

CASE STUDY:

Prevention of Soil Borne Pests in Organic Edible Ginger

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Location: Hawai'i Island, Papaikou Watershed



Background

Production of organic ginger *Zingiber officinale* Roscoe, Japanese variety, is subject to serious economic loss from several soil borne pests.¹ The plant parasitic root-knot nematode (RKN) *Meloidogyne incognita* is a persistent pest for ginger production in soils worldwide. Pathogenic bacteria *Ralstonia solanacearum*, which causes "bacterial wilt" of ginger, has become a serious threat of economic loss for Hawaii ginger growers.

In order to develop an acceptable degree of risk for growing organic ginger in fields with disease pressure, an investigation of the soil in Papaikou and of the standard cultural practices for raising organic ginger was undertaken in late 2001. The objectives were to 1. Investigate and determine the critical disease control points for RKN and bacterial wilt. 2. Create and imple-

ment a farming system that employs the microbial biomass in soil borne pest prevention.

The operating principal in use relies on information and acquired skills to develop, implement and monitor a pest preventative system employing a diversity of individual actions which limits pest damage while simultaneously providing benefits to the crop and farm ecology, beyond pest management alone.

The Papaikou field in this report located at 19° 46.62 N X 155° 07.85 W at 1,162 feet elevation on Kaiwiki soil series was previously monocropped sugar cane. Resident stands of non-native grasses were being grazed by cattle at time of ginger introduction on this site in 1999. There is 120-150 inches per year of rainfall. Soil texture at 2-12 inches depth is sandy clay loam. At 0-4 inches soil depth the predominate clay species is Allophane and

Overview of Sustainable Techniques Used

Biological & Chemical Soil Analyses

Compost & Compost Tea

Biofumigation

Cover Crops

Pest Exclusion

Sanitation



Halloysite in this dark brown, yellow-red soil (7.5 YR 3-4)². Before amendment for planting, the average exchange capacity was 3 ME. with 5% soil organic matter, pH 6.5 (water), extremely deficient calcium with 1:1 ratio calcium to magnesium, extremely deficient phosphate, iron copper and zinc and deficient potassium. Sodium was excessive at 120 lb/ac and at higher base saturation percentage compared with potassium.³ Structure at 2-12 inches depth is poor and with disc compaction at 9 inches depth and then an abrupt change at 18 inches depth to loam clay with poor structure. Microbiological analysis of soil at 0-4 inches depth shows this soil to have well balanced bacteria and fungi populations, with good species di-

versity. The soil has desirable Basidiomycete and Mycorrhizae fungi in significant populations. However, free-living nematode (beneficial non plant parasitic) populations are undesirably low, although the diversity of species is high. Earthworms are present at low populations during the cropping season.

Situation

The Papaikou field has a history of RKN pressure. There are two one (1) acre fields with bacterial wilt immediately down hill from the Papaikou field and there was a 100 square foot outbreak of bacterial wilt confirmed in the 2002-growing season. The disease outbreak was spotted early in development by monitoring and was immediately covered with plastic sheeting to prevent rain from transporting the bacteria from the outbreak site. The wilt was contained and did not cause a significant loss.

The Papaikou field's mineral analysis, physical character and history all help to explain why this soil was disease conducive in previous years. Typically when a field has bacterial wilt or high populations of RKN, organic ginger farmers will relocate to another field.⁴ There are, however, significant disadvantages in developing a new field. Establishing farming operations on a new field increases capital costs, may take a long search to find, choices are often limited to marginally acceptable land with associated low soil fertility and may require 3 years before qualifying for certified organic production. Increasing disease suppression of the soil is likely the more profitable alternative compared with moving the field, if a method to prevent pest damage can be demonstrated in the existing field.

Ginger roots spend a long time in the soil from the time of planting until harvest.⁵ This long period of time allows bacterial wilt and other pathogens ample opportunity to locate a host such as ginger. Although a technique such as growing a non-host cover crop may have measurable value, a stand-alone pest prevention method is seldom reliable.⁶ Successful organic production usually requires the synergistic effects of a broadly diversified and thoroughly integrated systems approach to management of pests.

Method

Lab analysis for mineral balance (chemistry) was used to guide mineral applications intended to feed the plant and to help create better soil structure. Good soil structure provides a physical space in the soil matrix where soil microbes can develop large populations. Applying compost and growing cover crops provide food energy by which soil microbes such as bacteria, fungi, nematodes and protozoa are able to increase their populations resulting in the increased uptake of minerals by

the ginger. Each of these materials, applied to soil, act to increase the desired effect of the other. These applications increase the microbial biomass and the healthy functioning of the soil food web that is the principal source of disease protection and nutrition for ginger.⁷ Soils with health food webs act to reduce the pest pressure on ginger and increase predation and parasitism on pests of ginger, simultaneously.⁸ High quality farming soils with a high degree of health resist erosion, are disease suppressive for the crops grown on them and grow high quality crops on a consistent basis.

Various forms of physical exclusion, intended to prevent new introductions of nematodes or wilt bacteria, can be found in a systematic preventative program. Drainages created during pre planting field preparation and cover crops are used to prevent soil erosion that could be transporting wilt bacteria to the ginger planting from adjacent land. Equipment is pressure-washed before being brought into the fields. Everybody entering the field washes their footwear or feet in an iodine solution to prevent introduction of wilt bacteria from an outside source. Seed ginger was obtained from bacteria wilt-free fields and visually inspected for nematode, or other pathogens, prior to selection as "seed" for planting.

After harvest in 2002 the field was disked and as much root debris as possible removed from the soil. The physical removal of un-harvestable ginger left in the field removed a reproductive source for both wilt bacteria and RKN. Seed ginger was boiled to destroy pathogens that could be imported with the ginger seed. These sanitation techniques after harvest and pre plant are crucial preventative techniques in lowering the risk in the subsequent crop to be planted.

Next, Sunn Hemp *Crotalaria juncea* L.⁹, a non-host plant for RKN, was planted and left to stand for 90 days. The Sunn Hemp seed was planted at high density and



left to stand for a long period of time as to provide good weed smothering, protection of erosive soil and development of lignified cover crop residues which have substantial value in improving soil quality. After turning brown while still standing the sunn hemp became brittle and easy to mow and then incorporate with a spader. Minerals and lime as required per soil analysis was applied prior to spading the Sunn Hemp residues.

A second cover crop *Raphanus sativa*, variety: fodder radish, cultivar Colonel¹⁰ was planted about 70 days before the April 2003 ginger planting date. Fodder radish, a Brassica family plant, has high concentrations of glucosinolates in their tissues. When Brassica family plants are incorporated into soil microbial decomposition of glucosinolates release 2-phenylethyl isothiocyanate lowering soil populations of wilt bacteria and RKN.¹¹ Minerals and lime as required per soil analysis were applied prior to spading the fodder radish residues.

Prior to planting the 2003 ginger, the soil-incorporated radish residues were allowed to decompose for 20 days. Next, planting trenches were banded with cured compost and minerals and then planted with seed ginger that was inoculated with mycorrhizae spores.

Cured compost made from woody feedstock and minerals are incorporated with the soil used to till the rapidly growing ginger in July. Compost tea made with earthworm castings high in fungi is applied to the ginger foliage and to the soil throughout the growing season. Foliar application of minerals intended to support the health of the ginger plant and therefore increase disease resistance is practiced throughout the season.

Pesticides can also be used in organic management of nematodes.¹² Plant extracts of garlic¹³ and many other plants have shown to be effective, with respect to site specifics, in preventing and eradicating RKN.¹⁴ Where preventative methods have failed, pesticides are applied to decrease the risk of loss due to pests.

Results

The use of cover crops, compost and mineral amendments more than tripled the exchange capacity to 10 ME that correlates more closely with the sandy clay loam textural class than comparisons found prior to amendment.¹⁵ Calcium to magnesium levels were brought to 6:1, sodium was lowered by 50% and potassium increased. The resulting pH was 6.6 (water) and the soil organic matter remained about the same at 5%. Phosphate and Iron are the only minerals that are persistently deficient which is due to the clay species characteristics and the relatively low soil organic matter.



There were low root knot nematode populations after growing sunn hemp. There were also large populations of beneficial saprophytic bacteria observed in the soil during the sunn hemp residue decomposition.¹⁶

There were high numbers of RKN in the soil near radish roots at time of their incorporation. There were low numbers of RKN in soil near growing ginger 30 days after planting where fodder radish had been incorporated. There is ample reason to believe that RKN, in our soils, reproduce successfully in fodder radish and should be classified as a host. However, There were lowered numbers of RKN after the fodder radish residues had time to decompose and biofumigate the soil. In that this project was intended to create disease preventative conditions under which organic ginger can be farmed with minimal risk, the results of these measures will not be fully known until 2004.

Discussion

The improved physio chemical soil factors are important indicators of improved soil health and the ability of this soil to be more disease suppressive for the ginger. The soil at Papaikou has improved in quality due to the farm's dedication to balanced soil inputs, information gathering that leads to understanding the soil better, and skillful execution of cultural practices including tillage. The improved soil health can be seen by chemical and biological lab analysis and by the current physical characteristics of the soil at the Papaikou field site. Increased monitoring and analysis, the development of disease suppressive healthy soil, developing a source of disease suppressive compost, biofumigation, choosing non host cover crops species and management for maximum soil health benefit, applying earthworm castings in compost tea, applying foliar application of micronutrients to prevent deficiency¹⁷ and the timely use biological nematocides all have integral "niche" roles minimizing the risk of loss to pests. Together these practices can be described as a "biologically integrated systems approach" to pest management.

How a small area of bacterial wilt could break out in the center of the Papaikou field in 2002 but not spread, is not completely understood. Normally, once bacterial wilt starts it spreads rapidly, ruining ginger quality and causing severe economic damage.¹⁸ Expert field scouting (monitoring) was apparently effective in allowing a quick isolation of the wilt-affected area that prevented spreading by rainfall. To what degree the soil's health and the associated ginger plant resistance to diseases may have had a role in preventing the wilt bacteria from spreading is unknown. It is also unknown for certain to what degree the biofumigation with fodder radish helped to lower the wilt bacteria presence and spread in the Papaikou field.

Biofumigation was apparently successful at reducing the RKN as nematode analysis found a sharp reduction in populations after incorporation of the fodder radish residues. The effect of the biofumigation was likely enhanced by ideal soil moisture for decomposition in the days after incorporation and increased humus levels from the sunn hemp grown previously. However, because the fodder radish was a good host for RKN during its growth cycle, another Brassica family plant other than fodder radish needs to be selected as a biofumigation cover crop.

Exclusion, sanitation, biofumigation, fertilizer selection, fungal compost and the development of a healthy soil food web in general are the system components that reduce the risk of loss by soil borne pests. However, at the end of the 2003-4 season is where the work we started in 2000 will be judged. The need for whole systems research and applied research for prevention of soil borne diseases is clearly demonstrated by this site's study. The materials that were employed are commonly available, or can be made on the farm such as in the case of woody fungal-dominated compost and compost tea. Ultimately it is the farmer who chooses how the crop will be grown and the degree of risk that is acceptable to work under. The attitude that it can be done, and the acceptance that the system approach must be practiced and "made" to work is the foundation upon which successful organic farming is practiced. The farming at Papaikou is a work in progress, and with little doubt, will offer more opportunity for learning during this crop cycle in the "school of hard knocks" called farming.

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Participants

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