Communications in Soil Science and Plant Analysis, 42:332–357, 2011
Copyright © Taylor & Francis Group, LLC
ISSN: 0010-3624 print / 1532-2416 online
DOI: 10.1080/00103624.2011.538884

Taylor & Francis
Taylor & Francis Group

Impact of Management Systems on Soil Properties and Their Relationships to Kiwifruit Quality

M. HASINUR RAHMAN,[1] ALLISTER W. HOLMES,[2]
ALAN G. MCCURRAN,[3] AND STEVEN J. SAUNDERS[4]

[1]GroPlus Ltd., Te Puna, Tauranga, New Zealand
[2]PollenPlus Ltd., Te Puna, Tauranga, New Zealand
[3]Bio Soil and Crop Ltd., Te Puna, Tauranga, New Zealand
[4]Plus Group Ltd., Te Puna, Tauranga, New Zealand

Crop quality depends on several factors, among which soil properties play a great role. The use of organic products as sources of plant nutrients to improve crop quality has been established. The use of biological nutrient sources to improve crop quality as well as improve soil physical, chemical, and biological properties could be a viable alternative to organic and/or conventional farming. However, there is little information available on how soil properties and kiwifruit quality are affected by the use of a biological farming system. Therefore, research was conducted with the objective of comparing the response of conventional, organic, and biological management systems on soil properties and kiwifruit quality in respect to Actinidia deliciosa *(Hayward) and* A. chinensis *(Hort16A). Greatest soil bulk density and lowest gas phase, maximum water-holding capacity, gravitational drainage, and hygroscopic moisture were observed in Hayward in both biological and conventional management systems. The variations in soil properties for total pH, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), and aluminium (Al) were linked to management practices, and electrical conductivity (EC), organic matter (OM), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and boron (B) were linked to cultural species. The Ca/Mg ratio of these orchards was more than 7:1, and the Mg/K ratio was less than 2:1, indicating application of dolomitic limestone is recommended over high-Ca liming materials. The greatest yield, total soluble solids, and ionic strength were obtained in Hort16A from conventional management. Greater P, Ca, Fe, Zn, and Cu levels were recorded in organic Hayward than in other management systems. However, greater total N, K, Mg, S, Na, Mn, and B contents were observed in conventional Hort16A than in organic, biological, or conventional Hayward. The results of this study indicated that all macronutrients flux in Hort16A better than in Hayward. On the other hand, flux of micronutrients in Hayward was greater than in Hort16A. The cost/benefit ratio is the most favorable, that is, lowest, for organic Hayward on volcanic soils in the Bay of Plenty.*

Keywords Biological management, cost–benefit analysis, intra- and interspecific variations, kiwifruit, nutrient flux

Received 8 June 2009; accepted 20 March 2010.

Address correspondence to M. Hasinur Rahman, GroPlus Ltd., Te Puna, Tauranga 3172, New Zealand. E-mail: hasinur65@yahoo.com; technical@groplus.co.nz

Introduction

About 90 elements are found in normal plant tissue, and only 16 or so elements are truly established as essential elements for plant growth. All 16 essential plant nutrients are naturally sourced from soil and microorganisms. There are not always enough of these nutrients in the soil for healthy plant growth; therefore, it is necessary to use fertilizers to add the nutrients to the soil to achieve desired quality plant yield. Since chemical fertilizers were first used commercially on a large scale, there have been claims that the use of agricultural chemicals produce less wholesome and less nutritious food crops. The organic farming movement began in part as a result of the belief that food grown using more traditional, chemical-free methods was more wholesome. Food grown by these methods came to be known as organic. Conventional farming systems allow the use of many synthetic chemical fertilizers, fungicides, insecticides, herbicides, and growth regulators, while organic farming must be carried out in accordance with relevant certification standards. For New Zealand organic kiwifruit growers, BIO-GRO New Zealand is an organic certifying organization that has strict input restrictions, and therefore organic growers must rely on the application of organic matter and slow-release soil nutrients (BIO-GRO NZ 2001; Worthington 2001); other soil additives; natural products such as bone or blood meal; and the management practices, such as crop rotation, tillage, and mulching, for nutrient balancing and to overcome pest and weed problems. Management practices may alter soil quality based on soil physicochemical and hydrological properties. Soil characteristics influence basic soil functions, such as moderating and partitioning water and solute movement and their redistribution and supply to plants; storing and cycling nutrients; filtering, buffering, immobilizing, and detoxifying organic and inorganic materials; promoting root growth; and providing resistance to erosion (Karlen et al. 1997).

The organic food market is a growing sector of the agricultural industry in many parts of the world, and it is possible to find organically produced food in most supermarkets in Europe, Asia, Australasia, and North America. The world market for certified organic foods was estimated to be worth US $23–25 billion in 2003 and is increasing at roughly 19% per year (Kortbech-Olesen 2003). In New Zealand, organic kiwifruit has been grown for several decades, but it was in 1990 that the Kiwifruit Marketing Board (KMB: now divided into ZESPRI International Ltd. and Kiwifruit New Zealand) first designated an organic fruit pool for export and offered a specific payment per tray for organic kiwifruit. Thereafter, production of organic kiwifruit (*Actinidia deliciosa*: Hayward-Green) has increased rapidly from 13,000 trays in 1991 to 2.9 million trays harvested in 2009 and is expected to increase further in the future. Net returns per hectare are between $5,500 and $6,500 greater for the organic group (http://www.maf.govt.nz/). The total acreage of *A. deliciosa* kiwifruit BIO-GRO certified is now 482 ha compared to 9,479 ha for conventional kiwifruit. *Actinidia chinensis* (Hort16A: Gold) has 100 ha BIO-GRO certified and 2032 ha managed conventionally (Zespri Outlook papers, February 2009; http://www.zespricanopy.com/f1503,44413/44413_3Yr_Outlook_ORG_FA2LR.pdf).

There are several factors influencing the quality of food, including food safety (free from harmful pesticide residues, mycotoxins, heavy metals, dioxins, and microorganisms); nutritional value (composition of energy, fat, minerals, and vitamins); taste; and appearance. Some researchers believe that organically produced foods contain lower concentrations of mycotoxins (Jestoi et al. 2004). However, others showed that mycotoxin concentrations are usually similar or reduced in organic produce compared with conventional products (FAO 2000). Woese et al. (1997) stated that no major differences could be observed between apples, pineapples, or strawberries produced by organic means and those produced by conventional means with respect to desirable constituents such as minerals, vitamins (viz., B1, B2, C), carbohydrates, proteins, and free amino acids as well as organic acids. Hassey et al. (1997) found that organically grown kiwifruit is firmer than those grown conventionally. On the other hand, Benge et al. (2000) reported that fruit grown under "KiwiGreen" (a low-input conventional integrated pest-management system) matured earlier than fruit from organic production, although they found the same fruit firmness between the two production systems. In their study, the concentrations of nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) in fruit did not differ significantly between production systems although the concentration of calcium (Ca) did tend to be greater in fruit from organic orchards rather than that from KiwiGreen orchards. There is ample, but circumstantial, evidence that on average organic fruit most likely contains more of certain nutrients than conventional fruit, allowing for the possibility that organically produced plant foods may in fact benefit human health more than corresponding conventional ones. It is well established that the use of organic nutrient sources in improving crop quality can be a viable alternative to conventional farming because organic farming restricts the use of certain agrichemicals and promotes soil conservation and restoration principles. Recently, conventional growers have begun to embrace biological management tools such as soil or foliar sprays to feed crops and to boost microbial activity in the soil. However, there is little information available on how kiwifruit production is affected by biological farming systems. Additionally, very few studies have compared the nutritional status (macro- and micronutrients) of kiwifruit produced by organic, biological, and conventional production systems. Discussions in the papers outlined previously conclude that application of organic composts and/or biological materials with differential nutrient compositions could change and/or enhance the nutritional quality of kiwifruit by changing soil properties. Therefore, the main goal of this research is to measure distribution of macro- and micronutrients in soil and kiwifruit with respect to organic, biological, and conventional fertilization.

Materials and Methods

Study Sites and Management

The experiment was conducted during the 2007–2008 growing season in Te Puna, located in the Bay of Plenty region of the North Island of New Zealand with the latitude of 37° 39′ S and longitude of 176° 11′ E. The average temperature and precipitation of the study area are depicted in Figure 1 (source: National Institute of Water and Atmospheric Research, New Zealand). All surface soils from experimental sites are classified as Allophanic Orthic Pumice soils (Vitrads/Vitricryands Andisol, USDA; Mollic Andosol, FAO) formed predominantly from ryolitic tephra between ∼4000 and 40,000 years ago during the region's geographic history of periodic volcanic eruptions (New Zealand Soil Bureau 1954; Molloy 1988; Hewitt 1993). In this study, four orchards, namely Harvest Ridge, Hardaker, Okaro-Green, and Okaro-Gold, were selected assuming the climate and soil type of the orchards to be similar, although it is likely there are slight differences because of their geographical separation. In all the orchards, vines were established in the early 1980s. Harvest Ridge has been under organic management with Hayward (popularized as Green) [*A. deliciosa* (A. Chev.) C.F. Liang and A.R. Ferguson var. *deliciosa*] since 2000. Hardaker has been under biological management with Hayward since 2000. Okaro-Green and Okaro-Gold has been under conventional management with Hayward since 1980, with Hort16A (popularized as Gold) [*A. chinensis* Planch.] grafted on the Hayward rootstock in 1999. The Harvest Ridge (organic Hayward), Hardaker (biological Hayward), Okaro-Green (conventional Hayward), and Okaro-Gold (conventional Hort16A) orchards were 48, 50, 27, and 27 m above the sea level, respectively. The experimental sites were silty loam soils for organic

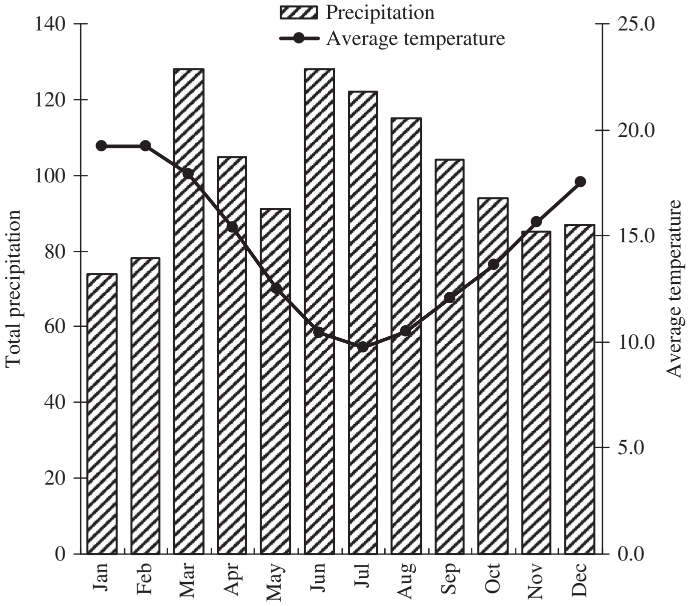

Figure 1. Monthly total precipitation (mm) and average temperature (°C) of study area.

Hayward and biological Hayward and sandy loam soils for conventional Hayward and conventional Hort16A. The soil colors of organic Hayward, biological Hayward, conventional Hayward, and conventional Hort16A were 7.5YR2.61/2.89, 7.5YR2.52/2.39, 7.5YR2.99/2.72, and 7.5YR2.87/2.52, respectively, according to Munsell soil color charts. Every year soil and leaf analysis is done in May and December, respectively, to achieve the required level of mineral content in soil. Based on the results of the soil and leaf tests, fertilizers from various sources are applied in August and December, according to kiwifruit industry standard directed by Bio Soil and Crops Ltd., Te Puna, Tauranga, New Zealand. The conventionally managed orchards received split applications of synthetic fertilizers, while the organic orchard received organic matter, slow-release soil nutrients, and other organic soil additives such as blood and bone meal. The organic orchards also used other management practices such as mulching to help balance nutrients and to overcome pest and weed problems. In the organic orchard, compost at a rate of ~6 t ha^{-1} (50:50 chicken manure / green waste compost with 1.3% N, 1.0% P, 1.1% K, 0.5% sulfur (S), 3.3% Ca, 0.3% Mg, and 0.1% sodium (Na) was applied on the soil once a year, and lime was added at a rate of 300 kg ha^{-1} every 4 years. In the biological management system, Vitec Crop V [liquid fish / Tasmanian kelp / plant extract / added elements & Vitamins 76:18:3:3 with 2.1% N, 0.6% P, 0.4% K, 0.5% Ca, 0.2% Mg, 0.3% Na, 730 mg L^{-1} copper (Cu), 750 mg L^{-1} zinc (Zn), 722 mg L^{-1} iron (Fe), 704 mg L^{-1} manganese (Mn), 34 mg L^{-1} boron (B), 1.3 mg L^{-1} molybdenum (Mo), 1.3 mg L^{-1} selenium (Se), 110 mg L^{-1} iodine (I), 12 iu L^{-1} vitamin A, 22 iu L^{-1} vitamin D, and 20 iu L^{-1} vitamin E] at a rate of ~40 L ha^{-1} is used for soil or foliar sprays to feed crops and to boost microbial activity in the soil. The conventionally managed orchards receive split applications of pesticides, fungicides, and herbicides, while the organic and biological management systems receive *Bacillus thuringiensis* subspecies *kurstaki* and "mineral spraying oils" as biological insecticides. All sprays are applied according to kiwifruit industry standard as defined by ZESPRI Programme, ZESPRI Ltd., Tauranga, New Zealand, during kiwifruit growth. The total inputs of N, P, K, Ca, Mg, S, and B were 100, 40.7, 184, 36, 47, 107, and 5 kg ha^{-1} yr^{-1}, respectively, for organic Hayward; 67, 28, 161, 154, 66, 98, and 4 kg ha^{-1} yr^{-1}, respectively, for biological Hayward; 124, 39, 218, 217, 91, 72, and 3 kg ha^{-1} yr^{-1}, respectively, for conventional Hayward; and 120, 46, 213, 301, 91, 89, and 4 kg ha^{-1} yr^{-1}, respectively, for conventional Hort16A.

Sampling

Undisturbed and disturbed soil samples were collected from plant row, wheel track, and grass alley with three replications from a depth of 0–15 cm using Daiki Soil Sampler (Daiki Rika Kogyo Co., Ltd., Japan), and 30 fruit and leaf samples from each orchard were collected just before harvest on 12 May 2008. A sample pair of fruit and adjacent leaf was collected from each of 30 vines to eliminate bias from the results. Leaf chlorophyll content was measured during sample collection by a chlorophyll meter (CCM-200, Opti-Sciences Corporation Inc., USA).

Soil Analysis

Bulk density (ρb) and particle density of soils were determined by the core method (Blake and Hartge 1986). Total porosity (*St*) and three-phase distributions (solid phase, SP; liquid phase, LP; gaseous phase, GP) were calculated by the volumetric method on pF 2.0 soils collected with 100-mL core samples (Kezdi 1974). The hanging water column technique with fritted glass Buchner funnel was used to measure moisture retention. Maximum water-holding capacity, field capacity, and gravitational drainage were estimated and calculated (www.daiki.co.jp). The individual soil samples were dried in a forced-air convection drier at 30 °C for 72 h and crushed to pass through a 2-mm sieve. Sand, silt, and clay contents of samples were measured by hydrometer method as per the instruction of Kalra and Maynard (1994a). The moisture held by air-dry soil was taken as the hygroscopic water content. Soil moisture content was measured after drying at 105 °C overnight (Gardner 1986). The pH of soils was determined in a 1:2.5 soil/water suspension (Jackson 1973) by a digital pH meter (IQ 160 pH meter, IQ Scientific Instruments, USA), and electrical conductivity (EC) of soil was measured in 1:5 suspension (Kalra and Maynard 1994b) by digital conductivity meter (IQ 170 conductivity meter, IQ Scientific Instruments, San Diego, Calif., USA). Soil organic matter was estimated by the modified Walkey–Black method (Blakemore, Searle and Day 1987), where the organic matter is oxidized by dichromate and sulfuric acid. Soil organic matter was also estimated by loss-on-ignition (LOI) in a CEM model 905410 microwave furnace (CEM Corp., Matthews, N.C., USA). Total N content of soil was determined by the Dumas combustion method (Kay and Hill 1998). Soil P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, B, and aluminium (Al) were analyzed using inductively coupled plasma–optical emission spectroscopy (ICP-OES) as the Mehlich 3 extended test (Mehlich 1984).

Fruit and Leaf Analysis

The fresh weights of fruit, leaf, and petiole were recorded. Leaf surface area (Boase, Wright, and McLeay 1993) and petiole length were measured. The fruit volume was determined by the amount of water displaced when the fruit was immersed in water. At both the blossom end and stem end of the fruit, total soluble solids (TSS: °Brix) and electrical conductivity (EC) were measured by a refractometer (Atago Co. Ltd., Japan) and EC/TDS/salt tester (Oakton Ltd., Malaysia), respectively, at 22 °C. The ionic strength was estimated according to Griffin and Jurinak (1973). Fruit and leaves were dried at 60 °C for 24 h using a ventilated oven (Hydraflow, Ezidri Ultra 1000FD, Hydraflow Industries Ltd., New Zealand), and the dry weight of each sample was weighed.

The leaf and fruit samples were dried at 80 °C for 24 h and ground to pass through a 1-mm sieve. Total N content of fruit and leaf was determined by Dumas combustion method (Kay and Hill 1998). The fruit and leaf samples were analyzed for basic elements. Phosphorus, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, B, and Al were analyzed by digesting at 205 °C in a 2:1 nitric acid / perchloric acid solution, and Mo and Co were analyzed by digesting at 205 °C in a 6:1 nitric acid / perchloric acid solution using inductively coupled plasma–optical emission spectroscopy (ICP-OES) and inductively coupled plasma–mass spectrometry (ICP-MS), respectively.

Calculation of Parameters

The variations in organic–conventional (intraspecific variation: *IaV*) and *A. deliciosa* (Hayward)–*A. chinensis* (Hort16A) (interspecific variation: *IeV*) are calculated as follows:

$$\%IaV = \left(\frac{Organic\ Hayward - Conventional\ Hayward}{Conventional\ Hayward}\right) \times\ 100 \tag{1}$$

$$\%IeV = \left(\frac{Conventional\ Hayward - Conventional\ Hort16A}{Conventional\ Hort16A}\right) \times\ 100 \tag{2}$$

Physiological efficiency (PE) and agronomic efficiency (AE) are calculated as

$$PE = \left(\frac{milligram\ of\ dry\ fruit\ weight}{milligram\ of\ element\ in\ fruit}\right) \tag{3}$$

$$AE = \left(\frac{milligram\ of\ dry\ fruit\ weight}{milligram\ of\ element\ applied}\right) \tag{4}$$

The nutrient flux (NF) is calculated as follows:

$$\%NF = \left(\frac{Nutrient\ in\ plant\ organ}{Nutrient\ in\ plant\ organ(s)\ +\ Nutrient\ in\ soil}\right) \times\ 100 \tag{5}$$

Experimental Design and Statistical Analysis

The experiment was conducted in the randomized block design with nine replications for soil and 30 replications for fruit and leaf. Samples were collected according to a systematic sampling design across S-shaped transects (Rahman and Sugiyama 2008). A one-way analysis of variance (ANOVA) was employed. The least significant differences (LSD) test was used to determine whether differences between means were statistically significant ($P < 0.05$). Duncan multiple-range tests (DMRTs) were conducted to compare the results with the variation at a 5% level of significance. Data were pooled to establish correlations between attributes and intercorrelation among attributes. All statistical analyses were conducted by JMP 4.0 (SAS Institute, Cary, N.C., USA). Unless otherwise noted, all the results are presented on an oven-dry basis.

Results and Discussion

Soil Properties

Changes in soil properties due to management and cultural practices are shown in Table 1 (physical) and Table 2 (chemical). There are significant differences in liquid phase, gas phase, maximum water-holding capacity, gravitational drainage, and hygroscopic moisture content among treatments. Bulk density was lowest in Hayward with organic management, although as we expected differences are not statistically significant between treatments. Lowest gas phase, maximum water-holding capacity, gravitational drainage, and hygroscopic moisture was observed in Hayward biological and conventional. The variations in bulk density, three-phase distribution, maximum water-holding capacity, gravitational drainage, and hygroscopic moisture content were linked to management practices (intraspecific) while variation for the field capacity was linked to species (interspecific). Inputs of organic manure are likely to be the main reason for lowest bulk density and greatest water-holding capacity in organic orchards. Our results are in accordance with the findings of Riley et al. (2008), who also observed a decrease in soil bulk density and increase in water-holding capacity with the application of composts and manures.

Organic-matter content and total N were greater, and pH and P were lower but not statistically significant in organic Hayward. Electrical conductivity was significantly greatest in conventional Hort16A. Significantly greater contents of K, Mn, and Cu were observed in organic Hayward. Zinc content was significantly greater in conventional Hort16A. Calcium, Fe, and B contents in conventional Hort16A are greater than others. Greater values for interspecific variation in EC, organic matter, Fe, Mn, Zn, Cu, and B were observed as compared to intraspecific. On the other hand, greater values for intraspecific variations in total N, P, K, Ca, Mg, and Na were observed as compared to interspecific. Our results indicate that EC, organic matter, and micronutrients are more related to cultural species than management practices. Conversely, variations in most of the macronutrients are dependent on management practices rather than cultural species.

The greatest Ca/Mg ratio was observed in organic Hayward, and the lowest was in Hayward biological. A productive soil would have the ideal ratio of 7:1 Ca/Mg. The Ca/Mg ratio we observed was more than 7:1 for all kiwifruit orchards, so application of high-Ca limestone or gypsum (Ca-sulfate) is not required. Calcium is usually adequate in kiwifruit if soil pH is maintained in the ideal range of pH 6.2–6.5. When Mg is low and the ratio of Mg/K ratio is less than 2:1; dolomitic limestone is preferred over high-Ca liming materials. Applying gypsum, high-Ca lime, or other Ca amendments is sometimes recommended to add Ca, increase Ca/Mg ratios, and improve soil structure as well as C storage capacity because of the interaction of Ca^{+2} with humic substances. Calcium ions with multiple positive charges help build good soil structure by acting as bridges that bind negatively charged clay particles together. These flocculated clays are basic building blocks in the formation of stable soil aggregates (Muneer 1987; Bladh et al. 2001).

Morphological Traits of Fruit and Leaf

Fruit traits varied with management practices (Figure 2 and Table 3). The greatest fruit yield, fruit volume, and fruit dry matter were observed in Hort16A compared to Hayward.

Table 1
Physical properties of soil (0–15 cm; average of grass alley, wheel track, and plant row) of kiwifruit orchard in different management systems

Properties	Unit	Organic Hayward	Biological Hayward	Conventional Hayward	Conventional Hort 16A	Intraspecific (%)	Interspecific (%)
Bulk density	$Mg\ m^{-3}$	0.75a[a]	0.81a	0.81a	0.79a	−7.41	−5.06
Porosity	%	70.69a	68.38a	68.24a	68.97a	3.59	2.49
Solid phase	%	29.31a	31.62a	31.76a	31.03a	−7.71	−5.54
Liquid phase	%	56.44b	61.35a	61.09a	55.99b	−7.61	0.80
Gas phase	%	14.25a	7.02b	7.15b	12.98b	99.30	9.78
MWHC[b]	%	84.78a	78.54b	77.41b	80.30ab	9.52	5.58
FC[c]	%	75.99a	75.98a	75.35a	70.82a	0.85	7.30
GD[d]	%	8.79a	2.56b	2.06b	9.48a	355.83	−0.95
HM[e]	%	4.30a	3.74b	3.82b	4.64a	12.57	−7.33

[a] Values within columns and parameters for variables with same letters are not significantly different at $p < 0.05$.
[b] MWHC, maximum water-holding capacity.
[c] FC, field capacity.
[d] GD, gravitational drainage.
[e] HM, hygroscopic moisture.

Table 2

Chemical properties of soil (0–15 cm; average of grass alley, wheel track, and plant row) of kiwifruit orchard in different management systems

Properties	Unit	Organic Hayward	Biological Hayward	Conventional Hayward	Conventional Hort16A	Intraspecific (%)	Interspecific (%)
pH		6.28a[a]	6.32a	6.44a	6.38a	−2.48	−1.57
EC	μS cm^{-1}	300.32c	420.51b	422.22b	724.85a	−28.87	−58.57
OM-WO[b]	%	11.37a	10.76a	—	10.53a	—	—
OM-LOI[c]	%	14.50a	14.10a	14.01a	12.95a	3.50	11.97
TN	g kg^{-1}	6.30a	5.70a	5.40a	5.80a	16.67	8.62
P	mg 100^{-1} g	5.43a	5.67a	6.03a	5.83a	−10.00	−6.86
K	mg 100^{-1} g	30.37a	19.00b	18.07b	21.83b	68.10	39.12
Ca	mg 100^{-1} g	260.00ab	204.00ab	177.67b	290.607a	46.34	−10.53
Mg	mg 100^{-1} g	22.50a	23.47a	18.93a	25.60a	18.84	−12.11
Na	mg 100^{-1} g	1.04ab	0.87b	1.70a	1.40b	−38.82	−25.71
Fe	mg 100^{-1} g	5.04ab	4.24b	4.81ab	6.08a	4.78	−17.11
Mn	mg 100^{-1} g	3.27a	2.85ab	2.14ab	1.65b	52.57	98.18
Zn	mg 100^{-1} g	1.15b	1.05b	0.92b	3.22a	24.95	−64.29
Cu	mg 100^{-1} g	0.44a	0.22b	0.34ab	0.29ab	30.69	51.72
B	mg 100^{-1} g	0.07a	0.05b	0.07a	0.09a	5.00	−22.22
Al	mg 100^{-1} g	117.66b	135.00ab	148.00a	140.00ab	−20.50	−15.96
C/N ratio	—	13.35a	14.35a	15.40a	12.97a	−11.29	3.06
Ca/P	—	47.88a	35.99a	29.46a	49.85a	62.51	−3.94
Ca/Mg	—	11.56a	8.69b	9.39ab	11.35a	23.12	1.79
(K+Mg)/Ca	—	0.20	0.21	0.21	0.16	−2.36	24.59
Mg/K	—	4.14ab	4.14ab	3.14b	4.39a	31.99	−5.63

[a] Values within columns and parameters for variables with same letters are not significantly different at $p < 0.05$.

[b] OM-OW, organic matter by wet oxidation.

[c] OM-LOI, organic matter by loss-on-ignition.

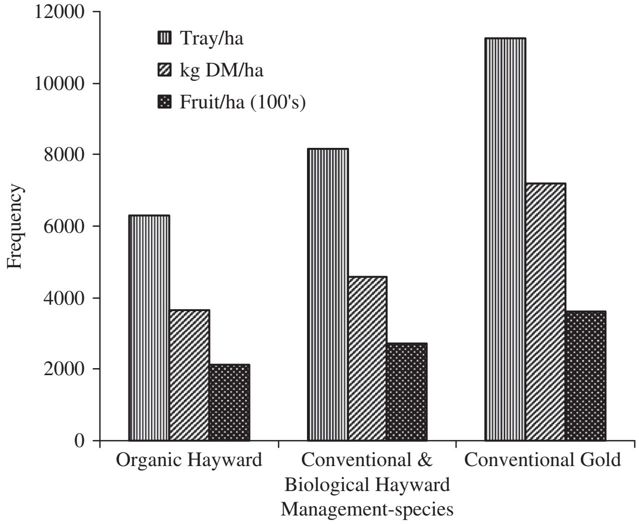

Figure 2. Yield of kiwifruit grown in different management practices.

Organic Hayward had greater fruit volume, fruit dry matter, leaf surface area, and leaf dry matter than conventional Hayward. The greatest fruit dry matter was recorded with Hort16A conventional and the lowest with biological Hayward. As a consequence, the lowest fruit moisture was obtained in conventional Hort16A as compared to the others. Conventional Hort16A also had the lowest leaf surface area as compared with organic Hayward and biological Hayward. Zespri (2008) found 6% and 11% greater yields in conventional Hayward and conventional Hort16A, respectively, compared to organic Hayward. Williams et al. (2000) observed greater water content in organic products than in conventional products, which is similar to the results found in this study. The dry-matter content of aboveground vegetables was greater in organic crops, whereas no difference was detected in the dry matter and starch contents of belowground vegetables (Woese et al. 1997). Also, no differences were observed either in dry-matter content and sensory properties between organic and conventional fruit in experiments done by Ventura et al. (1983). Greater dry-matter content in organic products can be explained by the fact that fertilizer application is generally less intense in organic agriculture, and therefore organic produce may be smaller than conventional produce. However, in this experiment larger fruit size is associated with greater dry-matter content in organic management compared to conventional management in Hayward. It may be noteworthy that except petiole dry matter, all fruit and leaf traits are not significantly different between Hayward and Hort16A (Table 3). Pronounced variations between organic and conventional (intraspecific) kiwifruit are found for the fruit volume, chlorophyll content, leaf surface area, leaf dry matter, leaf moisture, petiole length, petiole moisture, and petiole dry matter, whereas variation between Hayward and Hort16A (interspecific) was found for fruit moisture and fruit dry matter.

Fruit and Leaf Constituents

The °Brix (TSS) is the internal parameter with the greatest impact on taste. Greater TSS was recorded at the blossom end than the stem end, whereas lower ionic strength was at the blossom end regardless of management practices and species (Table 4). Greatest

Table 3
Fruit and leaf traits of kiwifruit (average of 30) grown in different management systems

Different traits	Organic Hayward	Biological Hayward	Conventional Hayward	Conventional Hort16A	Intraspecific (%)	Interspecific (%)
Fruit volume (cc)	133.87a[a]	132.27a	117.91a	135.00a	13.55	−0.84
Fruit moisture (%)	82.98a	83.71a	83.25a	82.27b	−0.32	0.95
Fruit dry matter (%)	17.02ab	16.29b	16.75ab	17.73a	1.61	−4.00
Chlorophyll content	30.75ab	33.26ab	35.17a	28.24b	−12.57	8.89
Leaf surface are (cm^2)	160.44a	157.86a	134.67a	148.06a	19.14	8.36
Leaf blade moisture (%)	67.85a	69.53a	69.18a	67.12a	−1.92	1.09
Leaf blade dry matter (%)	32.15a	30.47a	30.36a	31.15a	5.90	3.21
Petiole length (cm)	10.07a	11.38a	8.83a	11.60a	14.04	−13.19
Petiole moisture (%)	87.48a	89.71a	88.26a	87.84a	−0.88	−0.41
Petiole dry matter (%)	12.52a	10.29b	11.74ab	12.17a	6.64	2.88

[a] Values with columns and parameters for variables with same letters are not significantly different at $p < 0.05$.

Table 4

Total soluble solids and ionic strength of kiwifruit (average of 30) grown in different management systems

Different traits	Position	Organic Hayward	Biological Hayward	Conventional Hayward	Conventional Hort16A	Intraspecific (%)	Interspecific (%)
TSS[a]	Stem end	6.82	6.11	5.85	12.71	16.58	−46.34
	Blossom end	7.82	6.97	6.49	13.45	20.49	−41.86
	Av.	7.32b[c]	6.54c	6.17c	13.08a	18.54	−44.1
Ionic strength[b]	Stem end	9.82	9.31	9.25	11.03	6.20	−10.97
	Blossom end	8.23	7.43	8.89	8.78	−7.42	−6.26
	Av.	9.03ab	8.37b	9.07ab	9.91a	6.81	−8.62

[a] TSS, total sobuble solids in degrees Brix, a measurement of soluble solids concentration.

[b] mol/I at 22 °C: Ionic strength multiphied by 10^{-2}.

[c] Values within columns and parameters for variables with same letters are not significantly different at $p < 0.05$.

TSS was recorded in conventional Hort16A followed by organic Hayward, whereas the lowest was in the conventional Hayward system. In this study, the interspecific variation for TSS and ionic strength is more pronounced than intraspecific variation. Fertilizer type and the application rate directly influenced the level of plant-available nutrients and indirectly influenced plant physiology and chemical content. The TSS content in tomatoes increases with increasing P content (Weston and Barth 1997). Phosphorus shortage decreases the firmness of fruit (Sams 1999), and Ca increases firmness (Weston and Barth 1997). Increase in K causes a decline in the firmness of fruit (Sams 1999) and rise of both total and titrateable acid in tomatoes (Weston and Barth 1997). Other findings report that excess S decreases the "green" aroma and increases the pungency and S flavour in onion (Mattheis and Fellmann 1999). However, this research suggests that TSS and ionic strength in kiwifruit are influenced by genetic factors more than growing environment and management practices. Thus, the most important predictors of kiwifruit quality in terms of TSS and ionic strength are genetic factors.

Fertilizer management and method of application affected mineral and trace element contents of kiwifruit, but the effects are not the same for all elements (Table 5). Greater total N was accumulated in biological Hayward than both organic and conventional Hayward, but greatest total N was accumulated in conventional Hort16A. In this study, greatest total N in fruit and lowest in leaf (Table 6) is recorded in conventional Hort16A, however. In the organic system, a lower N-release rate was thought to be responsible for lower N in the fruit tissue. Vossen et al. (1994) stated that there is a trend for greater NH_4-N and lower NO_3-N concentrations in the organic than in the conventional system (i.e., greater mineralization rate) but lower nitrification, which may reflect the lower total N in kiwifruit in organic system. Worthington (2001) summarized the results of studies comparing nitrate levels in conventional and organic foods and found that in 127 of the cases the nitrate levels were greater in the conventional rather than organic foods, as opposed to 43 cases where the nitrate levels were greater in organic than conventional foods, with 6 cases where no difference was observed. The nitrate content in food is important because microbes convert nitrate into nitrite in the animal stomach and in most cases microorganisms further convert the nitrite to ammonia and ultimately amino acids and protein. However, if the rate of conversion of nitrate to nitrite is greater than the conversion of nitrite to ammonia, then nitrate toxicity occurs. Greatly accumulated nitrate can decrease oxygen-carrying capacity of the blood by binding with haemoglobin to form methemoglobin, therefore blocking binding of oxygen and ultimately constricting blood vessels, which can cause serious illness in animals and humans (Bruning-Fann and Kaneene 1993).

In fruit of Hayward, only Cu was significantly different between organic and conventional management. There was a trend toward increased P, K, Ca, Mg, Fe, Zn, Cu, and B contents and lower S, Na, and Mn contents in the fruit of organic rather than conventional system in Hayward (Table 5). On the other hand, there was a trend toward increased Mg and Fe contents and lower total N, K, P, Ca, S, Mn, Zn, Cu, and B contents in the leaf of organic rather than conventional Hayward (Table 6). Moreover, the lowest fruit total N, P, K, Ca, Mg, Cu and B and greatest S, Na, Fe, Mn, and Zn were recorded in conventional Hort16A compared to Hayward with different management practices. The interspecific variation in kiwifruit for total N, P, Mg, S, Na, Mn, Zn, and B was more pronounced than intraspecific variation. Greater intraspecific variation in kiwifruit nutrient was observed for K, Ca, Fe, and Cu. Burgos et al. (2008) stated that plant nutrient element concentrations may be different in different plant species. Based on extensive field and pot studies conducted by Beutel (1980), the total N and K was deficient and P, Ca, Zn, and B were adequate in kiwifruit leaf evaluated in late autumn (May) under a conventional growing

Table 5

Nutrient status of kiwifruit (average of 30) grown in different management systems

Properties	Unit	Organic Hayward	Biological Hayward	Conventional Hayward	Conventional Hort16A	Intraspecific (%)	Interspecific (%)
TN	g kg^{-1}	1.40a[a]	1.49a	1.41a	1.61a	−0.71	−13.04
P	mg 100^{-1} g	24.37a	24.30a	23.20a	21.43a	5.04	13.72
K	mg 100^{-1} g	280.67b	293.33ab	270.33b	303.67a	3.82	−7.57
Ca	mg 100^{-1} g	32.03a	27.37ab	30.20ab	26.93b	6.06	18.94
Mg	mg 100^{-1} g	2.50ab	2.70ab	1.51b	3.57a	66.67	−29.97
S	mg 100^{-1} g	12.47ab	12.43b	12.93ab	13.70a	−3.58	−8.98
Na	mg 100^{-1} g	14.20b	15.87ab	15.70ab	16.57a	−9.55	−14.30
Fe	mg 100^{-1} g	0.26a	0.21a	0.23a	0.25a	13.04	4.00
Mn	mg 100^{-1} g	0.09a	0.10a	0.10a	0.11a	−10.00	−18.18
Zn	mg 100^{-1} g	0.14a	0.11a	0.11a	0.12a	23.53	16.67
Cu	mg 100^{-1} g	0.14a	0.12b	0.12b	0.13ab	20.00	7.69
B	mg 100^{-1} g	0.19ab	0.20ab	0.17b	0.23a	9.62	−17.39
N/P	—	5.75a	6.13a	6.07a	7.51a	−5.48	−23.53
N/Ca	—	4.37b	5.44ab	4.67ab	5.99a	−6.38	−26.89
Ca/P	—	1.32a	1.12b	1.30ab	1.26ab	0.97	4.59
(K + Mg)/Ca	—	8.84b	10.82ab	9.00ab	11.41a	−1.78	−22.51
Mg/K	—	0.0089	0.0092	0.0055	0.0118	60.53	−24.23

[a] Values within columns and parameters for variables with same letters are not significantly different at $p < 0.05$.

Table 6

Nutrient status of leaf of kiwifruit (average of 30) grown in different management systems[a]

Properties	Unit	Organic Hayward	Biological Hayward	Conventional Hayward	Conventional Hort16A	Intraspecific (%)	Interspecific (%)
TN	$g\ kg^{-1}$	19.67a[b]	19.67a	21.67b	14.00b	−9.23	40.48
P	$mg\ 100^{-1}\ g$	18.67ab	22.67a	25.34a	13.66b	−26.32	36.59
K	$mg\ 100^{-1}\ g$	1333.33ab	1666.67ab	1833.33a	1133.33b	−27.27	17.65
Ca	$mg\ 100^{-1}\ g$	49.00b	66.33a	65.33a	42.33b	−25.00	15.75
Mg	$mg\ 100^{-1}\ g$	473.00a	428.67a	420.33a	417.33a	12.53	13.34
S	$mg\ 100^{-1}\ g$	45.67b	52.67b	60.67ab	81.00a	−24.73	−43.62
Na	$mg\ 100^{-1}\ g$	10.00b	10.00b	10.00b	20.00a	0.00	−50.00
Fe	$mg\ 100^{-1}\ g$	8.93a	7.73a	7.90a	9.97a	13.08	−10.37
Mn	$mg\ 100^{-1}\ g$	12.00b	15.33ab	13.67ab	17.33a	−14.63	−82.69
Zn	$mg\ 100^{-1}\ g$	2.10b	2.43b	2.97b	6.17a	−29.21	−65.95
Cu	$mg\ 100^{-1}\ g$	0.73a	0.80a	0.83a	0.80a	−12.00	−8.33
B	$mg\ 100^{-1}\ g$	3.40ab	3.20ab	4.77a	2.63b	−28.67	29.11
N/P	—	105.36a	86.77a	85.53a	102.44a	23.19	2.85
N/Ca	—	40.14a	29.64b	33.16ab	33.07ab	21.03	21.36
Ca/P	—	2.63ab	2.92ab	2.57b	3.10a	1.79	−15.26
(K + Mg)/Ca	—	12.37ab	8.97b	9.24ab	12.54a	33.92	−1.29
Mg/K	—	3.55ab	2.57ab	2.29b	3.68a	54.73	−3.66

[a] Blade and petiole.

[b] Values within columns and parameters for variables with same letters are not significantly different at $p < 0.05$.

system. Potassium, however, was much greater in the conventional system (Mäder et al. 1993). Phosphorus and K were greater in organic potatoes than in conventional potatoes (Woese et al. 1997; Mattheis and Fellmann 1999). No difference in any trace element was found from a review study by Woese et al. (1997) with the exception of Fe. Warman and Harvard (1998) compared organic and conventional potatoes and sweet corn, grown on low-fertility soil that had not been fertilized for at least 5 years, to overcome the effects of previous fertilization. They found that in the tubers of organic potatoes, P, Mg, and Na contents were greater and Mn was lower than in conventional tubers. In the leaves, however, B and Fe were greater in organic plants, whereas Mg, N, and Cu were lower. The amounts of Fe and Cu in leaves of sweet corn were greater in the conventional system. However, none of the differences found in those studies were statistically significant. Kumpulainen (2001) found conventionally grown potatoes and carrots had greater ash and N contents, while organically grown ones had greater K and sodium contents. Jorhem and Slanina (2000) did not find any significant differences in Cd, Pb, Cr, and Zn between organically and conventionally grown potatoes. It can be inferred that there are differences between plants of the same species grown under different management systems in how they accumulate mineral elements in their various parts, as well as differences between plant species.

Nutrient-Use Efficiency and Nutrient Flux in Kiwifruit

Nutrient-use efficiency can be categorized into physiological nutrient-use efficiency and agronomic nutrient-use efficiency. The results of nutrient-use efficiency for kiwifruit is calculated by equations (3) and (4) and furnished in Table 7. Remarkably greater physiological nutrient-use efficiency as well as agronomic nutrient-use efficiency for N, K, Mg, S, Na, Mn, and B was recorded in conventional Hort16A than in Hayward irrespective of managements. Greatest physiological nutrient-use efficiency for P, Ca, Fe, and Zn was observed in organic Hayward. In this study, organic Hayward showed lower physiological nutrient-use efficiency for total N and Mn than biological or conventional Hayward. Lowest physiological nutrient-use efficiency for Cu and B was recorded in conventional Hayward. The relation between the rate of ion absorption by plant organs and the concentration of the ion external to the root in the soil solution is important for plant nutrition studies to investigate ion absorption mechanisms and evaluate mechanisms supplying nutrients to roots growing in soil (Mengel and Farber 1974). There are certain species-specific differences in the ability to uptake and translocate various elements. We consider kiwifruit root, trunk, and leader as constant media for transporting ions to leaf and fruit from soil. The nutrient flux (transport) in kiwifruit is calculated by Equation (5), and results are depicted in Table 8. Out of a total of 17 essential elements, 11 macro- and microelements were included in this study to evaluate their flux in kiwifruit. The greatest total N, P, K, Mg, S, and B and lowest Ca, Na, Fe, Mn, Zn, and Cu flux from soil to fruit were observed in Hort16A as compared to Hayward. Moreover, the lowest total N, P, K, Mg, Cu, and B flux from soil to fruit were observed in conventional Hayward as compared to organic Hayward, biological Hayward, and conventional Hort16A. Out results indicate that with few exceptions all macronutrients flux in Hort16A performed comparatively better than Hayward. On the other hand, flux of micronutrients in Hayward regardless of management was greater than in Hort16A. It is therefore predictable from this research that there are some species-specific differences in ability of kiwifruit to take up and/or translocate various nutrient elements.

Correlation Study

In this study, we used Pearson's correlation coefficients for correlation analyses of (i) fruit traits versus soil physical properties, (ii) fruit traits versus soil chemical properties,

Table 7
Physiological nutrient use efficiency (PE), agronomic nutrient use efficiency (AE), nutrient flux (NF, %) in kiwifruit

Parameter	Management-Species	Nutrient											
		TN	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
PE[a]	Organic Hayward	140.0	24.4	28067	32.0	250	12.5	1420	0.26	9.00	0.14	14.0	0.19
	Biological Hayward	149.0	24.3	29333	27.4	270	12.4	1587	0.21	10.00	0.11	12.0	0.20
	Conventional Hayward	141.0	23.2	27033	30.2	250	12.9	1570	0.23	10.00	0.11	11.7	0.17
	Conventional Hort16A	161.0	21.4	30367	26.9	357	13.7	1657	0.25	11.00	0.12	13.0	0.23
	LSD	3.11	0.42	498.76	0.79	18.05	0.29	35.36	0.01	0.36	0.01	0.39	0.01
AE[b]	Organic Hayward	11.10	27.27	6.03	30.66	23.82	10.37	—	—	—	—	—	246.6
	Biological Hayward	22.38	53.56	9.31	9.74	22.72	15.30	—	—	—	—	—	374.9
	Conventional Hayward	14.19	45.41	8.07	8.13	19.29	24.53	—	—	—	—	—	516.8
	Conventional Hort16A	23.59	61.67	13.32	9.42	31.17	31.78	—	—	—	—	—	683.6
	LSD	2.60	6.73	1.29	4.60	2.30	4.01						98.79
NF	Organic Hayward	5.12	50.3	63.2	9.39	0.50	—	87.4	1.83	0.60	4.13	10.7	5.19
	Biological Hayward	5.55	46.2	61.2	9.19	0.59	—	89.5	1.72	0.55	3.06	10.5	5.80
	Conventional Hayward	4.95	42.5	57.3	11.05	0.34	—	85.3	1.78	0.63	2.83	9.1	3.46
	Conventional Hort16A	7.52	52.4	69.2	7.48	0.80	—	83.0	1.53	0.58	1.26	10.2	7.79
	LSD	0.57	1.78	2.00	0.59	0.07		0.98	0.05	0.01	0.47	0.29	0.57

[a] PE × 10^{-5}.
[b] AE × 10^{-3}.
[c] LSD (least significant difference) at $p < 0.05$ among treatments (rows).

Table 8

Correlation coefficients between kiwifruit traits and soil physical and hydrological properties

	Soil physical properties							
Fruit traits	Bulk density	Solid phase	Liquid phase	Gas phase	MWHC	FC	GD	HM
Volume	0.179	0.187	−0.369	0.205	−0.176	−0.514	0.291	0.340
Moisture	0.154	0.167	0.791	−0.667	−0.124	0.589	−0.709	−0.864
Dry matter	−0.154	−0.167	−0.791	0.667	0.124	−0.589	0.709	0.864
Total soluble 8olids	−0.046	−0.062	−0.718	0.569	0.089	−0.609	0.688	0.856
Ionic strength	−0.098	−0.066	−0.529	0.427	0.083	−0.411	0.490	0.531
TN	0.475	0.459	−0.362	0.091	−0.440	−0.770	0.234	0.515
P	−0.129	−0.124	0.407	−0.259	0.183	0.502	−0.271	−0.435
K	−0.045	−0.077	−0.372	0.313	0.120	−0.277	0.405	0.471
S	−0.376	−0.362	−0.092	0.215	0.293	0.251	0.097	−0.057
Ca	0.100	0.077	−0.225	0.140	−0.039	−0.279	0.224	0.380
Mg	0.486	0.450	0.148	−0.294	−0.399	−0.276	−0.195	0.018
Na	−0.199	−0.236	−0.587	0.540	0.298	−0.320	0.652	0.619
Fe	−0.612	−0.609	−0.611	0.708	0.544	0.007	0.621	0.534
Mn	0.276	0.242	−0.204	0.058	−0.229	−0.416	0.136	0.367
Zn	−0.337	−0.339	−0.614	0.602	0.308	−0.271	0.617	0.462
Cu	−0.430	−0.413	−0.507	0.550	0.432	−0.082	0.577	0.543
B	0.067	0.038	−0.402	0.290	0.053	−0.402	0.447	0.626

(iii) leaf nutrients versus fruit nutrients, (iv) different soil properties, and (v) different fruit traits that were established regardless of management practices and species. In many cases there is no statistically significant positive or negative correlation between fruit traits and soil physicochemical properties (Tables 8 and 9). Results of correlation analyses of fruit traits versus soil physical properties are shown in Table 8. Fruit dry matter and TSS showed significant negative correlation with soil liquid phase and field capacity, and positive correlation with soil gas phase, gravitational drainage, and hygroscopic moisture. Fruit total N showed significant negative correlation with soil field capacity. Fruit Fe content showed significant negative correlation with soil bulk density and liquid phase and positive correlation with gas phase, maximum water-holding capacity, gravitational drainage, and hygroscopic moisture. With few exceptions, fruit Na, Zn, and Cu showed the same correlations as Fe. Fruit B showed significant positive correlation with soil hygroscopic moisture. The correlation between fruit traits and soil chemistry is depicted in Table 9. Fruit dry matter, TSS, ionic strength, Ca, and B showed significant positive correlation with soil Fe and Zn. Fruit Mg significantly and negatively correlated with Mn and Cu. In this study, only P, Cu, and B exhibited statistically positive correlation between soil and fruit, indicating these nutrients rapidly transferred from soil to fruit without any interference (Table 9). Generally, it is believed that plants can maintain nutrient elements in their leaves at stable levels (Granato et al. 2004), which may translocate to other plant parts according to their requirements. In this study, out of 12 macro- and micronutrients, only P, Ca, Mg, Na, Fe, and Zn showed statistically positive correlations between leaf and fruit, confirming that leaf analysis for only these nutrients is a positive indication of those nutrients in fruit (Table 10). However, it is necessary to undertake similar analysis at different stages in crop development to accurately predict this relationship, and it is advisable to conduct an experiment analyzing other plant parts to predict kiwifruit nutrient translocation as well. The relationships between soil and fruit traits are shown in Tables 11 and 12. The relationships between macro- and micronutrients give an indication of the biochemistry of these elements in soil as well as in the plant. It is noticed that relationships between elements are often different in soil and in fruit, confirming quite different element behaviors in soil and fruit. Among soil properties, electrical conductivity showed significant positive correlation with Fe, Zn, and hygroscopic moisture and significant negative correlation with organic matter and Mn (Table 11). Organic matter significantly and negatively correlated with Zn and Al and positively correlated with Mn and field capacity. Soil total N significantly and positively correlated with soil P, K, Ca, Mg, Fe, Mn, and B and significantly and negatively correlated with Al (Table 11). Fruit dry matter significantly and positively correlated with fruit TSS, ionic strength, Zn, and B (Table 12). Correlation between Zn and B in soil and fruit is positive and statistically significant (Tables 11 and 12). This might be explained by the similar chemical characteristics of these two elements. Some pairs of elements are well correlated, indicating similar ability of the elements to enter into the plant (Kment et al. 2005).

Economic Analysis: Cost and Benefit Analysis

Zespri International Ltd. (2008) costs and gross revenue returns pertain only to the 2007–2008 crop season and are evaluated on a per-hectare basis in NZ dollars ($). Fertilizer costs were $1,400, $900, and $1,200 for organic Hayward, conventional Hayward, and conventional Hort16A, respectively. Pest-management costs were $1,200, $1,400, and $1,600 for organic Hayward, conventional Hayward, and conventional Hort16A, respectively. Weed-control costs were the same for conventional Hayward and conventional Hort16A. On

Table 9

Correlation coefficients between kiwifruit traits and soil chemistry

	Soil chemistry											
Fruit traits	TN	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	B	Al
Volume	0.147	−0.014	0.138	0.392	0.365	−0.295	0.160	0.126	0.280	0.010	0.091	−0.291
Moisture	−0.011	0.002	−0.192	−0.366	−0.102	−0.351	−0.620	0.388	−0.610	−0.255	−0.430	0.034
Dry matter	0.011	−0.002	0.192	0.366	0.102	0.351	0.620	−0.388	0.610	0.255	0.430	0.034
TSS	0.037	−0.008	0.049	0.581	0.412	0.184	0.694	−0.515	0.912	−0.144	0.529	0.115
Ionic strength	0.168	0.028	0.277	0.499	0.293	0.177	0.651	−0.394	0.665	0.063	0.480	0.045
TN	−0.083	0.120	−0.328	0.508	0.412	0.138	0.419	−0.389	0.735	−0.254	0.340	0.157
P	0.497	0.604	0.343	−0.045	0.120	−0.210	−0.073	0.777	−0.424	0.017	−0.036	−0.406
K	−0.123	−0.253	−0.181	0.317	0.368	−.0229	0.180	−0.359	0.601	−0.513	0.093	0.114
S	0.326	0.204	0.509	−0.097	−0.347	0.210	0.051	0.577	−0.457	0.607	0.001	−0.392
Ca	−0.088	0.119	−0.189	0.252	0.088	0.568	0.549	−0.392	0.562	−0.278	0.477	0.393
Mg	−0.455	−0.097	−0.487	−0.084	0.048	0.232	0.174	−0.695	0.466	−0.834	−0.020	0.711
Na	0.063	−0.238	0.116	0.481	0.443	−0.339	0.328	−0.298	0.673	−0.362	0.181	−0.108
Fe	−0.030	−0.313	0.359	0.150	−0.289	0.280	0.198	−0.043	0.141	0.360	0.183	−0.090
Mn	−0.189	0.090	−0.132	0.098	0.116	0.278	0.459	−0.511	0.569	−0.519	0.128	0.436
Zn	0.397	0.041	0.344	0.371	0.193	−0.175	0.246	0.254	0.072	0.642	0.239	−0.605
Cu	0.683	0.380	0.604	0.643	0.449	−0.087	0.506	0.565	0.324	0.588	0.493	−0.642
B	0.213	0.227	0.215	0.502	0.571	−0.104	0.540	−0.202	0.726	−0.252	0.615	−0.057

Table 10

Correlation coefficients between leaf and fruit traits

	Fruit											
Leaf	TN	P	K	Ca	Mg	S	Na	Fe	Zn	Mn	Cu	B
TN	−0.671	0.569	−0.816	0.552	−0.441	−0.478	−0.872	−0.265	−0.592	−0.112	−0.250	−0.728
P	−0.359	**0.624**	−0.614	0.3800	−0.166	−0.221	−0.715	−0.455	−0.254	−0.157	−0.076	−0.331
K	−0.462	0.448	−0.465	0.215	−0.217	−0.105	−0.742	−0.348	−0.237	−0.406	−0.287	−0.473
Ca	−0.443	0.164	−0.189	**0.590**	−0.372	−0.528	0.097	0.210	−0.547	0.556	0.006	−0.189
Mg	0.417	−0.586	0.533	−0.642	**0.547**	0.740	0.536	0.020	0.616	−0.156	−0.298	0.527
S	−0.396	0.210	−0.505	0.006	−0.453	0.108	−0.528	−0.692	−0.115	−0.265	−0.735	−0.409
Na	0.669	−0.531	0.690	−0.493	0.631	0.599	**0.747**	0.236	0.697	0.030	0.187	0.731
Fe	0.565	−0.338	0.391	−0.059	0.407	0.071	0.350	**0.612**	0.192	−0.114	0.555	0.254
Mn	0.459	−0.337	0.719	−0.777	0.448	0.880	0.647	−0.237	0.718	−0.343	−0.256	0.626
Zn	0.722	−0.615	0.592	−0.521	0.645	0.691	0.623	0.173	**0.727**	−0.098	0.033	0.654
Cu	0.147	−0.188	0.121	−0.185	0.328	0.369	−0.174	0.038	0.186	−0.554	−0.169	−0.385
B	−0.448	−0.433	−0.757	0.569	−0.033	−0.250	−0.864	−0.142	−0.181	−0.228	−0.034	−0.492

Table 11

Correlation coefficients among soil traits

	LOI	TN	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	B	Al	BD	MWHC	FC	GD	HM
EC	−0.726	−0.164	0.038	−0.314	0.362	0.373	0.303	0.560	−0.698	0.853	−0.428	0.458	0.455	0.214	−0.149	−0.491	0.300	0.556
LOI		0.403	0.320	0.319	−0.225	−0.158	−0.123	−0.241	0.816	−0.651	0.365	−0.204	−0.563	−0.290	0.235	0.535	−0.243	0.398
TN			0.699	0.699	0.726	0.749	−0.313	0.571	0.738	0.247	0.430	0.577	−0.837	−0.220	0.274	−0.037	0.352	0.252
P				0.180	0.480	0.620	0.228	0.625	0.517	0.264	0.174	0.633	−0.299	0.390	−0.335	−0.237	−0.159	0.059
K					0.473	0.288	−0.368	0.307	0.568	0.068	0.534	0.274	−0.772	−0.627	0.637	0.169	0.573	0.355
Ca						0.846	−0.130	0.804	0.212	0.780	0.293	0.787	−0.565	−0.035	0.085	−0.553	0.629	0.689
Mg							−0.326	0.650	0.288	0.664	−0.025	0.652	0.499	0.151	−0.037	−0.361	0.304	0.376
Na								0.350	−0.387	0.170	0.153	0.393	0.600	0.298	−0.361	−0.283	−0.144	0.175
Fe									−0.007	0.815	0.225	0.892	−0.203	0.085	−0.046	−0.591	0.516	0.705
Mn										−0.377	0.414	0.046	−0.796	−0.191	0.195	0.284	−0.047	−0.198
Zn											−0.116	0.729	0.021	0.147	−0.079	−0.669	0.552	0.770
Cu												0.372	−0.557	−0.420	0.306	−0.078	0.429	0.348
B													−0.206	0.025	0.021	−0.426	0.434	0.627
Al														0.432	−0.437	−0.034	−0.471	−0.228
BD															−0.979	−0.534	−0.619	−0.277
MWHC																0.565	0.610	0.267
FC																	−0.309	−0.595
GD																		0.879

Table 12
Correlation coefficients among fruit traits

	FM	FDM	Brix	IS	TN	P	K	Ca	Mg	S	Na	Fe	Zn	Mn	Cu	B
Volume (FV)	−0.185	0.185	0.266	0.152	0.230	0.058	0.446	−0.235	−0.051	0.037	0.423	0.046	0.026	0.194	0.210	0.289
Moisture (FM)		−1.000	−0.800	−0.533	−0.382	0.547	−0.274	−0.012	−0.345	−0.181	−0.455	−0.390	−0.597	−0.437	−0.202	−0.610
Dry matter (FDM)			0.800	0.533	0.382	−0.547	0.274	0.012	0.345	0.181	0.455	0.390	0.597	0.437	0.202	0.610
Brix				0.646	0.658	−0.524	0.700	−0.389	0.591	0.501	0.789	0.335	0.690	0.147	0.289	0.745
Ionic strength (IS)					0.162	−0.330	0.204	−0.135	0.341	0.359	0.303	0.247	0.520	−0.070	0.131	0.297
TN						−0.570	0.553	−0.529	0.390	0.428	0.543	−0.041	0.414	0.065	0.106	0.599
P							−0.244	0.521	−0.005	−0.294	−0.257	0.029	−0.338	−0.119	0.386	−0.294
K								−0.637	0.400	0.494	0.880	0.205	0.409	−0.105	0.262	0.542
Ca									−0.012	−0.580	−0.467	0.464	−0.274	0.299	0.391	−0.425
Mg										0.561	0.415	0.484	0.487	−0.158	0.243	0.261
S											0.417	−0.171	0.801	−0.573	−0.382	0.435
Na												0.262	0.445	0.190	0.301	0.708
Fe													0.006	0.156	0.578	−0.078
Zn														−0.294	−0.071	0.642
Mn															0.255	0.123
Cu																0.186

the other hand, no weed-control cost was required for organic Hayward because sheep were used (data not shown). Harvest and other cultural costs were greater in conventional Hayward and conventional Hort16A than in organic Hayward because of larger yields. Gross revenue return per ha was \$39,811 for organic Hayward, \$29,717 for conventional Hayward, and \$60,053 for conventional Hort16A. Receiving a greater price from Zespri is the norm for organically grown fruit with the grower receiving ∼\$1.85 more per tray. From our economic comparison, the cost/benefit ratio is graded as conventional Hayward $>$ conventional Hort16A $>$ organic Hayward. It can be inferred that growing kiwifruit organically is more profitable because of the lower cost/benefit ratio.

Conclusions

In this study, the changes in soil physical properties and macronutrients corresponded with management practices. Remarkable differences in fruit yield between the management practices were observed. Organic Hayward accumulated greater dry matter than both conventional and biological Hayward. This was expected because of the lower supply of N and therefore slower growth rate of organic kiwifruit. Significant differences in TSS and ionic strength were recorded between organic Hayward and biological or conventional Hayward. In terms of fruit nutrients, no significant differences can be established in chemical quality between organically and conventionally grown Hayward except Cu. However, this study confirmed that tradeoffs exist between organic and conventional production systems in kiwifruit. The results highlighted the need for further evaluation of other parameters such as vitamins, antioxidants, and mycotoxins of kiwifruit under different management systems in relation to human health. There have been remarkably few publications on product quality or human health issues of organic produce. A major challenge for the future is developing methods that link production systems to product quality and onward to human health and well-being. This has been, and in fact still remains, a basic tenet of organic agriculture that has not yet been fully explored. If we are to improve the sustainability of organic agriculture in the long term, there will continue to be a place for a series of research approaches to be employed.

Acknowledgments

We thank Doug Kirk and Doug McLeod for allowing us to use their orchards to conduct this experiment. We gratefully acknowledged the help of Dr. Shamima Sabreen for statistical analysis of data. All the staff of the Plus Group of companies are gratefully acknowledged for their help and cooperation.

References

Benge, J. R., N. H. Banks, R. Tillman, and H. Nihal de Silva. 2000. Pairwise comparison of the storage potential of kiwifruit from organic and conventional production system. *HortScience* 28:147–152.

Beutel, J. A. 1980. *Kiwifruit leaf analysis values: Preliminary leaf blade and petiole nutrient standards*. Davis, Calif.: Department of Extension Pomology, University of California.

BioGro NZ Ltd. 2001. Bio-Gro *New Zealand organic standards module 3.1. Standards for evaluation of inputs* (http://www.bio-gro.co.nz/content/files/1010430_inputs.pdf). Wellington, New Zealand: BioGro New Zealand Ltd.

Bladh, K. W., R. A. Bideaux, E. Anthony-Morton, and B. G. Nichols. 2001. *Handbook of mineralogy*. Chantilly, Va.: Mineralogical Society of America.

Blake, G. R., and K. H. Hartge. 1986. Bulk density. In *Methods of soil analysis, part 1: Physical and mineralogical methods*, 2nd ed., ed. A. Klute, 363–375. Madison, Wisc.: American Society of Agronomy.

Blakemore, L. C., P. L. Searle, and B. K. Day. 1987. *Methods of chemical analysis of soils*, 18–19. New Zealand: NZ DSIR, NZ Soil Bureau.

Boase, M. R., S. Wright, and P.L. McLeay. 1993. Coconut milk enhancement of axillary shoot growth in vitro of kiwifruit. *New Zealand Journal of Crop and Horticultural Science* 21:171–176.

Bruning-Fann, C. S., and J. B. Kaneene. 1993. The effects of nitrate, nitrite, and N-nitroso compounds on human health: A review. *Veterinary and Human Toxicology* 35 (6): 521–38.

Burgos, P., A. Pérez-de-Mora, P. Madejón, F. Cabrera, and E. Madejón. 2008. Trace elements in wild grasses: A phyto-availability study on a remediated field. *Environmental Geochemistry and Health* 30 (2): 109–114.

FAO. 2000. Food safety as affected by organic farming. In *Twenty-second FAO Regional Conference for Europe* (www.fao.org/docrep/meeting/x4983.htm).

Gardner, W. H. 1986. Water content. In *Methods of soil analysis, part 1: Physical and mineralogical methods*, 2nd ed., ed. A. Klute, 493–541. Madison, Wisc.: American Society of Agronomy.

Granato, T. C., R. I. Pietzer, G. J. Knafl, P. Tata, and C. Lue-Hing. 2004. Trace element concentrations in soil, corn leaves, and grain after cessation of biosolids applications. *Journal of Environmental Quality* 33:2078–2089.

Griffin, R. A., and J. J. Jurinak. 1973. Estimation of activity coefficients from the electrical conductivity of natural aquatic systems and soil extracts. *Soil Science* 116:26–30.

Hassey, J. K., R. S. Johnson, R. D. Meyer, and K. Klonsky. 1997. An organic versus conventional farming system in kiwifruit. *Acta Horticulturae* 444:223–228.

Hewitt, A. E. 1993. *New Zealand soil classification*. Dunedin, New Zealand: Mannaki Whenua-Landcare Research New Zealand Ltd.

Jackson, M. L. 1973. *Soil chemical analysis*. New Delhi, India: Prentice Hall of India Pvt. Ltd.

Jestoi, M., M. C. Somma, M. Kouva, P. Veijalainen, A. Rizzo, A. Ritieni, and K. Peltonen. 2004. Levels of mycotoxins and sample cytotoxicity of selected organic and conventional grain-based products purchased from Finnish and Italian markets. *Molecular Nutrition and Food Research* 48 (4): 299–307

Jorhem, L., and P. Slanina. 2000. Does organic farming reduce the content of cadmium and certain other trace metals in plant foods? A pilot study. *Journal of the Science of Food and Agriculture* 80:43–48.

Kalra, Y. P., and D. G. Maynard. 1994a. Particle-size analysis. In *Methods manual for forest soil and plant analysis* (Information Report NOR-X-319), 42–53. Edmonton, Alberta, Canada: Canadian Forest Service.

Kalra, Y. P., and D. G. Maynard. 1994b. Electrical conductivity and soluble salts. In *Methods manual for forest soil and plant analysis* (Information Report NOR-X-319), 35–41. Edmonton, Alberta, Canada: Canadian Forest Service.

Karlen, D. L., M. J. Mausbach, J. W. Doran, R. G. Cline, R. F. Harris, and G. E. Schuman. 1997. Soil quality: A concept, definition, and framework for evaluation. *Soil Science Society of America Journal* 61: 4–10.

Kay, T., and R. Hill. 1998. *Field consultations guide to soil and plant analysis: Field sampling, laboratory processing, and interpretation*. Hamilton, New Zealand: Soil and Plant Division, Hill Laboratory.

Kezdi, A. 1974. *Handbook of soil mechanics: Soil physics*, vol. 1. Amsterdam, the Netherlands: Elsevier Scientific.

Kment, P., M. Mihaljevič, V. Ettler, O. Šebek, L. Strnad, and L. Rohlová. 2005. Differentiation of Czech wines using multielement composition: A comparison with vineyard soil. *Food Chemistry* 91 (1): 157–165.

Kortbech-Olesen, R. 2003. Market. In *The world of organic agriculture*, ed. M. Yussefi and H. Willer, 21–26. Tholey-Tholey, Germany: International Federation of Organic Agriculture Movements.

Kumpulainen, J. 2001. Nutritional and toxicological quality comparison between organic and conventionally grown foodstuffs. *Proceedings of the International Fertilizer Society* 472:1–20.

Mäder, P., L. Pfiffner, U. Niggli, U. Balzer, F. Balzer, K. Plochberger, A. Velimirov, and J. M. Besson. 1993. Effects of three farming systems (bio-dynamic, bio-organic, conventional) on yield and quality of beetroot (*Beta vulgaris* L. var. *esculenta* L.) in a seven-year crop rotation. *Acta Horticulturae* 339:10–31.

Mattheis, J. P., and J. K. Fellmann. 1999. Preharvest factors influencing flavor of fresh fruit and vegetables. *Postharvest Biology and Technology* 15 (3): 227–232.

Mehlich, A. 1984. Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. *Communications in Soil Science and Plant Analysis* 15 277–294.

Mengel, D. B., and S. A. Farber. 1974. Rate of nutrient uptake per unit of corn root under field conditions. *Agronomy Journal* 66:399–402.

Molloy, L. 1988. Loamlands. In *Soils in the New Zealand landscape: The living mantle*, 55–69. Wellington, New Zealand: Mallinson-Rendel Publishers Ltd. and NZ Society of Soil Science.

Muneer, M. 1987. Effect of calcium on the mineralization of organic carbon and stability of soil aggregates. PhD thesis, University of Adelaide, Australia.

New Zealand Soil Bureau. 1954. *General survey of the soils of North Island, New Zealand* (New Zealand Soil Bureau Bulletin 5). Wellington, New Zealand: New Zealand Department of Scientific and Industrial Research.

Rahman, M. H., and S. Sugiyama. 2008. Dynamics of microbial community in Japanese Andisol of apple orchard production systems. *Communications in Soil Science and Plant Analysis* 39 (11–12): 1630–1657.

Riley, H., R. Pommeresche, R. Eltun, S. Hansen, and A. Korsaeth. 2008. Soil structure, organic matter, and earthworm activity in a comparison of cropping systems with contrasting tillage, rotations, fertilizer levels, and manure use. *Agriculture Ecosystems and Environment* 124:275–284.

Sams, C. E. 1999. Preharvest factors affecting postharvest texture. *Postharvest Biology and Technology* 15 (3): 249–254.

Ventura M., A. de Jager, H. de Putter, and F. P. M. M. Roelofs. 1983. Nondestructive determination of soluble solids in apple fruit by near infrared spectroscopy (NIRS). *Postharvest Biology and Technology* 14 (1): 21–28.

Vossen, P., D. Jolly, R. D. Meyer, L. Varela, and S. Blodgett. 1994. Disease, insect pressures make organic production risky in Sonoma County. *California Agriculture* 48 (6): 29–36.

Warman, P. R., and K. A. Harvard. 1998. Yield, vitamin, and mineral content of organically and conventionally grown potatoes and sweet corn. *Agriculture, Ecosystems and Environment* 68 (3): 207–213.

Weston, L. A., and M. M. Barth. 1997. Preharvest factors affecting postharvest quality of vegetables. *HortScience* 32 (5–7): 812–815.

Williams, C. M., O. Bridges, J. W. Bridges, H. Pennington, and P. B. Tinker. 2000. *Shades of green: A review of UK farming systems*, 73–100. London: Royal Agricultural Society of England.

Woese, K., D. Lange, C. Boess, and K. W. Boegl. 1997. A comparison of organically and conventionally grown foods: Results of a review of the relevant literature. *Journal of the Science of Food and Agriculture* 74 (3): 281–293.

Worthington, V. 2001. Nutritional quality of organic versus conventional fruits, vegetables, and grains. *Journal of Alternative and Complementary Medicine* 7:161–173.

Zespri International Ltd. 2008. 2008 season return analysis. *Kiwiflier* 276:4–5.