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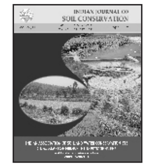

Fruit production and carbon sequestration potential of rainfed apple (*Malus* x *domestica* Borkh) under various moisture conservation techniques

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ABSTRACT

An experiment was conducted during 2011-13 on the effect of *in-situ* moisture conservation techniques for apple productivity and carbon sequestration potential under rainfed condition. Results indicated that mean maximum fruit yield (23.64 kg tree^{-1} and 14.77 t ha^{-1}) and productivity efficiency (0.221 kg cm^{-2} TCSA) were recorded in full moon water harvesting system. Among mulches, plastic mulch performed better in respect to fruit yield (20.55 kg tree^{-1} and 12.85 t ha^{-1}) and productivity efficiency (0.198 kg cm^{-2} TCSA), respectively. Maximum mean soil moisture content was estimated in full moon water harvesting system (12.92%) followed by half moon (12.71%), trench (12.12%), cup and plate (11.36%) and minimum (10.27%) was in control (without water harvesting system). Among mulches, plastic mulch conserved more moisture than organic mulch. The maximum biomass (35.34 Mg ha^{-1}), carbon stocks (16.54 Mg C ha^{-1}), soil carbon storage (31.59 Mg C ha^{-1}) and CO_2 sequestration (176.5 Mg CO_2 ha^{-1}) of apple was observed in apple established with full moon micro-catchment. Amongst mulches, maximum biomass (34.54 Mg ha^{-1}) and carbon stocks 16.16 Mg C ha^{-1} were recorded with polythene mulch. Whereas, maximum carbon storage (33.66 Mg C ha^{-1}) and CO_2 sequestration (178.7 Mg CO_2 ha^{-1}) were recorded in organic mulch treated plots. Interaction effect of full moon water harvesting system along with plastic mulching showed significantly maximum fruit yield, productivity efficiency, biomass, soil carbon storage, carbon stocks and soil moisture content in apple as compared to other treatment combinations under rainfed conditions of Kashmir valley.

1. INTRODUCTION

Apple is being cultivated on 4.83 m ha area and total production is about 76.7 million tonnes (mt) with 15.88 t ha^{-1} productivity of apple in the world, where China is leading country of apple production with a highest productivity (48.3 t ha^{-1}) followed by India (8.0 t ha^{-1}) in the world. In India, apple (*Malus* x *domestica* Borkh) is an important component of the Indian agricultural sector which is being cultivated on 0.31 m ha area and shares 2.9% (2.45 mt) of total fruit production of our country (NHB, 2015). Apple productivity of India is quiet low and is almost six and two times lower than china and world, respectively. The main causes of low productivity of apple in India are lack of drought and climate resilient cultivars, low chilling requiring cultivars, lack of soil and moisture conservation measures, poor integrated nutrient management, high incidence of pest and diseases and rainfed production systems in all hilly states. Out of these, rainfed production system is main cause behind lower apple productivity as more than 80% fruit production comes from rainfed areas in our country (NRAA, 2011). In India, apple occupies sixth position among major fruit species considering area and production. In India, it is mainly grown in hilly states like Jammu and Kashmir, Himachal Pradesh, Uttarakhand and North East regions. Among the apple growing states, Jammu and Kashmir is the leading apple producing states cultivated on 1.62 lakh ha and contributes about 66.0% (17.26 thousand tonnes) of total apple production with highest productivity 10.2 t ha^{-1} in India (Anon, 2016-17). Which can be increased many folds by providing suitable region specific technological interventions with augmentation of soil moisture conservation practices and scientific production systems in the region. Most of hilly states face severe moisture stress during fruit developmental stage in temperate fruit like apple. It is important for improving the productivity of rainfed apple under changing climate scenario, the conservation and utilization of rain water is of utmost important factor which requires efficient water harvesting and conservation techniques. The *in-situ* micro rain water conserving practices like full moon, half moon, cup and plate and trench system combined with different kind of mulches (plastic and organic) were shown most effective on moisture conservation during critical stages of fruit growth and development under rainfed condition (Kumar *et al*., 2014) in apple and almond (Kumar and Ahmed, 2015 and Kumar, 2016). In dry/rainfed region, water conserving practice is proven technology for productivity enhancement (Oweis and Hachum, 2003; Oweis and Hachum, 2006 and Manivannan and Desai, 2007). Mulching play an important role in soil moisture conservation in apple (Dwivedi *et al*., 2000; Lal *et al*., 2003; Neilsen *et al*., 2004 and Pande *et al*., 2005), cherry (Szwedo, 2000), plum (Sharma and Kathiravan, 2009) and strawberry (Ali and Gaur, 2007).

Moreover, apple not only provides nutritional and livelihood security of the farmers but also reduces carbon dioxide in the atmosphere by converging into tree biomass which is otherwise contributed to ever increasing carbon dioxide in the atmosphere (>400 ppm) by the mechanism of carbon sequestration. Sequestering carbon through plantation is considered as an attractive economic opportunity for carbon trading. Despite the recognized importance of fruit trees for nutritional/ livelihood security, carbon sequestration and climate change mitigation, the assessment of the fruit production with carbon sequestration potential of fruit trees is still lacking. Fruit tree orchards have received attention in recent years by virtue of their potential to act as carbon pools (Phani Kumar *et al.*, 2010 and Rathore *et al.*, 2018). It also offers opportunity to grow intercrops along with apple in the hilly region which has many advantages in reducing landslides, soil erosion, conserving moisture, carbon sequestration and environmental security. Fruit trees play an important role in carbon cycles in reducing carbon dioxide (CO_2) emissions and enhancing carbon sinks to meet the twin objectives of climate change adaptation and mitigation. Carbon sequestration is a mechanism for removal of CO_2 from the atmosphere and storing in different components of tree biomass and soils. Enhancing sequestration is one of the major strategies of reducing atmospheric carbon dioxide.

However, limited systematic work has been done on *in-situ* moisture conservation practices for improving production and carbon storage in apple under rainfed conditions of Kashmir valley. Hence, an attempt has been undertaken to identify suitable moisture conservation techniques for higher productivity and carbon storage in apple under rainfed conditions.

2. MATERIALS AND METHODS

Site Characteristics

An experiment was carried out at ICAR-Central Institute of Temperate Horticulture, Srinagar, Jammu and Kashmir, during 2011-13 on fruit production and carbon sequestration potential of apple under various moisture conservation techniques in rainfed Kashmir valley. The site is situated at 34^{0}05'N Latitude, 74^{0}50'E Longitude at 1640 m Altitude above mean seal level (msl). Soil of the experimental site was sandy clay loam with medium fertility status and received average annual rainfall of about 700 mm with 25-30% was available during the critical stages of fruit growth and development *i.e.* May, June and July.

Treatment Details

There were five soil moisture conserving micro-catchments were followed for moisture conservation *viz.*, half moon (W_1), full moon (W_2), cup and plate (W_3), trench (W_4), and without any micro catchment

(W_5-control) with three different mulches *viz.*, organic (M_1), plastic (M_2), and control (M_3). All the treatments were laid in factorial randomized block design with three replications. Seven years old apple cultivar 'Red Chief ' regular bearer, high yielding, better fruit yield and quality planted at 4 x 4 m spacing was selected for the study. Plants were received uniform cultural operations and adequate plant protection measures. Total 180 healthy plants of uniform thickness and size were selected and for getting precise results, four plants/replication were taken for recording the data. Apple trees were mulched with black polythene mulch (Ultra Violet resistant) of 100 mm thickness with 8-10 holes (10 mm) at equal distance to permit rain water into the soil under M_1 treatment. Similarly, locally available dry grass (35-40 kg tree^{-1} basin on dry weight basis) applied as organic mulch in M_2 treatment around tree basin leaving 30-45 cm distance from the tree trunk. Tree trunk girth was recorded before the execution and at the end of experiment during the year of study, a ring was made with red paint at 15 cm above the ground level and data was recorded from same marked point every year. The Trunk Cross-Sectional Area (TCSA) of tree was calculated by using formula *i.e.* Girth^2/4π (Westwood and Roberts, 1970). Plant height alongwith canopy spread were measured in two directions, *i.e.* east-west and north-south and expressed in meter. Tree volume was calculated by Castle's (1983) formula as given below: Tree volume = 0.5228 × plant height (m) × canopy diameter (m^2). Canopy volume was recorded after harvesting *i.e.* October during the course of study. Fruits were harvested at commercial maturity and yield per tree was estimated in kilogram and presented in t ha^{-1}. Soil moisture contents (0-30 cm depth) were recorded at 30 days interval from April to August by thermo-gravimetric method described by Black, 1965. The soil moisture content (%) was calculated by the formula = Fresh soil weight (g)-soil dry weight (g) / Soil dry weight (g) x 100. Soil Organic Carbon (SOC) varies from 0.53 to 0.68 in all the plots before establishment of orchard up to 30 cm soil depth.

Tree Biomass

Biomass was estimated by destructive method for stem, branch, leave, fruit and root parts in 10 year old apple trees. Likewise, branches of sampled apple were counted and classified into three groups based on their basal diameter, *viz.*, < 2, 2-6 and >6 cm. From each of sampled apple trees, two branches/branch group were randomly selected and weighed fresh. Sub-samples of each component were oven dried to constant weight at 65°C. Using the fresh/dry weight ratio and the number of branches, dry weight was determined. Similarly, root biomass was estimated considering coarse as well as fine root production through core sampling upto 30 cm soil depth.

Carbon Estimation in Tree and Soil

Carbon stock of apple in the different treatment was obtained by multiplying the dry weight of the different tree components by their average carbon concentration. Carbon was assumed to constitute 50% of the ash-free dry mass. Ash content was determined by igniting 1.0 g of powdered sample at 550°C for 6 h in muffle furnace. The carbon stock obtained in the different tree components was summed up to obtain Total Carbon Stock (TCS). The estimated TCSs were converted into CO_2 equivalents using (C × 44/12). SOC was determined following standard procedure in all plots at 30 cm soil depth. SOC was computed by multiplying the organic carbon (g kg^{-1}) by bulk density (g cm^{-3}) and depth (cm) and is expressed in Mg ha^{-1}.

Values of the different parameters were analysed statistically using analysis of variance (Gomez and Gomez, 1984). To determine the significance of the difference between the means of pairs of treatments, least significance differences were computed at the <*p 0.05* probability level.

3. RESULTS AND DISCUSSION

Fruit Yield and Productivity Efficiency

Fruit yield and productivity efficiency as influenced by moisture conservation techniques in apple (Fig. 1a and Fig. 1b). Maximum fruit yield (21.33 and 25.95 kg tree^{-1}) was recorded in W_2 treatment during 2011-12 and 2012-13 which was 34.15 and 55.20% higher over control treatment. The mean maximum yield (23.64 kg tree^{-1}) was recorded in W_2 treatment and superior to other treatments. Among mulches, plastic mulch performed better as far as fruit yield is concerned, maximum fruit yields (18.27 and 22.83 kg tree^{-1}) were recorded in M_2 treatment during 2011-12 and 2012-13. The mean maximum fruit yield (20.55 kg tree^{-1}) was also recorded in M_2 treatment and superior to organic mulch and control treatment. Productivity efficiency as influenced by water harvesting techniques and mulching in apple (Fig. 2a and Fig. 2b). Maximum productivity efficiency (0.204 and 0.237 kg cm^{-2} TCSA) was recorded in W_2 treatment and at par with W_3 and significantly superior over other treatments during 2011-12 and 2012-13. Mean maximum productivity efficiency (0.221 kg cm^{-2} TCSA) was recorded in W_2 treatment which was at par with W_3 and W_4 treatments and superior over other treatments. Among mulches, plastic mulch performed better as far as productivity efficiency is concerned but non significant variations were reported among treatment during 2011-12. Significant variations were found among treatment and maximum value (0.216 kg cm^{-2} TCSA) was recorded in M_2 treatment. Mean maximum productivity efficiency was recorded in M_2 treatment which was 14.45% higher over control treatment. The fruit yield and productivity efficiency was better in full moon water harvesting technique might be due to better vegetative growth resulted better fruit yield and productivity efficiency. Similar result was reported by Polara *et al.*, 2013; Kumar *et al.*, 2014 and Samant *et al.*, 2016. Among mulches, plastic mulch performed better in respect to yield and productivity efficiency might be due to retention of soil water for longer period which helped for better fruit growth and development. Similar findings were reported by Dwivedi *et al.*, 2000 and Panigrahi *et al.*, 2008. Interaction effect of water harvesting techniques in combination with mulching also showed maximum fruit yield and productivity efficiency in apple (Fig. 1c and Fig. 2c). Mean maximum fruit yield (15.81 t ha^{-1})

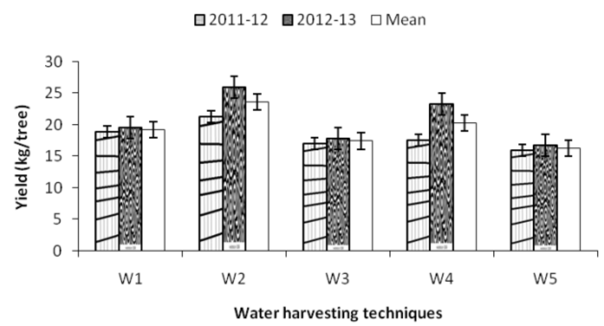

Fig. 1a. Effect of water harvesting techniques on fruit yield in apple

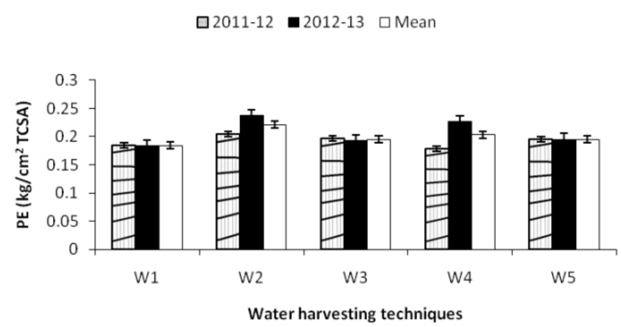

Fig. 2a. Effect of moisture conservation techniques on productivity efficiency of apple

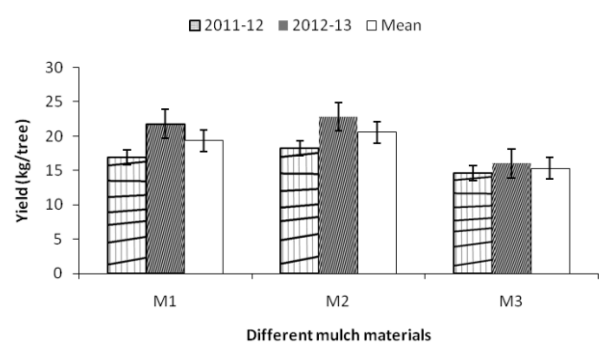

Fig. 1b. Effect of different mulches on fruit yield of apple

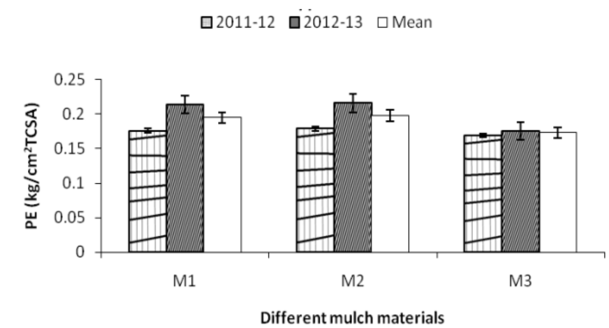

Fig. 2b. Effect of different mulches on productivity efficiency of apple

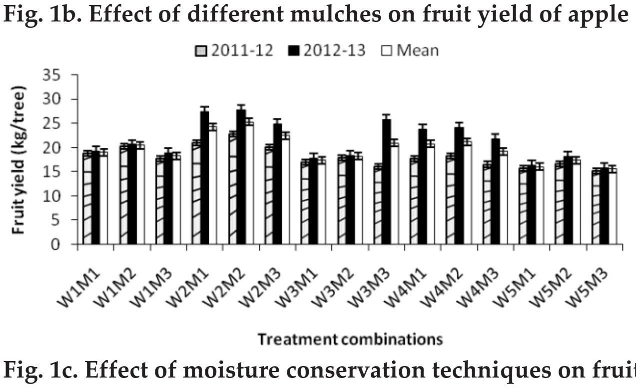

Fig. 1c. Effect of moisture conservation techniques on fruit yield of apple

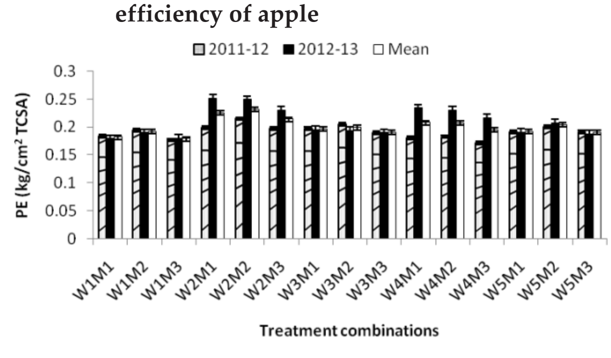

Fig. 2c. Effect of moisture conservation techniques on productivity efficiency of apple

and productivity efficiency (0.232 kg cm^{-2} TCSA) were recorded in full moon water harvesting technique combined with plastic mulch. Similar findings were reported by Kumar *et al*., 2016 and Joolka *et al*., 2008.

Biomass and Carbon Stocks in Apple Tree

Data on biomass and carbon stocks improved significantly by moisture conserving micro-catchments and mulching in apple established under rainfed condition (Fig. 3a, 3b and Fig. 3c) and carbon concentration in various apple tree components presented in Fig. 4. The maximum biomass (35.34 Mg ha^{-1}) and carbon stocks (16.54 Mg C ha^{-1}) of apple was

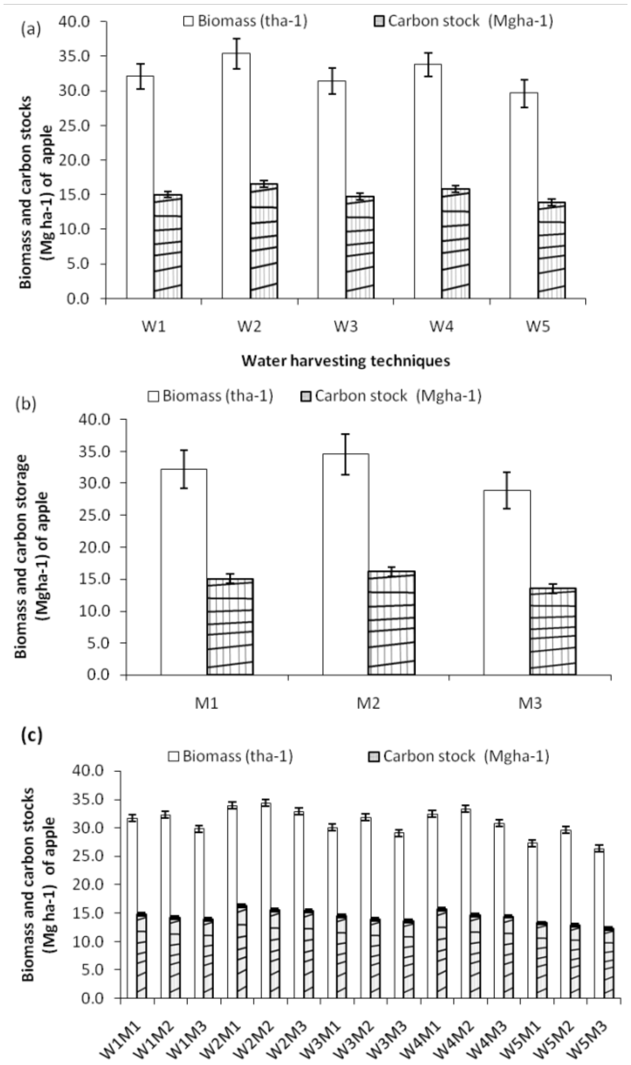

Fig. 3a. Effect of moisture conserving micro-catchments on biomass and carbon storage in apple, (b) Effect of moisture conserving mulches on on biomass and carbon storage in apple and (c) Effect of moisture conserving techniques on on biomass and carbon storage in apple

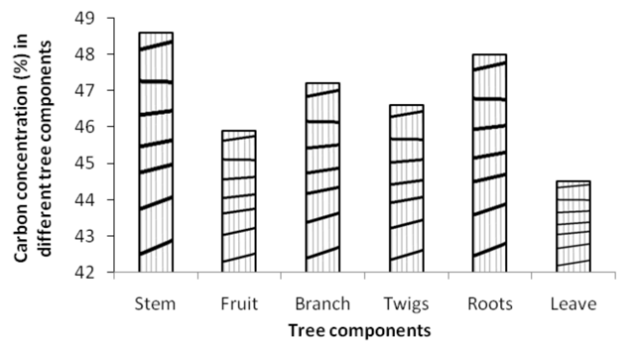

Fig. 4. Carbon concentration in different components of apple tree

observed in apple established with W_2 (full moon micro-catchment) which was 4.59, 10.0, 12.37, and 19.23% higher than W_4, W_1, W_3 and W_5 micro-catchments, respectively under rainfed conditions. Similarly, apple tree planted in trench micro-catchment (W_4) attained biomass (33.79 Mg ha^{-1}) and carbon stocks (15.81 Mg ha^{-1}) after W_2 treatment, which was 5.22, 7.44 and 14.0% more than W_1, W_3 and W_5 micro-catchments in rainfed situations. Likewise apple tree planted in W_1 micro-catchment produced biomass and carbon stock (32.12 and 15.03 Mg ha^{-1}) was 2.11-8.37% higher as compared to W_3 and W_5 micro-catchments, respectively. Similarly, apple tree established with polythene mulch (M_2) attained maximum biomass (34.54 Mg ha^{-1}) and carbon stocks (16.16 Mg C ha^{-1}) was 7.17-19.60% as compared to M_1 and M_3 treatments, respectively whereas apple tree with organic mulch could attained biomass (32.23 Mg ha^{-1}) and carbon stock (15.08 Mg C ha^{-1}) was 11.6% more than control (M_3) treatment. Interaction effect of moisture conserving micro catchments and mulching also showed significant variations in biomass production and carbon stocks (Fig. 6c). The maximum biomass and carbon stocks were also recorded in W_2M_2 treatment whereas minimum in case of W_5M_3 treatment. Maximum biomass and carbon stocks in apple tree recorded with full moon water harvesting micro-catchment (W_2) and because maximum conservation of soil moisture and uniform distribution around the basin area of the tree which infiltrated near active root zone (30 cm depth) and used by the plant for transpiration and manufacturing food which increased the tree volume, canopy volume, fruit yield, biomass and carbon stocks in apple tree. Rathore *et al.*, 2016 reported that higher fruit production, biomass and carbon stock was recorded in kinnow under high moisture conditions with organic mulching in the 1.0 m radius of plant basin. Rathore *et al.,* 2016 reported that higher fruit production, biomass and carbon stock was recorded in kinnow under high moisture conditions with organic mulching in the 1.0 m radius of plant basin.

Carbon Storage in Soil

Data on soil carbon storage in the soil (up to 30 cm soil depth) differed significantly under moisture conserving micro-catchments and mulching in apple established under rainfed condition (Fig. 5a, 5b and 5c). The maximum soil carbon storage (31.59 Mg C ha^{-1}) of apple was recorded in apple established with W_2 (full moon micro-catchment) which was 1.30, 4.20, 16.38 and 37.0% higher than W_4, W_1, W_3 and W_5 micro-catchments, respectively under rainfed conditions. Similarly, apple tree planted in trench micro-catchment (W_4) recorded carbon stocks in soil (31.19 Mg C ha^{-1}), which was 2.87, 14.91 and 35.29% more than W_1, W_3 and W_5 micro-catchments in rainfed situations. Likewise apple tree planted in W_1 micro-catchment stored carbon in the soil (30.32 Mg C ha^{-1}) was 11.70-31.50% higher as compared to W_3 and W_5 micro-catchments, respectively. Similarly, apple tree established with organic mulch (M_1) recorded maximum soil carbon storage (33.66 Mg C ha^{-1}) was 16.15-29.83% as compared to M_2 and M_3 treatments, respectively whereas apple tree with polythene mulch could stored soil carbon (28.98 Mg C ha^{-1}) was 11.78% more than control (M_3) treatment. Interaction effect of moisture conserving micro catchments and mulching also showed significant variations in carbon stocks in the soil (Fig. 5c). Significantly higher carbon stock (32.62 Mg ha^{-1}) in the soil was recorded in full moon water harvesting technique in combination with organic mulch (W_2M_1) treatment whereas minimum in case of W_5M_3 treatment (24.48 Mg ha^{-1}). Maximum biomass and carbon stocks in apple tree recorded with full moon water harvesting micro-catchment (W_2) and because maximum conservation of soil moisture and uniform distribution around the basin area of the tree which infiltrated near active root zone (30 cm depth) and used by the plant for transpiration and manufacturing food which increased the tree volume, canopy volume, fruit yield, biomass and carbon stocks in apple tree. This might be due to proper availability and retention of soil moisture for longer period of time favours for better vegetative growth. Rathore *et al.,* 2017 reported that carbon stock under different aonla cultivars in the soil (30 depth) was 41.00 (Mg C ha^{-1}) higher than the carbon stocks of aonla tree (23.80 Mg C ha^{-1}) higher fruit production, biomass and carbon stock was recorded in kinnow under high moisture conditions with organic mulching in the 1.0 m radius of plant basin. Rathore *et al.,* 2017 reported that carbon stock under different aonla cultivars in the soil (30 depth) was 41.00 (Mg C ha^{-1}) higher than the carbon stocks of aonla tree (23.80 Mg C ha^{-1}). Higher fruit production, biomass and carbon stock was recorded in kinnow

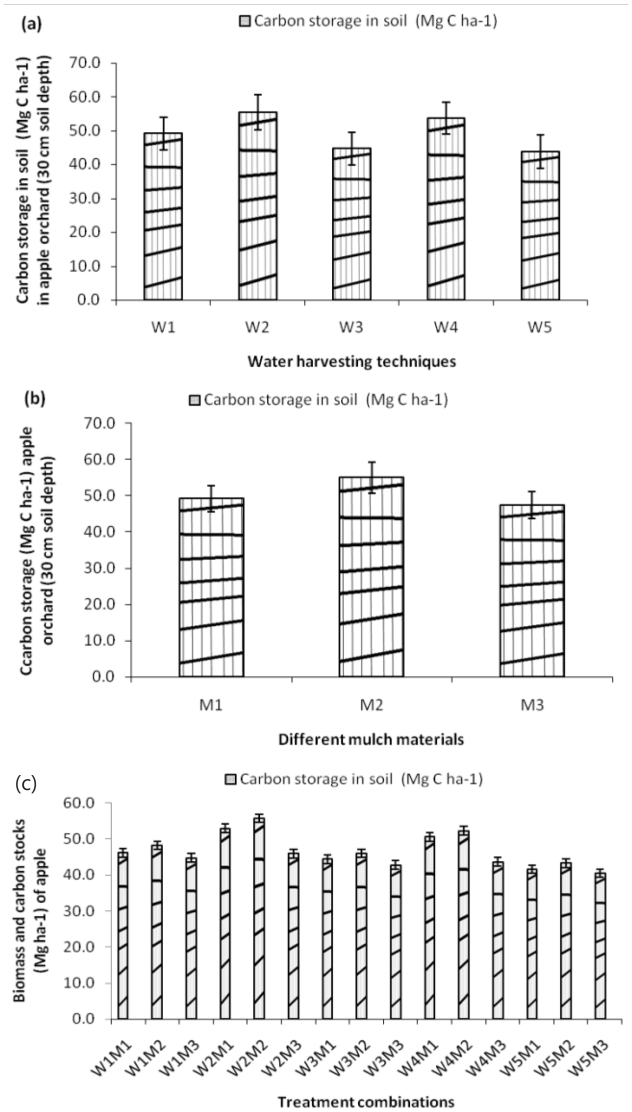

Fig. 5(a). Effect of moisture conserving micro-catchments on carbon storage in the soil (30 cm depth) of apple orchard, (b) Effect of moisture conserving mulches on carbon storage in the soil (30 cm depth) of apple orchard and (c) Effect of moisture conserving techniques on carbon storage in the soil (30 cm depth) of apple orchard

under high moisture conditions with organic mulching in the 1.0 m radius of plant basin. Rathore et al., 2018 also recorded higher carbon stock in soil then guava plant.

Total Carbon Dioxide Sequestration

In general CO_2 sequestration was two times higher in the soil as compared to apple tree (Fig. 6a, 6b and 6c). Among all the treatment, average CO_2 was sequestered in the apple tree (53.64 Mg CO_2 ha^{-1}) which was almost two times lower than CO_2 sequestered in the soil (106.43 Mg CO_2 ha^{-1}). Total CO_2 sequestration (tree + soil up to 30 cm soil depth) was improved significantly by moisture conserving micro-catchments and mulching in apple established under rainfed condition. (Fig. 5a, 5b and 5c). The maximum total CO_2 sequestration (176.5 Mg CO_2 ha^{-1}) of apple was recorded in apple established with W_2 (full moon micro-catchment) which was 4.14, 4.33, 14.97 and 30.30% higher than W_1, W_4, W_3 and W_5 micro-catchments, respectively under rainfed conditions. Similarly, apple tree planted in trench micro-catchment (W_4) recorded total CO_2 sequestration (169.1 Mg CO_2 ha^{-1}) after W_2 treatment, which was 10.20 and 24.93% more than W_3 and W_5 micro-catchments in rainfed situations. Likewise apple tree planted in W_1 micro-catchment sequestrated total carbon dioxide (169.50 Mg CO_2 ha^{-1}) was 10.40-25.20% higher as compared to W_3 and W_5 micro-catchments, respectively. Similarly, apple tree established with organic mulch (M_1) recorded maximum total CO_2 sequestration (178.7 Mg CO_2 ha^{-1}) was 7.97-23.58% as compared to M_2 and M_3 treatments, respectively whereas apple tree with polythene mulch could sequestered atmospheric CO_2 (165.50 Mg CO_2 ha^{-1}) was 14.46% more than control (M_3) treatment. Interaction effect of moisture conserving micro catchments and mulching also showed significant variations in total CO_2 sequestration in the soil as well as in the tree (Fig. 6c). Significantly higher total CO_2 sequestration (179.56 Mg CO_2 ha^{-1}) from soil and tree was recorded in full moon water harvesting technique in combination with organic mulch (W_2M_1) whereas minimum in case of W_5M_3 treatment (134.92 Mg CO_2 ha^{-1}). This might be due to proper availability and retention of soil moisture for longer period of time favours for better vegetative growth. Maximum total carbon sequestration in apple tree recorded with full moon water harvesting micro-catchment might be due to maximum conservation of soil moisture and uniform distribution around the basin area of the tree which infiltrated near active root zone (30 cm depth) and used by the plant for transpiration and manufacturing food which increased the tree volume, canopy volume, biomass and carbon stocks in apple tree. The results are in conformity with the findings of Rathore *et al.*, 2016; Rathore *et al.*, 2017; Newaj *et al.*, 2010 and Verma *et al.*, 2014.

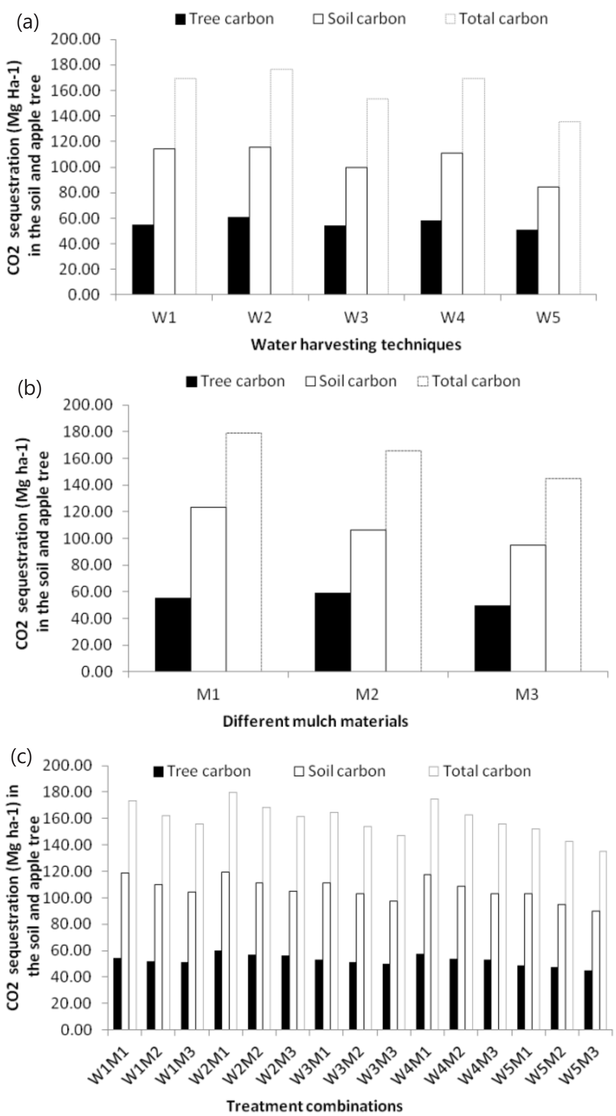

Fig. 6(a). Effect of moisture conserving micro-catchments on CO_2 sequestration in the soil (30 cm depth), apple tree and total (soil + tree), (b) Effect of moisture conserving mulches on Co_2 sequestration in the soil (30 cm depth), apple tree and total (soil + tree) and (c) Effect of moisture conserving techniques on CO_2 sequestration in the soil (30 cm depth), apple tree and total (soil + tree)

Soil Moisture Content

The soil moisture content at 0-30 cm depth were found better in all the water harvesting techniques during 2011-12 and 2012-13. The soil moisture data for five months (April, May, June, July and August) were pooled and presented in Fig. 7a and Fig. 7b. Maximum soil moisture content was recorded in full moon water harvesting system which was 26.67 and 25.09% higher over control plot during 2011-12 and 2012-13. Among mulches, plastic mulch performed better in respect to soil moisture retention/ conservation. Maximum soil moisture content was recorded with plastic mulch which was 12.14 and 14.33% higher during 2011-12 and 2012-13 over control treatment. Interaction effect of rainwater harvesting and mulching techniques indicated that maximum soil moisture was estimated with full moon water harvesting in combination with mulching in apple (Fig. 7c). The higher soil moisture content in full moon water harvesting system might be due to uniform distribution of moisture in soil profile leads to higher soil moisture in full moon water harvesting system. Among different mulches, comparatively higher moisture content was found under plastic mulch which may be due to efficient weed control and fact that water after evaporation condenses on the bottom side of the polythene sheet and drop down again on the soil surface that retained soil moisture for longer period of time. Raina (1992) have reported higher moisture content under black polythene mulch over control. These results are in accordance with the findings of Ghosh *et al*., 2007; Verma *et al*., 2010 and Das *et al*., 2010.

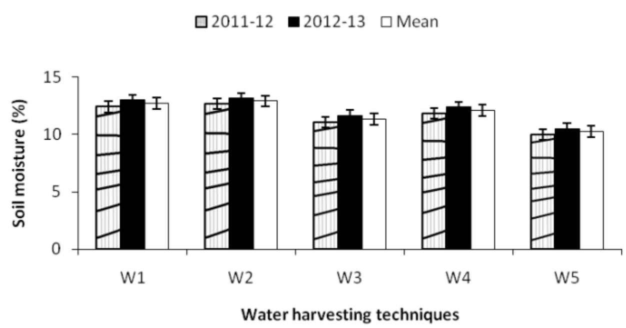

Fig. 7a. Effect of water harvesting techniques on soil moisture in apple

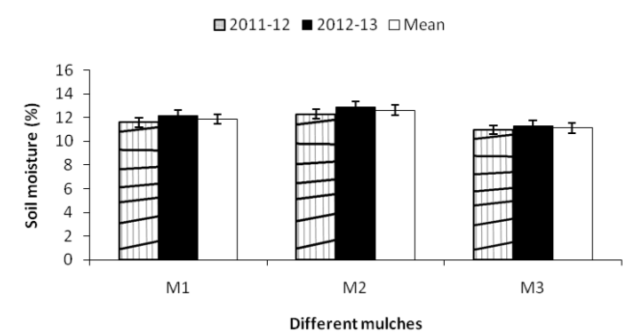

Fig. 7b. Effect of different mulches on soil moisture in apple

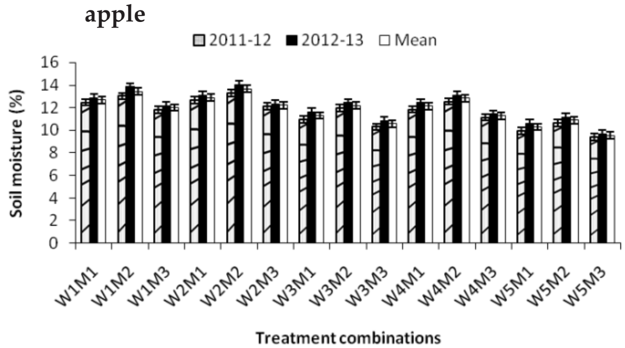

Fig. 7c. Effect of moisture conservation techniques on soil moisture in apple

4. CONCLUSIONS

The present study indicated that 44.94, 18.02 and 25.08% yield improvement with full moon, half moon and trench water harvesting techniques over control treatment. Among mulches, 33.96 and 26.14% yield improvement with plastic and organic mulch over control treatment. The combined effect of water harvesting and mulching techniques indicated that full moon water harvesting in combination with plastic mulch and full moon water harvesting in combination with organic mulch found to be effective for improving fruit yield (63.05% and 56.09%) over control treatment. The maximum biomass (35.34 Mg ha^{-1}), carbon stocks (16.54 Mg C ha^{-1}), soil carbon storage (31.59 Mg C ha^{-1}) and CO_2 sequestration (176.5 Mg CO_2 ha^{-1}) of apple was observed in apple established with full moon micro-catchment. Amongst mulches, maximum biomass (34.54 Mg ha^{-1}) and carbon stocks (16.16 Mg C ha^{-1} were recorded with polythene mulch. Whereas, maximum carbon storage (33.66 Mg C ha^{-1}) and CO_2 sequestration (178.7 Mg CO_2 ha^{-1}) were recorded in organic mulch treated plots.

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