Monitoring Soil Health in an Intensive Organic Vegetable Production System

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Abstract

Maintaining soil health and nutrition is fundamental to the establishment of a sustainable organic production system. A four year project was undertaken in Tasmania to test and evaluate on an intensive commercial scale, organic vegetable crop production protocols. In addition to data on production, costs, yields, and market premiums, a soil health monitoring program was included in the project. The purpose was to assess and measure the effects of organic production activities on soil health. Soil health was measured in terms of physical soil structure, available nutrients, organic carbon, soil pH, and balance of beneficial soil flora and fauna. After three years of organic production, soil measurements indicated:

- Physical soil structural improvements were still required.
- Soil organic carbon was stable but less than desirable.
- Soil nitrogen decreased depending on cropping history.
- Minimal change to available phosphorous (P) and potassium (K) levels.
- Minimal change to soil pH.
- Increased levels of bacterial and fungal biomass compared with a conventionally managed site.

Introduction

Organic farmers aim to create a soil that has good structure, is balanced in nutrients, and is high in biological activity (Laffan, 2000). Several factors affect soil health which has three major components; soil physical, chemical, and biological properties. In most intensive agricultural situations repeated tillage, vehicle traffic, and a constant push for maximum production, will cause a decline in the soil health characteristics. This decline in soil health may include degradation of soil structure, a decline in nutrient levels, a negative change in soil biota, or some combination of these changes (Cotching et al 2002). If severe enough this degradation can impact on crop yields, versatility of use and sustainability of the affected site.

A four year project was established in Tasmania to test and evaluate organic vegetable crop production protocols on an intensive commercial scale. A soil health monitoring program was included to assess and measure the effects of organic production activities on soil health compared to the effects of conventional crop management practices.

Methods

Soil health characteristics (soil structure, available nutrients, organic carbon, pH, and soil biota) were monitored over the course of the four-year organic vegetable production trial.

Soil structure

Soil structure was assessed at the start and end of the project and visual assessments were made during the trial. Soil structure was measured as soil penetration resistance, using a recording core penetrometer (which measures soil compaction). Resistance penetration was measured to 600mm depth and was carried out within the paddock beds. 10 Penetration resistance tests were taken to give a mean result.

Available nutrients, Organic Carbon(OC) and Soil pH

Composite soil samples for nutrient analysis, OC and pH(water) were collected from the top 10cm of each paddock unit. For each unit 10 sub-samples were collected and combined to form a bulk sample.

Soil samples were collected on an annual basis prior to the cropping season and submitted for laboratory assay, data from each unit was combined for the results presented.

Soil biota

At years two and four, assessment of soil micro flora and fauna (soil biota) was conducted. Soil from the top 10cm was sampled. For each unit 10 sub-samples were collected and combined to form a bulk sample. These were sent to Soil Foodweb Institute (Lismore, NSW) for analysis. Soil health comparisons were made with a neighbouring conventionally managed site located at Forthside Research Station (FRS).

Results and Discussion

Soil Structure

Degradation of soil physical properties can have significant consequences often due to reduced water filtration and root penetration. Degradation of soil structure is easy to affect, but slow and difficult to correct. Penetration resistance doubled over the 0-150mm depth (Fig 1) indicating that surface compaction has occurred. Whilst the value observed is less than 2000 kPa (considered the critical value beyond which root growth becomes severely impaired (Cass 1999)), this degradation of structure represents a major challenge for management of the site. Adoption of organic methods of fertiliser management and crop rotation does not necessarily give rise to better treatment of soil physical properties.

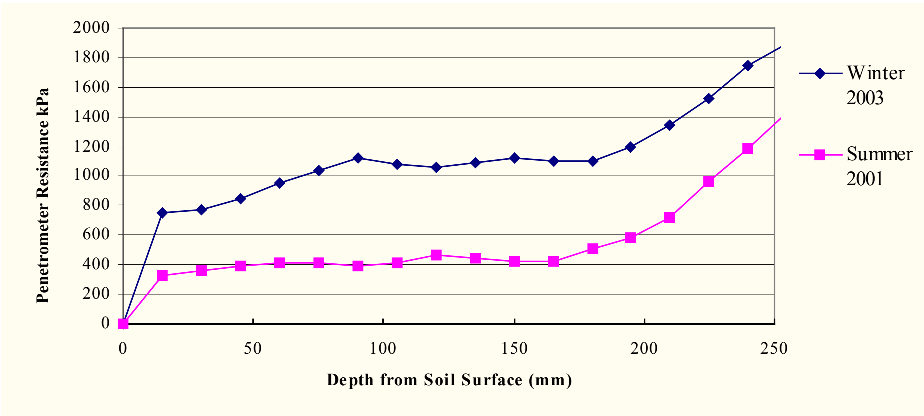

Figure 1. Soil Penetration resistance at the organic test site.

Visual evidence of compaction and soil structure degradation was also seen following the carrot harvest in the form of large angular soil clods. Also, establishment of faba beans in these parts of the site was much slower when compared to the areas of the site that were rested for a year. It is likely the difference in bean establishment was a direct consequence of the surface compaction depicted (Fig 1). Regular use of machinery for cultivation and other weeding operations would probably have contributed to the site compaction with a concentration of damage beneath wheel furrows. Another contributing factor to compaction could have been the use of heavy harvesting equipment operated on moist soil for easy removal of root crops which is characteristic of current commercial carrot production.

Penetration resistance is dependent on moisture content in structurally degraded soils (Cass 1999). As a compacted soil dries, penetration resistance is increased. The resistance readings from 2003 (Fig 1) were observed in moist soil and so as the soil dries the resistance will increase, possibly to a level great enough to impede root and root hair development (ie., greater than 2000kpa) as well as root access to nutrients. This type of shallow compaction has the potential to inhibit seed germination and seedling emergence (Cotching, pers.comm.). Crop performance depends on the ability of roots to extend into the soil and the presence of symbiotic microbes within the rhizosphere which is diminished by compaction.

Available Nutrients

Major nutrients such as nitrogen, sulphur, potassium and phosphorous are major constituents of plant components and play a vital role in correct plant function. At the organic test site soil nitrogen levels declined during the four year trial period despite inclusion of leguminous crops into the rotation (Fig 2a). To maintain sustainability and build soil nitrogen, an uninterrupted series of legumes in the rotation has been recommended. Soil sulphur levels increased in 2001 which is possibly attributed to the use of anti fungal copper sulphate sprays applied during the 2000- 2001 season (Fig 2a). Potassium levels remained relatively stable over the four year period (Fig 2b) and are considered to be sufficient for optimum growth. This could be due to nutrient availability from pre-1999 conventional cropping history, or could be due to the mineralisation of plant residues replacing the amounts of potassium used. Soil phosphorous (Colwell) measures indicate some variation at the site across the four year period and a slight trend downwards but with adequate amounts available to the crops being grown (Fig 2b). Colwell phosphorous compared favourably to the neighbouring conventionally managed site (100mg/kg).

Soil Organic Carbon

Soil organic carbon levels remained relatively stable (Fig 2c). Levels of organic carbon considered desirable are between 4 and 5 % (Cotching pers. comm) thus further improvements at the site are required for sustainable production. Increasing the organic carbon content of the soil in all units will reduce the risk of compaction damage, and improve biological activity and nutrient recycling. Soil organic carbon is the most important factor for soil health and is best achieved by avoiding long fallow periods and ensuring immediate replacement crops, such as green manures, are sown immediately after harvest of commercial crops (Pung *et al.* 2003).

Soil pH

Current pH remains well within the range best suited for temperate cropping (Fig 2c).

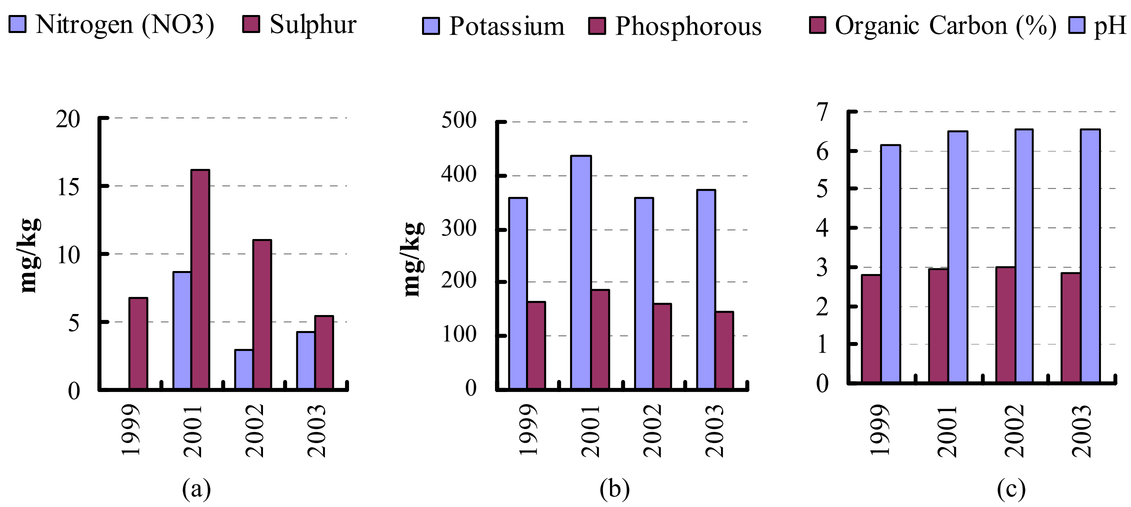

Figure 2. OC, pH and nutrient levels at the organic trial site over the trial period.

Soil Biota

The organic site had greater active fungal and active bacterial biomass than the conventionally managed site however the values were still low (Table 1). Total fungal and bacterial biomass, and the protozoan population at the both sites were low. Whilst both sites had an overall low number of soil biota, activity tended to be bacterial dominated rather than the desired 1:1 ratio considered indicative of a highly productive agricultural soil (Ingham, 2003).

Table 1. Organism biomass data .

Rotation	Active Bacterial Biomass (μg/g)	Active Fungal Biomass (μg/g)	Active Fungal to Active Bacterial Biomass	Total Fungal to Total Bacterial Biomass
Desired Range	**10-25**	**10-25**	**1:1**	**0.6-1.2**
Organic site	11.0	2.51	0.23	0.27
Conventionally managed site	*4.20*	*0.00*	*0.00*	*0.45*

Microbial activity and diversity needs be encouraged at the organic test site. Greater levels of soil organic carbon have been directly correlated with greater microbial biomass in these ferrosols (Sparrow *et al*. 1999). An increase in organic matter originating from a range of sources should provide the sustenance for building a healthy soil ecosystem. Increased fungal biomass will hasten soil structure repair and encourage nutrient cycling, fungal foods in particular could be provided in the form of compost or by using fertigation with compost teas. Heavy application of compost at the site has been considered as this would address the issues of low organic matter and low biological activity, however costs associated with handling and application of broad acre compost have made this uneconomic. As a compromise, an increased area of the site will be rested for two years with a ground cover of self mulching green manure crops, and the potential for an application of compost tea will be investigated.

Concluding Comments:

Monitoring soil health over the past four years has provided a baseline reference from which improvements in soil condition can be gauged and provides the means to establish an early warning system. The project has indicated some changes in soil properties due in part to the organic management practices. In continuing the monitoring program particular attention will be paid to changes in organic carbon and soil microflora and fauna. Management techniques such as reduced tillage will need to be considered at the site in order to maintain soil structure, encourage soil microbial activity, and sustain crop health. The use of cover crops should be increased to enhance soil organic matter levels. Long-term monitoring at the site is being planned to measure changes in soil health in subsequent years. Long term monitoring will quantify soil health differences between organic and conventional vegetable production and assist in making the optimum crop/soil management decisions.

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