Use of Organic Applications to Increase Productivity of High Density Apple Orchards

G.H. Neilsen, E.J. Hogue and D. Neilsen
Pacific Agri-Food Research Centre
Summerland, British Columbia
V0H 1Z0

T. Forge
Pacific Agri-Food Research Centre
Agassiz, British Columbia
V0M 1A0

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Abstract

Minimizing use of agrochemicals in fruit growing is a goal of integrated fruit production (IFP). Recently, a range of locally available organic materials have been advocated for possible orchard use. Over the past decade, a series of randomized, replicated field trials were established in grower and research orchards in British Columbia to test the effectiveness of these materials when applied to the surface as mulches or mixed to 30 cm depth as soil amendments. Mulch application most consistently affected tree growth, as indicated in a long term field trial where cumulative yield after 5 crop years was increased by surface application of shredded paper, alfalfa and biosolid mulches. Soil nutrient status and soil biological activity were altered by surface mulching and at another site trees were buffered against moisture stress. Initial growth stimulation from mulching was not sustained at a site where excessive irrigation reduced N availability. Rotovation of a biosolid-amendment to 0.3 m depth prior to planting improved the P-nutrition and initial growth of apple. Amendment treatment did not always affect apple tree performance. Effects were not observed at sites with strong fertigation regimes or fertile soils or when sites had overriding growth limitations unaffected by treatment (e.g. replant disease, K deficiency).

INTRODUCTION

In the semi-arid, irrigated fruit growing regions of the Pacific Northwest of North America, there are economic factors inducing greater intensification of fruit production, as typified by high density orchards of new apple cultivars on dwarfing rootstocks (Hampson et al., 2002). At the same time, environmental concerns are creating a trend towards minimizing the impact of these production systems on the environment by adoption of integrated fruit production (IFP) techniques (Intl. Soc. Hort. Sci., 1990). Increased use of organic materials as soil amendments or surface mulches have been advocated (Merwin et al., 1995) as compatible with IFP since fertilizer and herbicide inputs can be reduced. Their use may be particularly valuable on coarse-textured soils with limited nutrient and water holding capacity (Neilsen et al., 1998). Little information is available concerning the effects of mulches and amendments on apple tree performance and soil quality in typical modern orchards in semi-arid regions.

A series of field trials were established in British Columbia orchards to determine the effect of a range of organic materials used as mulches or amendments on growth, yield and nutrition of apple trees and alteration of orchard soil properties.

MATERIALS AND METHODS

All randomized and replicated field trials were established in high density apple orchards on dwarfing rootstocks (Table 1). Treatments involved either surface application of organic materials (mulching) or amendment of the surface soil by incorporation of the organic materials to 0.3 m depth. The check treatment at each site was the industry standard herbicide strip, usually 1-2 m wide. Fertilization and irrigation practices followed standard commercial production practices for the region (Brit. Col. Ministr. of Agr.& Food, 1998). Experimental designs were randomized complete blocks. Standard annual measurements were made of tree vigor, yield and leaf nutrition as previously

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described (Neilsen et al., 2002). At site 1, soil protozoa and *Pratylenchus penetrans* populations were identified by methods previously described (Forge et al., 2002). Soil C was determined by combustion analysis (LECO Corp., St. Joseph, MI, USA) and soil P by inductively coupled argon plasma spectrophotometry after extraction in 0.25M HOAC + 0.015M NH_4F (Van Lierop, 1988).

The organic materials used in the experiments exhibited a range of nutrient contents and chemical properties (Table 2).

Analysis of variance was performed on all plant and soil data to elucidate treatment effects using the general linear model of SAS Institute Inc. Means were separated using Duncan's multiple range test.

RESULTS AND DISCUSSION

Mulch Experiments

At site 1, after six growing seasons there was a large variation in size of apple trees, as indicated by differences in average trunk cross-sectional area (TCSA) among various mulch treatments (trts) (Fig. 1). Largest trees were associated with various combinations of shredded paper mulch (trts 3, 4 and 5) with TCSA more than 50% larger than check trees. Smallest trees were consistently observed for the check trees and for trees grown with 2 applications of 45 t ha^{-1} of Greater Vancouver Regional District (GVRD) - biosolids. Cumulative yield, 1995-1999, was higher for all trts relative to the check . The greatest cumulative yield (80% greater than check) was measured for trees grown with shredded paper mulch (trt 3). Despite having similar size, trees with trt 2 (GVRD-biosolids only) exceeded cumulative yield of check trees.

Soil properties in the 15 cm below the mulch were altered by surface mulching. For example, soil C was increased relative to check treatments beneath all but the black plastic mulch (trt 6, Fig. 2). Application of biosolids (trts 1, 4 and 5) increased extractable soil P relative to the standard check treatment. A stimulation of biological activity after biosolids application was indicated by a relative increase in protozoa numbers for trts 1 and 4 (Fig. 3). Also noteworthy was a decrease in population of the root-feeding nematode, *Pratylenchus penetrans*, associated with replant disorders, beneath mulches containing alfalfa (trt 2) or shredded paper combinations (trts 3, 4 and 5).

At site 2 (Table 1), first year TCSA increment and numbers of fruit in second year were significantly increased by 3 of 4 mulch treatments (Table 3) but effects faded by third year. Leaf N concentrations were generally low at this site and likely limited growth. Application of Ogogrow increased leaf N in the first year but only when co-applied with Newstech spray-on-mulch in second year. Frequent large applications of irrigation water with rates not adjusted to individual plots are applied in this block since the coarse-textured soils are prone to water stress. Under these conditions it is difficult to maintain sufficient N in the root zone even after the application of N-mineralizing mulches. Adjustments in irrigation may be required to maximize the benefits of mulching.

Mulch and Amendment Experiments

Growth of 'Gala' apple trees at site 3 (Table 1) was not strongly influenced by either mulch or amendment treatments (Fig. 4). An exception was trees mulched with Riverside wood waste after application of 45 t ha^{-1} of Envirowaste (trt 5) and trees amended twice with Envirowaste (trt 4) which had greater vigor (larger TCSA) than trees receiving the amendment alone (trt 1). The grower co-operator fertigated with both N and P daily from April - early June each year.

At site 4 (Table 1), growth and initial yield of 'Gala' apple trees in the first 2 growing seasons was unaffected by any soil management treatment (Fig. 5). In the third growing season, an irrigation treatment was created in which selected trees received 50% of atmometer-scheduled irrigation which was otherwise applied in this plot. Fruit size was reduced on average by 5% in this water stress treatment. This reduction in fruit size was not observed for trees growing in mulched or amended plots. All trees received a complete nutrient fertigation regime the first 10 weeks of each year, involving annual application (per tree) of 30-66 g N, 20 g P (first 2 yrs), 8-21 g K, .05-.15 g B, 7 g Zn, 24 g Mg and 35 g S. The strong fertilization regime may have reduced growth response to soil management treatments at this site.

Amendment Experiments

Treatments at site 5 (Table 1), which involved the rotovation of Ogogrow into the surface 0.3 m depth in a 1-m strip centered on the tree row, immediately prior to planting, improved first year shoot growth of 'Braeburn' apple (Fig. 6). Improved growth was associated with improved leaf P concentration. Best growth was measured when leaf P concentration exceeded 0.30%. These growth improvements were measured despite fertigation of 9.6 g N and 14 g P per tree on June 4 and an additional 33.6 g N per tree during the growing season. Since the organic material was applied to the soil prior to planting, it seems to have been superior at supplying P at the early stages of root growth. Previous research has indicated that high P is important in accelerating establishment, early growth and fruiting of newly planted apples (Neilsen and Yorston, 1991).

Amendment treatments established at three other orchard sites failed to improve apple tree performance (data not shown). This situation was observed where soils were fertile or where other growth limitations such as replant disease or an overriding K-deficiency became apparent.

CONCLUSIONS

Surface mulches can improve growth and yield of apple planted in high density systems. In part, this may be associated with release of nutrients in the applied organic material which can improve orchard soil nutrient availability and soil biological activity. Mulches can also buffer against moisture stress resulting from inadequate irrigation. Mulches may be ineffective at sites which have multi-nutrient fertigation regimes or frequent irrigation which leaches N excessively from the root zone. Application of a high P organic amendment to the root zone prior to planting young trees can stimulate first year tree growth. Amendments may however be ineffective if no limiting soil property is overcome or other overriding limitations such as replant disease or nutrient deficiencies exist that are unaffected by the amendment.

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Table 1. Experimental details at represented orchard sites.

Site	Soil	Cultivar/rootstock	Spacing	Experimental design	Non-check treatments (trt)
				Mulch (M) experiments	
1	Skaha gravelly sandy loam	Spartan/M.9	1.25 x 3.5 m	4 tree plots, 5 reps, 7 trts, yrs 1- 7.	1. 2 x 45 t ha^{-1} GVRD – biosolids
					2. (24 t ha^{-1} first year + 12 t ha^{-1} yr^{-1}) alfalfa straw
					3. 12 t ha^{-1} + 4 t ha^{-1} yr^{-1} shredded paper (SP, Table 2)
					4. SP + trt. 1
					5. SP + 2 x 45 t ha^{-1} Ogogrow (Og, Table 2)
					6. black polypropylene weed fabric
2	Osoyoos loamy sand	Gala/M.9	0.45 x 3 m	9 – 12 tree plots, 6 reps, 5 trts, yrs 1 – 3.	1. 90 t ha^{-1} Summerland compost (SC)
					2. 45 t ha^{-1} Og
					3. 50 t ha^{-1} Newstech (Table 2) + 45 t ha^{-1} Og
					4. 90 t ha^{-1} SC + 50 kg ha^{-1} organic - N
				Combination mulch (M) and/or Amendment (A) experiments	
3	Rutland gravelly sandy loam	Gala/M.9	0.6 m x3 m	3 tree plots, 5 reps, 7 trts, yrs 1 – 3.	(A) 1, 2. 45, 90 t ha^{-1} Envirowaste (E), yr 1.
					(A) 3. 45 t ha^{-1} per year Og first 2 yrs.
					(A) 4 . 45 t ha^{-1} per year E first 2 yrs.
					(A/M) 5 . 45 t ha^{-1} E yr 1 + 45 t ha^{-1} Riverside (R) mulch first 2 yrs.
					(A/M) 6. 45 t ha^{-1} R + 45 t ha^{-1} R mulch first year only..
4	Skaha sandy loam	Gala/M.9	1 x 3 m	3 tree plots, 6 reps, 8 trts, yrs 1 - 3	Factorial combination of deep ripping to 0.75 m depth, Riverside wood waste mulch (M) to 4 cm depth and 45 t ha^{-1} Og rototilled to 0.2 m depth (A). Fifty % irrigation trt replaced R trt in yr 3.
		Amendment Experiment			
5	Skaha loamy sand	Braeburn/M.26	1.25 x 3 m	3 tree plots, 12 reps, 6 trts, yrs 1 - 2	All rototilled to 0.3 m (A)
					1. 90 t ha^{-1} Og
					2. Og + 60 t ha^{-1} zeolite
					3. Og + 45 t ha^{-1} bentonite
					4. Og + 110 L $plot^{-1}$ Vermiculite (V)
					5. 110 L $plot^{-1}$ V

Table 2. Nutrient content and chemical properties of selected organic materials used in field trials.

Material	Nutrient Content								pH (1:2 water)	EC $mScm^{-1}$	CEC $cmol(+)kg^{-1}$
	C	N	C/N	P	K	Mg	Zn	Cu			
	%			%			ppm				
Ogogrow (Og) composted biosolids	37.9	1.9	19.9	1.8	0.59	0.62	234	393	6.1	8.1	89.7
GVRD – biosolids	39.6	3.3	12.	1.1	0.5	0.18	758	977	6.4	38.0	117.3
Riverside bark mulch	35.8	0.8	44.8	0.1	0.3	0.23	62	8	6.0	1.0	-
Envirowaste	37.2	1.8	20.7	0.5	0.75	0.43	128	92	7.0	6.9	74.7
Shredded Paper	-	0.2	-	0.03	0.02	0.10	0.1	0.07	-	-	-
Newstech	36	0.3	120	0.02	0.01	0.07	77	176	-	-	-

Table 3. Trunk cross-sectional area increment , yield and leaf N concentration as affected by treatments, yrs 1 – 3, site 2.

	Annual TCAI (cm^2)			Number fruit (n/tree)	Leaf N (% dw)		
Treatment	Yr 1	Yr 2	Yr 3	Yr 2	Yr 1	Yr 2	Yr 3
Cck	0.97c	0.74	0.81a	25b	2.18c	1.89b	2.00
1	1.07ab	0.79	0.80a	32.2ab	2.25bc	1.86b	2.00
2	1.12a	0.78	0.54b	38.3a	2.40ab	1.77b	2.16
3	1.06ab	0.87	0.65ab	40.5a	2.53a	2.08a	2.08
4	1.0bc	0.83	0.72ab	38.0a	2.26bc	1.78b	1.99
	*	NS	*	*	***	****	NS

Figures

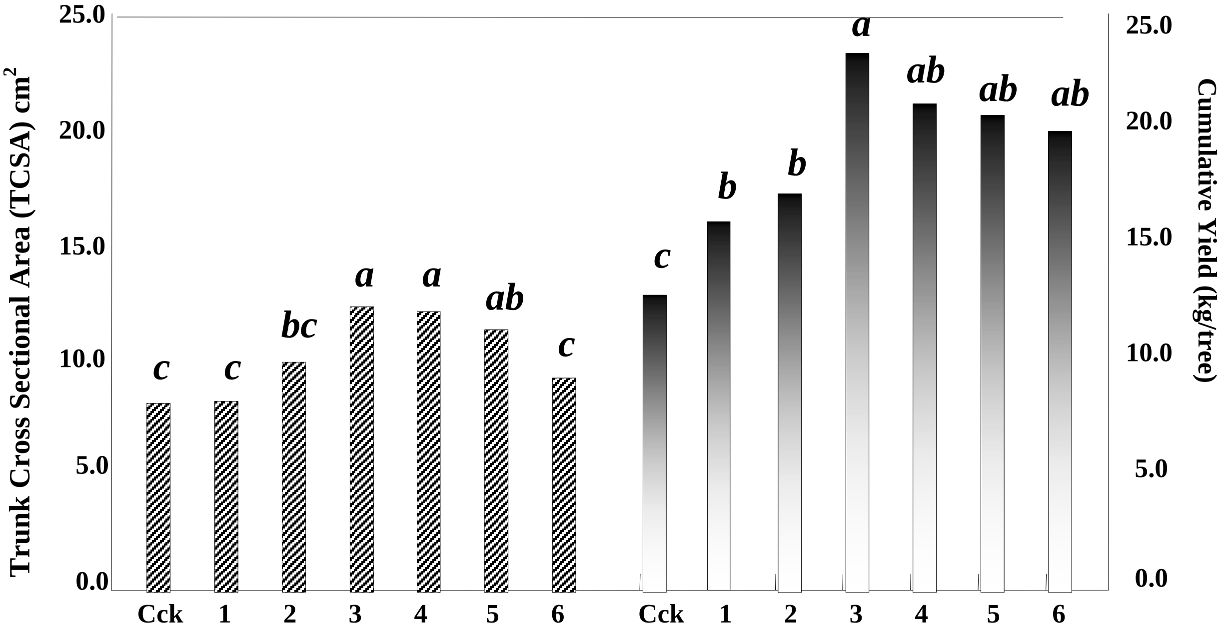

Fig. 1. Tree vigor and cumulative yield after six growing seasons of maintenance of different surface-applied mulches site 1. (adapted from Neilsen et al., 2003).

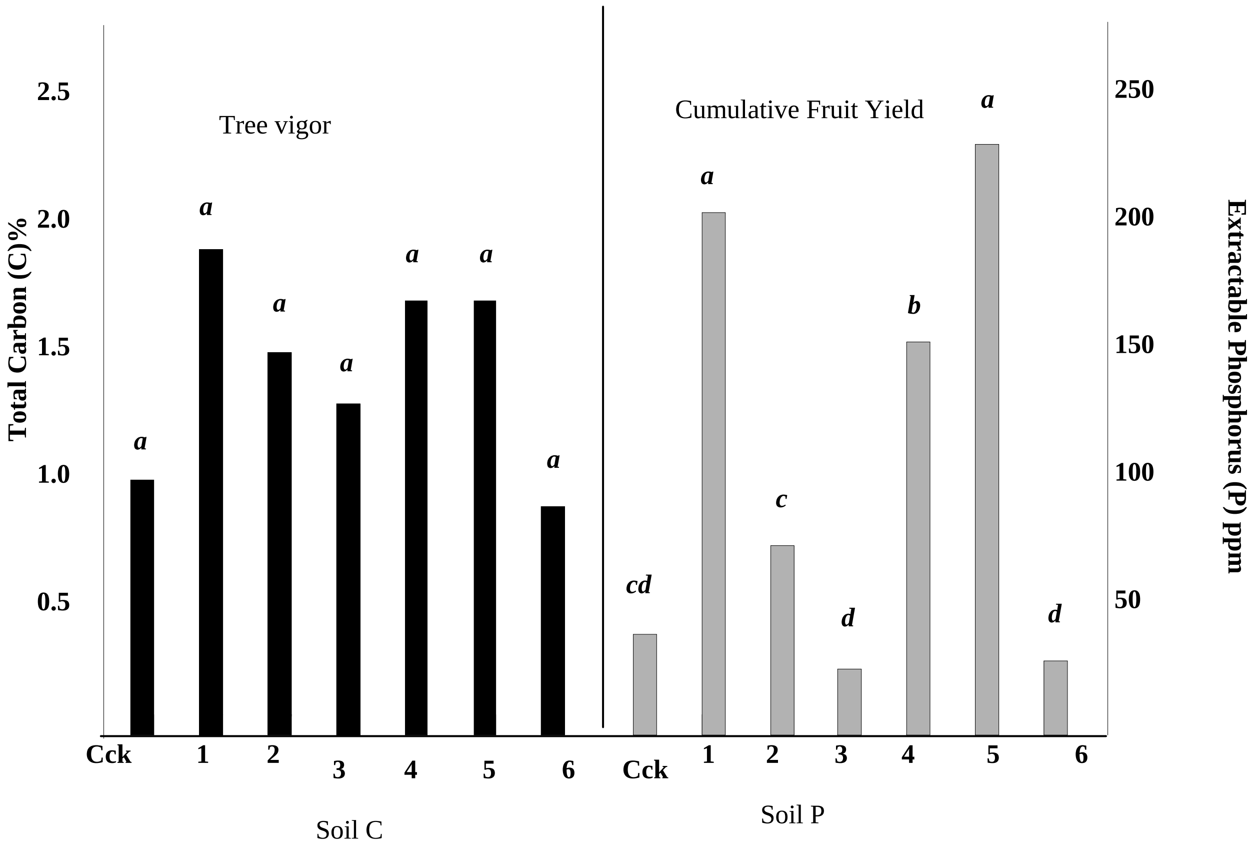

Fig. 2. Soil C and P status of site 1 soil, surface 0-15 cm, 7 years after initiation of different mulch treatments (adapted from Neilsen et al., 2003).

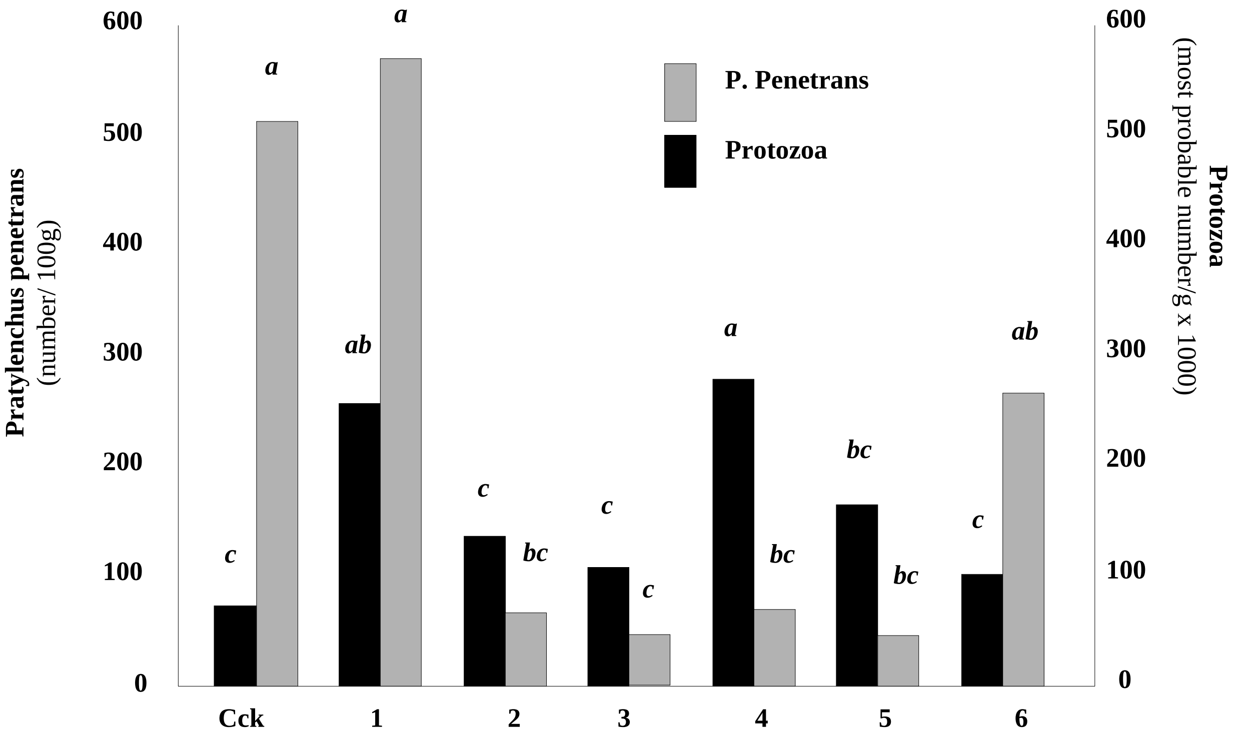

Fig. 3. Effect of site 1 mulch treatment on selected soil biological properties by years 5-7.

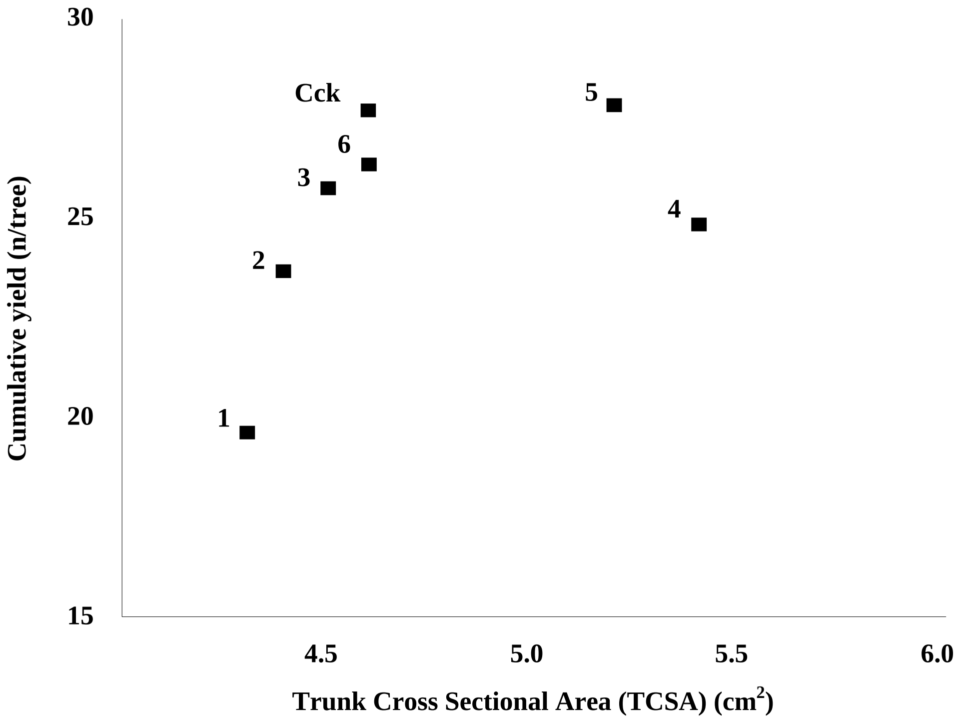

Fig. 4. Cumulative yield and TCSA at site 3 after 3 growing seasons as affected by mulch and amendment treatment.

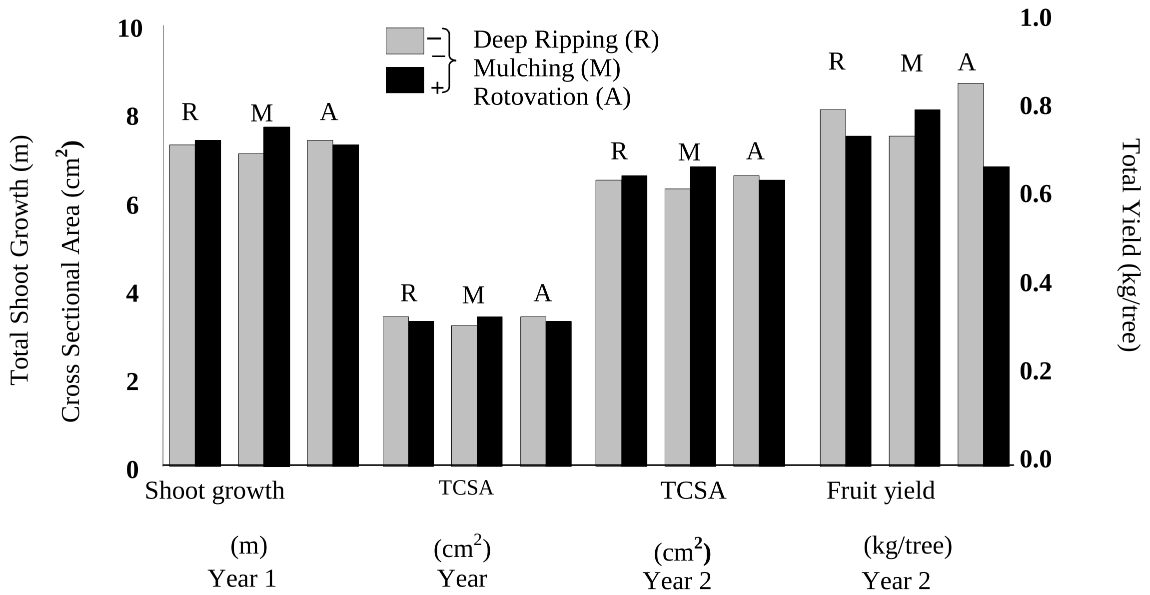

Fig. 5. The effect of soil amendment (A) or mulching (M) on growth and yield of site 4 trees also receiving complete nutrient fertigation in the first two growing seasons.

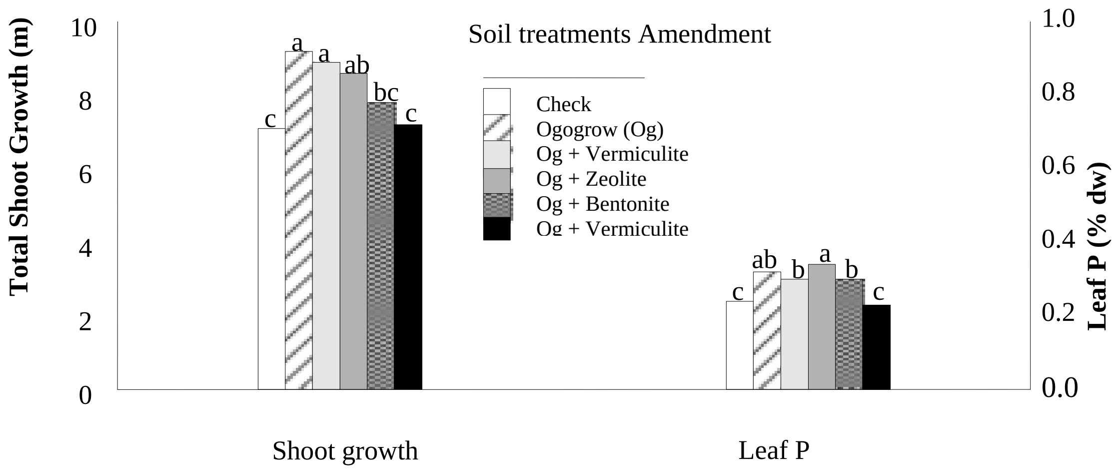

Fig. 6. The effect of soil amendment on first year shoot growth and leaf P of site 5 trees.