Biofumigation with *Brassica* Crops

Practical guidelines for alternative control of nematodes

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INTRODUCTION

There is an ever-increasing global focus on sustainability in the agricultural environment with the aim of producing healthy, good quality crops. One of the aspects is the increased interest in the development of alternative strategies with a low environmental impact in order to control soil-borne pathogens. Biofumigation could be considered the golden midway that fits into this integrated pest management strategy.

Some *Brassica* crops release biocidal compounds (glucosinolates) that acts as a biofumigant. The green tissues of these plants can be incorporated into the soil and can control an array of soil borne pathogens (insects, nematodes and diseases).

PRINCIPLES OF BIOFUMIGATION

Biofumigation is defined as the reaction that takes place after the incorporation of certain crops planted as a green manure. The technique relies on the fumigant action of volatile compounds released during biodegradation for the suppression of plant pathogens. This is not a new technique, keeping in mind that the first observations of the unique properties of glucosinolates and isothiocyanates (the active compounds released during biofumigation) were already recorded at the beginning of the 17th century during efforts to understand the sharp taste of mustard seeds.

Brassica (and certain other) crops produce sulphur containing secondary metabolites known as glucosinolates that in turn are hydrolysed by the enzyme myrosinase to form isothiocyanate. It is this isothiocyanate which has the toxic effect on many soil-borne pathogens. The release of the active compound isothiocyanate and other breakdown products takes place when the cell walls are damaged. Because of the necessity of cell damage that must take place before the active compounds are released, a number of different aspects have an effect on the release of glucosinolates.

Biofumigation may not always be effective, as the levels of glucosinolates vary in different plant species and between varieties of the same crop, as well as in different parts of the plant. It has been shown that when solarisation is used in conjunction with biofumigation the control is significantly increased.

The high volume of green material that needs to be added to the soil is also sometimes a major factor, as this can escalate costs.

PLANTS CONTAINING GLUCOSINOLATES

Glucosinolates are by no means confined to the *Brassicas*; at least 500 species of non-*Brassica* dicotyledonous angiosperms have been reported to contain one or more of the over 120 known glucosinolates. Each of these glucosinolates has its own chemical properties creating a great variation.

Most glucosinolate-containing genera are clustered within the Brassicaceae, Capparaceae and Caricaceae families. The plant species generally considered for the role of biofumigation are found in the genus *Brassica* and include broccoli, cabbage, cauliflower, kale, turnip, radish, canola, rapeseed and various mustards. The glucosinolate concentration in the cells of the various plants differs substantially and therefore it is crucial to identify *Brassica* species that meet the requirements for the aim of the application.

Table I: Some rotation crops in the *Brassica* genera that were tested for the presence of glucosinolate and the relative consentration in the plant cells

Crop - Cultivar	Scientific name	Relative glucosinolate content
Canola - 'Hyola 401'	*Brassica napus*	Low
Rapeseed - 'Dwarf Essex'	*Brassica napus*	Moderate
Turnip - 'Purple top'	*Brassica rapa*	Moderate
Radish (oilseed)	*Raphanus sativa*	Moderate
Yellow mustard - 'Ida Gold'	*Sinapis alba*	Moderate
Indian mustard (unknown)	*Brassica juncea*	High

BIOFUMIGATION AND ITS ROLE IN INTERGRATED PEST MANAGEMENT

The good biological activity of the glucosinolate (glucose and sulphur containing organic anions) degradation products towards some pathogenic fungi and nematodes opens some new perspective towards Integrated Pest Management. It is these perspectives that need more attention and where the principle of biofumigation can play its role in agriculture.

The three areas where biofumigation has proven to have a positive effect in terms of an Integrated Pest Management strategy are against weeds, plant diseases and nematodes. These areas are also of concern when talking about soil-borne diseases and the effect that certain biofumigation practices have either as preventative measures or curative measures.

ASPECTS THAT HAVE AN INFLUENCE ON GLUCOSINOLATE RELEASE AND ISOTHIOCYANATE ACTIVITY

1. Flail or chop to reduce particle size
2. Incorporate plant material into the soil
3. Add water if required

For the best release of isothiocyanates, a technique must be applied which ensures the maximum puncturing of the cells. This can be done by slashing the leaves with a weed slasher, and then rotivating or ploughing the leaves into the soil as quickly as possible for efficient biofumigation. The latter is particularly true of the *Brassica* species like the mustards, which have a high concentration of glucosinolates in the upper parts of the plant. The amount of biomass produced and incorporated into the soil, and the growth stage (emergence, rosette, flowering, seed filling, ripening) also have an influence on the success of the biofumigation with the highest content of glucosinolate present in the flowers.

Soil temperature is not a limiting factor for the enzymatic reaction that takes place during biofumigation, but the maximum activity is at 37°C. The enzymatic reaction becomes slower at lower temperatures, and therefore incorporation of the green manure is not recommended at soil temperatures close to 0°C.

According to Lazzeri (2007) the presence of organic matter seems to have an immobilizing effect on the degradation products and thus prevents them reaching the target pests. Other aspects that also have to be taken into consideration for effective biofumigation are the types of *Brassica* species and their environmental adaptability.

They are applied as green manures, but the main functional parts of the plants, the hydrolysed products formed and the biomass produced are some of the factors that make them unique for their specific application.

The choice of cultivar is determined by a number of factors. These include for what purpose the green manure is planted; such as the reduction of pathogens or as a suppressive agent; availability of water in growing season; is it intended as a cover crop among perennials or as a rotational crop in a rotation program; how long is the crop required to remain on the land; the biomass produced etc.

Practical aspects to be considered

A. Brassica juncea **cv. Caliente (119/199/61)**

The main concentration of glucosinolates is in the flowers and in the leaves although the stems and roots also have low glucosinolate content. As mentioned, the glucosinolate is situated in the cells which in turn need to be ruptured for the enzymatic reaction with myrosinase to take place and for the subsequent formation of primarily isothiocyanate and/or nitriles.

Glucosinolate and hydrolysis products present in different parts of the plant

The majority of the glucosinolate concentration is within the upper parts of the plant. The level of glucosinolates is dependent on genetic factors of the plant, but can also vary according to environmental conditions and the availability of soil sulphur.

Control of **Meloidogyne incognita** ***on*** **Vigna subterranean -** ***Field experiment***

Soil amendments with *Brassica* residues significantly reduced gall formation in the groundnut. The measure of control declined towards harvest in all amendments. Earlier reports showed that control was only effective for 6 weeks, but greatest reduction in nematode population took place within the first 4 weeks. None of the treatments were effective at 2 kg/m^{-2} (20 tons/ha). The 2 *Brassica* varieties used were Glory of Enkhuizen and Drumhead and were effective at 4 and 6kg/m^{-2} and 6kg/m^{-2} respectively. Forage rape is also effective at 4 and 6 kg/m^{-2}, in some instances more effective than cabbage.

Phytotoxicity occurred when higher dosages of Glory of Enkhuizen were added to the soil, rape seed and fenamiphos (pot trial). When used together, solarisation and biofumigation were as effective as the aldicarb treatment in the field.

Field trials showed that soil solarisation and biofumigation, when used in combination, with *Brassica oleracea capitata* L. variety Drumhead resulted in the same level of control of *Meloidogyne incognita* race 2 on bambara groundnut (*Vigna subterranea*) at 4 kg/m^{-2} than a standard application of aldicarb. The combined treatment had better results than soil solarisation or biofumigation only.

Other research has shown that green tissue of rapeseed can reduce populations of *M. chitwoodi*. Research conducted in Australia also showed effective control of *M. incognita, M. javanica* and *Tylenchulus semipenetrans* with rapeseed. *Brassica* crops give better results than other crops (Kwerepe and Labuschagne, 1999).