Report for Rothamsted Research Ltd

Winter wheat:

The DEFRA Wheat Genetics Improvement Network (WGIN) take-all trials 2004 - 2006

(DEFRA No. AR0709)

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SUMMARY

A study was conducted to compare the performance of six UK winter wheat cultivars in first and second wheat situations, primarily to test for cultivar by rotational position interaction and to investigate possible causes. Cultivars were selected on their yield performance when grown as a second wheat, based on the data provided by the annual Recommended List trials; three cultivars were considered to have performed well and three had performed poorly.

The relative performance of varieties in contrasting rotational positions was characterised in the field with the use of artificial inoculum and by 'phasing-in' previous cropping (2005-06 only), using highly replicated trial designs. The experiments removed the confounding of rotational position and site which interferes with the interpretation of second wheat performance in RL trials. Experiments were carried out over a two year cropping period (2004-05 and 2005-06) at two sites which differed in soil type and disease pressure. Treatments included natural infection in a first and second wheat situation and artificial inoculation with *Gaeumannomyces graminis* var. *tritici* (*Ggt)* within a first wheat situation. Development of the take-all epidemic was monitored by means of sequential sampling in discard plots of susceptible cv. Equinox. Take-all was assessed in all plots during grain filling or post-harvest. All plots were taken to yield and samples were retained for grain quality determination.

The relative performance of varieties was broadly consistent across the two contrasting experimental sites, despite differences in disease pressure, and significant cultivar by rotational position interactions for yield were found at both sites. Cordiale showed lower levels of take-all than the other varieties, consistently across experiments, although the differences were usually not significant. Differences in yield loss between varieties within each experiment were greater than differences in disease severity, suggesting that second wheat performance differences are due more to tolerance/intolerance (yield loss per unit disease severity) than resistance. At any given level of take-all severity, yield losses were greater in phased second wheat plots than in *Ggt* inoculated first wheat plots. The last of these findings was not explained by differences in cereal cyst nematode burden or eyespot severity, both of which were at negligible levels in all trials. Possible mechanisms to explain the effects seen include differences in (i) crop nutrition, (ii) absolute healthy root number, affecting below-ground resource capture, or iii) the temporal or spatial distribution of the inoculated and natural (2nd wheat) take-all epidemics. Fertile shoot/ear numbers (which are sensitive to nitrogen uptake), total root counts and the disease progress curves did not differ sufficiently between treatments to support nutrition, healthy root number or epidemic timing differences as plausible explanations. A more likely hypothesis for the greater yield loss per unit disease in second wheat plots is that primary infection lesions arising from artificial inoculation, and the secondary infections arising from them, were largely confined to the sampled upper roots. Whereas lesions arising from natural inoculum in the second wheats may also have resulted in lesions on roots below those sampled.

Candidate tolerance traits could be studied using mapping populations derived from crosses between the varieties which contrasted most strongly for second wheat performance at a given level of first wheat performance; most obviously Robigus X Cordiale or Napier. Genetic control of the possible quantitative resistance or escape of Cordiale could be studied further by crossing with Equinox or Istabraq. However, although Cordiale showed consistently lower severity than the other varieties tested, the lack of statistical significance suggests that field phenotyping would need to be highly replicated and conducted over many sites and seasons to obtain reliable data.

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INTRODUCTION

The proposal for work addressing 'Second Wheat Syndrome' arose from priorities determined from the WGIN 'Traits Workshop' on 10 June 2004, discussions at the WGIN Management Committee meeting on 6 July 2004 and a working group meeting on 19 July 2004.

Second and subsequent wheat crops receive at least the same level of nutrient, pesticide and energy inputs as first wheat crops, but yield around 1.0 t ha-1 less (RL trials). Hence, resource use efficiency is poor.

There is evidence for variation in performance as second wheats in modern adapted UK germplasm. RL trials (Anon. 2006) suggest an interaction between wheat variety and rotational position, with certain varieties performing relatively poorly or relatively well in second wheat as compared with first wheat situations. However, RL trials confound rotational position with site, leading to uncertainty about whether the interactions seen are related to rotational position or differences in 'attainable yield' between sites (Sue Welham, Rothamsted, pers. comm.). Work by NIAB and ADAS using silthiofam seed treatment to selectively control take-all also found some evidence for variety effects (Spink et al., 1998; Bayles et al., 2002). Earlier HGCA funded work carried out by the University of Nottingham and ADAS to find variety 'horses for courses' coincided with a run of sites/seasons when yield effects of take-all were atypically small. Again, there were indications of interactions, but these were not conclusive (Foulkes et al., 1998). However, a small number of varieties have been identified repeatedly by these different research approaches (and by grower experience) as contrasting in their performance as second wheats. The cause of this variation is not known. Hence, lack of understanding is hindering genetic improvement.

The working group considered the Defra survey and experimental evidence, and concluded that whilst eyespot and cereal cyst nematode (CCN) effects may play a part, take-all (TA) remains the most likely cause of loss. Variation in resistance to take-all is unlikely to explain fully the differences observed in variety performance, as work to identify and select for resistance has found few consistent differences (evidence reviewed by Scott, 1981). However, an interaction between the disease and rooting, which affects the relationship between disease severity and below-ground resource capture, may offer some explanation.

OBJECTIVES

1. To test experimentally the hypothesis that certain UK wheat varieties are more tolerant of the second wheat situation than others.

2. To examine the extent to which differences observed in the relative performance of varieties as first and second wheats can be attributed to take-all.

3. To determine whether variation in performance related to take-all is due to differences in disease severity.

4. To indicate possible candidate traits and population parents to aid future mapping and genetic characterisation.

MATERIALS AND METHODS

Field experiments were carried out at two locations, NIAB Cambridge and ADAS Rosemaund (near Hereford), in each of two seasons, 2004 - 2005 and 2005 - 2006. Winter wheat varieties were selected on their yield performance when grown as a second wheat compared to a first wheat, based on the data provided by the annual RL trials. Six varieties were chosen, three performed relatively poorly and three performed relatively well in second wheat situations.

Table 1. Performance of varieties in RL trials grown in first and second wheat situations (HGCA Recommended List of winter wheat varieties for 2004 - 2005)

	Yield % controls		
Variety	1st wheat	2nd wheat	performance as 2nd wheat
Equinox	101	96	poor
Robigus	106	99	poor
Claire	101	99	poor
Napier	103	104	good
Istabraq	106	107	good
Cordiale	101	104	good

<u>2004 - 2005</u>

There were two experiments at each site, one in a first wheat situation and the other in a nearby second wheat situation. In the first wheat experiments, plots of each variety were either inoculated with *Gaeumannomyces graminis* var. *tritici (Ggt*) or left uninoculated. In the second wheat experiments plots remained uninoculated. For inoculation, inoculum of four *Ggt* isolates bulked in the NIAB laboratory on a mixture of maize-meal and vermiculite (Hollins, pers. comm.) was mixed with the seed at drilling at a rate of approximately 10ml m^{-2}. Isolates (codes 04.597.22.5 S, 04.597.22.10 S, 04.NF.34.4 S and 04.NF.36.9 IS) were provided by Rothamsted Research (Dr Geoff Bateman).

Cambridge

Experiments were located in adjacent fields on the NIAB trial ground, separated by a distance of approximately 100m. Soil type in both fields was a sandy clay loam. Previous cropping history for the first wheat experiment was potatoes 2004, winter wheat 2003, oilseed rape 2002 and for the second wheat experiment winter wheat 2004, vegetables and potatoes 2003, pulses 2002.

The first wheat experiment was designed as a randomised split plot with eight replicates, with the six varieties as main plots and two inoculation treatments as sub plots. The second wheat experiment was designed as a randomised block with eight replicates and six varieties. In both experiments, extra plots of the variety Equinox were drilled at the end of each replicate for sequential sampling for take-all assessment.

Plots 10.5m x 2m were drilled on 01 November 2004 at seed rates aimed at producing plant populations of 250 plants m^{-2}. General husbandry was in accordance with good experimental practice, with appropriate fertiliser, herbicides and pesticides being applied across all plots. Nitrogen fertiliser was applied as a two-way split.

Extra plots of Equinox in inoculated blocks of the first wheat experiment and in the second wheat experiment were sampled on three dates to monitor the early development of the take-all epidemic. Samples comprising twenty plants per plot, taken from five sample points each of four plants, were assessed to determine a Take-all index using the categories in Table 2, below. In addition to this, counts of healthy and diseased roots were made on a sub-sample of ten plants per plot. Sample dates are summarised in Table 3.

Table 2. Categories used for take-all assessments

Categories	Proportion of root area affected
none	0
slight 1	1% - 12%
slight 2	13% - 25%
moderate 1	26% - 50%
moderate 2	51% - 75%
severe	>75%

Table 3. Sample dates and crop growth stage for Cambridge trials 2004 - 2005

Sample date	Crop growth stage
12 January, 2005	12
31 March, 2005	30
25 May, 2005	39

Take-all was assessed on all plots of the 1st wheat trial on 29 June 2005 (GS75) and the 2nd wheat trial on 7 July 2005 (GS75), by taking samples of forty plants per plot. Simultaneously, ten plants per plot were sampled from extra plots of Equinox in the first wheat trial for determination of diseased and healthy root numbers.

Plants from each treatment, from across the replicates, were inspected for eyespot prior to sampling for take-all assessment. Fewer than 10% tillers were affected by moderate or severe lesions and full assessment was therefore not carried out.

Two bulked soil samples, each comprising thirty 15cm cores taken in ‘W’ patterns across the first and second wheat trial areas, were taken for cereal cyst nematode (*Heterodera avenae*) counts on 6 January 2005. Both egg and cyst counts were zero.

Plots were harvested for yield on 11 August 2005 (first wheat) and 17 August 2005 (second wheat) and samples taken for specific weight and 1000-grain weight determination.

<u>Rosemaund</u>

Experiments were located in adjacent fields at ADAS Rosemaund, separated by a distance of approximately 250 metres. Soil type in both fields was silty clay loam, Bromyard series. Previous cropping history for the first wheat experiment was 2004 spring beans, 2003 winter wheat, 2002 winter barley and for the second wheat experiment 2004 spring wheat, 2003 maize, 2002 maize.

The first wheat experiment was designed as a randomised split plot with eight replicates, with variety as the main plot factor and inoculation as the sub-plot factor. The second wheat experiment was a randomised block with eight replicates and six varieties. In both experiments, extra plots of the variety Equinox were drilled at each end of the trial for sequential sampling for take-all assessment.

Plots 24m x 2m were drilled on 18 October 2004 (first wheat) and 11 October 2004 (second wheat) at seed rates aimed at producing plant populations of 250 plants m^{-2}. General husbandry was in accordance with good experimental practice, with appropriate fertiliser, herbicides and pesticides being applied across all plots. Nitrogen fertiliser was applied as a two-way split and rates were in accordance with RB209 recommendations. All plots were treated routinely with a comprehensive foliar fungicide programme (excluding the use of strobilurin before GS39) to control foliar and ear diseases and eyespot.

Plants from each treatment, from across the replicates, were inspected for eyespot and other stem base diseases between GS59 and GS71.. The level of eyespot did not exceed 10% tillers affected by moderate or severe lesions and full assessment was therefore not carried out.

Extra plots of Equinox were sampled on three dates to monitor the early development of the take-all epidemic. Samples comprising twenty plants per plot, taken from five sample points each of four plants, were assessed to determine a Take-all index (see Table 2 for assessment categories). In addition to this, counts of healthy and diseased roots were made on a sub-sample of ten plants per plot. Sample dates are summarised in Table 4.

Table 4. Sample dates and crop growth stage for Rosemaund trials 2004 - 2005

Sample date	Crop growth stage
24 November, 2005	12
18 March, 2005	25 - 30
18 May, 2005	37 - 39

Take-all was assessed on all plots on 01 July (GS71-73), by taking samples of forty plants per plot, in a 'W' pattern from across the whole plot area.

A bulked soil sample comprising thirty 15cm cores taken in a 'W' pattern across the second wheat trial area was taken on 24 November 2004 for cereal cyst nematode (*Heterodera avenae*) counts. Both egg and cyst counts were zero.

Plots were harvested for yield on 9 August 2005 (second wheat) and 12 August 2005 (first wheat) and samples were taken for grain quality analysis.

<u>2005 – 2006</u>

There was a single experiment at each site. The experimental area had been prepared in the previous season by growing randomised blocks of wheat and oats in order to provide first and second wheat entry for 2005 drilling within a single randomised and replicated experiment. First wheat plots of each variety were either inoculated with *Ggt* or left uninoculated. Second wheat plots remained uninoculated. Inoculation followed the same procedure as in 2004 - 2005.

<u>Cambridge</u>

The experiment was located on the NIAB trial ground. Soil type was a sandy clay loam. Previous cropping for the first wheat plots was winter oats 2004, vegetables/ potatoes 2003, winter wheat 2002 and for the second wheat plots winter wheat 2004, vegetables/ potatoes 2003, winter wheat 2002.

The experiment was designed as a randomised split lattice with ten replicates, with three treatments (first wheat uninoculated, first wheat inoculated and second wheat) as main plots and six varieties as sub plots. Plots 10.5m x 2m were drilled on 11 October 2005 at seed rates aimed at achieving plant populations of 250 plants m^{-2}. General husbandry followed the same principles as in 2004 - 2005.

Extra plots of Equinox in first wheat inoculated and second wheat main plots were sampled for take-all assessment on 02 January 2006 (GS13). The same plots, together with first wheat uninoculated plots, were sampled for take-all assessment on 28 March 2006 (GS23) and 20 May 2006 (GS45). Samples comprised twenty plants per plot, taken from five sample points each of four plants. Counts of healthy and diseased roots were made on a sub-sample of ten plants per plot.

Take-all was assessed on all plots between 27 June and 29 June 2006 (GS75), by taking samples of forty plants per plot. Diseased and healthy root numbers were counted on a sub sample of ten plants per plot.

Plants from each treatment, from across the replicates, were inspected for eyespot prior to sampling for take-all assessment. Fewer than 10% tillers were affected by moderate or severe lesions and full assessment was therefore not carried out.

Plots were harvested for yield on 5 August 2006.

<u>Rosemaund</u>

The experiment was located at ADAS, Rosemaund. Soil type was a silty clay loam, Bromyard series. Previous cropping for the first wheat plots was winter oats 2004, oilseed rape 2003, winter wheat 2002 and for the second wheat plots winter wheat 2004, oilseed rape 2003, winter wheat 2002.

The experiment was designed as a randomised split plot with eight replicates, with three treatments (first wheat uninoculated, first wheat inoculated and second wheat) as main plots and six varieties as sub plots. Extra plots of the variety Equinox were drilled at the end of each replicate for sequential sampling for take-all assessment.

Plots 24m x 2m were drilled on 20 October 2005 at seed rates aimed at achieving plant populations of 250 plants m^{-2}. General husbandry followed the same principles as in 2004 – 2005.

Extra plots of Equinox were sampled for take-all assessment on 14 March 2006 (GS25) and on 21 May (GS39). Samples comprised twenty plants per plot taken from five sample points each of four plants. Counts of healthy and diseased roots were made on a sub-sample of ten plants per plot. All plots were sampled for take all assessment on 17 August, two weeks post harvest, by taking stubble samples of 40 plants per plot. The late sampling may have biased the assessment, but disease levels in all treatments were low throughout the season, so it is unlikely that sampling time affected the findings substantially. Diseased and healthy root numbers were counted on a sub sample of ten plants per plot for Equinox only.

Plants from each treatment, from across the replicates, were inspected for eyespot and other stem base diseases between GS59 and GS71 using the ‘whole plot’ method. The level of eyespot did not exceed 10% tillers affected by severe lesions and full assessment was therefore not carried out.

Plots were harvested for yield on 3 August 2006.

RESULTS

All data are summarised in Appendix 1:

2004 - 2005	Cambridge	Tables 5-14
	Rosemaund	Tables 15-23
2005 - 2006	Cambridge	Tables 24-29
	Rosemaund	Tables 30-34

2004 - 2005 Cambridge

There was a highly significant effect of inoculation on take-all index in the first wheat trial, with the mean take-all index being increased from 19.2 to 32.8 (Table 6). Take-all index in the inoculated first wheat plots was at a very similar level to that in the adjacent second wheat trial (Table 7), where the mean index was 31.7. There was no significant effect of variety on take-all index in either the first or second wheat trial, although the latter was approaching significance (0.078).

The effect of inoculation on yield was highly significant (Table 8), with a mean reduction of 0.47 t/ha. There were highly significant differences in yield between varieties, but no significant variety x inoculation interaction. The mean yield of the second wheat trial was 0.92 t/ha below that of the first wheat (Table 9).

In general, the effects of variety and inoculation on the grain quality parameters (1000-grain weight and specific weight) were significant but variety x inoculation interactions were non-significant.

2004 - 2005 Rosemaund

The mean take-all index was increased significantly by inoculation in the first wheat trial, from a value of 18.2 to 27.2 (Table 16) but cultivar and interaction effects were non-significant. Little take-all was detected in the second wheat trial; possibly due to the preceding wheat crop being spring sown.

There was a highly significant effect of inoculation on yield in the first wheat trial, with a reduction in mean yield of 0.4 t/ha, similar to that in the Cambridge trial (Table 17). The effect of cultivar on yield was also highly significant but there was no cultivar x inoculation interaction. The mean yield in the nearby second wheat trial exceeded that in the first wheat trial by nearly 3 t/ha (Table 18), although direct comparisons are not possible, and highly significant affects of cultivar on yield were observed. There were no obvious reasons (such as poor establishment) to explain the lower yield of the first wheat.

Akin to the Cambridge site, the effects of cultivar on 1000-grain weight were highly significant or significant for both trials. However, inoculation did not have an effect and interactions were non-significant (Tables 19-20). Varietal effects on specific weight were significant for both trials but inoculation effect and interactions were non-significant (Table 21-22).

Inoculation did not have an effect on ear numbers for either the Cambridge or the Rosemaund site but significant varietal differences were observed (Table 14 and 23).

2005 - 2006 Cambridge

The effect of 'treatment' on take-all severity was highly significant. Inoculation increased the take-all index from 5.8 in the uninoculated first wheat plots to 33.8 (Table 25). Take-all index in the second wheat plots was higher again at 46.3. Variety and interaction effects on take-all index were non-significant.

The effects of 'treatment', variety and treatment x variety interaction on yield were all significant (Table 29). Inoculation reduced mean first wheat yields by 0.26 t/ha, from 9.86 t/ha to 9.60 t/ha. Second wheat yields were substantially lower, being reduced on average by 2.83 t/ha, to 7.03 t/ha. Robigus lost significantly more yield in the second wheat situation than the other five varieties, while Cordiale lost significantly less yield than Claire, Equinox, Robigus and Istabraq. These results support the published RL data sets that indicate Robigus is a relatively poor, and Cordiale a relatively good, second wheat variety.

2005 - 2006 Rosemaund

Take-all severity was low throughout the trial, with a mean index of 2.7 in inoculated first wheat and 4.5 in second wheat (Table 31). Despite the low index scores, variety and 'treatment' effects were highly significant and a significant interaction also occurred. In the second wheat situation, Cordiale had the lowest take-all index and Equinox had the highest, which was also true for the Cambridge site (Table 25).

Variety, treatment and interaction effects on yield were all significant (Table 32). Mean first wheat yield was reduced by 0.16 t/ha by inoculation and mean second wheat yields were reduced by 1.11 t/ha, despite low levels of take-all. Robigus and Claire lost more yield as a second wheat than did Napier or Cordiale, tending to confirm the hypothesis that Robigus and Claire are poor second wheats and Napier and Cordiale are good second wheats. However, Equinox, generally believed to be a poor second wheat, suffered less yield loss than the other varieties.

Cross-site summary for 2005-2006

The combined results from the trials at Cambridge and Rosemaund in 2005-2006 are shown in Figures 1 and 2. Figure 1 shows the yields of the six varieties in first and second wheat rotational positions in these trials and compares them with data for first and second wheats from the HGCA Recommended List for 2005-2006. In all three sets of data, Cordiale and Napier tend to lie above a line with a slope equal to one, indicating better than expected second wheat performance, while Robigus lies below the line, indicating poorer than expected second wheat performance.

Figure 2 relates take-all index to yield loss in inoculated first wheats and in second wheats. Overall there was little correlation between TA severity and yield loss, although Cordiale was generally less severely infected than the other varieties and suffered a relatively low yield loss. In contrast, Robigus stood out as suffering a high yield loss as a second wheat, but this was not consistently related to high levels of take-all in the variety.

CONCLUSIONS

Conclusions are presented below in relation to each of the original objectives for the study.

1 *To test experimentally the hypothesis that certain UK wheat varieties are more tolerant of the second wheat situation than others.*

The relative performance of varieties in contrasting rotational positions was characterised in the field by artificial inoculation with *Ggt*, 'phasing-in' previous cropping and using highly replicated trial designs. Both artificial inoculation and phasing-in treatments successfully generated take-all epidemics across the cultivars.

The experiments removed the confounding of rotational position and site which interferes with the interpretation of second wheat performance in RL trials. The relative performance of varieties was found to be broadly consistent across the two contrasting experimental sites despite differences in disease pressure. Significant variety by rotational position interactions for yield were found at both sites, thus demonstrating conclusively that some wheat varieties are more or less suited to second wheat rotational positions.

2 *To examine the extent to which differences observed in the relative performance of varieties as first and second wheats can be attributed to take-all.*

Yield was only loosely related to take-all severity, partly because at any given level of take-all severity, yield losses were greater in phased second wheat plots than in *Ggt* inoculated first wheat plots. This was not explained by differences in cereal cyst nematode burden or eyespot severity. Cereal cyst nematode egg and cyst counts were zero and fewer than 10% tillers were affected by moderate or severe eyespot lesions at either site. Possible mechanisms to explain the effects seen include differences in (i) crop nutrition, (ii) absolute healthy root number, affecting below-ground resource capture (Pillinger *et al*., 2005), or iii) the temporal or spatial distribution of the inoculated and natural (2nd wheat) take-all epidemics.

Fertile shoot/ear numbers (which are sensitive to nitrogen uptake), total root counts and the disease progress curves did not differ sufficiently between treatments to support nutrition, healthy root number or epidemic timing differences as plausible explanations. A more likely hypothesis for the greater yield loss per unit disease in second wheat plots is that primary infection lesions arising from artificial inoculation, and the secondary infections arising from them, were largely confined to the sampled upper roots. Whereas lesions arising from natural inoculum in the second wheats may also have resulted in lesions on roots below those sampled.

3 *To determine whether variation in performance related to take-all is due to differences in disease severity.*

The data from the experiments support the published RL data sets that indicate Robigus is a relatively poor, and Cordiale a relatively good second wheat cultivar. Cordiale showed lower levels of take-all than the other cultivars, consistently across experiments, although the differences were usually not significant. Robigus and Claire lost more yield as a second wheat than did Napier or Cordiale.

Differences in yield loss between varieties within each experiment were greater than differences in disease severity, suggesting that second wheat performance differences are due more to tolerance/intolerance (yield loss per unit disease severity) than resistance.

4 *To indicate possible candidate traits and population parents to aid future mapping and genetic characterisation.*

Candidate tolerance traits could be studied using mapping populations derived from crosses between the varieties which contrasted most strongly for second wheat performance at broadly comparable levels of first wheat performance; most obviously Robigus X Cordiale or Napier. Genetic control of the possible quantitative resistance or escape of Cordiale could be studied further by crossing with Equinox or Istabraq. However, although Cordiale showed consistently lower severity than the other varieties tested, the lack of statistical significance suggests that field phenotyping would need to be highly replicated and conducted over many sites and seasons to obtain reliable data.

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Appendix I

Table 5. 2005 Cambridge. Take all index and infected roots, sequential Equinox samples

	Take-all index		
	GS 12	GS 30	GS 39
1st inoc	2.8	6.4	19.4
2nd	4.5	10.4	22.3

	Infected and total roots (per plant)								
	GS 12	GS 12	GS 12	GS 30	GS 30	GS 30	GS 39	GS 39	GS 39
	infected	total	%infected	infected	total	%infected	infected	total	%infected
1st inoc	0.15	5.63	2.66	0.55	11.80	4.66	2.51	14.48	17.33
2nd	0.20	5.08	3.94	0.66	10.48	6.30	2.15	15.53	13.84

Table 6. 2005 Cambridge. First wheat trial. Take-all index GS75.

	Inoculation with *Ggt* -	Inoculation with *Ggt* +	Mean	Inoculation effect
Claire	20.20	35.10	27.65*	14.90
Equinox	21.80	31.90	26.85*	10.10
Robigus	18.30	34.30	26.30*	16.00
Cordiale	16.40	31.00	23.70*	14.60
Istabraq	20.60	33.90	27.25*	13.30
Napier	17.90	30.70	24.30*	12.80
Mean	19.20**	32.82**	26.01**	13.62

Variety, p value	for comparing variety means (marked *)	NS (0.247)
SED		1.972
LSD		3.927
Inoculation, p value	for comparing inoculation means (marked **)	<0.001
SED		1.139
LSD		2.267
Var x Inoc, p value	for comparing varieties within an inoculation treatment or inoculation treatments within a variety	NS (0.737)
SED		2.789
LSD		5.554

Table 7. 2005 Cambridge. Second wheat trial. Take-all index GS75

	TAI
Claire	35.60
Equinox	33.30
Robigus	31.50
Cordiale	27.20
Istabraq	35.10
Napier	27.40
Mean	31.68
Variety, p value	0.078
SED	3.610
LSD	7.180

Table 8. 2005 Cambridge. First wheat trial. Grain yield (t/ha)

	Inoculation with *Ggt*		Mean	Inoculation effect
	-	+		
Claire	8.88	8.50	8.69	- 0.38
Equinox	9.61	9.13	9.37	- 0.48
Robigus	9.54	9.13	9.34	- 0.41
Cordiale	9.04	8.74	8.89	- 0.30
Istabraq	9.64	8.90	9.27	- 0.74
Napier	9.74	9.21	9.48	- 0.53
Mean	9.41	8.94	9.17	- 0.47
Variety, p value			<0.001	
SED			0.174	
LSD			0.347	
Inoculation, p value			<0.001	
SED			0.101	
LSD			0.201	
Var x Inoc, p value			NS (0.853)	
SED			0.247	
LSD			0.491	

Table 9. 2005 Cambridge. Second wheat trial. Grain yield (t/ha)

	Yield (t/ha)
Claire	8.41
Equinox	8.49
Robigus	8.48
Cordiale	8.29
Istabraq	8.39
Napier	8.88
Mean	8.49
Variety, p value	0.080
SED	0.181
LSD	0.360

Table 10. 2005 Cambridge. First wheat trial. 1000-grain weight (g)

	Inoculation with *Ggt*		Mean	Inoculation effect
	-	+		
Claire	39.50	37.60	38.55	- 1.90
Equinox	44.00	43.60	43.80	- 0.40
Robigus	40.50	40.10	40.30	- 0.40
Cordiale	39.80	39.60	39.70	- 0.20
Istabraq	42.80	41.40	42.10	- 1.40
Napier	44.40	42.20	43.30	- 2.20
Mean	41.83	40.75	41.29	- 1.08
Variety, p value			<0.001	
SED			0.565	
LSD			1.126	
Inoculation, p value			0.002	
SED			0.326	
LSD			0.650	
Var x Inoc, p value			NS (0.331)	
SED			0.800	
LSD			1.592	

Table 11. 2005 Cambridge. Second wheat trial. 1000-grain weight (g)

	TGW (g)
Claire	38.20
Equinox	43.90
Robigus	40.00
Cordiale	39.30
Istabraq	42.80
Napier	42.50
Mean	41.12
Variety, p value	<0.001
SED	0.754
LSD	1.500

Table 12. 2005 Cambridge. First wheat trial. Specific weight (Kg/hl)

	Inoculation with *Ggt*		Mean	Inoculation effect
	-	+		
Claire	73.70	71.50	72.60	- 2.20
Equinox	71.70	71.40	71.55	- 0.30
Robigus	75.00	74.60	74.80	- 0.40
Cordiale	76.20	76.30	76.25	0.10
Istabraq	74.90	73.60	74.25	- 1.30
Napier	73.40	73.10	73.25	- 0.30
Mean	74.15	73.42	73.78	- 0.73
Variety, p value			<0.001	
SED			0.648	
LSD			1.291	
Inoculation, p value			0.067	
SED			0.374	
LSD			0.745	
Var x Inoc, p value			NS (0.550)	
SED			0.917	
LSD			1.826	

Table 13. 2005 Cambridge. Second wheat trial. Specific weight (Kg/hl)

	Specific weight (Kg/hl)
Claire	72.44
Equinox	72.42
Robigus	74.76
Cordiale	75.77
Istabraq	74.34
Napier	72.54
Mean	73.72
Variety, p value	<0.001
SED	0.5965
LSD	1.187

Table 14. 2005 Cambridge. First wheat trial. Number of ears m^{-2}

	Inoculation with *Ggt*		Mean	Inoculation effect
	-	+		
Claire	496.10	467.80	481.95	28.30
Equinox	421.60	425.00	423.30	-3.40
Robigus	506.70	501.00	503.85	5.70
Cordiale	498.50	539.90	519.20	-41.40
Istabraq	452.40	451.90	452.15	0.50
Napier	486.10	446.60	466.35	39.50
Mean	476.90	472.03	474.47	4.87
Variety, p value			<0.001	
SED			23.060	
LSD			45.920	
Inoculation, p value			NS (0.715)	
SED			13.32	
LSD			26.510	
Var x Inoc, p value			NS (0.591)	
SED			32.620	
LSD			64.950	

Table 15. 2005 Rosemaund. Take all index and infected roots, sequential Equinox samples

	Take-all index		
	GS 12	GS 25-30	GS 37-39
1st inoc	7.28	20.04	11.16
2nd	5.28	12.46	9.29

	Infected and total roots (per plant)								
	GS 12 infected	GS 12 total	GS 12 %infected	GS 25-30 infected	GS 25-30 total	GS 25-30 %infected	GS 37-39 infected	GS 37-39 total	GS 37-39 %infected
1st inoc	0.90	4.37	20.6	2.79	11.19	24.93	4.47	26.74	16.00
2nd	0.70	5.11	13.7	1.69	13.64	14.37	1.21	21.39	5.53

Table 16. 2005 Rosemaund. First wheat trial Take-all index

	Inoculation with *Ggt*		Mean	Inoculation effect
	-	+		
Claire	18.14	30.23	24.19	12.09
Equinox	21.94	34.56	28.25	12.62
Robigus	21.06	22.57	21.82	1.51
Cordiale	15.96	23.24	19.60	7.28
Istabraq	16.28	27.90	22.09	11.62
Napier	15.79	24.43	20.11	8.64
Mean	18.20	27.15	22.68	8.95
Variety, p value			NS (0.164)	
SED			3.460	
LSD			7.030	
Inoculation, p value			<0.001	
SED			2.170	
LSD			4.380	
Var x Inoc, p value			NS (0.680)	
SED			5.110	
LSD			10.18	

Table 17. 2005 Rosemaund. First wheat trial. Grain yield (t/ha)

	Inoculation with *Ggt*		Mean	Inoculation effect
	-	+		
Claire	7.99	7.57	7.78	- 0.42
Equinox	8.27	7.66	7.97	- 0.62
Robigus	9.29	8.75	9.02	- 0.54
Cordiale	8.89	8.62	8.76	- 0.27
Istabraq	9.29	8.80	9.04	- 0.49
Napier	8.88	8.83	8.86	- 0.05
Mean	8.77	8.37	8.57	- 0.40
Variety, p value			<0.001	
SED			0.292	
LSD			0.592	
Inoculation, p value			<0.001	
SED			0.076	
LSD			0.153	
Var x Inoc, p value			NS (0.311)	
SED			0.320	
LSD			0.642	

Table 18. 2005 Rosemaund. Second wheat trial. Grain yield (t/ha)

	Yield (t/ha)
Claire	10.76
Equinox	11.84
Robigus	11.41
Cordiale	12.02
Istabraq	12.18
Napier	11.69
Mean	11.64
Variety, p value	<0.001
SED	0.203
LSD	0.413

Table 19. 2005 Rosemaund. First wheat trial. 1000-grain weight (g)

	Inoculation with *Ggt*		Mean	Inoculation effect
	-	+		
Claire	43.40	42.61	43.01	- 0.79
Equinox	55.01	55.12	55.06	0.11
Robigus	41.38	41.78	41.58	0.41
Cordiale	45.58	44.99	45.29	- 0.60
Istabraq	48.42	48.23	48.33	- 0.19
Napier	52.30	50.82	51.56	- 1.48
Mean	47.68	47.26	47.47	- 0.42
Variety, p value			<0.001	
SED			0.821	
LSD			1.667	
Inoculation, p value			NS (0.189)	
SED			0.318	
LSD			0.642	
Var x Inoc, p value			NS (0.581)	
SED			0.989	
LSD			1.976	

Table 20. 2005 Rosemaund. Second wheat trial. 1000-grain weight (g)

	TGW (g)
Claire	42.04
Equinox	51.64
Robigus	39.03
Cordiale	41.43
Istabraq	47.06
Napier	45.38
Mean	44.43
Variety, p value	<0.001
SED	0.634
LSD	1.287

Table 21. 2005 Rosemaund. First wheat trial. Specific weight (Kg/hl)

	Inoculation with *Ggt*		Mean	Inoculation effect
	-	+		
Claire	78.06	77.29	77.68	- 0.78
Equinox	77.61	76.78	77.19	- 0.84
Robigus	77.23	69.31	73.27	- 7.91
Cordiale	81.09	80.76	80.93	- 0.33
Istabraq	79.39	76.44	77.91	- 2.95
Napier	77.69	74.74	76.21	- 2.95
Mean	78.51	75.89	77.20	- 2.62
Variety, p value			0.027	
SED			2.071	
LSD			4.204	
Inoculation, p value			0.032	
SED			1.184	
LSD			2.390	
Var x Inoc, p value			NS (0.457)	
SED			2.915	
LSD			5.805	

Table 22. 2005 Rosemaund. Second wheat trial. Specific weight (Kg/hl)

	Specific weight (Kg/hl)
Claire	77.31
Equinox	76.61
Robigus	77.93
Cordiale	79.16
Istabraq	79.66
Napier	75.68
Mean	77.73
Variety, p value	<0.001
SED	0.814
LSD	1.653

Table 23. 2005 Rosemaund. First wheat trial. Number of ears m^{-2}

	Inoculation with *Ggt* -	Inoculation with *Ggt* +	Mean	Inoculation effect
Claire	447.68	457.41	452.55	-9.73
Equinox	433.33	456.48	444.91	-23.15
Robigus	515.28	506.94	511.11	8.34
Cordiale	497.68	447.68	472.68	50.00
Istabraq	444.91	442.59	443.75	2.32
Napier	484.72	487.04	485.88	-2.32
Mean	465.97	470.99	468.48	-5.02
Variety, p value			0.008	
SED			19.560	
LSD			39.710	
Inoculation, p value			NS (0.582)	
SED			9.050	
LSD			18.260	
Var x Inoc, p value			NS (0.305)	
SED			25.060	
LSD			49.990	

Table 24. 2006 Cambridge. Take all index and infected roots, sequential Equinox samples

	Take-all index		
	GS 13	GS 23	GS 45
1st uninoc	-	12.3	4.9
1st inoc	18.6	22.8	23.0
2nd	15.1	17.8	25.8

	Infected and total roots (per plant)								
	GS 13 infected	GS 13 total	GS 13 %infected	GS 23 infected	GS 23 total	GS 23 %infected	GS 45 infected	GS 45 total	GS 45 %infected
1st uninoc	-	-	-	0.8	10.79	7.41	0.55	26.28	2.09
1st inoc	1.54	8.75	17.60	1.44	10.80	13.33	3.43	25.54	13.43
2nd	0.92	9.54	9.64	1.19	11.59	10.27	3.94	25.93	15.19

Table 25. 2006 Cambridge. Take-all index. GS75

	1st wheat		2nd wheat	mean	Inoculation effect	2nd wheat effect
	- Ggt	*+ Ggt*				
Claire	3.60	33.95	48.85	28.80	30.35	45.25
Equinox	11.60	34.90	49.85	32.12	23.30	38.25
Robigus	3.75	34.90	48.45	29.03	31.15	44.70
Cordiale	4.85	28.80	39.75	24.47	23.95	34.90
Istabraq	5.65	37.30	44.95	29.30	31.65	39.30
Napier	5.05	32.65	45.80	27.83	27.60	40.75
Mean	5.75	33.75	46.28	28.59	28.00	40.53
				NS		
Variety, p value				(0.178)		
SED				2.820		
LSD				5.570		
Main plot, p value				<0.001		
SED				1.994		
LSD				3.939		
				NS		
Main plot x var, p value				(0.877)		
SED				4.884		
LSD				9.648		

Table 26. 2006 Cambridge. Number of. infected roots per plant GS75

	1st wheat		2nd wheat	mean	Inoculation effect	2nd wheat effect
	- Ggt	*+ Ggt*				
Claire	3.56	7.15	8.85	6.52	3.59	5.26
Equinox	5.62	6.84	9.86	7.44	1.22	8.64
Robigus	4.24	7.35	9.34	6.97	3.11	6.23
Cordiale	3.61	7.17	8.39	6.39	3.56	4.83
Istabraq	4.97	7.67	8.74	7.13	2.70	6.04
Napier	2.45	7.20	9.00	6.22	4.75	4.25
Mean	4.08	7.23	9.03	6.78	3.16	5.88
				NS		
Variety, p value				(0.362)		
SED				0.641		
LSD				1.267		
Main plot, p value				<0.001		
SED				0.453		
LSD				0.896		
				NS		
Main plot x var, p value				(0.676)		
SED				1.111		
LSD				2.194		

Table 27. 2006 Cambridge. Total number of roots per plant GS75

	1st wheat		2nd wheat	mean	Inoculation effect	2nd wheat effect
	- Ggt	*+ Ggt*				
Claire	21.97	22.36	22.32	22.22	0.39	0.35
Equinox	21.81	22.80	22.09	22.23	0.99	0.28
Robigus	22.08	22.24	22.26	22.19	0.16	0.18
Cordiale	21.42	22.15	22.01	21.86	0.73	0.59
Istabraq	21.86	22.28	21.74	21.96	0.42	-0.12
Napier	21.05	22.88	22.04	21.99	1.83	0.99
Mean	21.70	22.45	22.08	22.08	0.75	0.38
Variety, p value				NS (0.886)		
SED				0.382		
LSD				0.755		
Main plot, p value				0.006		
SED				0.270		
LSD				0.534		
Main plot x var, p value				NS (0.897)		
SED				0.662		
LSD				1.308		

Table 28. 2006 Cambridge. % infected roots GS75

	1st wheat		2nd wheat	mean	Inoculation effect	2nd wheat effect
	- Ggt	*+ Ggt*				
Claire	16.57	32.42	39.89	29.63	15.85	23.32
Equinox	26.10	30.27	45.04	33.80	4.17	18.94
Robigus	19.85	33.23	41.76	31.61	13.38	21.91
Cordiale	16.75	32.60	38.51	29.29	15.85	21.76
Istabraq	23.21	34.46	40.70	32.79	11.25	17.49
Napier	11.88	31.98	41.04	28.30	20.10	29.16
Mean	19.06	32.49	41.16	30.90	13.43	22.10
Variety, p value				NS (0.340)		
SED				2.869		
LSD				5.667		
Main plot, p value				<0.001		
SED				2.028		
LSD				4.007		
Main plot x var, p value				NS (0.666)		
SED				4.969		
LSD				9.816		

Table 29. 2006. Cambridge. Grain yield (t/ha).

	1st wheat - *Ggt*	1st wheat + *Ggt*	2nd wheat	mean	Inoculation effect	2nd wheat effect
Claire	9.61	9.43	6.80	8.61	-0.18	-2.82
Equinox	9.53	9.26	6.79	8.53	-0.27	-2.74
Robigus	10.22	9.79	6.26	8.71	-0.43	-3.96
Cordiale	9.72	9.34	7.67	8.91	-0.39	-2.05
Istabraq	10.17	10.04	7.20	9.14	-0.13	-2.98
Napier	9.89	9.75	7.48	9.04	-0.15	-2.41
Mean	9.86	9.60	7.03	8.76	-0.26	-2.83
Variety, p value				<0.001		
SED				0.203		
LSD				0.401		
Main plot, p value				0.019		
SED				0.144		
LSD				0.284		
Main plot x var, p value				0.020		
SED				0.352		
LSD				0.695		

Table 30. 2006 Rosemaund. Take all index and infected roots, sequential Equinox samples

	Take-all index GS 25	Take-all index GS 39
1st uninoc	2.54	0.48
1st inoc	4.63	0.07
2nd	2.75	1.10

	Infected and total roots (per plant) GS 25 infected	GS 25 total	GS 25 %infected	GS 39 infected	GS 39 total	GS 39 %infected
1st uninoc	0.31	12.54	2.50	0.08	20.49	0.36
1st inoc	0.56	12.18	4.78	0.15	20.87	0.73
2nd	0.25	11.73	2.20	0.14	20.55	0.67

Table 31. 2006 Rosemaund. Take-all index post harvest

	1st wheat		2nd wheat	mean	Inoculation effect	2nd wheat effect
	- Ggt	*+ Ggt*				
Claire	0.45	3.00	5.34	2.93	2.55	4.89
Equinox	0.41	3.92	6.14	3.49	3.51	5.73
Robigus	0.57	2.93	4.62	2.71	2.37	4.05
Cordiale	0.24	2.00	1.73	1.32	1.76	1.49
Istabraq	0.90	1.83	4.03	2.25	0.93	3.13
Napier	0.80	2.52	4.93	2.75	1.71	4.13
Mean	0.56	2.70	4.47	2.58	2.14	3.90
Variety, p value				<0.001		
SED				0.445		
LSD				0.883		
Main plot, p value				<0.001		
SED				0.347		
LSD				0.745		
Main plot x var, p value				0.021		
SED				0.785		
LSD				1.555		

Table 32. 2006. Rosemaund. Grain yield (t/ha)

	1st wheat		2nd wheat	mean	Inoculation effect	2nd wheat effect
	- Ggt	*+ Ggt*				
Claire	9.10	8.86	7.91	8.62	-0.24	-1.19
Equinox	8.92	8.77	8.09	8.59	-0.15	-0.84
Robigus	9.06	9.01	7.56	8.54	-0.05	-1.50
Cordiale	9.46	9.23	8.49	9.06	-0.23	-0.97
Istabraq	9.56	9.36	8.33	9.08	-0.20	-1.23
Napier	9.62	9.57	8.69	9.29	-0.05	-0.93
Mean	9.29	9.13	8.18	8.87	-0.15	-1.11
Variety, p value				<0.001		
SED				0.062		
LSD				0.123		
Main plot, p value				0.002		
SED				0.263		
LSD				0.565		
Main plot x var, p value				<0.001		
SED				0.281		
LSD				0.590		

Table 33. 2006. Rosemaund. 1000-grain weight (g)

	1^{st} wheat		2^{nd} wheat	mean	Inoculation effect	2^{nd} wheat effect
	- Ggt	*+ Ggt*				
Claire	39.65	33.36	35.50	36.17	-6.29	-4.15
Equinox	47.75	46.94	44.78	46.49	-0.81	-2.97
Robigus	37.29	37.61	34.62	36.51	0.32	-2.67
Cordiale	39.61	38.24	37.69	38.51	-1.37	-1.92
Istabraq	42.30	43.04	40.02	41.79	0.74	-2.28
Napier	47.55	44.88	43.20	45.21	-2.66	-4.35
Mean	42.36	40.68	39.30	40.78	-1.68	-3.06
Variety, p value				<0.001		
SED				1.088		
LSD				2.157		
Main plot, p value				0.030		
SED				1.018		
LSD				2.182		
Main plot x var, p value				NS (0.394)		
SED				1.999		
LSD				3.965		

Table 34. 2006. Rosemaund. Fertile tiller number m^{-2}

	1^{st} wheat		2^{nd} wheat	mean	Inoculation effect	2^{nd} wheat effect
	- Ggt	*+ Ggt*				
Claire	578	567	565	570	-11	-13
Equinox	571	557	528	552	-14	-43
Robigus	600	626	572	599	26	-28
Cordiale	661	617	584	621	-44	-77
Istabraq	568	548	563	560	-20	-5
Napier	625	650	619	631	25	-6
Mean	600	594	572	589	-6	-28
Variety, p value				<0.001		
SED				17.720		
LSD				35.140		
Main plot, p value				NS (0.149)		
SED				14.250		
LSD				30.560		
Main plot x var, p value				NS (0.677)		
SED				31.440		
LSD				62.290		

Figure 1. Yields of six wheat varieties in first and second wheat rotational positions in trials at Cambridge and Rosemaund 2006. Data from HGCA Recommended List 2005/2006 for comparison

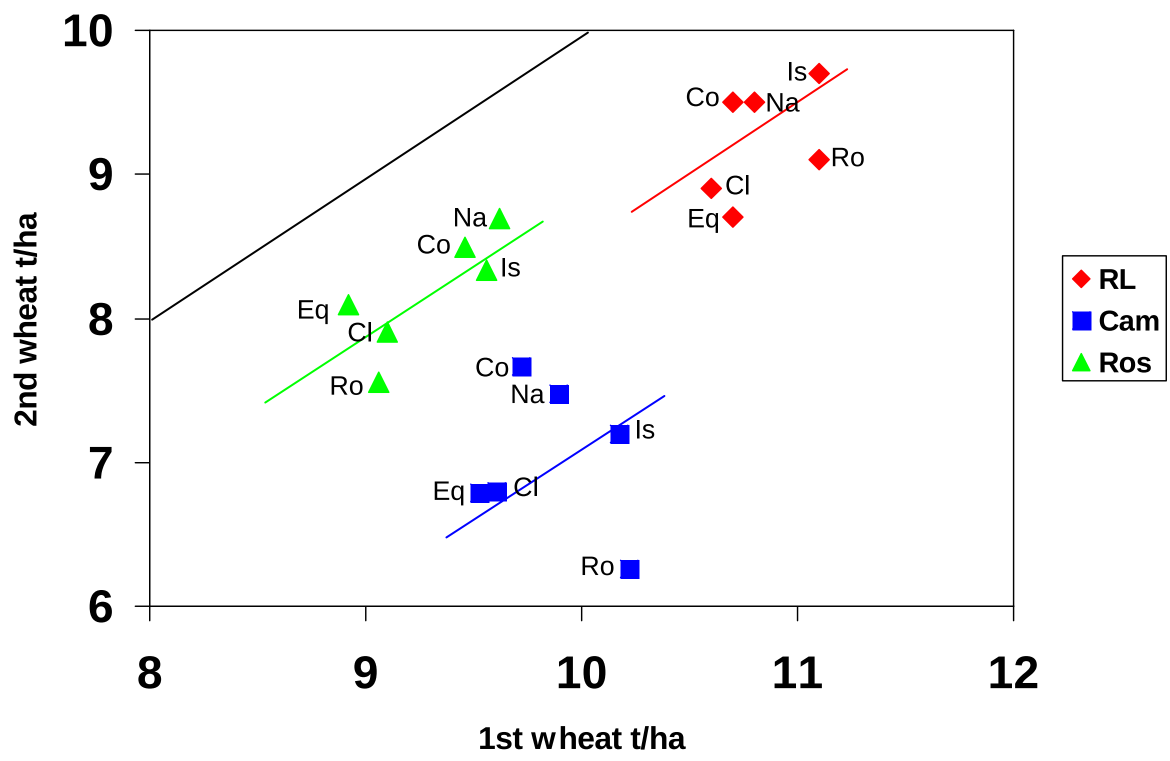
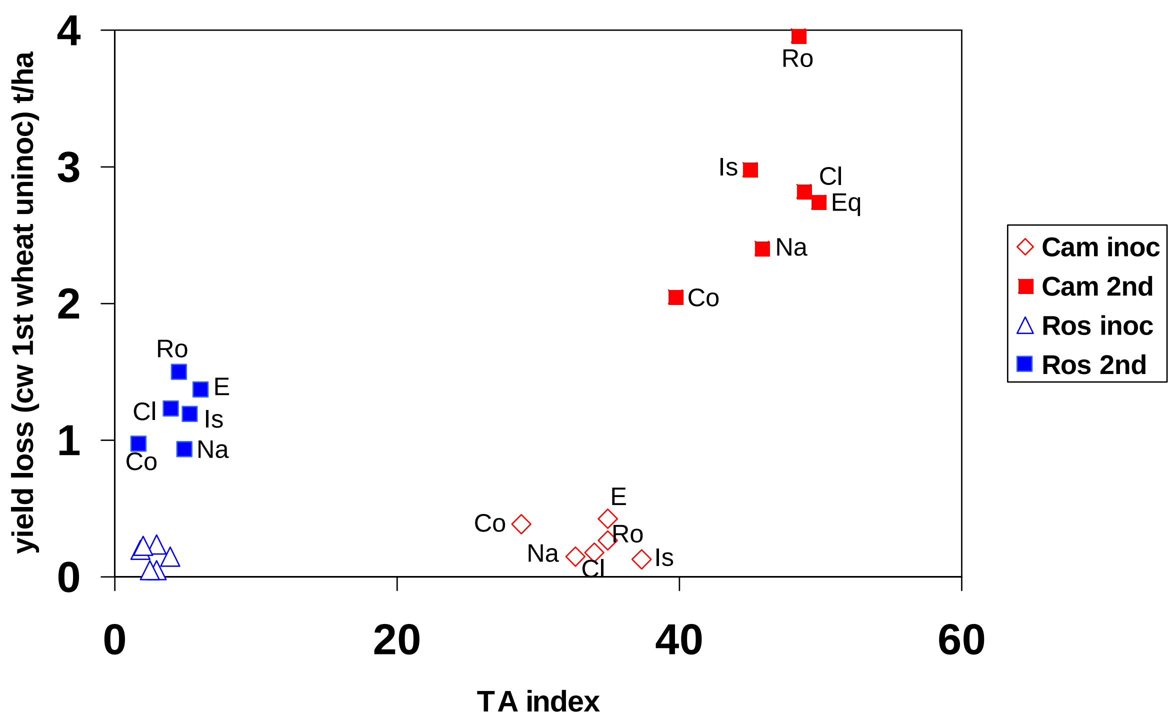


Figure 2. Take-all severity and yield loss in 2nd wheat rotational position and in 1st wheat inoculated with Ggt at Cambridge and Rosemaund 2006.



Appendix II.

Site details for take-all experiments at ADAS Rosemaund, Hereford, 2004 - 2005

Site	ADAS Rosemaund, Herefordshire (1st wheat)
Field name	Prestons
Soil texture	Silty Clay Loam (Bromyard Series)
Soil analysis:	
N (from SMN)	111.6
P	Index 4
K	Index 3
Mg	Index 3
pH	6.9
Drainage	Free
Cultivar	As per protocol
Sowing date	18 October 2004
Harvest date	11 August 2005

Previous Cropping

Harvest year:	
2004	Spring beans
2003	Winter wheat
2002	Winter barley
2001	Winter wheat

Nutrition

Fertilisers:	
11/03/05	21:0:0:60 @ 73 kg/ha
15/03/05	34.5:0:0 @ 119 kg/ha
21/04/05	34.5:0:0 @ 228 kg/ha

Crop protection

Fungicides:	
29/04/05	Proline @ 0.6 l/ha + Bravo @ 1.0 l/ha
11/05/05	Unix @ 1.0 l/ha
25/05/05	Opus @ 0.8 l/ha + Bravo @ 1.0 l/ha
26/05/05	Fortress @ 1.0 l/ha
Herbicides:	
17/11/05	Crystal @ 2.5 l/ha + Panther @ 0.5 l/ha + IPU 500 @ 2.5 l/ha
12/04/05	Tigress @ 2.0 l/ha
22/04/05	Eagle @ 25 g/ha + Ally @ 20 g/ha
Insecticides:	
07/03/05	Optica @ 0.83 l/ha + Cypermethrin @ 0.25 l/ha
Molluscisides:	
11/11/05	Mini Slugs @ 7.5 g/ha
04/03/05	Hardy Slug P @ 12.4 kg/ha
PGR's:	
12/04/05	Chlormequat 70% @ 2.25 l/ha

Site details for take-all experiments at ADAS Rosemaund, Hereford, 2004 - 2005

Site	ADAS Rosemaund, Herefordshire (2nd wheat)
Field name	Prestons East
Soil texture	Silty Clay Loam (Bromyard Series)
Soil analysis:	
N (from SMN)	136.5
P	Index 3
K	Index 3
Mg	Index 3
pH	6.6
Drainage	Free
Cultivar	As per protocol
Sowing date	11 October 2004
Harvest date	09 August 2005

Previous Cropping

Harvest year:	
2004	Spring wheat
2003	Maize
2002	Maize
2001	Maize

Nutrition

Fertilisers:	
11/03/05	21:0:0:60 @ 73 kg/ha
15/03/05	34.5:0:0 @ 119 kg/ha
21/04/05	34.5:0:0 @ 228 kg/ha

Crop protection

Fungicides:	
25/04/05	Opus @ 0.6 l/ha + Bravo @ 1.5 l/ha + Tern @ 0.15 l/ha
11/05/05	Unix @ 1.0 l/ha
25/05/05	Opus @ 0.8 l/ha + Bravo @ 1.0 l/ha
Herbicides:	
17/11/05	Crystal @ 2.5 l/ha + Panther @ 0.5 l/ha + IPU 500 @ 2.5 l/ha
10/05/05	Terpal @ 1.0 l/ha
Insecticides:	
07/03/05	Monitor @ 25 g/ha + Cypermethrin @ 0.25 l/ha
14/06/05	Dursban @ 0.75 l/ha
Molluscisides:	None
PGR's:	
12/04/05	Chlormequat 70% @ 1.25 l/ha + Moddus @ 0.2 l/ha

Site details for take-all experiments at ADAS Rosemaund, Hereford, 2005 - 2006

Site	ADAS Rosemaund, Herefordshire
Field name	Flatfield
Soil texture	Silty Clay Loam (Bromyard Series)
Soil analysis:	
N (from SMN)	61.96
P	Index 2
K	Index 2+
Mg	Index 2
pH	6.7
Drainage	Free
Cultivar	As per protocol
Sowing date	20 October 2005
Harvest date	03 August 2006

Previous Cropping

Harvest year:	
2005	Winter oats (1st wheat), Winter wheat (2nd wheat)
2004	Winter oilseed rape
2003	Winter wheat
2002	Winter oats

Nutrition

Fertilisers:	
21/03/06	34.5:0:0 @ 112 kg/ha
11/04/06	34.5:0:0 @ 225 kg/ha
03/05/06	34.5:0:0 @ 26 kg/ha

Crop protection

Fungicides:	
21/03/06	Proline @ 0.3 l/ha
18/04/06	Proline @ 0.4 l/ha
10/05/06	Opus @ 0.5 l/ha + Corbel @ 0.3 l/ha
07/06/06	Fandango @ 1.5 l/ha
Herbicides:	
14/12/05	Crystal @ 2.5 l/ha
10/04/06	Ally @ 30 g/ha
26/04/06	Starane 2 @ 0.75 l/ha + Axial @ 0.75 l/ha + Terpal @ 1.0 l/ha
Insecticides:	
14/12/05	Cypermethrin @ 0.25 l/ha
Molluscisides:	
24/11/05	Hardy Slug P @ 7.5 kg/ha
PGR's:	
10/04/06	Chlormequat 70% @ 1.25 l/ha + Moddus @ 0.2 l/ha

Site details for take-all experiments at NIAB, Cambridge, 2004 - 2005

Site	NIAB, Cambridge
Field name	32 (1st wheat)
Soil texture	Sandy clay loam
Cultivar	As per protocol
Sowing date	01 November 2004
Harvest date	11 August 2005

Previous Cropping

Harvest year:	
2004	Potatoes
2003	Winter wheat
2002	Winter oilseed rape

Nutrition

Fertilisers:	
07/02/05	MnSO4 @ 2.0 kg/ha
19/04/05	Nitrogen @ 99 kg/ha

Crop protection

Fungicides:	
21/05/05	Opera @ 1.5 l/ha + Bravo @ 1.0 l/ha + Opus @ 0.2 l/ha + Orka @ 1.5 l/ha
14/06/05	Amistar @ 0.6 l/ha + Folicur @ 0.5 l/ha
Herbicides:	
11/12/04	Lexus Class @ 60 g/ha + Duplosan @ 1.5 l/ha
18/05/05	Starane @ 2.0 l/ha + Ally @ 30 g/ha
Insecticides:	
11/12/04	Toppel @ 0.25 l/ha
17/02/05	Dursban @ 1.0 kg/ha
11/06/05	Cyren @ 1.0 l/ha
Molluscisides:	
25/02/07	Metarex @ 8.0 kg/ha
PGR's:	
15/04/05	Cycocel @ 1.75 l/ha
11/05/05	Cycocel @ 0.75 l/ha

Site details for take-all experiments at NIAB, Cambridge, 2004 - 2005

Site	NIAB, Cambridge
Field name	33 (2nd wheat)
Soil texture	Sandy clay loam
Cultivar	As per protocol
Sowing date	01 November 2004
Harvest date	17 August 2005

Previous Cropping

Harvest year:	
2004	Winter wheat
2003	Split cropped (non-cereal)
2002	Pulses

Nutrition

Fertilisers:	
07/02/05	MnSO4 @ 2.0 kg/ha
	Nitrogen @ 99 kg/ha + S @ 49.2 kg/ha

Crop protection

Fungicides:	
21/05/05	Opera @ 1.5 l/ha + Bravo @ 1.0 l/ha + Opus @ 0.2 l/ha + Orka @ 1.5 l/ha
14/06/05	Amistar @ 0.6 l/ha + Folicur @ 0.5 l/ha
Herbicides:	
01/12/04	Avadex Excel @ 15.0 kg/ha
13/12/04	IPU @ 4.0 l/ha + Stomp @ 3.0 l/ha
18/05/05	Starane @ 2.0 l/ha + Ally @ 30 g/ha
Insecticides:	
13/12/04	Toppel @ 0.28 l/ha
17/02/05	Dursban @ 1.0 kg/ha
11/06/05	Cyren @ 1.0 l/ha
Molluscisides:	
25/02/05	Metarex @ 8.0 kg/ha
PGR's:	
15/04/05	Cycocel @ 1.75 l/ha
11/05/05	Cycocel @ 0.75 l/ha

Site details for take-all experiments at NIAB, Cambridge, 2005 - 2006

Site	NIAB, Cambridge
Field name	32
Soil texture	Sandy clay loam
Cultivar	As per protocol
Sowing date	11 October 2005
Harvest date	05 August 2006

Previous Cropping

Harvest year:	
2005	Winter oats (1st wheat), winter wheat (2nd wheat)
2004	Split cropped (non-cereal)
2003	Winter wheat

Nutrition

Fertilisers:	
22/03/06	MOP @ 75 kg/ha + TSP @ 125 kg/ha
04/04/06	Nitraprill @ 145 kg/ha
05/04/06	Double Top @ 150 kg/ha
20/04/06	Nitraprill @ 260 kg/ha

Crop protection

Fungicides:	
24/04/06	Proline @ 0.6 l/ha + Bravo @ 1.0 l/ha
12/06/06	Folicur @ 0.5 l/ha + Amistar @ 1.0 l/ha
Herbicides:	
06/03/06	Glyphosate @ 3.0 l/ha
Insecticides:	
10/02/06	Dursban @ 1.0 kg/ha
06/06/06	Cyren @ 1.0 l/ha
Molluscisides:	
21/10/05	Metarex @ 8 kg/ha
PGR's:	
10/04/06	Cycocel @ 1.75 l/ha
12/05/06	Cycocel @ 0.75 l/ha