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Growth and yield of Kinnow (*Citrus reticulata Blanco*) and soil physical properties as affected by orchard floor management practices in Punjab, Pakistan

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Abstract

Improvement of soil physical properties through orchard floor management is a desired option because it results in improved yields, better nutrients and water use efficiency and reduced runoff. Studies were carried out to determine effect of weed management practices on growth, fruit production and changes in soil physico-chemical parameters in a citrus orchard. Studies comprised of two orchard floor management practices i.e. cultivation and mowing. In cultivation, weeds emerging in the orchard were controlled by cultivation/ploughing to keep their growth at minimal, while in mowing, weeds were cut at about 5 cm height to keep their growth under check and the cut weeds to act as mulch. After 8 years of continuous practice, determinations were made to compare effectiveness of the management practices in terms of plant growth and yield, changes in soil physico-chemical and water retention characteristics. The data indicated that all the growth parameters responded significantly to management practices. Similarly, soil physico-chemical parameters were also affected. Shoot growth, canopy diameter, Trunk Cross-sectional Area (TCSA) and fruit yield were increased. Soil bulk density was decreased and consequently soil porosity was increased. Mowing promoted accumulation of soil organic matter and soil aggregation. The increased water retention in soil profile and enhanced saturated hydraulic conductivity were attributed to conditions conducive to organic matter accumulation in the soil profile. The results indicated superiority of mowing practice over conventional cultivation towards plant growth, yield and improvement in soil physical properties.

Key words: Orchard floor management, soil aggregation, penetration resistance, saturated hydraulic conductivity, citrus growth performance

Introduction

Citrus is an important fruit crop of Pakistan grown on a large scale. It is grown all over the country as it can fit in any agro-ecological zone of the country. Floor management has always been a serious concern for the citrus growers like any other fruit crop. Weed control is important aspect in a newly established orchard and also for older plants because competition with plants can reduce tree growth and fruit production. Management practices are essential to keep weeds suppressed below a critical threshold level. Various management options include clean cultivation, mulching, herbicide application and mowing etc.

Cultivation of soil for weed control is well established in fruit production (Lord and Vlach, 1973) but it has serious disadvantages of higher costs and root damage (Hogue and Neilsen, 1987). In the absence of reliable herbicides approved for use in organic systems, orchard growers often control weeds with intensive cultivation. This practice can result in degrading soil structure (Six *et al*., 1998), disrupt soil faunal communities (Fiscus and Neher, 2002), and accelerate nutrient cycling and organic matter loss (Cambardella and Elliott, 1993). Cultivation of soils generally results in more mineral N compared to soil under grass (Haynes and Goh, 1980). Cultivation may improve water infiltration in some soils, but frequent shallow cultivation may damage feeder root near the surface reducing tree vigor. In contrast, cultivated soils are more likely to experience leaching of essential mineral nutrient like K, Ca, and Mg compared to soil under grass (Komosa, 1990).

Orchard growers generally prefer the use of herbicides, however; cultivation in the tree row is currently the most common management practice in fruit orchards. It provides weed control but is costly and impairs soil quality and N availability (Cambardella and Elliot, 1993; Granatstein, 2004; Sanchez *et al*., 2007). Alternative groundcover strategies that reduce costs and improve N mineralization of organic fertilizers are needed. Possible groundcovers include organic mulches and leguminous cover crops. Numerous studies have reported reduced tree growth and yield due to increased competition between trees and cover crops (Sanchez *et al*., 2003; Hoagland *et al*., 2008). Weed

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management practices that reduce mechanical disturbance of orchard soils and ground covers may ameliorate negative impacts on soil quality and enhance N availability. Such weed control practices include application of herbicides (Boyd and Brennan, 2006), mulching with wood chips (Oliveira and Merwin, 2001), maintenance of a vegetative cover or "living mulch" (Sanchez *et al*., 2003; Sánchez *et al*., 2006) and soil amendment with Brassica seed meal (Balesh *et al*., 2005).

The desired outcomes of orchard floor management are focused on good tree performance (tree growth) and a high consistent yield of quality fruit. Other considerations like changes in soil organic matter, bulk density, porosity, mineral nutrient (Walsh *et al*., 1996; Hoagland *et al*., 2008), microbial diversity (Laurent *et al*., 2008) and soil carbon sequestration need due consideration.

The study was undertaken to evaluate the performance of two management practices i.e. cultivation and mowing on citrus growth, yield performance and their impact on soil physico- chemical properties.

Material and Methods

A long term field experiment was initiated at field area of Horticultural Research Institute, NARC Islamabad on Nabipur soil series (*Typic Camborthids*). The surface soil (0-15 cm) was silt clay loam (sand, 22%; silt, 53% and clay, 25%) having pH, 7.9 and EC, 0.28 dS $m^{-1.}$ The study was conducted on 15 years old citrus (Kinnow Mandarin) orchard commencing from 2001 to 2010. Data for growth, yield and soil properties were recorded from 2007 to 2009. For Orchard Floor Management Practices (OFMP), the experimental area was split in two equal blocks comprising of 1 acre each. In one half, weeds were controlled by cultivation. For cultivation treatment space within plant rows was ploughed 5-6 times a year for inhibiting weed proliferation, where as in the second half mowing practice was done (when weeds had grown to a height of 15-20 cm, they were cut with a mower running behind a tractor allowing about 5 cm height, the cut part of weeds was left in the field to act as mulch and decompose subsequently). The mowing was also performed 5-6 times each year. All other agronimic practices like irrigation, fertilization and pruning, etc. were carried out equally as and when required as per plant requirements.

Recording of yield and tree growth data

Mowing and cultivation practices were carried out from 2001 to 2010 but data on tree growth (shoot growth, canopy diameter and trunk cross sectional area) and yield (number of fruits/tree and weight of fruits) were recorded during 2007 to 2009. Shoot growth data were recorded for three flushes (spring, summer & late summer fall flush) each year. Flush length was measured for the tagged branches from four sides of the plant. Shoot growth data were taken at maturity/cease of growth. While, canopy diameter and trunk cross sectional area was measured in (m) and (cm^2), respectively.

Yield per treatment was recorded by counting the total number of fruits per tree at the time of harvesting. While fruit weight was recorded by weighing harvested fruit from each treatment unit on WUE-SEP digital electric balance. Average of 20 fruits was calculated and the data was expressed in grams.

Soil sampling and analytical methods

During winter (August, 2009), at moisture contents close to field capacity, undisturbed soil cores were taken from the field using a core soil sampler of 98.125 cm^3. For core sampling, 4 plants from each treatment were selected randomly and 3 points around the tree equally spaced were marked for sampling. These samples were taken from an area of approximately 130-140 cm radius from the tree trunks within each plot. Each value reported in the text is mean of 12 figures (4 replicates × 3 samples). Thus the samples were taken from an area away from the tracks of tractors (from edges of tree canopy) where machinery had not affected the soil during field operations.

For gravimetric water determinations, core sampling was done at 0-15 cm, 15-30 cm, 30-50 cm and 50-100 cm depth with a weekly interval during September to October 2009 when Moonsoon rains had subsided. Samples were immediately sealed in plastic containers and were shifted to laboratory. Fresh weights of samples were recorded and then dried in an oven at 105 ˚C. Water content was determined by calculating diffence in loss in weight on oven dry basis (Black, 1965). Separate sets of core sampling was done from each treatment at soil depths of 0-15, 15-30, 30-50 and 50-100 cm for soil bulk density, porosity, penetration resistance and water retention characteristics as well as for other physico-chemical determinations.

Soil pH and EC were determined in 1:1 soil to water suspension using pH and EC meters. Percent lime in soil was determined using calcimeter method. Soil organic matter was determined by wet oxidation method of Walkley (1947) as described by Black (1965). Phosphorus in soil extract was determined vanedomolybedate blue colour method colorimetrically (Olsen *et al*, 1954).

For the measurements of soil penetration resistance (PR), intact soil samples contained in the cores were equilibrated on sand column maintained at 20 cm suction column prior to PR measurements. The PR measurements were made using a receded shaft cone penetrometer having cone diameter of 2 mm with an angle of 30°. The cone was driven into the sample at a constant speed of 12 mm per minute. The sample was kept at a digital balance. The force required to drive the cone through the sample was recorded on the balance and converted into PR values (kPa) (Townend *et al*., 1996). These values were recorded at 1 cm interval depth wise in each sample and averaged. In each sample, penetrometer probe was driven for 4 times at 1 cm apart and values obtained were averaged.

Saturated hydraulic conductivity was determined *in situ* using Guelph Permeameter (Elrick *et al*., 1984). A well of 5 cm diameter was dug at desired soil depth and head of the Permeameter was lowered into the well. Water was allowed to pass through the soil at constant head of 5 cm. Reading of saturated hydraulic conductivity was recorded when a steady state had achieved.

Aggregate stability was determined by wet sieving method (Kemper and Rosenau, 1986). Soil was sieved to pass through a 2 mm sieve and aggregates retained on a 1 mm sieve beneath were used in the determinations. Four grams of 1-2 mm air dried aggregates were taken into 0.25 mm sieve holder. Aggregates were moistened 5-10 minutes before shaking was done under water for 5 minutes. The aggregates remaining on 0.25 mm sieve were oven dried at 105°C and weighed. The water stability index was calculated as the percentage of air dry aggregates remaining on 0.25 mm sieve.

Data obtained was analyzed statistically using 02 Floor Management practices 04 soil depths and 04 replications in 2 factor factorial randomized complete block design using Minitab software. The means were compared with least significant difference (LSD) test. Where this was not met, standard error of means was computed.

Results and Discussion

Tree growth characteristics

Data in Table 1 and 2 indicated that floor management practices (Mowing & Cultivation) had a significant impact on tree vegetative growth and yield whereas nonsignificant difference was observed within the years.

Shoot growth was measured on three flushes (spring, summer and late summer) and at maturity in a year. Average of 3 years (2007-2009) was calculated. In mowed treatment shoot growth was found significantly higher than cultivated treatment (Table 1). Maximum shoot growth (46 cm) was observed with mowed treatment than cultivation (30 cm) (Table 1). Shoot growth of the 3 flushes individually was also higher on trees under mowing of 19, 12 and 15 cm for spring, summer and late summer flush respectively, compared to shoot growth on trees under cultivation treatment of 12, 8 and 10 cm for spring, summer and late summer flush, respectively. Under both the treatments, summer and late summer flush had little difference in mean values but clear difference was observed on spring flush (Table 1). Tree growth showed a positive response to mowing than clean cultivation probably because of improved soil physical conditions and increased nutrient availability. These results are in agreement with the findings of Yao *et al.* (2005) who reported that shoot growth, tree health and yield increased with the groundcover management.

The perusal of data in Table 2 indicated that plant canopy diameter differed significantly between floor management practices; a higher canopy diameter was recorded in mowed treatment (3.30-3.60 m) than in cultivation treatment (2.90-3.10 m). In mowed treatment the highest canopy diameter (3.60 m) was recorded in year 2009 compared to (3.10 m) in cultivation treatment. More canopy diameter in mowed treatment may be attributed to more flush growth/ shoot growth (Table 1).

Trunk Cross Sectional Area (TCSA) differed significantly between the floor management treatments (Table 2). TCSA in mowed treatment was significantly higher in all years than cultivation. It ranged from 47 to 59.75 cm^2 in mowed treatment compared to 40.0-45.50 cm^2 in cultivation. In 2009 the TCSA in mowed treatment was the highest (59.75 cm^2) than in cultivation treatment (45.50 cm^2). More tree growth under mowed than cultivation treatment may be attributed to increased soil organic matter, phosphorus and decreased soil penetration resistance (Table 4 and Figure 1). These findings are in close consonance with Hoagland *et al.* (2008) who found that ground cover management resulted in excellent tree growth with increased TCSA.

Yield data was taken by counting the total number of fruits harvested per plant. The average of 3 years was subjected to statistical analysis. Data in Table 2 indicated that orchard floor management practices affected the yield (fruits/tree) significantly. The interaction among two practices was significant at $\alpha = 0.05$. The yield (fruits/tree) in mowed treatment was higher in all years than in cultivation. It ranged from 1400-1675 fruits/tree in mowed treatment compared to 1100-1300 fruits/tree in clean cultivation. Yield in mowed treatment was the highest (1675 fruits/tree) in year 2009 compared to that in cultivation treatment (1300 fruits/tree). Higher yields in mowed treatment may be attributed to more shoot growth and canopy spread. In this context results are consistent with Sanchez *et al*. (2006) who found that the long-term soil cultivation under tree canopy resulted in the reduction of soil N and organic matter, poor tree vigor and reduced fruit bearing potential.

treatment, the highest fruit weight (130 g) was recorded in year 2009 followed by 116 g and 103 g in year 2008 and 2007, respectively. While in cultivation, the highest value

Table 1: Effect of mowing and cultivation on shoot growth (cm) of new flushes recorded at maturity

Treatment	Spring Flush* (15 May)	Summer Flush* (15 Aug)	Late Summer Flush* (15 Oct)	Total Growth* (cm)
Mowing	19 ± 0.91	12 ± 0.57	15 ± 0.40	46
Cultivation	12 ± 0.40	8 ± 0.45	10 ± 0.20	30

*Values are mean (n=04) ± SE

Table 2: Effect of mowing and cultivation on tree growth and yield of 15 year old Kinnow plants

Year	Treatment			
	****CD (m)***	*****TCSA (cm^2)***	**No. of fruits/Tree***	**Weight/fruit (g)***
		Sowing		
2007	3.30±0.07 B	47.00±0.20 C	1400.0±56.82 B	103.00±2.01 C
2008	3.40±0.07 B	51.00±0.20 B	1565.0±44.01 **A**	116.00±1.82 B
2009	3.60±0.08 **A**	59.75±0.59 **A**	1675.0±56.82 **A**	130.00±3.34 **A**
		Cultivation		
2007	2.90±0.07 D	40.00±0.35 E	1100.0±42.62 D	87.10±0.54 E
2008	3.00±0.07 CD	43.00±0.20 D	1250.0±45.64 C	89.00±0.64 DE
2009	3.10±0.07 C	45.50±0.45 C	1300.0±62.08 BC	93.80±0.95 D

Critical T value = 2.131 at alpha = 0.05; *Mean values ± Standard error;
** CD: Canopy Diameter; ***TCSA: Trunk cross-sectional area

Table 3: Effect of floor management practices on soil pH, EC and lime contents in a Citrus orchard

Values are mean (n=12)

Soil Depth	Lime (%)		$pH_{1:1}$		$EC_{1:1}$ (mS m^{-1})	
	Mowed	**Cultivated**	**Mowed**	**Cultivated**	**Mowed**	**Cultivated**
0─15	7.50	8.50	7.66	7.82	311	227
15─30	10.00	9.00	7.78	7.97	290	186
30─50	7.50	8.00	7.72	7.95	327	194
50─100	9.50	10.00	7.79	7.98	286	164
Mean	**8.5**	**8.88**	**7.73**	**7.93**	**304**	**193**

Table 4: Effect of floor management practices on soil organic matter, bulk density and phosphorus concentration in soil of a Citrus orchard

Values are mean (n=12)

Soil Depth	Organic Matter (%)		Bulk Density (g cm^{-3})		P (mg kg^{-1})	
	Mowed	**Cultivated**	**Mowed**	**Cultivated**	**Mowed**	**Cultivated**
0─15	1.16	0.53	1.50	1.71	9.99	3.24
15─30	0.52	0.26	1.66	1.69	4.54	3.19
30─50	0.44	0.22	1.64	1.67	2.98	2.57
50─100	0.36	0.12	1.68	1.66	2.88	2.37
Mean	**0.62**	**0.31**	**1.62**	**1.68**	**5.10**	**2.84**

To elucidate the precise impact of orchard floor management practices on physical and chemical characteristics of single fruit, weight per fruit was measured. Data indicated that treatment effect was significant under different years (Table 2). In mowed treatment fruit weight ranged from 103g to 130g compared to 87.10 to 93.80 g in cultivation treatment. In mowed of 93 g was recorded in year 2009 and the lowest of 87.10 g in year 2007. Results showed that mowing increased the fruit weight. These results confirm the findings of Nielsen *et al*. (2003) who observed that orchard floor management increased the tree fruit yield, fruit weight and improved the soil physical properties.

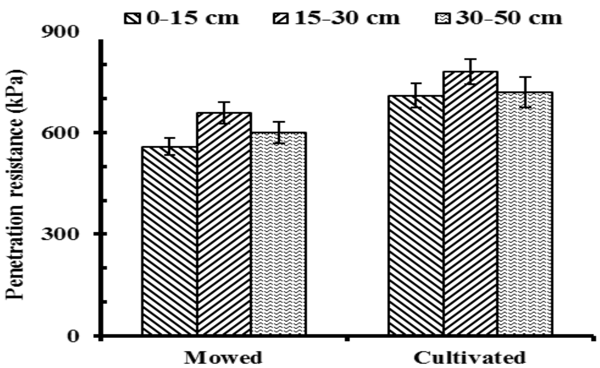

Figure 1: Effect of floor management practices on soil penetration resistance of the profile. Values are means (n=12) ±SE

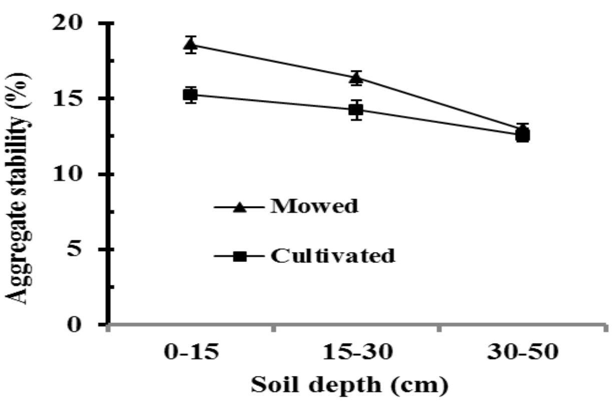

Figure 2: Effect of floor management practices on aggregate stability of the profile. Values are means (n=12) ±SE

Soil pH, lime content and electrical conductance (EC)

Data in Table 3 indicated that floor management practices differently affected soil pH, lime and electrical conductance. Lime concentration under two floor management treatments was not affected though lower soil depths had more lime contents. Significantly lower pH was recorded in mowed treatment than in clean cultivated tratments. However, these reductions were not consistent with soil depth. Electrical conductivity was significantly affected by management practices. Higher EC values were observed with mowed cultivation than in clean cultivation. In mowed treatment, it ranged from 286 to 327 mS m^{-1} compared to 164-227 mS m^{-1} in clean cultivation treatment. In mowed treatment, the highest EC was recorded at 30-50 cm depth followed by 0-15cm and and 15-30 cm. The lowest values were observed at 50-100 cm depth.

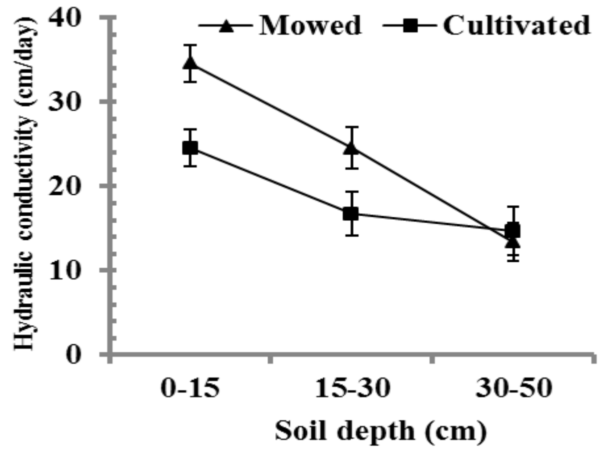

Figure 3: Effect of floor management practices on saturated hydraulic conductivity of the profile. Values are means (n=12) ±SE

Soil organic matter and soil phosphorus

Data in Table 4 indicated that floor management practices affected soil organic matter significantly. The organic matter content in mowed practice was significantly higher at all soil depths than in clean cultivation treatments. It ranged between 0.36 g kg^{-1} to 1.16 g kg^{-1} in mowed treatment compared to 0.12 g kg^{-1} to 0.53 g kg^{-1} in clean cultivation. Organic matter content decreased with increased soil depths in both management practices. These results are in agreement to those of Merwin and Stiles (1994) who observed significant increase in soil organic matter content due to floor management practices.

Phosphorus concentrations in soil solution differed significantly among the floor mangemnt practices. Mowed treatment had greater P concentration than clean cultivation. Highest concentration (9.99 g kg^{-1}) was recorded at 0-15 cm depth which decreased gradually with incresed soil depth. The lowest value (2.88 g kg^{-1}) was observed at 50-100 cm depth. In clean cultivation, lower P concentration were observed at all depths than in mowed cultivation. However, a pattern similar to that of mowed treatmnet was observed for depth wise P concentrations.

Soil bulk density, soil penetration resistance and aggregate stability

Table 4 indicated that bulk density of the soil was affected significantly under two floor management practices. Relatively lower bulk density was observed in mowed treatment throughout the soil profile. The lowest value of 1.5 g cm^{-3} was recorded at surface (0-15 cm) and lower depths had higher values ranging from 1.64 g cm^{-3} to

1.68 g cm^{-3}. In clean cultivation treatments the highest values of 1.71 g cm^{-3} was observed in surfaces (0-15 cm) and the lowest values of 1.66 g cm^{-3} at 50-100 cm depth.

Soil bulk density is a measure of weight per unit volume. Higher bulk density occurs when soil particles are pressed together reducing overall pore space. This may be caused by tilling and heavy axle loads when soils are wet. The use of heavy equipment and repeated passes on agricultural fields lead to higher bulk density causing soil compaction (Mari and Chang, 2008). Soil organic matter plays an important role in reducing compaction – by promoting better soil particle aggregation and increased porosity and infiltration. In mowing treatment, relatively less frequent machinery had been involved than in cultivated treatment. Further, plant materials left on the soil surface as result of mowing could cushion the effect of external load and subsequently may reduce the severity of compaction (Ohu *et al*., 2001). Moreover, soil profile indicated higher contents of soil organic matter which might have contributed in lowering soil bulk density.

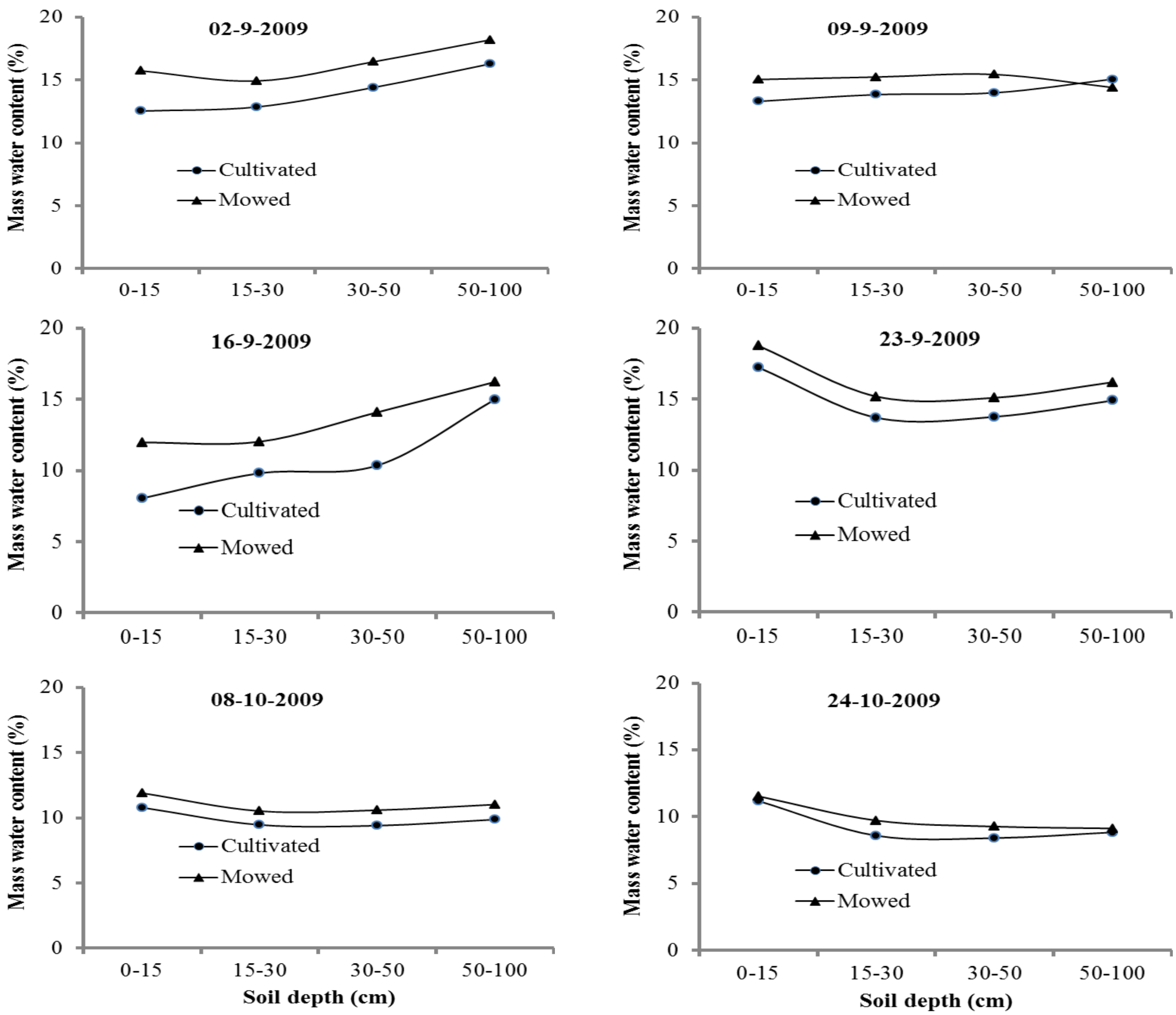

Figure 4: Effect of floor management practices on water retention of soil profile at different time intervals. Values are means (n =12)

Soil penetration resistance (PR) indicates resistance experienced by the root while penetrating it. Data in Figure 1 indicated that management practices significantly affected

PR of the soil. Soil under mowing had lower PR values than cultivated. In mowing, PR values increased with increasing depth from 0-15 to 15-to 30 cm. A similar trend was observed in cultivated treatment but with higher PR values.

Aggregate stability was strongly affected by the two management practices (Figure 4). Higher aggregation was observed in mowing treatment than in cultivated treatments. At 0-15 cm, a value of 18.25 was recorded for mowing whereas a value of 15.36 was noted for cultivated treatment.

Soil aggregate stability is a measure of the persistence of soil aggregates to maintain their structural integrity under a disruptive force and is used as an index in soil structure. Aggregation is promoted by soil organic matter, biota, and clay and carbonates that act as binding agent in aggregate formation (Chenu, *et al*., 2000). Soil texture and organic matter content largely influence aggregate stability (Le Bissonnais, 1996). In present study, lime content in soils under two management practices is almost similar and the increased aggregate stability may be attributed to enhanced soil organic matter levels under mowed treatment that may have resulted by more root activity and greater decomposition of plant biomass in the soil. Increasing organic matter promotes biological activity in the soil increasing aggregate stability (Adams, 2011).

Saturated hydraulic conductivity and soil profile water contents

Figure 3 indicated that saturated hydraulic conductivity (HC) in floor management practices differ significantly. The HC in mowed treatment (34 cm day^{-1}) at 0-15 cm was significantly higher than in cultivated treatment (25 cm day^{-1}). A similar trend was depicted at 15-30 soil depths. However, at 30-50 cm depth, differences in HC were nonsignificant. Surface soil had the highest HC in both mowed and cultivated treatments. Subsurface depth (15-30 cm) had lower HC than the surface soil. At 0-15 m soil depth, HC of 35 cm day^{-1} was observed in mowed treatment where as 24 cm day^{-1} was recorded in cultivated treatment. Similarly, at 15-30 cm soil depth HC of 23 cm day^{-1} was recorded in mowed treatment as compared to 19 cm day^{-1} in cultivated treatments.

Water contained in soil profile through September to October 2009 was depicted in Figure 4. It indicated that floor management practices differed significantly in soil water content throughout the study period. The mowed treatment retained higher water contents than the cultivated treatments. The higher water content in mowed treatment may be attributed to higher organic matter contents and greater porosity that resulted due to greater plant root action.

Conclusion

The main objective of an orchard floor management is to create optimum conditions for growth and productivity of tree fruits, facilitate routine orchard operations allowing grower access to the trees for cultural and harvest activities and prevents environmental degradation of agricultural resources like soil and water. Orchard floor management options are varied and of diverse nature. Citrus growers in Pakistan maintain orchard floors relatively free of weeds mostly through cultivation and partly by weedicide application while other practices are uncommon. Cultivation practices are not only expansive in terms of energy and resources but also are laborious. Whereas mowing practice can save time and energy and improve soil physico-chemical environment resulting in higher yields and higher farm returns.

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