Biofumigation with *Brassica juncea* Pellets and Leek Material in Carrot Crop Rotations

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Abstract

Biofumigation denotes the use of plant material to treat fields infected with soil borne diseases or nematodes. The plants are usually *Brassica* species such as *B. juncea*, *Sinapis alba* or *Raphanus sativus*, but also *Allium* species have been used. The principle in biofumigation is that the plant material is macerated and incorporated into the soil where it releases toxic substances. In *Brassica* species these are mostly isothiocyanates that are liberated from glucosinolates by an enzymatic process. In *Alliums* the toxic substances are various sulphides liberated after maceration and incorporation. In two carrot fields infected with carrot-cyst nematodes (*Heterodera carotae*) and various fungal diseases, experiments with application of Biofence® (pellets of dried *B. juncea*) and leek (*Allium porrum*) material were carried out. The Biofence (3 t/ha) and leek material (100 t/ha) were incorporated (early April) into the soil (top 15-20 cm) in a randomised block design with three replicates. Control plots with no biofumigation were treated as for other plots. All treatments were carried out with or without plastic covering immediately after incorporation. Nematode concentrations in the soil were recorded prior to, and 2 weeks after treatment. After 2 weeks from treatment, plastic coverings were removed and carrots (cultivar 'Bolero') were sown in all plots. At harvest, around early November, the plot soil was again analysed for nematodes. Approx. 80 kg of carrots from each plot were cool stored (1°C and >95% RH) until March next year, when the degree of fungal storage diseases (*Sclerotinia*, *Phytium*, *Rhizoctonia*, *Rhizoglyphus*, *Rhizoglyphus*, *Mycocentrospora*, *Streptomyces*) was assessed. No significant effect of either Biofence® or leek material on the number of live nematode in soil samples at carrot harvest could be detected. The incidence of fungal diseases in March on the stored carrots also did not show any significant effects of the biofumigation treatments.

INTRODUCTION

Biofumigation denotes the use of plant material to treat fields infected with diseases or nematodes (Kierkegaard and Matthiessen, 2004). The plants are usually *Brassica* species such as *B. juncea*, *Sinapis alba* or *Raphanus sativus*, but also *Allium* species (Arnault et al., 2006). The principle in biofumigation is that the plant material is macerated and incorporated into the soil where it releases toxic substances. In *Brassica* species, these are mostly isothiocyanates that are liberated from glucosinolates by an enzymatic process. In *Alliums* the toxic substances are various sulphides liberated after maceration and incorporation. In organic carrot fields in Denmark, there can be a problem with the build-up of soil borne diseases such as *Sclerotinia*, *Phytium*, *Rhizoctonia*, *Rhizoglyphus*, *Rhizoglyphus*, *Mycocentrospora*, *Streptomyces* and carrot-cyst nematodes (*Heterodera carotae*). The aim of this research was to test whether biofumigation could be used to reduce the number of nematodes as well as the incidence of diseases on cool stored carrots.

MATERIALS AND METHODS

Experiments were carried out on two farms (Lammefjord: 55°46'; 11°25' and 55°47'; 11°25') with fields infected with carrot-cyst nematodes and also various soil borne fungal diseases. The soils are reclaimed sea bed and high in organic matter (5-10% humus). The treatments were application of 3 t DM/ha of Biofence® (pellets of dried *Brassica juncea*, company CRA-ISCI, Italy) and 100 t FW/ha of chopped leek (*A. porrum*) material. The treatments were applied in the beginning of April 2008. Control plots were left as bare soil, and all treatments were established with or without black plastic film covering just after incorporation. The plastic film was sealed with soil around the edges of the plots. The leek material (whole freshly harvested leek) was chopped in a wood chip machine (LOMA, Denmark) just prior to being spread onto the plot area. The experimental area (10×17=170 m²) was established in beds (1.65 m wide) and the individual plot area was 5×1.6=9 m². The leek and Biofence® materials were incorporated with a rotovator (Fobro, Switzerland) and control plots were also rotovated. Soil temperature in 5 cm depth was recorded by data loggers (Tinytag). The Statistical design was in blocks with three replicates (2×2×3=12 plots) at two locations.

The nematode concentrations in the soil were recorded by soil samples (20 subsamples per plot, 20 cm depth and about 1000 g in all) prior to treatment and again 2 weeks after treatment. After 2 weeks from treatment the plastic covering was removed and carrots ('Bolero') were sown in the plot area.

At carrot harvest in early November, the plot soil was again analyzed for nematodes. Approximately 80 kg of carrots from each plot were cool stored (1°C and >95% RH) in wooden crates until March 2009. In March, the incidence of fungal storage diseases was assessed, as well as the incidence of visual nematode attack on carrots.

RESULTS AND DISCUSSION

The daily temperature in the soil (at 5 cm depth) during treatment with the biofumigants was between 9 and 18°C, with only minor differences between covered and non covered plots.

The results of the analysis of number of nematodes in soil samples showed no significant effects of the biofumigation treatments or plastic covering (Fig. 1). The number of viable eggs present in soil samples before treatment, two weeks after treatment and again at harvest of the carrots showed no statistical differences as a result of either Biofence® or the leek material treatment. However, there was a large degree of variation in the number of nematodes. The number of viable eggs in the control plot samples, taken with a two-week interval did not show a significant correlation. Both sample techniques and nematode analysis need to be re-evaluated prior to further experiments.

The incidence of fungal disease attack in cool stored carrots also showed no significant effects of either biofumigation treatments or plastic covering (Fig. 2). The stored carrots were also assessed for visual nematode attack and this result was also not significant with respect to the biofumigation treatment (Fig. 2).

The reason for the unexpected non-significant effects of the biofumigation treatments might be attributed to the high content of organic carbon in the fields (humus 5-10%). A high content of organic carbon tends to absorb the liberated isothiocyanates (Gimsing and Kirkegaard, 2009) and this may also be the case with the sulphides liberated from the leek material. There could also be a soil-type dependant effect on efficacy of biofumigation as shown in the results by Michel (2008), in experiments with *Verticillium dahliae* where the clay content of the soil had a significant effect on the outcome of the biofumigation treatment. The soil temperature during our biofumigation treatments was relatively low (daily between 9-18°C) and this tends to slow down the enzymatic process of liberating isothiocyanates from the *B. juncea* pellets. The experimental area was not irrigated following biofumigation, but the water content in the spring soil was near field capacity. According to Springett and Adams (1989) and Stütze (pers. commun.) the optimum temperature for myrosinase activity is over 30°C. If the average temperature of approximately 14°C in our experiment is critically low for myrosinase

activity, then the more northern countries have a potential challenge in successfully implementing biofumigation in spring and autumn.

CONCLUSIONS

No significant effect was determined for our treatment with either Biofence® or leek material on the number of carrot-cyst nematodes in soil samples. The fungal disease attacks on carrots after storage also did not show any significant response to biofumigation. The reasons for the failed treatment effects will be investigated in future experiments.

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Figures

Fig. 1. Carrot-cyst nematodes: the numbers of viable eggs in soil samples were assessed in April 2008 before treatment, after 2 weeks of biofumigation and again at harvest of carrots in November. Biofumigation treatments included: control plots that were only rotavated, Biofence® pellets 3 t DW/ha, leek material at 100 t FW/ha. All treatments were assessed with and without plastic cover. Result from two farms. Error bars are SE (n=3).

Fig. 2. Carrot diseases: results of biofumigation on quality grading of carrots stored for 5 months. Percentage nematode attacked, discarded because of disease, and marketable. Biofumigation treatments included: control plots that were only rotavated, Biofence® pellets 3 t DW/ha, leek material at 100 t FW/ha. All treatments were assessed with and without plastic cover. Result from two farms. Error bars are SE (n=3).