,* (2013) reported that the herbicide treatments significantly inhibited the development of microbial populations in the soil, and the degree of inhibition was closely related to the rates of their applications and varied with the types of herbicide as, Paraquat caused the highest inhibitory effect to bacteria and actinomycetes, whereas fungi were most affected by glyphosate. Application of pre and post emergence herbicides in jute affected the total bacteria, actinomycetes and fungi population in soil initially but the microbial population improved gradually and reached to normal level by harvest of jute (Sarkar and Majumdar, 2013). The highest microbial population was observed in control plots as compared to those in herbicidal treatments and there was decrease in viable counts of bacteria, actinomycetes and fungi at fifteen days after spray as compared to zero day after spray. Thereafter, the microbial population started regains and an increase was observed in counts indicating reduced toxicity, probably due to degradation of herbicidal chemicals (Saini *et al.,* 2013).

Khairnar *et al.,* (2014) reported that initially after the herbicides treatment (15 days, 30 days and at harvest) microbial counts were slightly less in pre-emergence application of pendimethalin and pemdimethalin + imazethapyr, reaching a maximum between thirty days after sowing and at harvest. They also observed that, toxic effect of herbicides normally appears immediately after application when their concentration in the soil was highest. Zhang *et al.,* (2014) observed decrease in fungal numbers due to the toxicity of herbicides (0-500 μg kg^{-1}). The effect was merely short term and cannot lead to negative effects on soil microbial population. They also reported that some cultivable specific bacteria and actinomycetes use herbicides as their carbon and energy source.

Kaur *et al.*(2014) observed that the herbicides *viz.* pendimethalin, butachlor, thiobencarb, anilofos, pretilachlor, oxadiargyl and pyrazosulfuron-ethyl as pre-emergence and bispyribac as post-emergence were safe for soil microbial populations at recommended rates. They also inferred that the microbial population started to regain after the weeds were also killed by the herbicides and got mixed in the soil during this period and these might have served to increase the nutrients. Abbas *et al.,* (2014) reported that the herbicide had toxic effects on soil microbial parameters, and confirmed that continuous use of herbicide affected the quality of soil and sustainable crop production. They also inferred that reduction in the biomass carbon might be because of decrease in organic matter in the soil due to the mortality of soil microbes by the herbicide residues. Root debris and root mucilage stimulate microbial growth and consequently would lead to the accumulation of microbial mucilage that may serve as additional binding agents, in the rhizosphere (Gunina and Kuzyakov, 2015).

Kumar *et al.,* (2015) noticed the positive soil nutrient build up when fodder crop was intercropped with aonla tree. They also recorded higher fungi population of rhizosphere soil in pearl millet (multicut) intercropped with cowpea however lowest fungal population of 3.12 x 10^5 cfu per gram rhizosphere soil was recorded where aonla was grown exclusively. Sarathambal *et al.,* (2015) found that the intercropping of green gram-pea-green gram had higher population of bacteria (21.7 x 10^6 cfu/g) followed by intercropping of cowpea-pea-cowpea (19.5x10^6 cfu g^{-1}). Fungi and actinomycetes population was highest in intercropping of green gram-pea-green gram combined with herbicide application treatment (14.4 x 10^3 cfu/g and 8.2 x 10^3cfu/g, respectively) followed by intercropping of cowpea-pea-cowpea in mango orchard. Similar trends were also observed in citrus orchard. Wang *et al.*, (2016) hypothesized that plastic-film mulch cropping increased soil microbial activity. Plastic film mulching and manure fertilization significantly increased the relative abundances of soil bacterial groups, played significant role in shaping the bacterial community structure and prevented loss of soil bacterial diversity and abundance during long-term fertilization as reported by Farmer *et al.*, (2017).

Benefit: cost ratio under different orchard floor management practices

Singh *et al.*, (1991) evaluated fluchloralin @ 1.0-1.5 kg ha^{-1}, pendimethalin @ 1.0-1.5 kg ha^{-1} and oxyfluorfen @ 0.15-0.2 kg^{-1}, applied alone or in various combinations for weed control in *Capsicum annuum* cv. California Wonder and observed that pendimethalin + oxyfluorfen resulted in the greatest net profit (Rs 18379 ha^{-1}) and cost: benefit ratio (1:1.47), whereas oxyfluorfen resulted in the least net profit (Rs 1495) and Cost: Benefit ratio (1:0.12). Shaikh (2005) while recommending effective and economic weed control method for rabi chilli concluded that cost due to treatment was lowest with oxyfluorfen (Rs.1040 ha^{-1}) and return due to treatment was highest with pendimethalin + weeding (Rs. 27,140 ha^{-1}), followed by oxyfluorfen + weeding (Rs. 25,560 ha^{-1}).

Hussain *et al.*, (2018) investigated 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.

Gautam and Chauhan (1984) conducted an experiment in peach nursery seedlings and compared simazine, atrazine, diuron, bromacil and terbacil in different concentration and reported that use of appropriative herbicide at a selective concentration is economical for weed control in the peach nursery. They obtained approximate saving of Rs. 2175 ha^{-1} by chemical weed control over seventeen hand weedings. Bajwa *et al.*, (1993) conducted a study on chemical weed control in grape vines. They found that hexuron at pre-emergence stage and Roundupat post-emergence were most effective. They further reported approximate saving of Rs. 3650 and Rs. 4080 ha^{-1}, respectively over control. Bajwa *et al.*, (1992) conducted a study on effect of various herbicides on weed control in pear orchard and concluded that application of hexuron @ 4 kg ha^{-1} as pre- emergence stage and glycel (glyphosate 4 litres ha^{-1}) at post-emergence stage proved most economic as compared to other treatments including hand weeding with a net profit of Rs. 2750 and Rs. 2500 ha^{-1}, respectively.

Khokhar *et al.*, (2007) evaluated pendimethalin and oxadiazon @ 0.825 and 0.240 litre a.i. ha^{-1}, respectively, applied one week before and two days after transplanting in chillies. The treatment oxadiazon one week before transplanting in combination with one hand weeding at 45 days after transplanting had net return 194% higher than weedy check while it was 3.6% higher than weed free treatment. Tiwari *et al.*, (1980) conducted an experiment in young non-bearing apple orchard infested with sixteen weed species. They tested eight herbicides and their combinations and calculated the economics of herbicidal applications. The economics of herbicidal applications reveals that all herbicides proved beneficial. Maximum net saving of Rs. 39,450 ha^{-1} was obtained under pendimethalin 3kg ha^{-1} followed by glyphosate.

Mulches are not traditionally used in vineyards due to the expense of bringing in mulch material and the labour required for application. Using cover crop biomass as a mulch has been researched as a method for effective weed control in vineyards (Fredrikson *et al.,* 2011), but it is not a widely accepted practice in use by the grape industry. By using cover crops grown on-site and applying the biomass with a side discharge mower to the vine rows, the costs associated with utilizing mulch may be reduced compared to purchasing and transporting off-site mulch materials. Bhat (2015) recorded highest benefit: cost ratio in cherry trees intercropped with pea followed by cabbage and French bean.

In conclusion, the review summarizes the main finding as effect of orchard floor management practices have a significant role on apple production. 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. In general, to meet the multiple objective, paddy straw mulch followed by glyphosate 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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