Cereal Seed Health and Seed Treatment Strategies: Exploiting new seed testing technology to optimise seed health decisions for wheat.

Technical Paper No. 6

Quantifying the risk of spread of bunt (*Tilletia tritici*).

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INTRODUCTION

The experiments described focus on the risk posed by windblown bunt spores to neighbouring crops, as this risk is of substantial concern to the industry. The risk was quantified experimentally in two ways:

a) A large-scale field experiment, in which spore dispersal was measured over long distances and the risk to following crops determined. With the objective to determine the likely spread of bunt from an infected crop of wheat to adjacent fields during harvesting and to determine the risk such spread would pose to crops subsequently drilled into infested soil resulting from the drift of bunt spores; and

b) Wheat grown in soil inoculated with various levels of bunt spores to quantify the relationship between inoculum in the soil and resulting plant infection.

METHOD

Large-scale field experiment to determine bunt spread

A single large plot (c. 20m x 5m) of bunt-contaminated seed cv. Consort was sown in late October 1999. This was located in a large field at the southern end of the ADAS Boxworth farm (prevailing wind direction South-South west). Adjacent fields down-wind of this field are not separated by hedges or other obstructions.

<u>Spore trapping during harvesting 2000</u>

Flat sticky spore traps were used to measure the dispersal of spores from the infected plot during harvesting. The plot was combined with a commercial plot combine with straw chopper. Spore traps consisted of glass laboratory slides attached to plastic stakes and positioned horizontally 1-2 cm above the ground. The upper surfaces of the slides were covered in double sided sticky tape. Slides were be positioned downwind of the source plot in a narrow radial pattern (c. 30 degrees angle from centre of source plot). Traps were positioned downwind at distances of 1m, 2m, 4m, 8m, 16m, 64m, 256m, and 1024m from the plot (Table 1).

Table 1 Number of spore traps at each position from source plot.

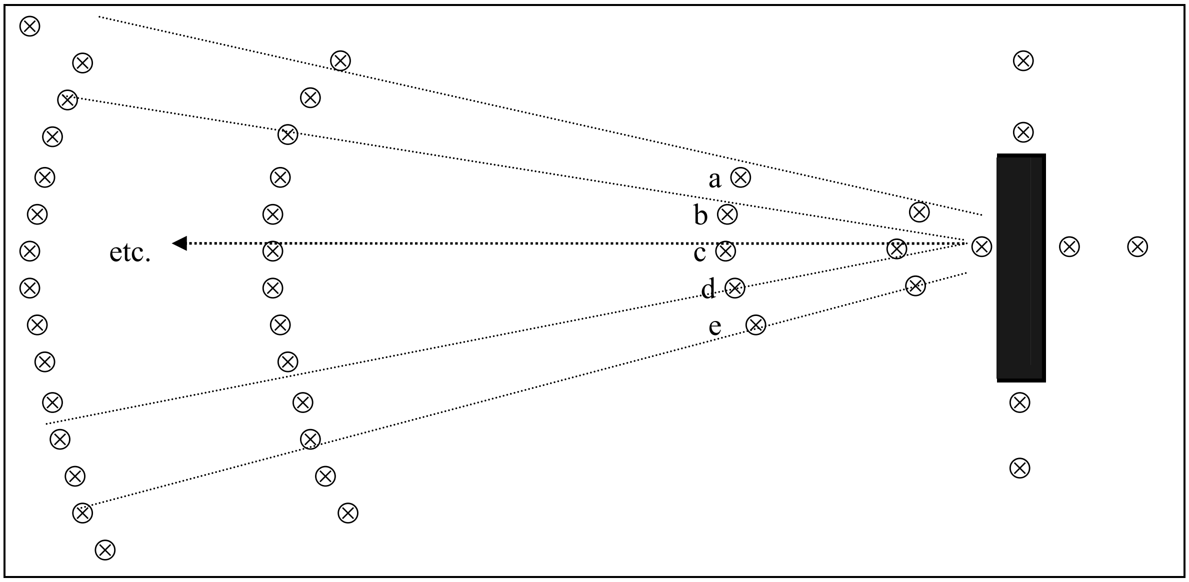
Distance from source plot (m)	1	2	4	8	16	64	256	1024
Number of spore traps in arc	5	5	10	10	50	50	100	100

Additional traps were positioned at 1m and 4m from the edge of the plot on the remaining 3 sides of the plot (see Figure 1). Slides were labelled with their distance from the edge of the source plot and their relative position in the arc of traps.

Spores from the infected plot which were blown downwind at harvest were caught in the spore traps. The concentration of spore deposition on the spore traps was measured by counting spores on the slides. In high density traps a proportion of the slide was counted. In low density slides the entire slide was scanned and all spores counted.

<u>Trap crops sown after harvest 2000</u>

The day after harvesting the bunt-infested plot, 'trap' crops of untreated wheat seed cv. Consort were sown at a range of distances from the original plot. These were at distances of 1m (adjacent to original plot), 2m, 4m, 8m, 16m, 64m, 256m, and 1024m (8 plots in total). The harvesting of the infested plot was delayed until all of the crops in the surrounding area had been harvested, cultivated and seed bed prepared. Trap crop plots were 20m x 5m. These plots were sampled at the milky ripe / early dough stage (pre-harvest 2001) to determine the level of bunt infection (% ears infected). Plots were sampled by removing 5 x 1m lengths of row, removing samples to the lab and rubbing out ears. The total number of ears and the number of infected ears were recorded. Plots were harvested in a strict order, with the most distant plots harvested first to minimise cross contamination between plots. A healthy wheat plot was also harvested between each trap plot, to clean the combine. A sample of the seed combined from the trap plots (2 kg per plot) was collected and tested for bunt contamination by the Official Seed Testing Station for Scotland, SASA.



Position of spore trap: ⊗

Figure 1 Position of spore traps in relation to bunt infected wheat plot on day of harvest 2000

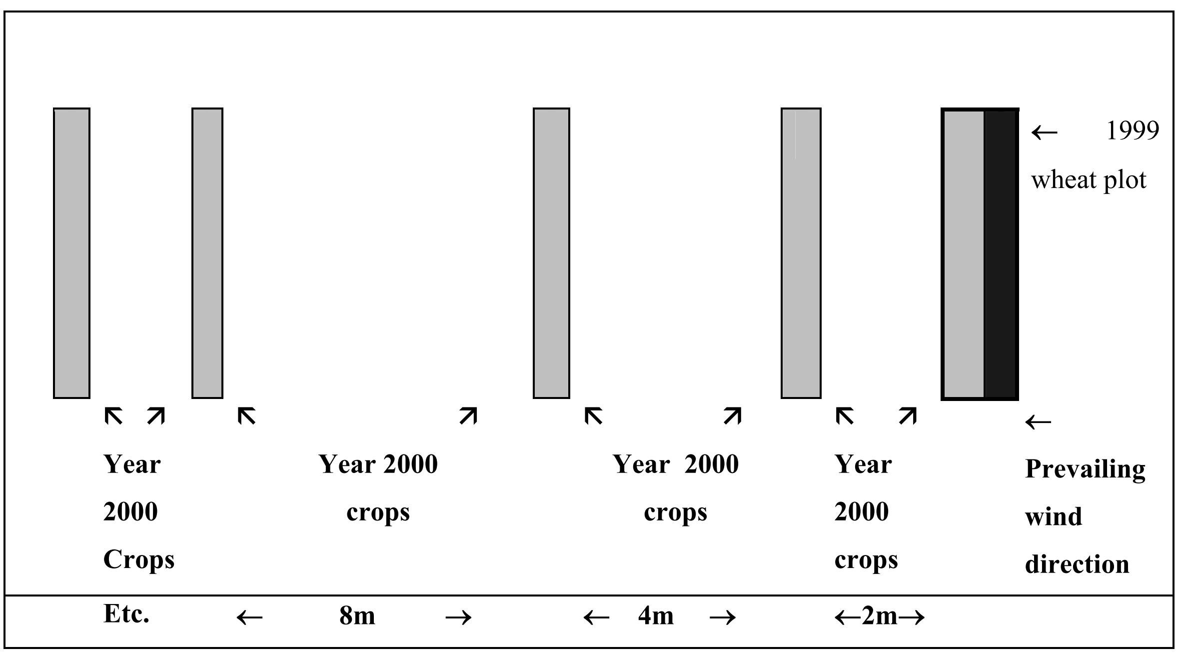


Figure 2 2000/2001 cropping plan, position of trap-crops sown following harvest 2000.

Soil inoculation experiments

In October 1999, plots, $5m^2$ in size were inoculated with bunt spores at a range of concentrations from 0.00005 g/m^2 to 1.0 g/m^2. Bunt spores were mixed with 100g fine sand per m^2 and incorporated by raking to a depth of 3-4 cm. Wheat seed cv. Consort was then sown immediately into plots at a depth of 3-4 cm.

Table 2 Soil inoculation rates

Treatment	1	2	3	4	5	6	7
Bunt spores g/m^2	1.0	0.5	.0.05	0.005	0.0005	0.00005	Nil

Sampling procedure

When the crop was beyond GS75, up to the soft dough stage (GS85), four samples per plot were removed, each sample comprising 5 x 1m lengths of row, selected at random from within the plot. Each ear was broken open to determine the percentage of ears affected by bunt. Occasionally partial ears are affected by bunt. For the purposes of assessment, whole and partial ears affected were assessed as infected ears.

RESULTS

Large-scale field experiment to determine bunt spread

The results showed a steep gradient of deposition of bunt spores from the infected source. Results from spore counts on the spore traps indicated that the majority of spores fell within the first 10m from the inoculum source (Figure 3). However, spores and, more particularly, crop debris carrying spores of the fungus were trapped up to 1000 metres downwind. Bunt spores are therefore capable of long distance spread during the harvesting of infected crops. These spores can survive in soil and are capable of infecting newly-sown crops.

No visual symptoms of bunt were detected in the trap crops prior to harvest but bunt spores were detected on harvested grain. Results are shown in Table 3. Clearly bunt spores spread by wind can infect recently sown wheat, but infection levels are small compared with seed-borne infection.

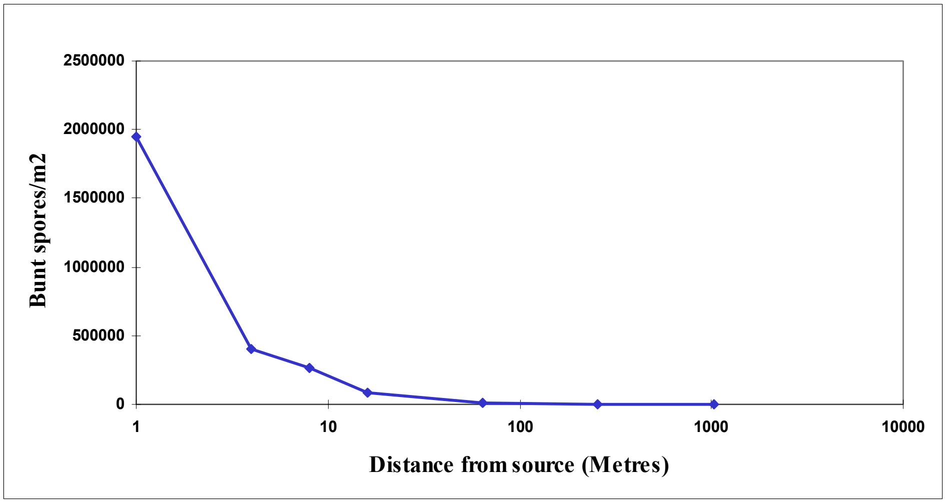


Figure 3 The spread of bunt spores from an infected source at harvest.

Table 3 Concentration of spores trapped downwind of an infected source plot during harvesting. ADAS Boxworth 2000.

Metres from source	Spores/m^2 trapped
1	1952820
4	401984
8	262888
16	86404
64	15189
256	493
1024	473

Table 4 Levels of bunt spores on harvested grain from trap plots downwind of an infected source plot during harvesting. ADAS Boxworth 2000.

Metres from source	Bunt contamination in harvested grain (Spores/seed)
1	1.66
2	0.99
4	28.67
8	1.2
64	0.51
256	1.28
1024	0.68

Soil inoculation experiments

Field infection levels up to 20% ears infected were found. There was a good correlation between the spore loading in the soil and the field infection levels. Figure 4 shows the relationship between soil contamination levels and the resulting ear infection levels. Work by NIAB estimated the average number of bunt spores per gram to be 300 million. Thus, the soil contamination figures shown in Figure 4 can be converted to spores/m^2 and so related to the spore deposition measurements carried out in the long-distance spread experiment. From this experiment, soil contamination with bunt spores at a concentration of less than 1.5 million/m^2 resulted in less than 1% ear infection (Table 5). This was in the worst-case scenario of drilling immediately following spore deposition on soil.

Table 5 Field expression of bunt in relation to soil contamination levels

Contamination rate (bunt spores/m^2)	Field expression (% ears infected)
15000	0.82
150000	0.85
1500000	0.47
15000000	3.59
150000000	12.96
300000000	13.98

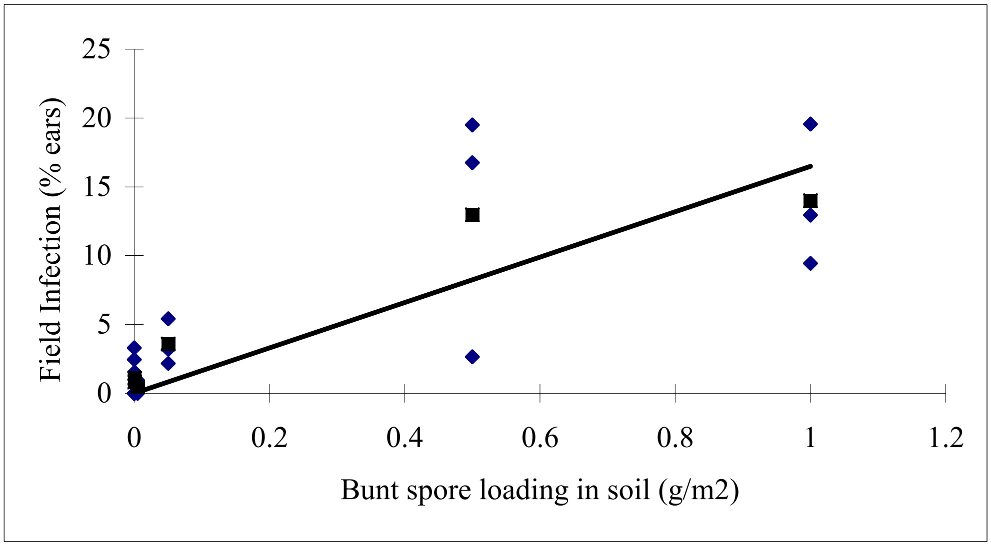


Figure 4 Relationship between soil infestation and resulting field infection levels. Each replicate result is shown (♦) and the mean of three replicates (■).

DISCUSSION

A field experiment has shown that bunt has the potential to spread via wind blown spores, travelling more than 1000 metres from an infected source during combining. Spore traps beyond 64m trapped less than 100,000 spores/m^2. Accepting that the spore traps only trap a proportion of the spores arriving, it seems likely that there is a potential risk to adjacent fields if bunt-infested crops are harvested up-wind of them. However, the deposition gradient is very steep and only crops immediately adjacent to infected crops are likely to be at risk. Mathematical modelling (Anthony & Paveley, 2004) using the results from this data and information on infection rates has suggested that the risk of these spores infecting seedlings from crops sown from healthy seed is very small.

To put this risk to adjacent crops in context there are 3 issues to be addressed:

i) The worst-case scenario of spore loading on seed sown as a 'commercial' crop.

ii) The risk that a wheat crop will be sown close to the date of harvesting of an adjacent infected wheat crop.

iii) The likelihood that the soil will remain dry between the spores arriving on the field and the field being sown with the next crop. (Bunt spores germinate in response to moisture and if no susceptible crop is present then the spores will die).

Firstly, in the spread experiment, the experiment was conducted using very heavily contaminated wheat seed, with 16 million spores per seed. The maximum infection level recorded in the 1992-94 seed-borne disease surveys (Cockerell & Rennie, 1996) was 121 spores per seed. In those surveys over 90% of samples were contaminated at less than 1 spore per seed. We may deduce from those surveys that the risk to adjacent crops from crops grown from seed with <1 spore per seed is likely to be negligible.

Data from the Nitrate Sensitive Areas Scheme (ADAS, 1996/97) was examined to see the temporal proximity of subsequent wheat crops. This is shown in Figure 6. There was some overlap between harvesting the 1996 crop and sowing the 1997 crop and there are a significant number of fields which are sown within 10 days of another crop being harvested. However, these crops may not necessarily be in close physical proximity.

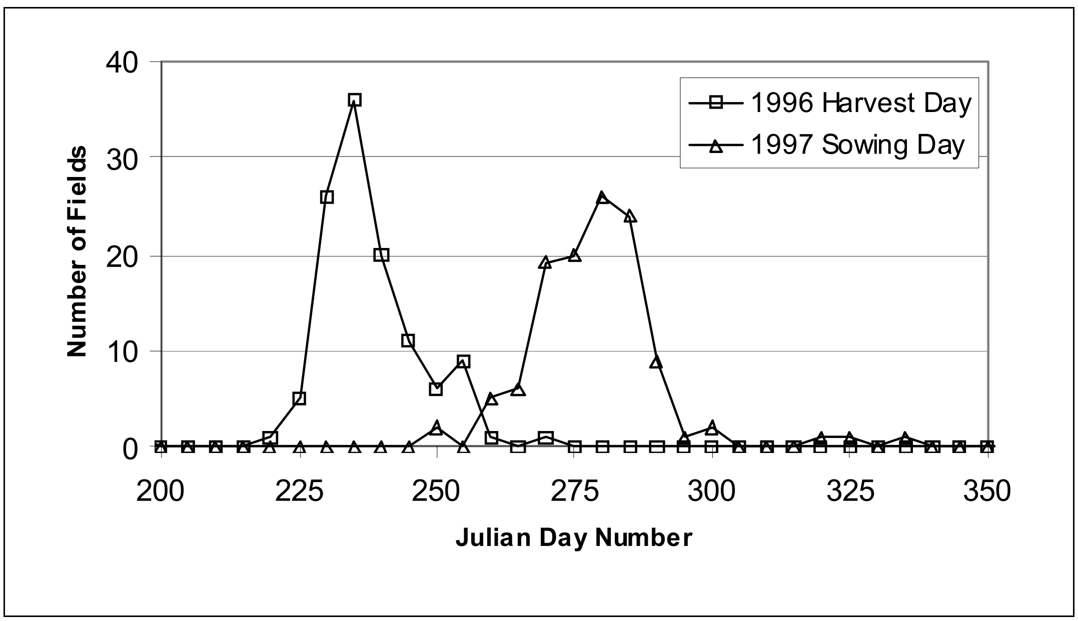


Figure 6 Temporal proximity of harvesting and sowing of wheat crops 1996-1997.

Thirdly, the likelihood that the soil will remain dry between the spores arriving on the field and the field being sown with the next crop was investigated for a typical East Anglian site (Coltishall). The statistical distribution of time delays between potential harvest days and the first occurrence of rainfall is shown in Figure X. Even for East Anglia there is a 100% probability that at least 1mm rain will fall if there is a 30 day delay between harvest and sowing. This probability is only reduced to 90% if the rainfall criteria is raised to 5mm.

Assuming a typical harvest date of early August and a typical sowing date of early October there is close to a 90% probability that at least 10mm rain will fall between harvest and sowing. This would normally be assumed to be sufficient to stimulate the germination of any free bunt spores in the top few centimetres of soil.

These three factors all tend to mitigate against the likelihood of an infected crop spreading spores to adjacent crops and causing high levels of crop infection. Although the spread of spores has been clearly demonstrated, the typical concentration of spores landing on adjacent fields is likely to be small. Adjacent harvesting and sowing of wheat crops are unlikely to be temporally close and rainfall between harvest and sowing is likely to markedly reduce the survival of any free bunt spores which may be present in soil.

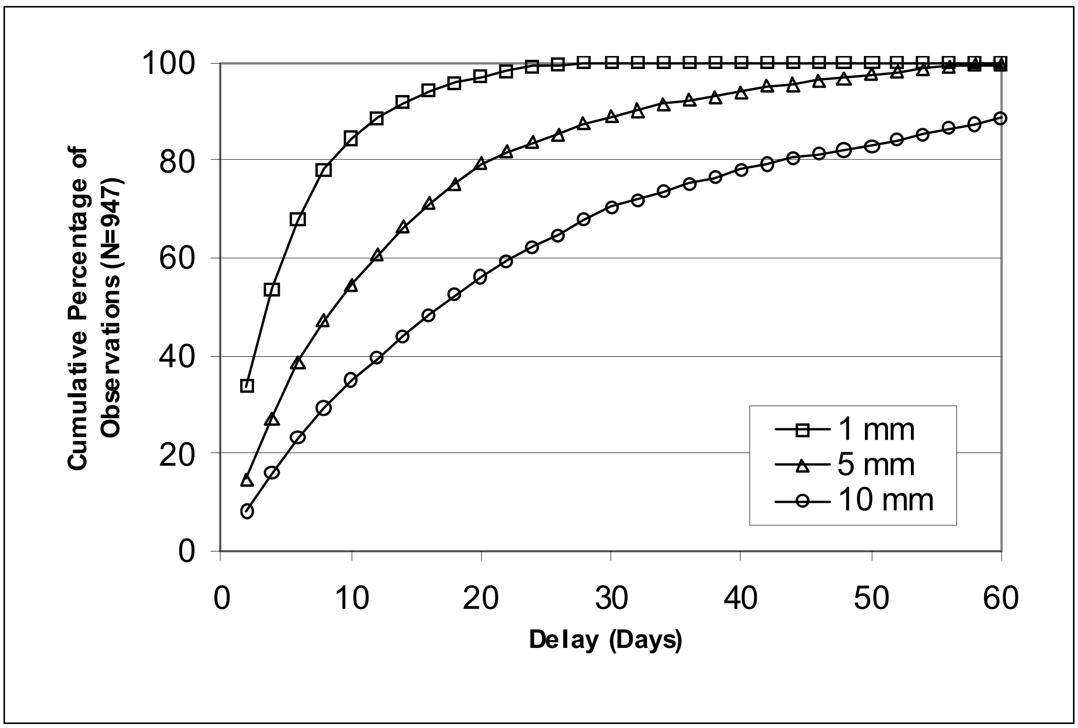


Figure 6 Statistical distribution of observed time delays between potential harvest days and first occurrence of daily rainfall of at least 1, 5 and 10 mm, at Coltishall, Norfolk (1975-95).

ACKNOWLEDGEMENTS

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