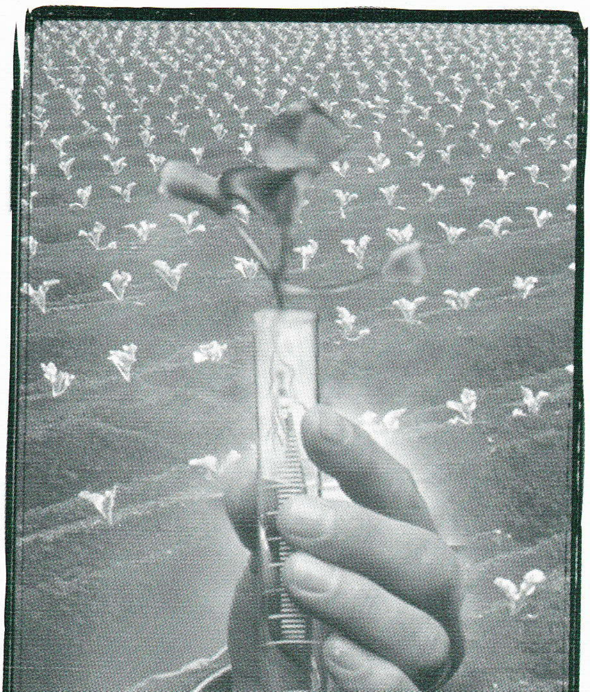
Volume 3, Number 1 2000
(#5)

ISSN: 1092-678X

Journal of Crop Production™



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Biological Control of Common Bunt (*Tilletia tritici*)

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SUMMARY. Common bunt (*Tilletia tritici* syn. *T. caries*) is a significant seed-borne plant disease in organic agriculture. General measures in ecological crop protection like crop rotation and manuring have in practice failed to control this disease, and direct seed treatment may be necessary to ensure yield and food quality. The present study indicates that biological control can be successfully used without negative effects on seed germination and vigor. A combination of biocontrol agents and milk powder improves the efficacy of biocontrol. Application of compost to the soil increases the frequency of this disease. The potential role of biocontrol within the principles of ecological disease management is discussed. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: getinfo@haworthpressinc.com <Website: http://www.HaworthPress.com>]*

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The authors thank sponsors and the companies who delivered the products knowing that the purpose was not to promote or depreciate any specific product or method, but only to screen the agents not previously tested with this disease. They specially thank Erik Nielsen (Sonnerup Eco-Advisors) and Berndt Gerhardson (SLU) also for information about EM and *Pseudomonas* and Birgit Jensen and Inge Knudsen (Department of Plant Biology, KVL) for help with application of *Gliocladium* and other supports. The authors also thank the staff of the Department of Agricultural Sciences, KVL for practical assistance in the experimental process.

[Haworth co-indexing entry note]: "Biological Control of Common Bunt (*Tilletia tritici*)." Borgen, Anders, and Mehrnaz Davanlou. Co-published simultaneously in *Journal of Crop Production* (Food Products Press, an imprint of The Haworth Press, Inc.) Vol. 3, No. 1 (#5), 2000, pp. 157-171; and: *Nature Farming and Microbial Applications* (ed: Hui-lian Xu, James F. Parr, and Hiroshi Umemura) Food Products Press, an imprint of The Haworth Press, Inc., 2000, pp. 157-171. Single or multiple copies of this article are available for a fee from The Haworth Document Delivery Service [1-800-342-9678, 9:00 a.m. - 5:00 p.m. (EST). E-mail address: getinfo@haworthpressinc.com].

KEYWORDS. Common bunt, compost, biocontrol, ecological agriculture, effective microorganisms, EM. seed treatment, stinking smut, *Tilletia caries*, *Tilletia tritici*

INTRODUCTION

Common bunt (*Tilletia tritici* syn. *T. caries*) is potentially one of the most devastating plant diseases. The fungus grows systemically in infected wheat plants (*Triticum aestivum*) and develops ovaries filled with fungal spores (bunt balls). During threshing, the bunt balls break and the spores attach to the healthy seeds during seed handling. When spore-contaminated seeds are sown, the spores germinate synchronously with the seeds and infect the germinating plants.

Simple nitrogen components like trimethylamine volatilize from the fungal spores (Ettel and Halbsguth, 1963), giving bunt-infested grain a smell like rotten fish. This is also the reason for the disease to be called stinking smut. Only a small number of infected heads in the field will reduce the quality of the wheat because of the stench of the bunt spores. Control of common bunt is therefore crucial for the production of quality wheat. In a Swedish experiment, 50% of the people could smell the presence of only 1000 spores per gram of seeds (Johnsson, 1991). This level can occur with a field frequency of less than 0.1% infected heads (Borgen et al., 1992). Ingestion of contaminated grain may also be hazardous to human health as it is for some animals (Westermann et al., 1988).

Common bunt is an ancient plant disease. Spores have been found on 4000 year old seeds from the ancient Mesopotamia (Johnsson, 1990), and it is likely that the disease has been a problem for wheat production ever since its domestication. Since then, the disease has been one of the most intensively treated in plant protection (Woolman and Humphrey, 1924; Buttress and Dennis, 1959; Sharvelle, 1979). Since cheap and effective seed treatments with organic mercury started in the 1920s, research in this disease has been limited. Mercury is now banned in most industrialized countries for environmental reasons, and modern synthetic pesticides have taken its place in the control of bunt.

The multiplication of bunt frequency from year to year, will, in untreated seeds, depends on the wheat variety and meteorological conditions especially during germination, but is often about 100-fold under Danish weather conditions in susceptible varieties (Borgen et al., 1992). In order to prevent multiplication of the bunt infections from year to year, the sum of all involved control measures must therefore have an efficiency of more than 99%. In conventional agriculture, this control level is exclusively reached by seed treatments, and at least in Denmark almost all seed lots of winter wheat are

seed treated with pesticides mainly because of this disease (Nielsen et al., 1998). In organic agriculture, seed treatments with synthetic pesticides are excluded. Common bunt is therefore potentially a very serious disease for wheat production in organic cropping systems (Piorr, 1991; Borgen et al., 1992).

Research on alternative control of common bunt is going on in Europe, mainly focussing on different seed treatments like uses of plant extracts, cereal flour, milk powder and other organic compounds, hot water and hot air treatments and antagonistic bacteria and fungi (Spiess and Dutschke, 1991; Becker and Weltzien, 1993; Heyden, 1993, 1997; Borgen et al., 1995; Knudsen et al., 1995; Bergman, 1996; Borgen and Kristensen, 1996; Gerhadson, 1997). In the tradition of research in organic agriculture, the use of compost and EM (Effective Microorganisms) have played a central role in plant protection, since these products simultaneously attempt to improve soil fertility and create a beneficial microbial soil flora, and thereby prevent development of some plant diseases (Tränkner, 1992, 1993; Sangakkara et al., 1999). Furthermore, one of the negative effects of seed treatments is often that seed vigor in terms of germination speed is reduced. Low doses of EM have been shown to improve germination speed (Sangakkara and Attanayake, 1993). Fast and even germination is essential for yield potential also in conventional agriculture, but in organic agriculture the influence is likely to be higher since it also influences the competition with weeds and some pests and pathogens which are not easily be regulated without pesticides.

Our current study investigated different biological methods for their potential to control common bunt in organic agriculture.

MATERIALS AND METHODS

Trials were conducted over three years to screen different biological material and products for their effect on bunt infection and for side effects on germination vigor.

In the first year (1994-1995) two field trials were conducted. Spore-contaminated seeds of winter wheat (*Triticum aestivum*, cultivar 'Kosack') were treated either with liquid manure in a dose of 30 ml/kg, or with 130 g milk powder per kg or with both. Seed treatments were done in a spinning-wheel seed-dresser (Hege no. 11). In the second experiment in year 1994-5, seeds were treated with 21.7 g/kg of the commercial product Mycostop containing *Streptomyces griseoviridis* stain K61 which contains 10^8 CFU/gram (Lahdenperä et al. 1991). Water (26 ml/kg) was used as carrier.

Field trials were conducted at Højbakkegård, an experimental farm of the Royal Veterinary and Agricultural University and located 18 km east of Copenhagen, Denmark (55°40′ N, 12°18′ E, 28 m above mean sea level).

The soil type is a moreanic sandy loam, and common bunt had not been recorded in the experimental area beforehand. Untreated seeds were sown in 8 replications, and seeds for each treatment were sown in four replications in 4 m × 5 m plots. Heads in the first and second row in each plot were diagnosed for bunt infection. An average of 2392 heads were diagnosed for each treatment.

In the second year (1996-7) a field trial was also conducted in which seeds of winter wheat (cultivar 'Pepital') were contaminated with spores of *T. tritici* at a dose of 5 g per kg resulting in a spore contamination of 1,975,000 spores per gram seed tested by the ISTA Haemocytometer Method (Kietreiber, 1984). Where nothing else is noted, seed samples of 100 g were treated after contamination in a spinning-wheel seed-dresser (Hege no. 11) with milk powder and the biological agents listed below.

A bacterial suspension containing 10^9 spores per ml of *Pseudomonas chlororaphidis* strain MA 342, was applied in 300 ml water per kg seed for two hours in a closed plastic bag and afterwards dried with cold air (Gerhadson, 1997). We compared this treatment with the application of lower doses of 150 ml/kg and 40 ml/kg of the same suspension applied in the seed dresser, the last dose both with and without 20 g milk powder per kg seed.

EM (Effective Microorganisms) is a commercial product containing 80 species of beneficial microorganisms, the major part being yeast and lactic acid bacteria. EM was applied in a dose of 40 and 150 ml/kg seed, and the lower dose was applied with and without 20 g milk powder per kg seed.

To see the effect of metabolites and growth media in the suspensions the doses of 150 ml/kg of both water, EM and the *Pseudomonas* suspension were also applied after the suspensions had been autoclaved for 20 minutes at 120°C at 0.2 MPa.

'Symbioplex' is a commercial product which according to the list of ingredients contains 5 × 10^8 spores per gram of each of the lactic acid bacteria *Lactobacillus acidophilus, Bifidobacterium bifidus* and *Streptococcus thermophillus.* This product was applied with and without 20 g milk powder per kg seed in a dose of 5 g + 20 ml water per kg seed (total 7.5 × 10^9 spores/kg).

One strain of *Trichoderma harzianum* in the commercial product Supresivit, containing 10^9 bacterial spores per g, was tested at a dose of 2 g/kg. The bacterial powder was added with 30 ml water/kg.

The isolate of *Gliocladium roseum* IK726 was applied in a lower dose of 2.5 × 10^9 CFU per kg seed, and a higher dose at 4.5 × 10^9 CFU per kg. Three ml of sterile water was in both cases used as carrier. The lower dose was applied with and without milk powder.

Two samples of compost were used. One type was composted garden waste which had been stored for more than one year; the other compost type

was from a fresh compost heap of cattle manure and straw. The temperature in the cattle compost heap was about 60°C at the time of collection, which was three days before seed treatment. Compost extracts were made by mixing the compost with water to give a thick paste (50% D.M.) which was filtered through a 0.5-mm sieve. The concentrations and composition of active microorganisms in the compost extracts were not measured.

Rumen juice was taken from a cow through a rumen fistula and was applied at a dose of 40 and 150 ml/kg to the seeds. The lower dose was applied with and without milk powder.

After treatment, seeds were dried in the open air at room temperature, and where more than 40 ml/kg liquid had been added, the treatment was divided into a series of treatments with each application of no more than 20 ml water. The seeds were then dried with the help of a cold air stream. After treatment, the seeds were stored at 5°C in paper bags. Samples removed for a field test which took place 2-6 days after seed treatment. Germination tests were conducted 1-3 months thereafter.

After sowing, 100 g of compost was put into each row of an untreated control, equivalent to 6 t/ha. The compost was placed by hand directly into the rows in close contact with the seeds in the rows.

Germination tests were conducted in plastic plates containing 1.5 kg sand with water (65 ml water/kg quartz sand). One hundred seeds were sown in each of three replicates at a depth of 1.5 cm and at a temperature of 10°C. Emerged plants were counted over 3 consecutive days.

Each treatment was sown in rows of 1.25 m with 10 replicates at Højbakkegård. In each treatment, an average of 1869 heads were diagnosed for bunt infection based on visible macro-symptoms after heading.

In 1998-1999 a container experiment was conducted using combinations of seed and soil treatments with EM. One ml EM was applied on 18 August 1998 to 30 cm × 40 cm boxes (= 83 liters/ha) containing 18 liters pre-fertilized peat soil (Pinstrup whole mixture no. 2). Application was repeated on 26 August. EM was diluted 1:500 with water before applications; another treatment received the same volume of water but no EM. On 21 September, seeds of the spring wheat cultivar 'Cadenza' contaminated with 951,000 spores per gram of seeds, were treated with EM, and two days later 16 seeds were sown in each of 20 boxes for each treatment. Seed treatment included concentrated fresh EM at a dose of 20 ml/kg and a water-diluted solution of 1:200 at the same dose. The boxes were placed in open air from 18 August when the first soil application was done until the end of November, when the boxes were brought into a greenhouse. Plants were then grown to the heading stage and were then diagnosed for bunt infection. The same germination test was conducted as in the field trial.

RESULTS AND DISCUSSION

Results from the field experiments are presented in Tables 1 and 2. In addition to the presented results in Table 2 the recommended dose of *Pseudomonas* MA 342 of 300 ml/kg gave a reduction in bunt infection of 96.2% and the autoclaved treatment 150 ml/kg a reduction of 58.1%. The autoclaved treatment of EM 150 ml/kg resulted in a reduction of 76.5%. All these effects were statistically significant ($p < 0.001$) when tested against untreated controls by a Generalized Linear Model (GENMOD-procedure in SAS ver. 6.12.), as was a decrease in germination vigour for the seed treatments when tested by the Generalized Linear Mixed Model (GLIMMIX procedure in the software SAS ver. 6.12).

Results from the container experiments are presented in Table 3. Seed treatments resulted in a minor, but non-significant decrease in germination speed.

The principles of organic agriculture are driven by an attempt to promote beneficial life forms, rather than directly to kill damaging ones. Killing organisms always creates a biological vacuum, which may be the basis for migration of other possibly damaging organisms. The killing of pathogens also often includes killing of beneficial organisms which may help in protecting the plants from pathogens (Neergaard, 1977). Hence, the fundamental principles of ecological disease control is to optimize growth conditions for the plants rather than to kill the pathogens. This principle includes adequate crop rotation, resistant varieties, mixed cropping, balanced plant nutrition and the aerobic composting of manure (IFOAM, 1998). However, these principles only have a limited potential in the control of common bunt.

Being a seed-borne disease, crop rotation only has a very limited effect

TABLE 1. Results from two field trials with treatments of biologically based products in control of common bunt (*Tilletia tritici*). Treatments statistically tested against untreated control. Bunt frequency in the control was 53.2% for the first five treatments, and 35.2% for the last treatment.

Treatment	Dose	Reduction of bunted heads (%)
Control	0	0
Milk powder	130 g/kg	95.8 ***
Milk powder + Liquid manure	130 g/kg + 30 ml/kg	94.5 ***
H_2O	30 ml/kg	13.1 *
Diluted liquid manure	15 + 15 ml/kg	13.4 *
Liquid manure	30 ml/kg	÷2.3 (n.s.)
Streptomyces griseoviridis + H_2O	2.2×10^9 CFU/kg + 30 ml/kg	45.7 ***

*, ** and *** mean significance at P = 0.05, P = 0.001 and P = 0.001, respectively

TABLE 2. Control of common bunt with biological agents in combination with a low dose of milk powder. The doses (low and high) are not based on previous trials or recommendations for this disease, and the effectiveness and potentials of the products are therefore not comparable. Treatments statistically tested against untreated control. Bunt frequency in the control was 27.4%. Regression lines for logarithmically-transformed data for the germination curve is tested against untreated control by a Generalized Linear Mixed Model.

		Low dose (1)	higher dose (2)	Low dose(*) +2% milkpowder
Control + H_2O	Reduction of bunted heads	0%	9.6% n.s.	÷42% (3)
	Mean Germination Time, days	9.08	8.81 n.s.	
Uncontaminated seeds	Reduction of bunted heads	97.4% ***		
	Mean Germination Time, days	8.85 n.s.		
Compost in field	Reduction of bunted heads	÷61.1% ***		
Pseudomonas MA342	Reduction of bunted heads	63.7% ***	87.6% ***	97.2% ***
	Mean Germination Time, days	9.19 n.s.	9.68 **	9.16 n.s.
Thricoderma harzianum	Reduction of bunted heads	0.4% n.s.		
	Mean Germination Time, days	8.70 n.s.		
Gliocladium roseum	Reduction of bunted heads	14.7% n.s.	45.9% **	86.6% ***
	Mean Germination Time, days	8.50*	8.68 n.s.	8.77 n.s.
Lactic acid bacteria	Reduction of bunted heads	3.0% n.s.		59.3% ***
	Mean Germination Time, days	9.05 n.s.		9.02 n.s.
EM	Reduction of bunted heads	0.9% n.s.	87.6% ****	72.8% ***
	Mean Germination Time, days	9.11 n.s.	9.83 ***	9.35 n.s.
Garden compost	Reduction of bunted heads	8.6% n.s.	10.3% n.s.	64.7% ***
	Mean Germination Time, days	8.73 n.s.	8.93 n.s.	9.03 n.s.
Thermo compost	Reduction of bunted heads	0.1% n.s.	40.8% ***	45.3% ***
	Mean Germination Time, days	9.04 n.s.	9.09 n.s.	9.13 n.s.
Rumen juice	Reduction of bunted heads	3.9% n.s.	76.3% ***	47.0% ***
	Mean Germination Time, days	9.01 n.s.	9.13 n.s.	9.16 n.s.

(1) low dose is for *Gliocladium roseum* = 2.5×10^9 CFU/kg, for Symbioplex = 7.5×10^9 spores/kg, for *Thricoderma harzianum* 2×10^9 spores/kg and for *Pseudomonas* MA342 40×10^9 spores/kg. For the rest of the treatments the microbial content was not estimated and they were dosed by 40 ml/kg seeds except for the control, where nothing was applied.
(2) High dose is for *Gliocladium roseum* = 4.5×10^9, CFU/kg, for *Pseudomonas* MA342 150×10^9 spores/kg. For the rest of the treatments 150 ml/kg seeds.
(3) Result for milk powder and water are extrapolated from a logistic dose-response curve. 1% milk powder application reduced the bunt infection by 12.2% (n.s.) and 3% applied reduced attack by 74.1% (***) (Borgen and Kristensen, unpublished).
*, ** and *** mean significance at P = 0.05, P = 0.001 and P = 0.001, respectively

against common bunt. Spores can survive in the soil for an extended period of time and infect wheat later in a rotation (Johnsson, 1990; Borgen and Kristensen, 1997). Crop rotation is therefore important to prevent uninfected crops from being infected, but it has no influence in preventing the multiplication of the disease from year to year in an already infected seed lot. Being a systemic disease, plant nutrition has a very limited effect on the disease once

TABLE 3. Semi field trial with control of common bunt with EM as seed treatment and as soil amendment. Bunt infection in the untreated control was 67.7%. Seed treatment caused minor statistical insignificant reductions in germination speed. Treatments statistically tested against untreated control.

	Reduction of bunted heads (%)
Control	0
1 × soil treatment (83 l/ha)	5.0 n.s.
2 × soil treatment (2 × 83 l/ha)	−10.2 n.s. (P = 0.08)
2 soil treatment +	
Seed treatment (2% diluted EM 1:200)	8.6 n.s.
Seed treatment (2% diluted EM 1:200)	−1.4 n.s.
2 × soil treatment +	
Seed treatment (2% concentrated EM)	42.4 ***
Seed treatment (2% concentrated EM)	49.8 ***

*, ** and *** mean significance at P = 0.05, P = 0.001 and P = 0.001, respectively

the plant is infected. Breeding for resistant varieties has a potential, but for the time being, the variety, 'Stava', is the only variety available in Denmark known to be fully resistant, and this variety is not optimal for Danish meteorological conditions. In many regions of the world the situation is the same. Wheat grown for baking purpose also sets strong limitations for the choice of varieties and the possibilities for crop mixing.

The use of biological control of pathogens in organic agriculture implies a dilemma. On the one hand it is a pesticide-free control measure that promotes beneficial life-forms rather than actively kills pathogens. On the other hand there may be problems connected to the use of some biological control measures parallel to problems related with pesticides. In organic agriculture, e.g., plants juices can be used in plant protection, but single chemical compounds isolated from plants or copies hereof are unwanted because they are not used in the concentration and in a chemical and organic environment where they naturally occur. In the same way the use of a single or a very limited number of microorganisms may disturb the existing balance in the soil flora, and the use of non-indigenous species not already present in the local soil is certainly questionable in organic agriculture. If a biological agent is cheap, easy and effective against a specific problem, the use of this agent has the same problem as synthetic pesticides; it removes the problem, but does not resolve the cause of the problem. If problems are treated rather than prevented, they are likely to show up in another form. If, for example, a problem with a disease related to mono-cropping is removed by a treatment, other problems related to the mono-cropping system will remain. In the case of common bunt, the mono-cropping system has been still more intensive with narrower crop rotations and less focus on resistance in the period where pesticide seed treatment has been used. Now, where the sustainability of the pesticides are in question, we are 70 years behind in development of sustainable control methods against this disease. With a few exceptions, the use of specific microorganisms in biocontrol of pathogens is therefore excluded in the standards of the Danish Organic Farmers Association (LØJ, 1999) and many other organic standards, although the international minimum standards which apply in Denmark are open for the possibility (IFOAM, 1998; EU, 1991). The claim for a specific biological control agent to be included in the organic standards is being discussed among organic farmers in Denmark and in IFOAM. Beside the existing risk assessment from the authorities the discussion centres around the following principles

- the problem to be treated is significant for the production,
- the use of biocontrol is necessary in control, meaning that the problem can not be prevented with known methods or be substituted by less critical methods,
- the microorganisms are naturally-occurring in the local soil already in the actual form. Any use of genetically manipulated organisms are excluded,
- the microorganisms are non-toxic for higher organisms including the farmer, and
- the use will not irreversibly change the balance of the soil microflora.

Even seed treatment is not an optimal way to control plant diseases according to the principles of organic agriculture, it may be necessary until more resistant varieties have been bred and marketed. Our current study shows that seed treatments with biological agents may have a potential against this pathogen in organic agriculture.

The frequency of infections by common bunt are affected by some of the treatments presented in this study, others not. The most promising results are obtained by a combination of milk powder and some of the specific microorganisms, of which *Pseudomonas* strain MA342 gave almost full control without significant reduction of germination vigour. *Pseudomonas* MA 342 alone had a significant effect on bunt even at the low dose of 40 × 10^9 spores/kg, and the effect was improved considerably in combination with milk powder and came out with a result better than the recommended high dose of 300 ml/kg (300 × 10^9 spores/kg) and without significant negative effect on germination vigor.

Pseudomonas MA 342 has been shown in previous studies to control bunt fully at the full dose (300 ml/kg) and with 92.3-98.0% in half dose (Gerhadson, 1997). Considering the small amount of bunt infection in the uncontaminated control plots in 1997 which indicates a minor background infection from soil or machinery, the result confirms previous studies. For commercial purposes the formulation used in this study is now exchanged in favor of an oily suspension using only about 6 ml/kg. This product is sold in many European countries as "Cedomon." However, this product is not approved for winter cereals today (1999), since problems with germination vigor are observed with this formulation. This study indicates that a combination of *Pseudomonas* MA 342 with milk powder may lead to a solution of the problems with germination vigor in the product. *Pseudomonas* MA 342 was isolated from cereal roots in a Swedish soil and has been found in many other European soils as well (Gerhadson, personal communication).

Gliocladium roseum isolate IK726 reduced the bunt frequency in the higher dose of 4.5×10^9 CFU per kg, but did not significantly do so at the lower dose. In neither doses were negative side effects on germination observed. This indicates that the dose could be increased further and thereby improve the product efficacy. This experiment can therefore not exclude the potential of this isolate of *Gliocladium roseum* as a control agent against common bunt, and further experiments are planned to evaluate this. The current strian of *Gliocladium roseum* IK726 was isolated from barley roots in a Danish field soil (Knudsen et al., 1995).

Streptomyces griseoviridis strain K61 in the product Mycostop reduced the bunt frequency at the dose of 2.2×10^9 CFU/kg tested, but this was inadequate to give full control. There might therefore be a potential for this product, but further studies with higher doses or combinations with other treatments are needed to determine the full potential.

Trichoderma harzianum in the product Supresivit did not show any effect on bunt frequency or germination vigour. The dose of 2×10^9 spores/kg may be too low for the purpose. Further studies with higher doses or combinations with other treatments are needed to determine whether this product has a potential as seed treatment in control of common bunt.

EM1 reduced the frequency of common bunt, but only in concentrations where germination vigour was also reduced. The effect of the product can therefore not be improved by increasing the dose. The product has a low pH, about 3.5 and contains various other metabolites from the microbial activity. The treatment with the high dose of fresh EM only gave an insignificant improvement in effect as compared with autoclaved EM. Lactic acid bacteria are the major group of organisms in EM. The results with Symbioplex containing only lactic acid bacteria shows that this group of bacteria has no effect on bunt infection at least in the concentration of 7.5×10^9 spores/kg used here. This indicates that the major effect of EM as seed treatment in this study is not biological, but probably chemical.

The container experiment with EM basically confirms the results from the field experiment that common bunt cannot be fully controlled by EM used as a seed treatment, even it has a reducing effect when used in concentrated form. Seed treatment with diluted EM seemed to have no influence on bunt frequency or on germination speed. In this study it increased mean germination time, but this effect was not statistically significant. In previous studies on the effect of diluted EM on germination, EM has been applied to the water used in the germination test. In this study it has been used as an application to the seed, and fresh water is applied in the germination test. The dose applied in this study is therefore not comparable with previous studies on the effect of EM on germination of seeds which may explain the contradictory results reported earlier (Sinqueira et al., 1993; Sangakkara and Attanayake, 1993). The use of EM as a soil inoculant seems to have no influence on bunt infection of the seedlings. The microorganisms in the EM product are formulated in Japan, and information on the occurrence of the same strains of organisms in other regions is limited, which makes the use questionable in organic agriculture elsewhere. In Denmark the Demeter Association has decided to ban the use in biodynamic agriculture, while the Organic Farmers Association are still discussing the issue.

Milk powder can reduce infection of common bunt, but full control is often related to problems with field emergence (Winter et al., 1997; Borgen et al., 1995; Becker and Weltzien, 1993; Tränkner, 1993). Tränkner (1993) concluded that even the effectiveness of the milk powder in control of the disease could be improved by mixing with compost extracts as shown by Becker and Weltzien (1993), the effect is limited and could be better obtained by an increase of the amount of milk powder. This conclusion is generally confirmed by this study. Compost and rumen juice used as seed treatment had a very limited effect on bunt infection. Microorganisms growing in the fresh compost at 60°C must be thermofillic. Soil temperature under Danish conditions at the start of October is about 5-10°C, and the bacteria in the fresh compost may therefore not be well-adapted to this environment. The same can be expected for the rumen juice, where the microorganisms are mainly obligate and facultatively anaerobic and selected for growth at 39°C in the cow rumen (Van Soest, 1982). The well-composted garden waste had no effect when used alone, but had a tendency to improve the effect of the milk powder. A higher concentration of organisms in this treatment may have improved the effect.

Liquid manure has been used for centuries in Europe as a seed treatment against common bunt (Buttress and Dennis, 1959). Also modern research has included treatments with liquid manure (Borgen et al., 1995; Heyden, 1993), but in these trials seeds were washed in liquid manure. The effect of the treatments were therefore a combination of the washing and the biological/chemical effect of the liquid manure. In the current experiment the seeds were not been dipped in the liquid, but only added as a surface amendment.

This treatment seems to have no effect on bunt infection which indicates that the effect shown in previous experiments is mainly a washing effect.

The application of compost to the soil significantly increased the infection of common bunt. This confirms previous field trials by Rabien (1928), even if it could not be confirmed in greenhouse experiments by Voss (1938). Rabien explained the effect of compost by the fact that oxygen in the seed-surface environment is a liming factor for the infection of bunt, and compost increases the air volume in the soil compared with normal mineral field soil. Even application of compost to the soil has many beneficial effects on plant production, including the increasing effect of air volume, it may therefore have a negative side effect on bunt infection in cases where seeds or soil are contaminated with bunt spores. In the current experiment the compost was deliberately put into the row close to the seeds, while in normal farming practice the physical distance between seeds and compost is likely to be greater. On the other hand, 6 t compost per hectare as used in this experiment is relatively low compared with the manuring practice for cereals on many organic farms. Whether the normal use of compost will have practical implications for bunt infection can not be decided by this experiment.

Among the well characterized products in this screening test, *Pseudomonas* MA 342 is the only product previously tested against common bunt. The high effect of this product compared with the others must be seen in relation to the 10-20 fold higher number of organisms applied to the seeds in the treatments. The doses chosen to test the effect of the other treatments are therefore not qualified, but must be characterized as preliminary screenings. "No effect" for a product does not necessarily mean "no potential effect," but may indicate that the dose tested was too low for the control of this pathogen. Evaluation of the products at this stage must therefore be viewed in combination with the side-effects on seed germination and vigor.

CONCLUSION

In organic agriculture infection by plant pathogens should if possible be prevented by general means to improve growth conditions for the plants. In the case of common bunt (*Tilletia tritici*) these general means are at the present stage inadequate to control the disease, and other control measures are therefore necessary. The current study shows that the selected general substances with high concentration of microorganisms like liquid manure, compost extracts, rumen juice and EM (Effective Microorganisms) have a limited potential in the control of common bunt. The application of compost to the soil even increases the infection of common bunt. Some selected microorganisms used for biological control of other seed pathogens seem to have a potential also in the control of common bunt. *Pseudomonas* MA 342 can give full control of common bunt in combination with milk powder with no negative effect on germination vigor of the seeds, while further studies on *Trichoderma harzianum, Streptomyces griseoviridis* and *Gliocladium roseum* are needed to evaluate the potential of these fungi. Combinations of active biological agents with milk powder indicates that this combination can improve the potential of the biological treatments, i.e., in cases where physical limitations hinders the application of the dose needed to obtain adequate control of the pathogen.

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