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FUNGICIDE INSENSITIVITY IN YELLOW RUST OF WHEAT AND BARLEY

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FUNGICIDE INSENSITIVITY IN YELLOW RUST OF WHEAT AND BARLEY

by

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ABSTRACT

An *in vivo* bioassay was developed for screening isolates of yellow rust (*Puccinia striiformis*) for sensitivity to the fungicides triadimenol and fenpropimorph. In total, 303 isolates, collected between the early 1960's and 1990, were tested. There was no indication that fungicide sensitivity had declined generally over this period. However, a single isolate collected in 1990 showed a marked decrease in sensitivity to both fungicides and was able to make limited growth on seedlings treated with fungicide equivalent to 2/3 field rate.

Isolates varied in their sensitivity to low rates of fungicide. There was evidence that this variation was associated both with the specific virulence of isolates and with their geographical origin. Isolates possessing the virulence combination WYV 6,9 and those originating from Scotland and Northumberland tended to be more sensitive than isolates without virulence WYV 6,9 and those originating from the south of the UK.

There was no relationship between the sensitivity of isolates and the intensity of fungicide application to the crops from which they had been collected.

OBJECTIVES

The main objective was to establish a baseline measure of fungicide sensitivity in *Puccinia striiformis* (yellow rust of wheat and barley), against which future changes could be gauged. Additionally, variation in sensitivity between isolates would be related to year of collection, crop fungicide application history, their geographical origin and specific virulence factors.

INTRODUCTION

In recent years fungicide insensitivity of cereal pathogens has become an increasing problem and has led to decreased fungicide efficacy.

The first cases of insensitivity occurred in the late 1960's with the discovery of mercury-resistant strains of oat leafspot (Pyrenophora avenae) in Scottish seed oats (Nobel et al., 1966).

This was followed in the early 1970's by the development of insensitivity by barley powdery mildew (Erysiphe graminis f.sp. hordei) to ethirimol, which had been used extensively as a seed treatment since the late 1960's. In 1973 changes in sensitivity were noticed and initial surveys of population variation were carried out at the Plant Breeding Institute, Cambridge and ICI Jealott's Hill Research Station (Shephard, et al., 1975). There was a shift back towards greater sensitivity to ethirimol in the late 1970's and early 1980's, following a reduction in its use, but recent evidence shows a slight reduction in sensitivity again (ADAS, 1989). The use of triazoles to control barley powdery mildew since the early 1980's has been followed by a build-up of insensitivity to this group of chemicals (Fletcher & Wolfe, 1981; Wolfe et al., 1984).

Fungicides in the morpholine group are now used increasingly for mildew control, and changes in sensitivity to the morpholines have been detected (Wolfe et al., 1987). Wheat powdery mildew (Erysiphe graminis f.sp. tritici) in southern England showed an increase in insensitivity from 1986-87, although insensitivity declined in other areas (Wolfe & Slater, 1988).

The failure of MBC fungicides to control eyespot (Pseudocercosporella herpotrichoides) in winter wheat was first reported in 1981 (Griffin et al., 1982). Surveys carried out by ADAS in 1983-85 showed a steady increase in the proportion of resistant isolates in the eyespot population (Locke, 1986). The mean percentage of resistant isolates per field in 1982 and 1983 was greater where several bendimidazole fungicides had been applied to cereals in previous seasons from 1975 onwards (Griffin & King, 1985).

MBC resistance in Septoria tritici of wheat was first detected in an ADAS survey in 1985 (ADAS, 1989). More recently, strains of Fusarium nivale on wheat have also developed resistance to MBC's (Locke et al., 1987). MBC resistant strains of Fusarium culmorum were discovered in the East Midlands in 1985 and in eastern and south eastern regions of England in 1987 (ADAS, 1989).

Sensitivity of Rhynchosporium secalis of barley to the triazole fungicides has been investigated (Hollomon, 1984; Hunter, Jordan & Kendall, 1986). Surveys carried out by Long Ashton Research Station in 1986 and ADAS in 1987 found that strains with reduced sensitivity to the triazoles triadimenol and propiconazole were widespread in England and Wales. However, field trials in 1988 did not indicate reduced efficacy of these fungicides (ADAS, 1989).

Strains of loose smut (Ustilago nuda) of winter barley resistant to carboxin seed treatments developed in 1984. A survey in 1986 showed that spring barley and other cereals were not affected. The problem appeared to be linked to stocks of the cultivar Panda from France (Locke, 1986). In 1985 there was some loss of control of barley leaf stripe (Pyrenophora graminis) treated with organomercury seed dressing. The problem occurred predominantly in the spring barley cultivar Triumph, as organomercury had been used on the seed stock for several years (Anon, 1989).

Until the initiation in 1987 of H-GCA-sponsored projects at the East of Scotland College of Agriculture and the National Institute of Agricultural Botany, no work had been carried out to investigate the sensitivity of the cereal rusts to the fungicides used to control them. Boyle et al., (1988) reported variations in sensitivity to the triazole fungicides propiconazole and triadimefon in populations of brown rust of wheat (Puccinia recondita) and brown rust of barley (Puccinia hordei). Fungicides from the triazole and morpholine groups have been used during the past decade to control yellow rust (Puccinia striiformis) of wheat and barley. It is likely therefore that populations of these pathogens may shift towards insensitivity to these fungicides as selection pressure is continued. This project aimed to evaluate the current base-line levels of sensitivity to representative fungicides from the triazole and morpholine groups and to examine evidence for changes over the past twenty years or so.

Variation in the UK yellow rust populations for virulence for the specific resistances of cultivars has been monitored routinely by the UK Cereal Pathogen Virulence Survey since 1967. The Survey therefore holds a unique collection of yellow rust isolates, each classified on the basis of virulence, source cultivar, date and location of collection and information on fungicide application to the crop of origin. This isolate collection was the main source of material for fungicide sensitivity tests, allowing correlation of sensitivity with other attributes, both for historic isolates and for current isolates received by the Survey during this investigation.

The terminology used to describe the virulence of pathogen isolates is outlined in the reports of the UK Cereal Pathogen Virulence Survey (ADAS, 1991). Virulence is designated in terms of 'specific virulence factors', which interact with 'specific resistance factors' in the host. Specific virulence factors for wheat yellow rust are numbered WYV 1, WYV 2, WYV 3 .... WYV 14, with the corresponding specific resistance factors being WYR 1, WYR 2, WYR 3 .... WYR 14. Hence, an isolate possessing the virulence WYV 1 alone is virulent on cultivars possessing the resistance WYR 1 alone. Virulence for cultivars possessing more than one resistance factor eg WYR 1, 2,3 requires the possession of all the corresponding virulences (in this example WYV 1,2,3).

During the course of the project, the UKCPVS detected a new virulence combination, WYV 6,9, conferring virulence for the resistance of the new wheat cultivar Hornet (WYR 6,9) (Bayles et al., 1989). By 1990, the frequency of isolates possessing the WYV 6,9 combination had risen to 60% of those tested (Bayles & Stigwood 1991). This meant that isolates tested for fungicide insensitivity fell into one of two main virulence groups of approximately equal size i.e. those possessing WYV 6,9 and those without WYV 6,9. Each broad category encompassed many virulence types, but with the common characteristic of virulence or otherwise for the cultivar Hornet.

Another broad grouping of isolates was made on the basis of geographical origin, with a 'North' region comprising Northumberland and Scotland and a 'South' region spanning the rest of England and Wales. This is justified on the basis of environmental similarities between the cereal growing areas of Northumberland and the east of Scotland, from whence most of the yellow rust isolates for the 'North' region were derived.

Information on the date of each isolate and its history of fungicide application were also used as classifying characters.

MATERIALS AND METHODS

Primary screening

An *in vivo* bioassay was developed for mass screening of wheat yellow rust isolates for sensitivity to triadimenol and fenpropimorph.

Ten seedlings of the universally susceptible (possessing no specific resistance) wheat cultivars Sappo or Vuka were grown in 2½" square pots, with two replicate pots per treatment. They were sprayed at the first leaf stage (7-8 days after sowing) with a range of concentrations of either triadimenol or fenpropimorph.

Dose rates for the initial 53 isolates screened:

Triadimenol	31.25 mg a.i.l^{-1}	($^1/_{20}$ th field rate)
	15.63 mg a.i.l^{-1}	($^1/_{40}$ th " ")
	7.82 mg a.i.l^{-1}	($^1/_{80}$ th " ")
	0.00 mg a.i.l^{-1}	(nil rate)
Fenpropimorph	375.00 mg a.i.l^{-1}	($^1/_{10}$ th field rate)
	187.50 mg a.i.l^{-1}	($^1/_{20}$ th " ")
	62.50 mg a.i.l^{-1}	($^1/_{60}$ th " ")
	0.00 mg a.i.l^{-1}	(nil rate)

Adjusted does rates for the subsequent 250 isolates screened:

Triadimenol	25.00 mg a.i.l^{-1}	($^1/_{25}$ th field rate)
	19.53 mg a.i.l^{-1}	($^1/_{32}$ nd " ")
	15.63 mg a.i.l^{-1}	($^1/_{40}$ th " ")
	0.00 mg a.i.l^{-1}	(nil rate)
Fenpropimorph	288.50 mg a.i.l^{-1}	($^1/_{13}$ th field rate)
	234.00 mg a.i.l^{-1}	($^1/_{16}$ th " ")
	187.50 mg a.i.l^{-1}	($^1/_{20}$ th " ")
	0.00 mg a.i.l^{-1}	(nil rate)

The wetting agent, Pluronic, was used at a concentration of 0.025% for all treatments, including the control of water at nil chemical rate.

Spraying was by means of a field application simulator sprayer delivering 200 $l.ha^{-1}$ at a pressure of 2 bars and travelling at 1 $m.sec^{-1}$. Seedling were inoculated 24 hours after spraying with a mixture of fresh spores and talc (1 part spores to 20 of talc), using a rotary spore inoculator. Spores of a control wheat yellow rust isolate (coded WYR 83/62) were multiplied for each test from a pure stock stored in a freeze-dried state in ampoules to ensure consistency of reaction over time. This was necessary to facilitate comparisons between tests.

Following incubation at 7°C for 48 hours at high humidity, seedlings were transferred to a controlled environment growth room (16 hours light at 18°C, 8 hours dark at 11°C).

Assessment and evaluation of results

The proportion of each first seedling leaf, from base to tip, on which pustules were present was assessed. This was carried out 4-5 days after the appearance of pustules on the untreated seedlings.

Infection tended to be greatest towards the proximal end of the leaf and least towards the distal end, presumably due to the movement of the fungicide towards the leaf tips. There was generally a clear cut-off point where infection ceased (see Figure 1).

In order to facilitate comparison of isolates between screens, a formula was devised to allow infection data to be expressed as a value 'D', which compares the performance of a test isolate with that of the control isolate (WYR 83/62) at any particular fungicide rate.

$$D = 100 . \frac{Ix_t}{Ic_t} - 100 . \frac{Ix_c}{Ic_c}$$

Ix_t = Proportion of leaf infected with test isolate at rate x.

Ic_t = Proportion of leaf infected with test isolate at nil rate.

Ix_c = Proportion of leaf infected with control isolate at rate x.

Ic_c = Proportion of leaf infected with control isolate at nil rate.

Positive values of D indicated test isolates which were less sensitive to fungicide than the control, whilst negative values of D indicated isolates which were more sensitive than the control.

Isolate classification

Isolates collected during the U.K. Cereal Pathogen Virulence Survey were classified according to year of collection, their source (location by county, and variety collected from), virulence factors and whether or not the crop from which they were taken had received a fungicide application. If fungicide had been applied then product group used and the number of applications were also recorded.

This information (shown in Appendix I) was used to divide isolates into various groups for comparisons. The broad classification of all isolates tested is shown in Figure 2a.

Isolates were first divided according to year of collection. Five time periods were initially compared, those collected in 1960-79, 1980-87, 1988, 1989 and 1990. However, due to small numbers of values in the earlier groups, isolates were compared again after placing all isolates collected prior to 1989 into a single group. Figures 26-d show the isolate classification divided into time periods of pre-1989, 1989 and 1990.

Isolates were then placed into groups according to whether or not they originated from crops which had received a fungicide application irrespective of chemical type. They were further divided by whether or not they possessed the virulence factors WYV 6,9, (enabling them to overcome the resistance of the cultivar Hornet) and then on their origin (north or south of the River Tyne).

The possession or lack of WYV 6,9 was considered important as this was a new virulence combination that first appeared in 1988 (Bayles et al

1989). No other virulence combinations could be examined in this way because of the small numbers of revelant isolates available.

Using these groups, isolates having different backgrounds were compared, and therefore any effect a character had on fungicide sensitivity could be evaluated.

Initially broad groups were compared, e.g. all fungicide-treated isolates with all untreated isolates. The isolates were broken down by year of collection into their three time periods (pre-1989, 1989 and 1990) and compared again. To take out any additional effect of either geographical origin or virulence factor possessed, smaller groups were compared with these variables removed. These smaller groups were generally only compared when all isolates tested were included as the number of values became too low to give reliable comparisons.

Fungicide-treated and untreated isolates were compared to see if fungicide application influenced sensitivity. This was further investigated by comparing isolates which had only one fungicide application prior to collection with those that had two or more applications.

Insufficient isolates were collected from crops that had only received either a morpholine or a triazole fungicide application to investigate whether fungicide group influenced sensitivity.

Any influence of collection location (either north or south of the River Tyne) was evaluated. Further comparisons were made to see whether or not there was any difference between isolates collected in the east of England (East Anglia and Lincolnshire; yellow rust "hot-spots") and those from the rest of the southern region.

The influence of the "Hornet virulence" (WYV 6,9) was investigated.

The data are shown in the form of D value distributions (Figures 3a-14d). Medians were estimated as a measure of position of the distributions. To determine whether the medians of different groups differed significantly a Mann-Whitney U test (2-tailed) was employed (Campbell, 1981).

Secondary screening

The isolate WYR 90/20 showed a clear difference in sensitivity in primary screenings. It was thus selected for further testing. The test was the same as for primary screening except that five replications were made at the seven higher rates of each fungicide given below:

Triadimenol

625.00 mg a.i.l^{-1} (field rate)

416.70 mg a.i.l^{-1} ($^2/_3$rds field rate)

312.50 mg a.i.l^{-1} ($^1/_2$ " ")

208.30 mg a.i.l^{-1} ($^1/_3$rd " ")

104.20 mg a.i.l^{-1} ($^1/_6$th " ")

52.10 mg a.i.l^{-1} ($^1/_{12}$th " ")

31.30 mg a.i.l^{-1} ($^1/_{20}$th " ")

0.00 mg a.i.l^{-1} (nil rate)

Fenpropimorph

3,750.00 mg a.i.l^{-1} (field rate)

2,500.00 mg a.i.l^{-1} ($^2/_3$rds field rate)

1,875.00 mg a.i.l^{-1} ($^1/_2$ " ")

1,250.00 mg a.i.l^{-1} ($^1/_3$rd " ")

625.00 mg a.i.l^{-1} ($^1/_6$th " ")

312.50 mg a.i.l^{-1} ($^1/_{12}$th " ")

187.50 mg a.i.l^{-1} ($^1/_{20}$th " ")

0.00 mg a.i.l^{-1} (nil rate)

The percentage of first-leaf area covered by uredia was compared between the control (WYR 83/62) and test (WYR 90/20) isolates using an analysis of variance of the means, for each rate of fungicide.

RESULTS

303 wheat yellow rust isolates were screened for sensitivity to triadimenol and fenpropimorph. Results were obtained for 298 isolates to triadimenol, and 278 isolates to fenpropimorph.

Primary screening

Dvalues were compared between groups of isolates. The lower the values (more negative) the greater their sensitivity to the fungicide. Distribution graphs were presented for the dose rates common throughout the primary screens i.e. 1/40th field rate triadimenol and 1/20th field rate fenpropimorph.

Influence of year

i) Triadimenol

No consistent changes in the sensitivity of isolates with time were found. Isolates collected in 1989 were less sensitive than those collected either prior to 1989, or during 1990 when tested at 1/40th and 1/32nd field rate (Table 1a and Figs 3a and b). Isolates collected prior to 1989 did not differ from 1990 isolates (Fig 3c).

When the isolates collected prior to 1989 were divided into three groups (those collected between 1960 and 1979, 1980 and 1987 and in 1988) and the comparison made again, the 1989 isolates were less sensitive than those collected during 1980-87 when tested at 1/40th and 1/32nd field rate. The 1989 isolates were also less sensitive than those collected in 1988 at 1/32nd field rate only. At 1/25th field rate, isolates from 1988 appeared less sensitive than those from 1980-87 (Table 1b).

ii) Fenpropimorph

No changes in isolate sensitivity were found with time when pre-1989, 1989 and 1990 isolates were compared (Table 2a and Figs 4a-c). Some differences in sensitivity were found between years when the isolates collected prior to 1989 were divided into three groups (Table 2b). Isolates from the period

1980-87 appeared less sensitive than those collected in 1988 when tested at 1/16th and 1/13th field rate. They were also less sensitive than those collected in 1990 at 1/16th field rate and nearly significantly less sensitive at 1/20th field rate. Isolates from 1989 and 1960-79 were less sensitive than those from 1988 at 1/13th field rate.

The data in Tables 1b and 2b must be treated with caution as the small numbers of values may give a false impression of overall sensitivity. On balance the evidence suggests that by 1989 isolates had decreased slightly in sensitivity to triadimenol. However, in 1990 there was a return to previous sensitivity levels.

There was no evidence to suggest that there had been any decrease in sensitivity to fenpropimorph with time.

Influence of fungicide application

i) Triadimenol

Table 3a and Figure 5a show the comparison of all isolates from fungicide-treated and fungicide-untreated plots. There was no significant difference between the sensitivities of "treated" and "untreated" isolates, although at 1/32nd field rate the "treated" isolates were almost significantly less sensitive.

Table 3b and Figure 5b show the comparison of all "treated" and "untreated" isolates screened to triadimenol when only southern isolates not possessing WYV 6,9 are compared. "Treated" isolates were less sensitive at 1/32nd field rate.

When isolates from the south possessing WYV 6,9 were compared, the reverse occurred. "Untreated" isolates were significantly less sensitive than "treated" at 1/40th field rate (Table 3c and Fig. 5c). However, this result should be interpreted with caution because of the small number of isolates involved.

When individual year groups were analysed, no differences were found in the sensitivities of "treated" and "untreated" isolates (Tables 3d-f).

ii) Fenpropimorph

Table 4a and Figure 6a show the comparison of all "treated" and "untreated" isolates. Although there were no significant differences between the medians, the "treated" isolates had higher D value medians, (i.e. towards insensitivity), than the "untreated" isolates at all three rates of fungicide.

When only southern isolates without WYV 6,9 were compared, the medians of the "treated" isolates were again higher than those of the "untreated" isolates at all three fungicide rates, but they were not significantly different (Table 4b and Fig. 6b).

Southern isolates, possessing WYV 6,9 showed no significant differences between "treated" and "untreated" isolates (Table 4c and Fig. 6c).

Isolates from the pre-1989 and 1990 group showed no effect of fungicide treatment (Tables 4d and f) but the "treated" isolates from 1989 were almost significantly different from the "untreated" at 1/20th field rate (Table 4e). When only southern isolates without WYV 6,9 were compared, the "treated" isolates were significantly less sensitive at 1/20th and 1/16th field rate (Table 4g).

Influence of the number of fungicide applications

No decrease in sensitivity to triadimenol or fenpropimorph was found when isolates which originated from crops which had received two or more fungicide applications were compared with those which received only one application (Tables 5 and 6 and Figs 7 and 8).

Influence of geographical location

a) North v. south

i) Triadimenol

When all isolates from the north were compared with those from the south, large differences were found. Southern isolates were highly significantly less sensitive at 1/40th and 1/32nd field rate. They were also less sensitive, although not significantly so, at 1/25th field rate (Table 7a and Fig. 9a).

When only "untreated" isolates without WYV 6,9 were compared, no significant differences were found, although the southern isolates appeared less sensitive at all three rates (Table 7b and Fig. 9b).

When all "untreated" isolates with WYV 6,9 were compared, the southern isolates were significantly less sensitive at 1/40th field rate and almost so at 1/32nd field rate. They also appeared less sensitive than the northern isolates at 1/25th field rate (Table 7c and Fig. 9c).

There was no significant difference in sensitivity between northern and southern isolates collected before 1989, although the southern isolates again appeared less sensitive at almost all the fungicide rates (Table 7d).

Southern isolates from 1989 were significantly less sensitive at 1/32nd field rate and almost so at 1/40th field rate (Table 7e).

The southern isolates collected in 1990 were almost significantly less sensitive at 1/40th field rate only, and had higher medians but were generally less sensitive at the other two rates, but not significantly (Table 7f).

ii) Fenpropimorph

Southern isolates were highly or very significantly different from the northern isolates, being less sensitive at all three rates (Table 8a and Fig. 10a). Significant reduction in sensitivity was also seen with the "untreated" isolates without WYV 6,9 at 1/20th field rate (Table 8b and Fig. 10b) and with the "untreated" isolates with WYV 6,9 at all rates (Table 8c and Fig. 10c).

Isolates collected from the south prior to 1989 were less sensitive than northern isolates at all rates, highly significantly so at 1/20th field rate (Table 8d). Isolates from 1989 (Table 8e), and from 1990 also had lower sensitivity when from the south, very significant for 1990 collections tested at 1/20th rate (Table 8f).

b) East Anglia and Lincolnshire v. rest of south

i) Triadimenol

No difference in sensitivity was found when isolates from East Anglia and Lincolnshire were compared with those from the rest of the southern region (Table 9a and Fig. 11a). When these isolates were subdivided into groups "untreated" isolates without WYV 6,9, "untreated" isolates with WYV 6,9, and "treated" isolates without WYV 6,9, no differences in sensitivity were detected between the two areas (Tables 9b-d and Figs 11b-d).

ii) Fenpropimorph

No differences were found between isolates from the two geographic areas (Table 10a and Fig. 12a). "Untreated" isolates without WYV 6,9 from East Anglia and Lincolnshire were significantly less sensitive at 1/20th field rate only (Table 10b and Fig. 12b). For "untreated" isolates possessing WYV 6,9, those from the east again appeared less sensitive (Table 10c and Fig. 12c).

When comparing "treated" isolates, however, of isolates possessing WYV 6,9 those from the bulk of the southern region were significantly less sensitive than the eastern isolates at all three fungicide rates (Table 10d and Fig. 12d). This was in contrast to the results for "untreated" isolates, but as there was only a small number of isolates the results should be interpreted with caution.

Influence of the virulence type WYV 6,9

i) Triadimenol

Isolates without WYV 6,9 were significantly less sensitive than isolates with this virulence combination at 1/40th and 1/25th field rate (Table 11a and Fig. 13a). However, when the isolates were divided into groups, and any influence of geographical origin removed, fewer differences were found.

"Untreated", southern isolates showed no differences when compared with or without this virulence combination (Table 11b and Fig. 13b). When "treated" isolates from the south were compared, the isolates without WYV 6,9 were significantly less sensitive at 1/40th field rate only (Fig. 13c). At 1/32nd and 1/25th field rates these isolates also had higher median values (although not significantly so) (Table 11c).

"Untreated", northern isolates showed no differences in sensitivity related to virulence, although there were few data values for isolates without WYV 6,9 (Table 11d and Fig. 13d).

When isolates were grouped according to collection years, those collected before 1989 showed no significant differences between isolates with or without the virulence combination, although isolates not possessing WYV 6,9 had higher medians (Table 11e).

Isolates from 1989 also did not differ significantly in sensitivity, although at 1/40th field rate, those not possessing WYV 6,9 were almost significantly more sensitive than those without it (Table 11f).

In 1990, however, the isolates without WYV 6,9 appeared less sensitive although their median values were not significantly higher (Table 11g).

Isolate division by year group alone results in virulence combination and geographical origin being statistically confounded and should be treated with caution. Reference to Figures 2b-c shows that the WYV 6,9 virulence factor was only present in northern isolates before 1989, but that by 1989 and 1990 this virulence was possessed by isolates from both origins while still absent from only some southern isolates.

ii) Fenpropimorph

Isolates without WYV 6,9 were highly significantly different at all three rates of fungicide (Table 12a and Fig. 14a). When the confounding effect of isolate origin was removed and either the "untreated" or "treated", southern isolates compared (Tables 12b and c), isolates without WYV 6,9 appeared less sensitive at 1/20th field rate only (Figs 14b and c). The isolates without WYV 6,9 were significantly less sensitive at 1/16th field rate and almost so at 1/20th (Table 12c and Fig. 14c). No differences were found when all "untreated", northern isolates were compared (Table 12d and Fig. 14d).

Significant differences were found within each year group, isolates without WYV 6,9 having reduced sensitivity (Table 12e-g). However due to confounded interactions with geographical origins, the significance of possession of WYV 6,9 should be treated with reserve.

Secondary screening

WYR 90/20

WYR 90/20 showed a markedly decreased sensitivity, compared with the control isolate (WYR 83/62), to both triadimenol and fenpropimorph to a similar degree (Figs. 15a and b). WYR 90/20 clearly grew more vigourously in the presence of fungicide than the control isolate, and had a shorter latent period on treated plants. The difference in the proportion of the leaf on which WYR 90/20 would grow and produce pustules compared to WYR 83/62 was represented diagrammatically for all fungicide rates of triadimenol (Fig. 16a) and fenpropimorph (Fig. 16b).

EC75 (75% effective concentration) values were estimated, to give the concentration of fungicide which reduced the area of uredia production to 25% of that on control leaves.

i) Triadimenol (Field rate 625 mg a.i.l -1)

Isolate	EC75 mg a.i.l^{-1}	Proportion of field rate
WYR 83/62	46.8	$^1/_{13}$ - $^1/_{14}$th
WYR 90/20	177.8	$^1/_3$ - $^1/_4$th

ii) Fenpropimorph (Field rate 3,750 mg a.i.l -1)

Isolate	EC75 mg a.i.l^{-1}	Proportion of field rate
WYR 83/62	501.2	$^1/_7$ - $^1/_8$th
WYR 90/20	1258.9	$^1/_3$rd

To reduce WYR 90/20 uredia production by 75% required over three times the concentration of triadimenol and over twice the concentration of fenpropimorph required to restrict the development of WYR 83/62 to the same extent.

DISCUSSION

To date, there have been no substantiated reports of the failure of the fungicides triadimenol or fenpropimorph to control yellow rust in the field and there was no evidence from this investigation to suggest that the sensitivity of Puccinia striiformis to either fungicide has declined over the past twenty years. With the exception of a single isolate, yellow rust development was discernible only at very low rates of fungicide application, up to a maximum of 1/20th field rate of triadimenol and 1/10th field rate of fenpropimorph. Despite this, a number of significant contrasts emerged when median values were compared for groups of isolates differing in origin and virulence. These indicated possible effects of selection acting on variability for fungicide sensitivity in the pathogen population.

The only isolate to show a marked and consistent shift towards insensitivity (WYR 90/20) was able to make limited growth at fungicide rates as high as 1/2 to 2/3 of field rate of both chemicals and to achieve 40% to 50% of the infection level on untreated seedlings at 1/12 to 1/6 field rate. If this performance were to be paralled in the field, it would represent a major step towards the eventual reduction of fungicide efficacy.

One of the most consistently significant comparisons was that between isolates of different virulence type, with isolates possessing the virulence combination WYV 6,9 being more sensitive than others to both fungicides. The WYV 6,9 combination was detected relatively recently, in 1988, when it was identified in a few isolates from Northumberland and Scotland. It seems possible therefore that the initial mutations to WYV 6,9 took place in populations which were, by chance, relatively sensitive to fungicide, before southward migration of the new virulence type. The tendency for 'Northern' isolates to be more sensitive than those from the remainder of the UK suggests that northern populations were in any case relatively sensitive at the critical time.

Comparisons between isolates of northern and southern origin showed marked differences, with southern isolates being less sensitive to both triadimenol and fenpropimorph. This geographical difference was apparent for both WYV 6,9 isolates and non-WYV 6,9 isolates, indicating that it was partly independent of the preponderance of the less sensitive non-WYV 6,9 types in the south. The trend may be related to more intensive and longer term fungicide use in the cereal growing areas of the south. It is difficult to explain the observation that isolates from the East Anglia/Lincolnshire area, traditionally known for high input cereal growing and vulnerability to yellow rust infection, should be more sensitive to fenpropimorph than isolates from the remainder of the south.

Although there was no evidence of a general decline in fungicide sensitivity over time, a number of year-related comparisons were significant. The most obvious of these was that isolates collected in 1989 were less sensitive to triadimenol than isolates from earlier years or from the following year, 1990. This may be partly due to the outstanding severity of the yellow rust epidemic in 1989 and the intensive use of fungicides to control the disease in crops of the highly susceptible cultivar Slejpner. It is interesting that a similar effect was not detected with respect to fenpropimorph sensitivity, since in general, sensitivity to the two fungicides appeared to be closely related.

There was little evidence that fungicide application to a crop influenced the sensitivity of isolates collected from it. The only significant comparisons for triadimenol gave conflicting indications and, for fenpropimorph, significant comparisons were derived only from a small sub-group of isolates. However, the lack of detailed information on fungicide products and timing in relation to sampling date made it difficult to analyse the results satisfactorily. In particular, it was rarely possible to judge whether the isolate had been derived from plants reinfected by ingress of inoculum from outside the crop or by inoculum produced from infections present in the crop at the time of spraying. Ingress of inoculum might well mask the effects of selection taking place within the crop.

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Tables 1a and b. Median D values for isolates screened at three rates of triadimenol, compared between collection years, with significant differences shown by Mann-Whitney U tests.

Table 1a. Isolates collected before 1989, in 1989 and in 1990.

Time Period	1/40		1/32		1/25	
	Median	n	Median	n	Median	n
<1989 (1960-1988)	-3.4	101	-6.1	58	-1.6	59
1989	-0.1	115	-1.4	115	-2.4	116
1990	-3.5	74	-3.9	77	-2.4	75

No significant differences $(P>0.05)$ between isolate years,
<u>except</u> at 1/40 1989 less sensitive $(P\leq 0.05)$ than pre-1989 and
1989 less sensitive $(P\leq 0.01)$ than 1990,
at 1/32 1989 less sensitive $(P\leq 0.05)$ than 1990 and
1989 less sensitive $(P\leq 0.01)$ than pre-1989.

Table 1b. Isolates collected between 1960-79, 1980-87, in 1988, 1989 and 1990.

Time Period	1/40		1/32		1/25	
	Median	n	Median	n	Median	n
1960-79	- 2.8	22	- 5.6	22	- 1.6	21
1980-87	- 4.0	34	- 6.1	18	- 4.4	19
1988	- 3.4	45	- 6.0	18	0.1	19
1989	- 0.1	115	- 1.4	115	- 2.4	116
1990	- 3.5	74	- 3.9	77	- 2.4	75

No significant differences $(P>0.05)$ between isolate years,
<u>except</u> at 1/40 1989 less sensitive $(P\leq 0.05)$ than 1980-87 and
1989 less sensitive $(P\leq 0.01)$ than 1990,
at 1/32 1989 less sensitive $(P\leq 0.05)$ than 1989-87,
1988 and 1990,
at 1/25 1988 less sensitive $(P\leq 0.05)$ than 1980-87.

Tables 2a and b. Median D values for isolates screened at three rates of fenpropimorph compared between collection years, with significant differences shown by Mann-Whitney U tests.

Table 2a. Isolates collected before 1989, in 1989 and in 1990.

Time Period	1/20		1/16		1/13	
	Median	n	Median	n	Median	n
<1989 (1960-1988)	-10.2	94	-2.5	56	-4.5	58
1989	-8.4	111	-5.2	112	-5.1	112
1990	-7.8	62	-6.5	61	-4.2	58

No significant differences (P>0.05) between isolate years.

Table 2b. Isolates collected between 1960-79, 1980-87, in 1988, 1989 and 1990.

Time Period	1/20		1/16		1/13	
	Median	n	Median	n	Median	n
1960-79	-11.0	21	- 0.9	21	- 3.3	21
1980-87	- 2.0	30	3.1	18	- 2.0	19
1988	-13.0	43	- 5.5	17	- 8.6	18
1989	- 8.4	111	- 5.2	112	- 5.1	112
1990	- 7.8	62	- 6.5	61	- 4.2	58

No significant differences (P>0.05) between isolate years,
<u>except</u> at 1/16 1980-87 less sensitive (P⩽0.05) than 1988 and 1990.
at 1/13 1980-87 less sensitive (P⩽0.05) than 1988 and
1989 less sensitive (P⩽0.05) than 1988.

Tables 3a-f. Median D values for isolates screened to three rates of triadimenol compared according to whether or not fungicide was applied prior to sampling (F+ or F-). Values significantly different ($P \leqslant 0.05$)* or nearly significantly different ($P \leqslant 0.1$)≠, or not significantly different ($P > 0.05$) NS, by Mann-Whitney U tests.

Table 3a. All isolates.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/40	- 1.6	76	- 2.6	214	NS
1/32	- 2.6	64	- 3.8	186	≠ (0.07)
1/25	- 4.4	64	- 2.1	186	NS

Table 3b. Southern isolates, not possessing WYV 6,9.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/40	- 0.6	52	- 1.3	88	NS
1/32	1.5	42	- 3.8	67	*
1/25	- 2.6	42	- 0.8	68	NS

Table 3c. Southern isolates, possessing WYV 6,9.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/40	-10.1	16	- 1.0	45	*
1/32	- 3.6	16	- 2.2	46	NS
1/25	- 5.4	16	- 2.9	45	NS

Table 3d. Isolates collected before 1989.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/80	- 2.7	12	0.6	34	NS
1/40	- 4.7	18	- 3.4	83	NS
1/20	- 1.3	12	1.4	37	NS

Table 3e. Isolates collected in 1989.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/40	- 1.3	29	- 0.2	86	NS
1/32	1.1	29	- 1.6	86	NS
1/25	- 4.3	29	- 2.1	87	NS

Table 3f. Isolates collected in 1990.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/40	- 1.5	29	- 4.5	45	NS
1/32	- 3.6	29	- 5.7	48	NS
1/25	- 2.8	29	- 2.1	46	NS

Tables 4a-g. Median D value for isolates screened to three rates of fenpropimorph compared according to whether or not fungicide was applied prior to sampling (F+ or F-). Values significantly different ($P \leqslant 0.05$)*, or nearly significantly different ($P \leqslant 0.1$)≠, or not significantly different ($P > 0.05$) NS, by Mann Whitney U tests.

Table 4a. All isolates.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/20	- 5.5	72	- 9.8	195	NS
1/16	- 4.8	61	- 5.5	168	NS
1/13	- 2.8	59	- 5.5	169	NS

Table 4b. Southern isolates, not possessing WYV 6,9.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/20	- 3.7	50	- 4.7	81	NS
1/16	- 2.4	41	- 6.3	63	NS
1/13	- 2.1	41	- 3.4	62	NS

Table 4c. Southern isolates possessing WYV 6,9.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/20	-11.4	14	- 8.8	38	NS
1/16	-11.4	15	- 4.1	37	NS
1/13	- 4.4	12	- 4.8	38	NS

Table 4d. Isolates collected before 1989.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/20	- 9.8	11	- 0.5	31	NS
1/16	- 5.3	17	-10.3	77	NS
1/13	- 0.1	11	- 0.0	35	NS

Table 4e. Isolates collected in 1989.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/20	- 4.7	28	- 9.8	83	≠ (0.08)
1/16	- 4.5	28	- 5.7	84	NS
1/13	- 2.7	28	- 5.7	84	NS

Table 4f. Isolates collected in 1990.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/20	- 7.6	27	- 8.0	35	NS
1/16	- 5.0	27	- 7.6	34	NS
1/13	- 3.3	24	- 4.7	34	NS

Table 4g. Southern isolates not possessing WYV 6,9 collected in 1989.

Rate	F+		F-		Significance level
	Median	n	Median	n	
1/20	- 2.2	20	- 6.3	35	*
1/16	- 1.3	20	- 6.5	35	*
1/13	- 1.7	20	- 4.8	35	NS

Table 5. Median D values for isolates screened to three rates of triadimenol, compared according to the number of fungicide applications to the crop before sampling. Values not significantly different (P>0.05) NS.

Rate	1 application		2 or more applications		Significance level
	Median	n	Median	n	
1/20	- 5.3	45	- 3.4	19	NS
1/16	- 4.9	39	- 0.2	17	NS
1/13	- 1.9	35	- 4.1	18	NS

Fig. 7. Comparison of D value frequency distributions between isolates collected after either one or more fungicide applications to the crop and screened to triadimenol at 1/40th field rate. Median values not significantly different (P>0.05) NS.

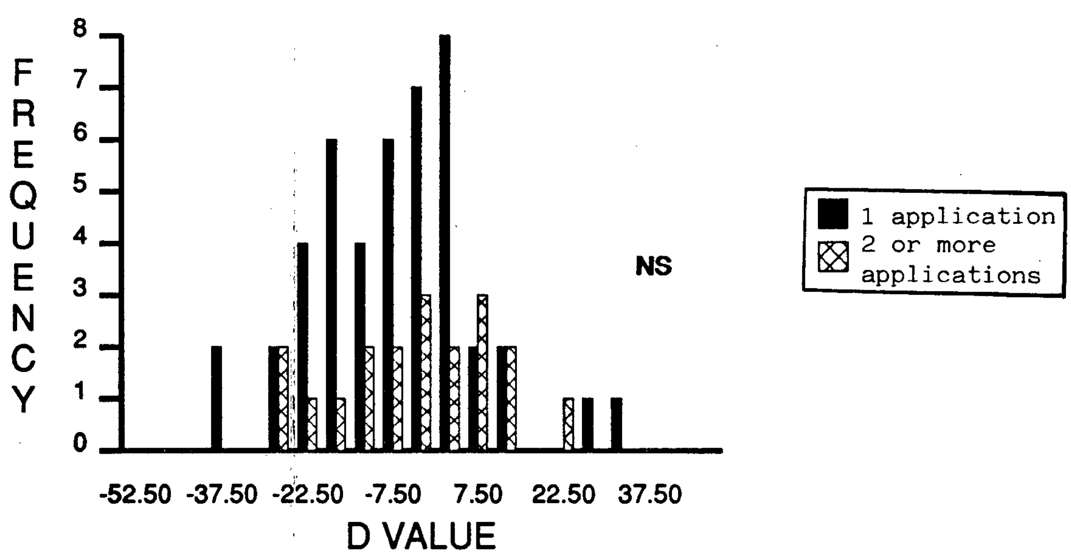
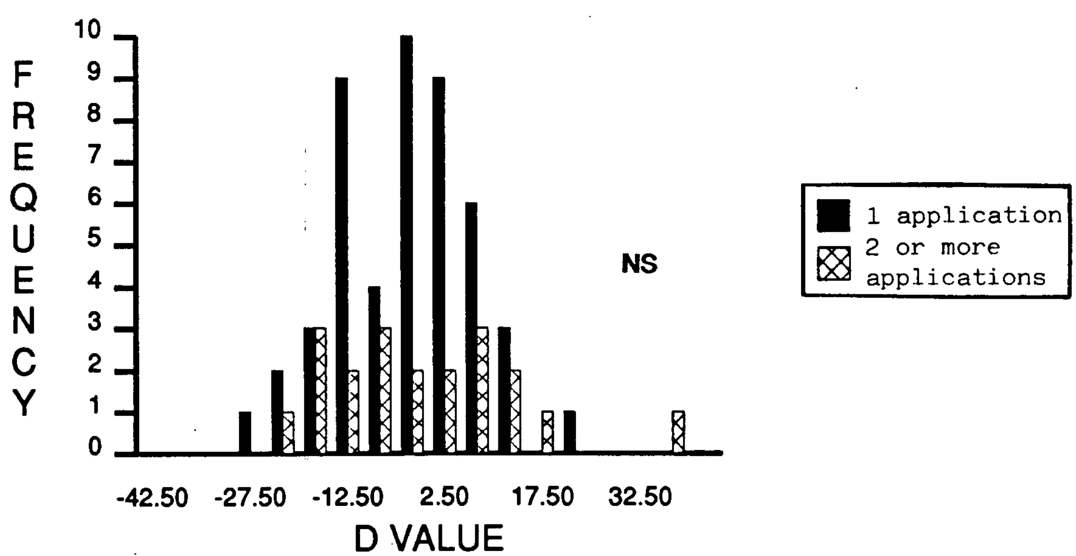


Table 6. Median D value for isolates screened to three rates of fenpropimorph, compared according to the number of fungicide applications to the crop before sampling. Values not significantly different (P>0.05) NS.

Rate	1 application		2 or more applications		Significance level
	Median	n	Median	n	
1/40	- 1.5	48	- 3.7	20	NS
1/32	0.0	41	- 4.0	17	NS
1/25	- 2.8	41	- 7.6	17	NS

Fig. 8. Comparison of D value frequency distributions between isolates collected after either one or more fungicide applications to the crop and screened to fenpropimorph at 1/20th field rate. Median values not significantly different (P>0.05) NS.



Tables 7a-f. Median D values for isolates screened to triadimenol at three rates compared according to northern or southern origin. Values significantly different (P⩽0.01)**, (P⩽0.05)*, or nearly significantly different (P⩽0.1)≠, or not significantly different (P>0.05)NS.

Table 7a. All isolates.

Rate	North		South		Significance level
	Median	n	Median	n	
1/40	- 5.6	70	- 1.3	204	**
1/32	- 6.4	58	- 3.3	175	**
1/25	- 5.0	58	- 2.0	175	NS

Table 7b. "Untreated" isolates, not possessing WYV 6,9.

Rate	North		South		Significance level
	Median	n	Median	n	
1/40	- 4.2	15	- 1.3	88	NS
1/32	- 8.3	10	- 3.8	67	NS
1/25	- 4.9	10	- 0.8	68	NS

Table 7c. "Untreated" isolates possessing WYV 6,9.

Rate	North		South		Significance level
	Median	n	Median	n	
1/40	- 6.2	50	- 1.0	45	*
1/32	- 5.4	45	- 2.2	46	≠ (0.09)
1/25	- 5.1	45	- 2.9	45	NS

Table 7d. Isolates collected before 1989.

Rate	North		South		Significance level
	Median	n	Median	n	
1/80	- 4.7	16	1.5	28	NS
1/40	- 4.5	33	- 3.3	52	NS
1/32	- 7.4	20	- 4.4	22	NS
1/25	- 5.1	20	- 1.3	23	NS
1/20	1.1	18	2.0	28	NS

Table 7e. Isolates collected in 1989.

Rate	North		South		Significance level
	Median	n	Median	n	
1/40	- 4.0	23	1.1	92	≠ (0.09)
1/32	- 4.0	22	- 0.3	92	*
1/25	- 3.0	23	- 2.3	92	NS

Table 7f. Isolates collected in 1990.

Rate	North		South		Significance level
	Median	n	Median	n	
1/40	- 9.0	14	- 1.7	60	≠ (0.08)
1/32	- 4.8	16	- 3.9	61	NS
1/25	- 6.1	15	- 1.8	60	NS

Tables 8a-f. Median D values for isolates screened to fenpropimorph at three rates compared according to northern or southern origin. Values significantly different (P⩽0.001)***, (P⩽0.01)**, (P⩽0.05)*, or nearly significantly different (P⩽0.1)≠, or not significantly different (P>0.05)NS.

Table 8a. All isolates.

Rate	North		South		Significance level
	Median	n	Median	n	
1/20	-16.1	66	- 5.5	186	***
1/16	- 6.6	53	- 4.9	160	**
1/13	- 9.6	55	- 3.8	157	***

Table 8b. "Untreated" isolates not possessing WYV 6,9.

Rate	North		South		Significance level
	Median	n	Median	n	
1/20	-21.4	14	- 4.7	81	**
1/13	-10.7	10	- 3.4	62	NS

Table 8c. "Untreated" isolates possessing WYV 6,9.

Rate	North		South		Significance level
	Median	n	Median	n	
1/20	-15.6	47	- 8.8	38	**
1/16	- 6.1	42	- 4.1	37	*
1/13	- 8.5	42	- 4.8	38	*

Table 8d. Isolates collected before 1989.

Rate	North		South		Significance level
	Median	n	Median	n	
1/60	-12.1	14	- 0.8	25	NS
1/20	-23.1	30	- 1.8	49	***
1/16	-15.7	18	2.5	23	*
1/13	- 9.9	19	- 3.1	24	*
1/10	- 1.4	15	0.1	28	*

Table 8e. Isolates collected in 1989.

Rate	North		South		Significance level
	Median	n	Median	n	
1/20	-13.1	22	- 6.7	89	*
1/16	- 5.5	23	- 5.2	88	NS
1/13	- 8.2	23	- 4.1	88	*

Table 8f. Isolates collected in 1990.

Rate	North		South		Significance level
	Median	n	Median	n	
1/20	-17.3	14	- 5.9	48	**
1/16	-21.8	12	- 5.0	49	*
1/13	-11.0	13	- 2.3	45	≠ (0.07)

Tables 9a-d. Median D values for southern isolates screened to triadimenol at three rates, compared according to area of origin. Values not significantly different (P>0.05)NS.

Table 9a. All isolates.

Rate	South excluding E.A. & Lincs		East Anglia & Lincs		Significance level
	Median	n	Median	n	
1/40	- 1.5	61	- 1.5	144	NS
1/32	- 4.6	57	- 3.0	121	NS
1/25	- 1.9	59	- 2.1	119	NS

Table 9b. "Untreated" isolates, not possessing WYV 6,9.

Rate	South excluding E.A. & Lincs		East Anglia & Lincs		Significance level
	Median	n	Median	n	
1/40	- 0.8	24	- 2.0	63	NS
1/32	- 3.4	21	- 3.3	47	NS
1/25	- 0.4	22	- 0.9	47	NS

Table 9c. "Untreated" isolates, possessing WYV 6,9.

Rate	South excluding E.A. & Lincs		East Anglia & Lincs		Significance level
	Median	n	Median	n	
1/40	- 3.2	19	0.05	26	NS
1/32	- 5.4	20	- 2.2	26	NS
1/25	- 2.0	20	- 3.3	25	NS

Table 9d. "Treated" isolates, not possessing WYV 6,9.

Rate	South excluding E.A. & Lincs		East Anglia & Lincs		Significance level
	Median	n	Median	n	
1/40	1.4	11	- 1.5	43	NS
1/25	- 4.7	10	- 3.7	34	NS

Tables 10a-d. Median D values for southern isolates screened to fenpropimorph at three rates, compared according to area of origin. Values significantly different ($P \leqslant 0.05$)*, or not ($P > 0.05$)NS.

Table 10a. All isolates.

Rate	South excluding E.A. & Lincs		East Anglia & Lincs		Significance level
	Median	n	Median	n	
1/20	- 9.0	55	- 5.2	133	NS
1/16	- 4.1	53	- 4.9	110	NS
1/13	- 4.1	52	- 3.4	108	NS

Table 10b. "Untreated" isolates not possessing WYV 6,9.

Rate	South excluding E.A. & Lincs		East Anglia & Lincs		Significance level
	Median	n	Median	n	
1/20	-11.1	21	- 3.7	58	*
1/16	- 7.9	20	- 6.0	44	NS
1/13	- 5.2	20	- 2.7	43	NS

Table 10c. "Untreated" isolates possessing WYV 6,9.

Rate	South excluding E.A. & Lincs		East Anglia & Lincs		Significance level
	Median	n	Median	n	
1/20	-11.1	16	- 6.7	23	NS
1/16	- 5.3	16	- 3.4	21	NS
1/13	- 5.8	17	- 4.8	21	NS

Table 10d. "Treated" isolates not possessing WYV 6,9.

Rate	South excluding E.A. & Lincs		East Anglia & Lincs		Significance level
	Median	n	Median	n	
1/20	0.6	12	- 5.2	40	*
1/16	5.9	10	- 4.8	33	*
1/13	3.5	10	- 3.1	33	*

Tables 11a-g. Median D values for isolates screened to triadimenol at three rates, compared according to possession of WYV 6,9 or not (WYV -6,9). Values significantly different ($P \leqslant 0.05$)*, or nearly significantly different ($P \leqslant 0.1$)≠, or not significantly different ($P > 0.05$)NS.

Table 11a. All isolates.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/40	- 3.7	114	- 1.2	171	*
1/32	- 4.1	110	- 3.6	136	NS
1/25	- 3.8	109	- 0.9	137	*

Table 11b. "Untreated", southern isolates.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/40	- 1.0	45	- 1.3	88	NS
1/32	- 2.2	46	- 3.8	67	NS
1/25	- 2.9	45	- 0.8	68	NS

Table 11c. "Treated", southern isolates.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/40	-10.1	16	- 0.6	52	*
1/32	- 3.6	16	1.5	42	NS
1/25	- 5.4	16	- 2.6	42	NS

Table 11d. "Untreated", northern isolates.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/40	- 6.2	50	- 4.2	15	NS
1/32	- 5.4	45	- 8.3	10	NS
1/25	- 5.1	45	- 4.9	10	NS

Table 11e. Isolates collected before 1989.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/40	- 4.8	16	- 3.4	83	NS
1/32	- 6.7	10	- 5.4	48	NS
1/25	- 5.3	10	- 1.3	49	NS

Table 11f. Isolates collected in 1989.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/40	- 1.9	57	- 2.6	58	≠ (0.07)
1/32	- 1.4	57	- 1.5	58	NS
1/25	- 3.1	58	- 1.6	58	NS

Table 11g. Isolates collected in 1990.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/40	- 5.3	41	- 1.2	30	≠ (0.1)
1/32	- 5.6	43	- 3.7	30	NS
1/25	- 6.0	41	- 0.8	30	NS

Tables 12a-g. Median D values for isolates screened to fenpropimorph at three rates, compared according to possession of WYV 6,9 or not (WYV -6,9). Values significantly different (P⩽0.001)***, (P⩽0.01)**, (P⩽0.05)*, or nearly significantly different (P⩽0.1)≠, or not significantly different (P>0.05)NS.

Table 12a. All isolates.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/20	-12.7	102	- 5.3	160	***
1/16	- 5.6	96	- 4.8	129	**
1/13	- 6.4	95	- 3.0	129	**

Table 12b. "Untreated", southern isolates.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/20	- 8.8	38	- 4.7	81	≠ (0.09)
1/16	- 4.1	37	- 6.3	63	NS
1/13	- 4.8	38	- 3.4	62	NS

Table 12c. "Treated", southern isolates.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/20	-11.4	14	- 3.7	50	≠ (0.07)
1/16	-11.4	15	- 2.4	41	*
1/13	- 4.4	12	- 2.1	41	NS

Table 12d. "Untreated" northern isolates.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/20	-15.6	47	-21.4	14	NS
1/13	- 8.5	42	-10.7	10	NS

Table 12e. Isolates collected before 1989.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/20	-21.0	14	- 7.5	78	**

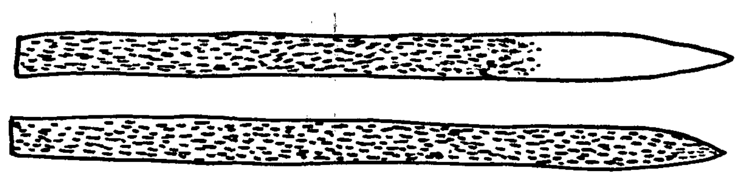
Table 12f. Isolates collected in 1989.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/20	-12.1	56	- 4.8	55	**
1/16	- 5.4	56	- 5.2	56	NS
1/13	- 6.2	56	- 3.4	56	≠ (0.07)

Table 12g. Isolates collected in 1990.

Rate	6,9		-6,9		Significance level
	Median	n	Median	n	
1/20	- 9.1	32	- 5.6	27	≠ (0.08)
1/16	-12.7	31	- 6.5	27	≠ (0.08)
1/13	- 8.2	30	- 0.7	25	NS

Fig. 1. Representation of wheat yellow rust uredia production on first seedling leaves showing an infection cut-off point towards the leaf tip following fungicide application.



Figs. 2a-2d. Classification of wheat yellow rust isolates according to whether or not fungicide was applied to the crop (F+ or F-); possession or lack or virulence factors (WYV 6,9 or WYV -6,9); and geographical origin north (N) or south (S) of the River Tyne.

Fig. 2a. All isolates.

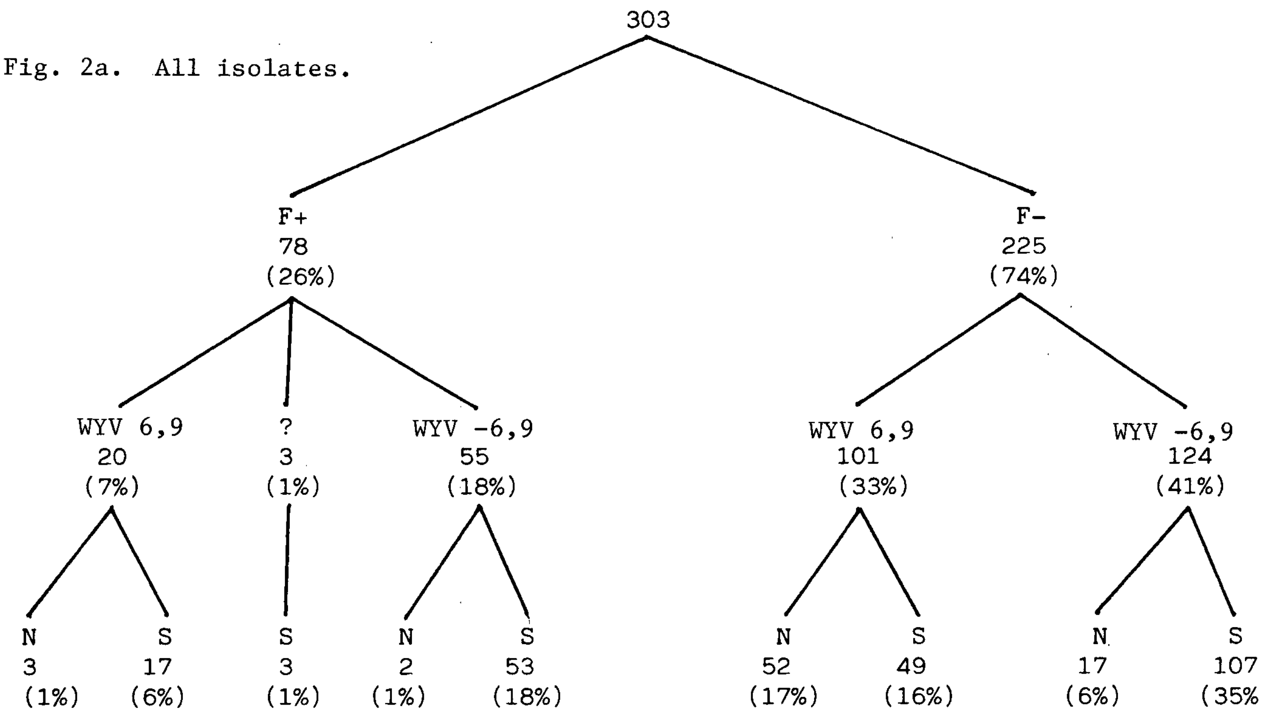


Fig. 2b. Isolates collected before 1989.

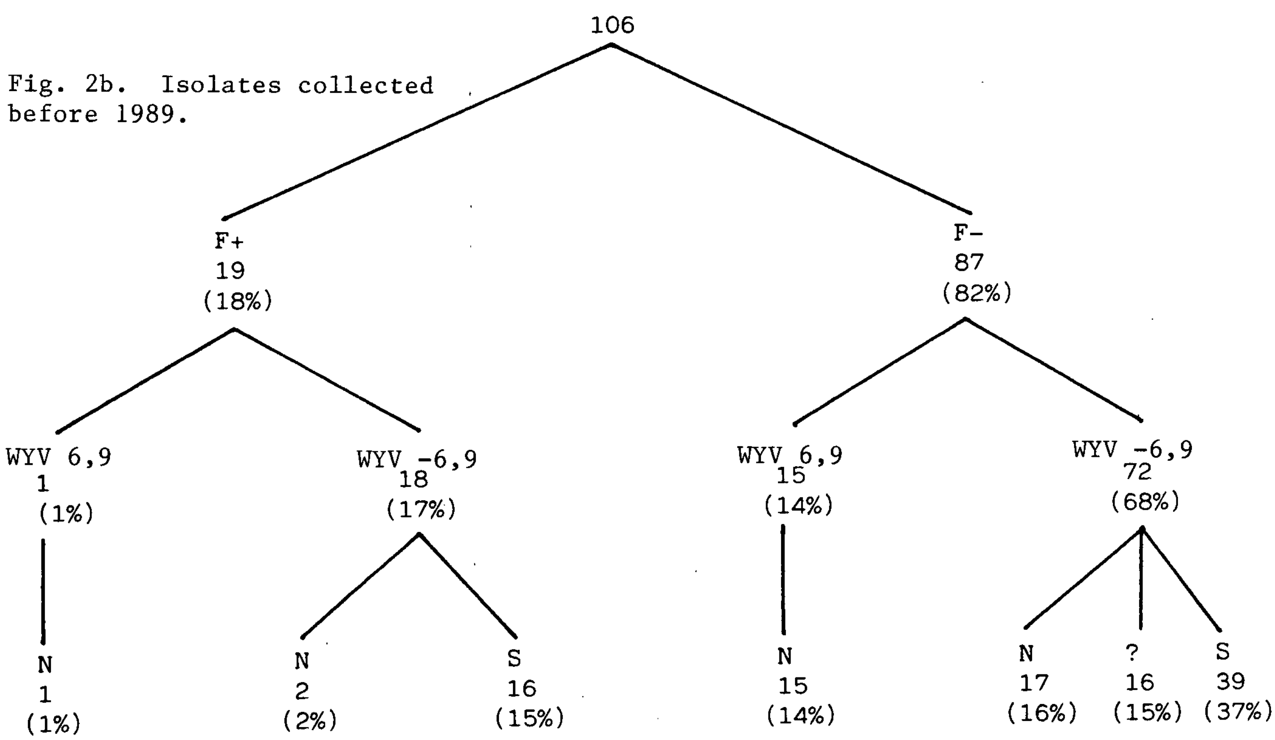


Fig. 2c. Isolates collected in 1989.

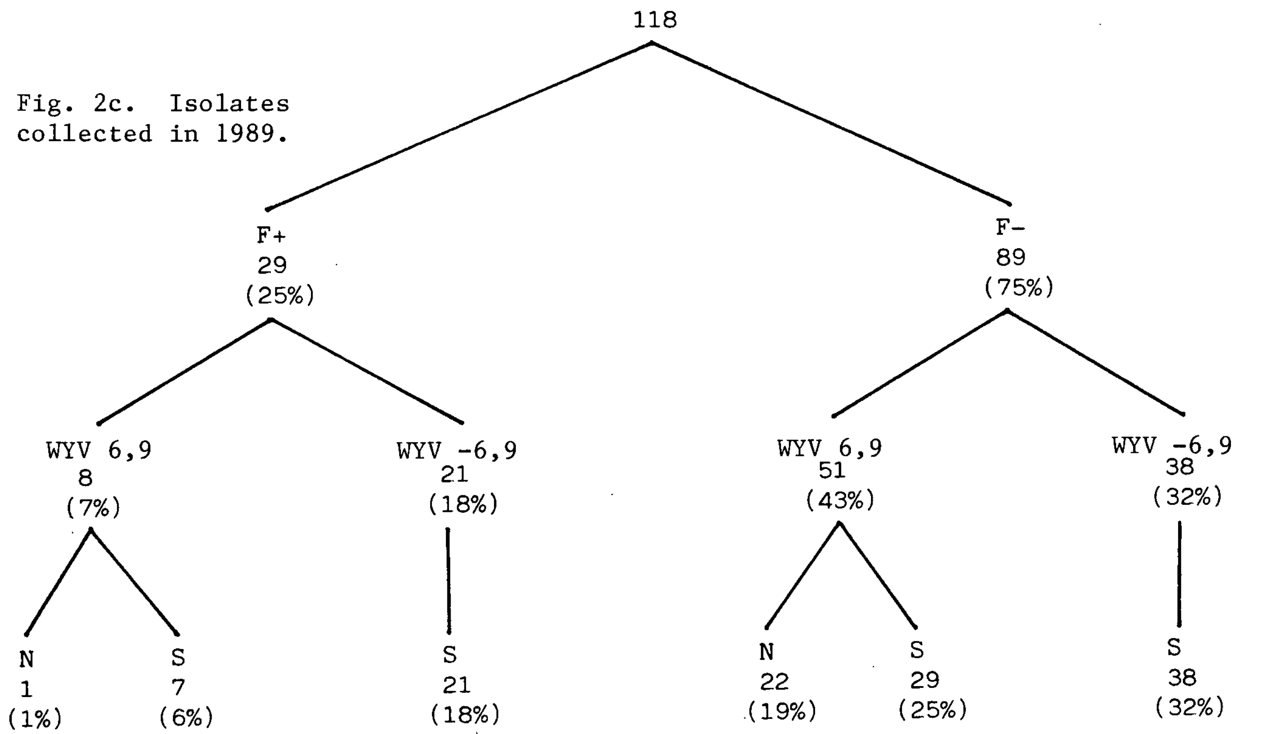
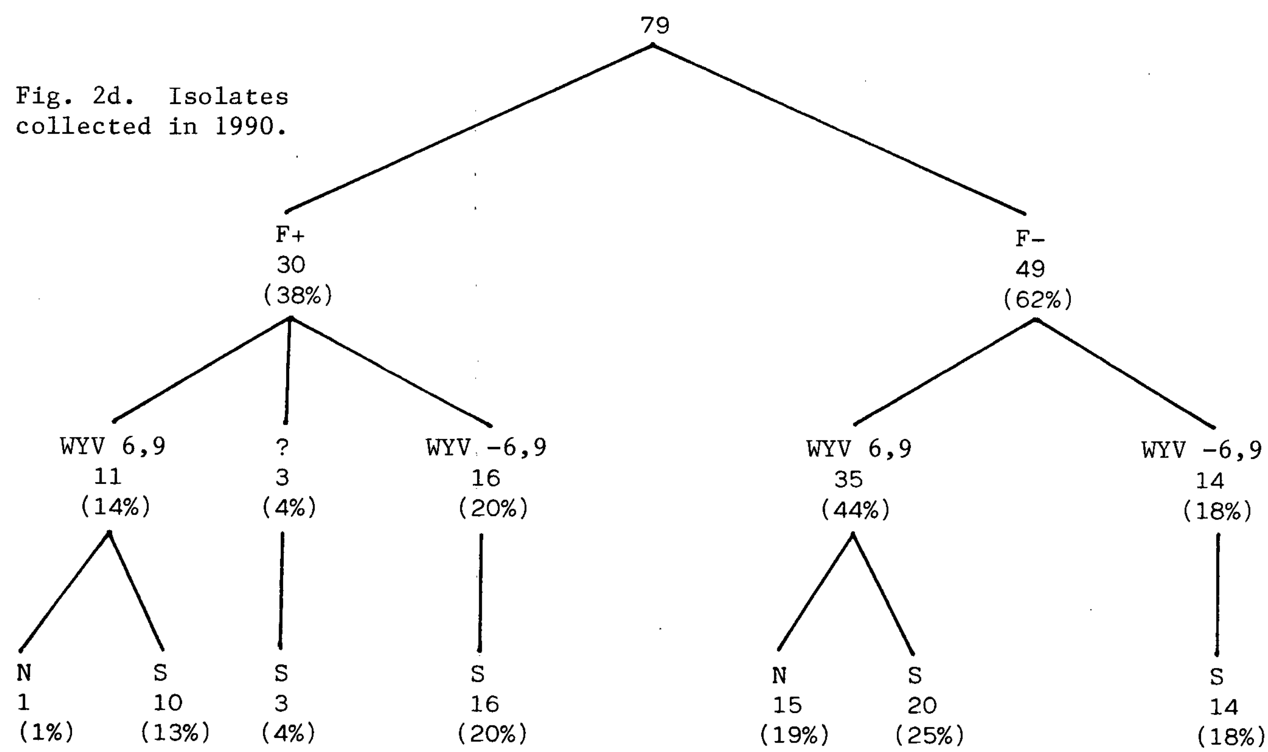


Fig. 2d. Isolates collected in 1990.



Figs 3a-c. Comparisons of D value frequency distributions between collection years for isolates screened to triadimenol at 1/40th field rate. Median values significantly different (P⩽0.01)**, (P⩽0.05)*, or not significantly different (P>0.05) NS.

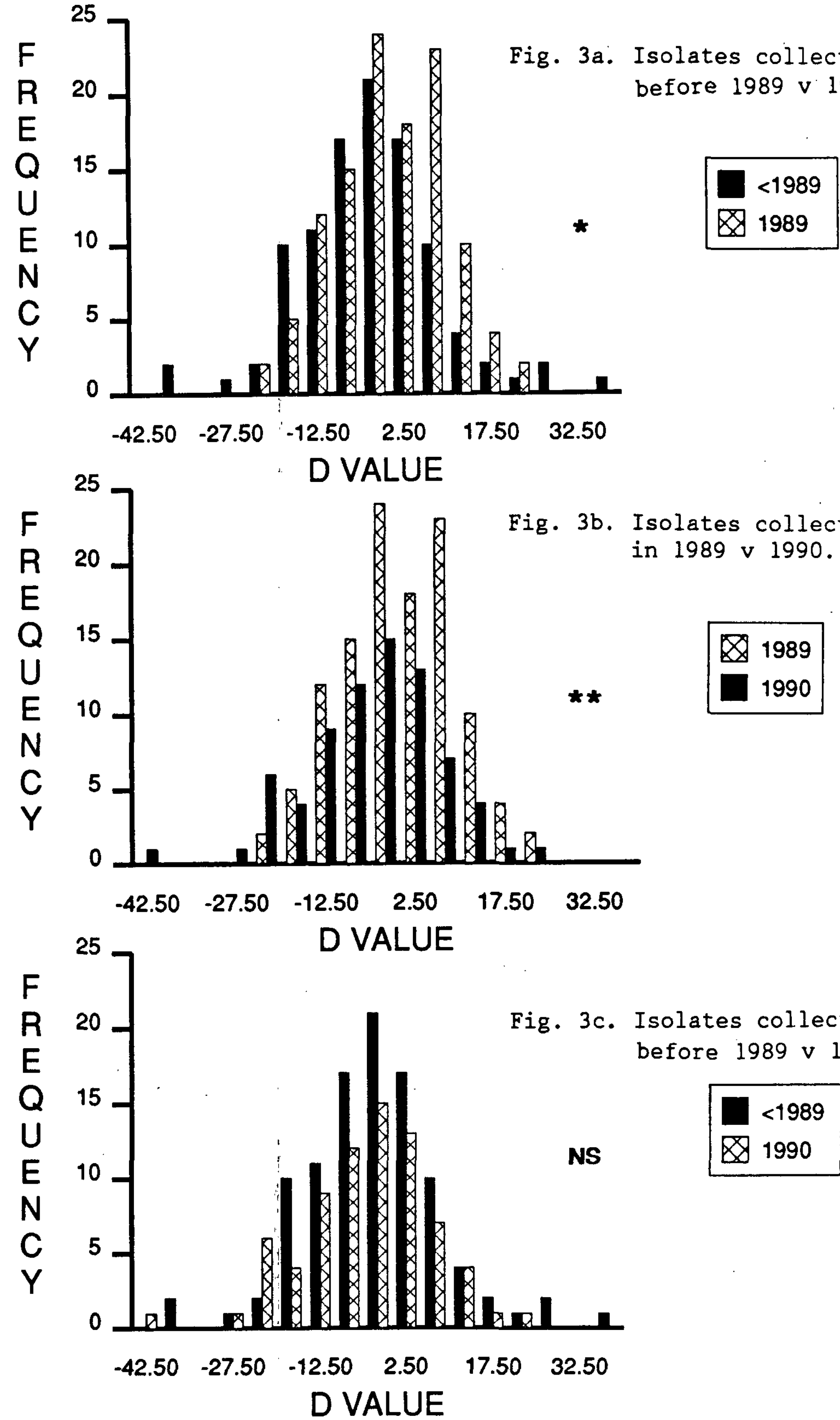
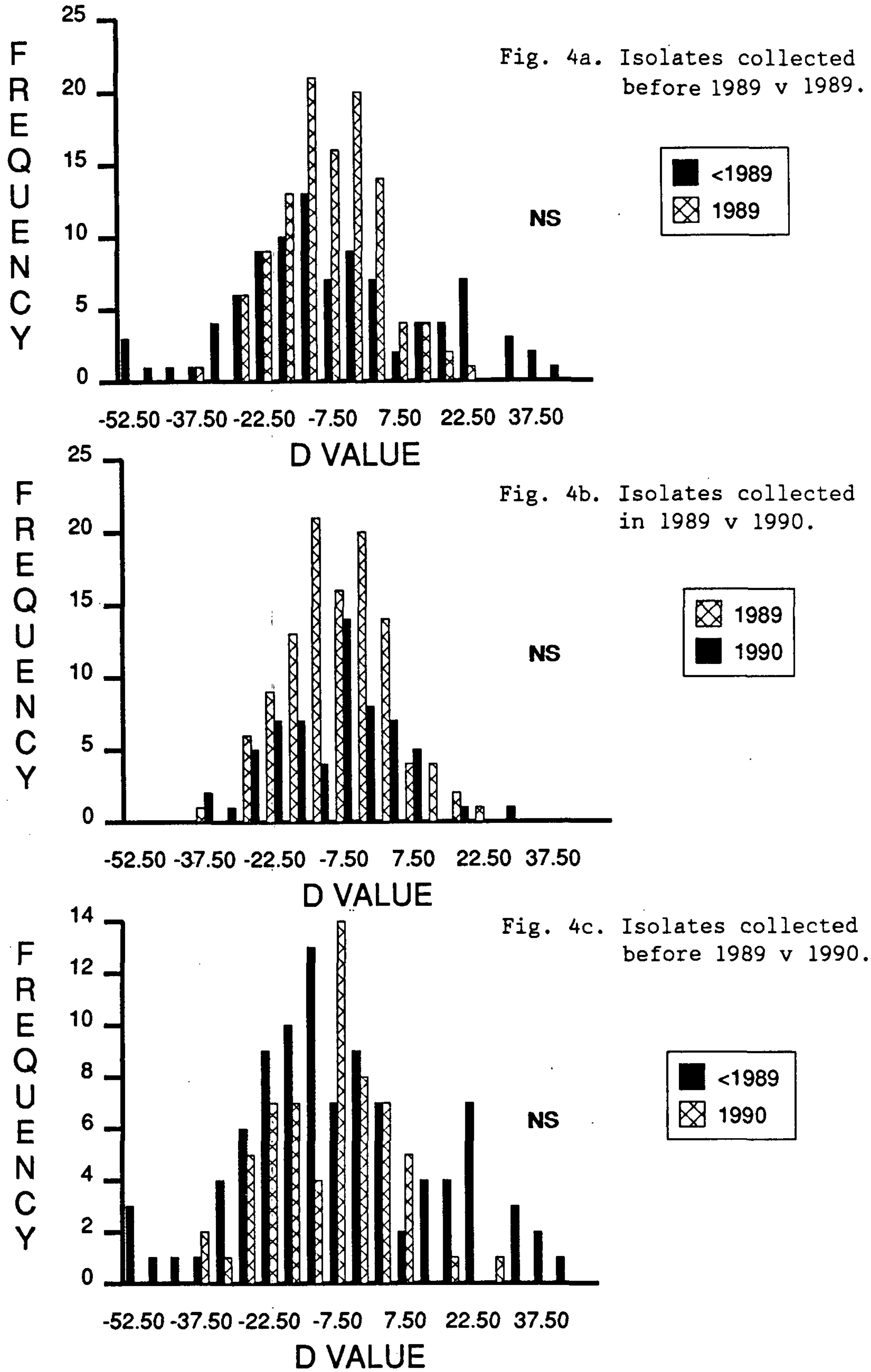


Fig. 3a. Isolates collected before 1989 v 1989.

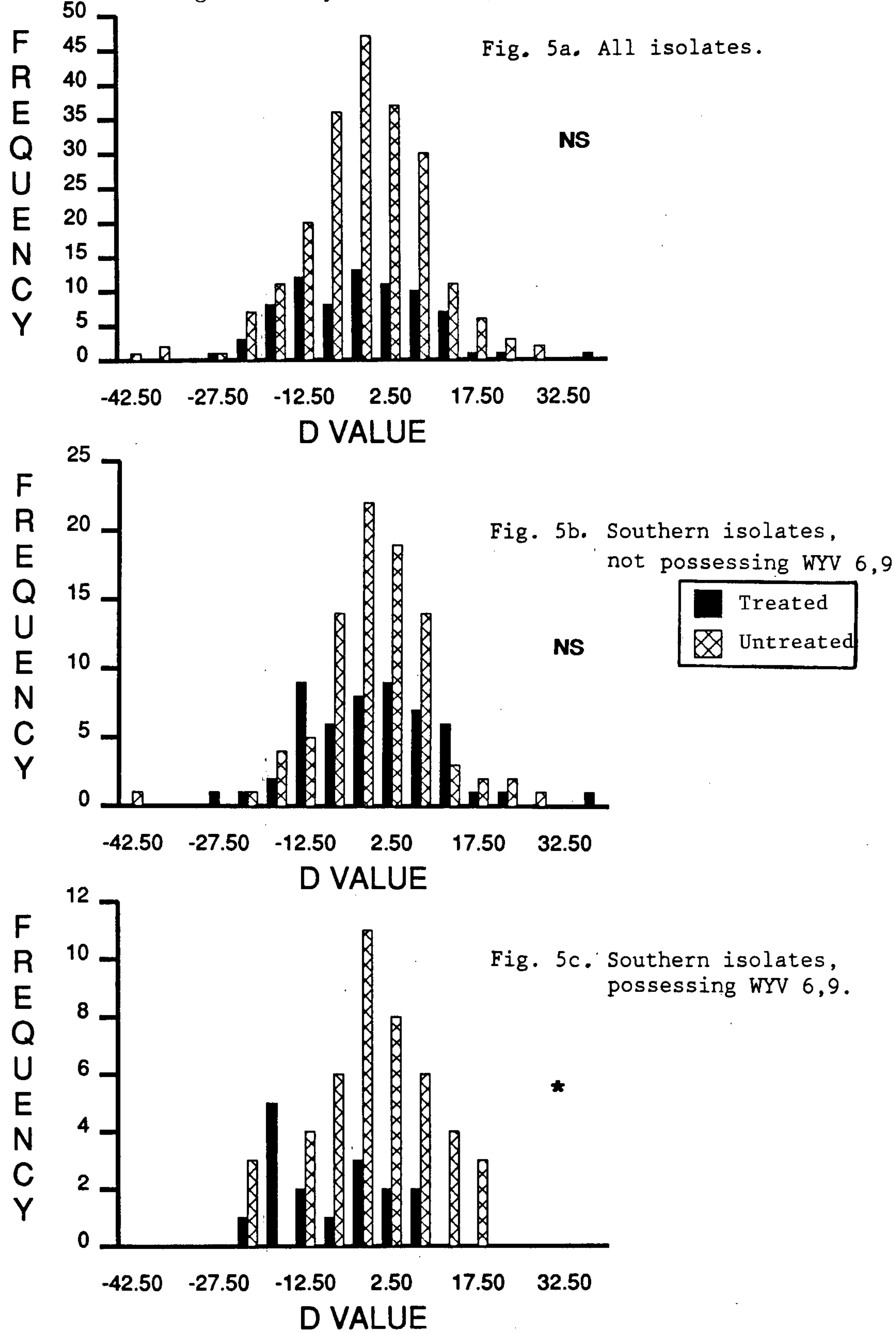
Fig. 3b. Isolates collected in 1989 v 1990.

Fig. 3c. Isolates collected before 1989 v 1990.

Figs 4a-c. Comparisons of D value frequency distributions between collection years for isolates screened to fenpropimorph at 1/20th field rate. Median values not significantly different (P>0.05) NS.



Figs 5a-c. Comparisons of D value frequency distributions between isolates collected from fungicide treated and untreated crops, for isolates screened to triadimenol at 1/40th field rate. For all isolates and southern isolate groups. Median values significantly different (P⩽0.05)*, or not (P>0.05) NS.



Figs 6a-c. Comparisons of D value frequency distributions between isolates collected from fungicide treated and untreated crops, for isolates screened to fenpropimorph at 1/20th field rate. For all isolates and southern isolate groups. Median values not significantly different (P>0.05) NS.

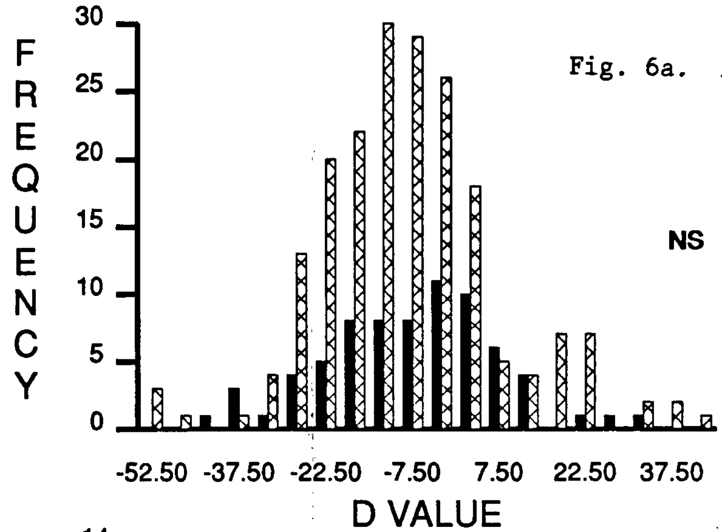


Fig. 6a. All isolates.

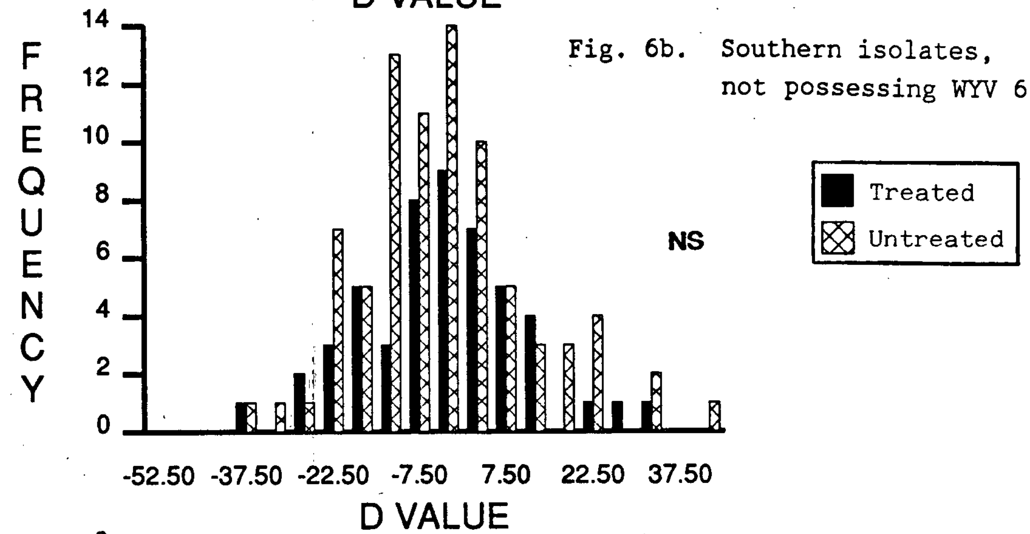


Fig. 6b. Southern isolates, not possessing WYV 6,9.

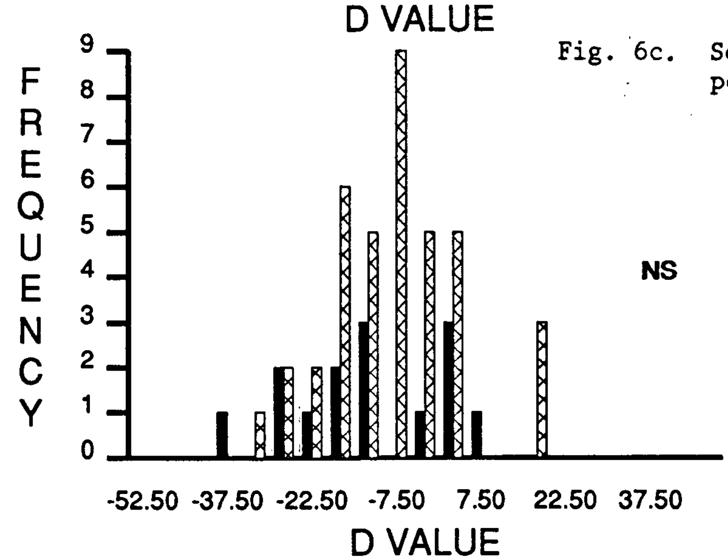


Fig. 6c. Southern isolates, possessing WYV 6,9.

Figs 9a–c. Comparisons of D value frequency distributions between northern and southern isolates screened to triadimenol at 1/40th field rate. Median values significantly different (P⩽0.01)**, (P⩽0.05)*, or not significantly different (P>0.05) NS.

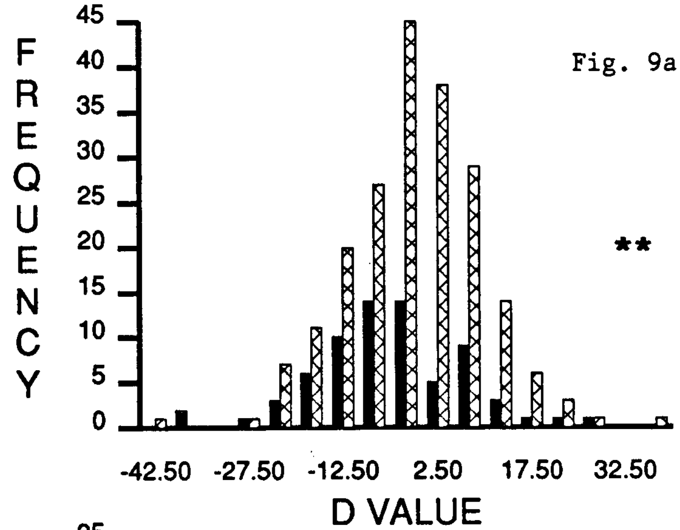


Fig. 9a. All isolates.

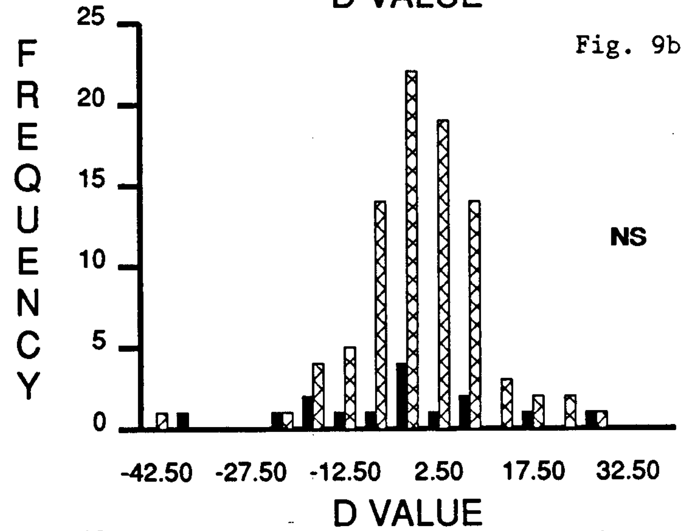


Fig. 9b. "Untreated" isolates, not possessing WYV 6,9.

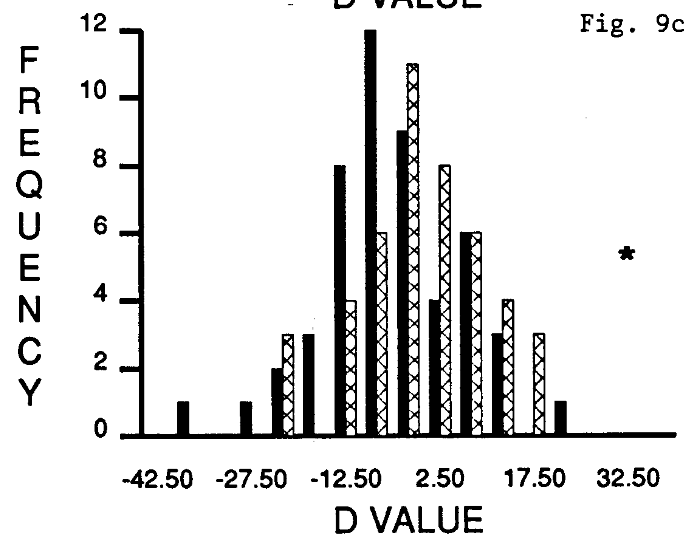
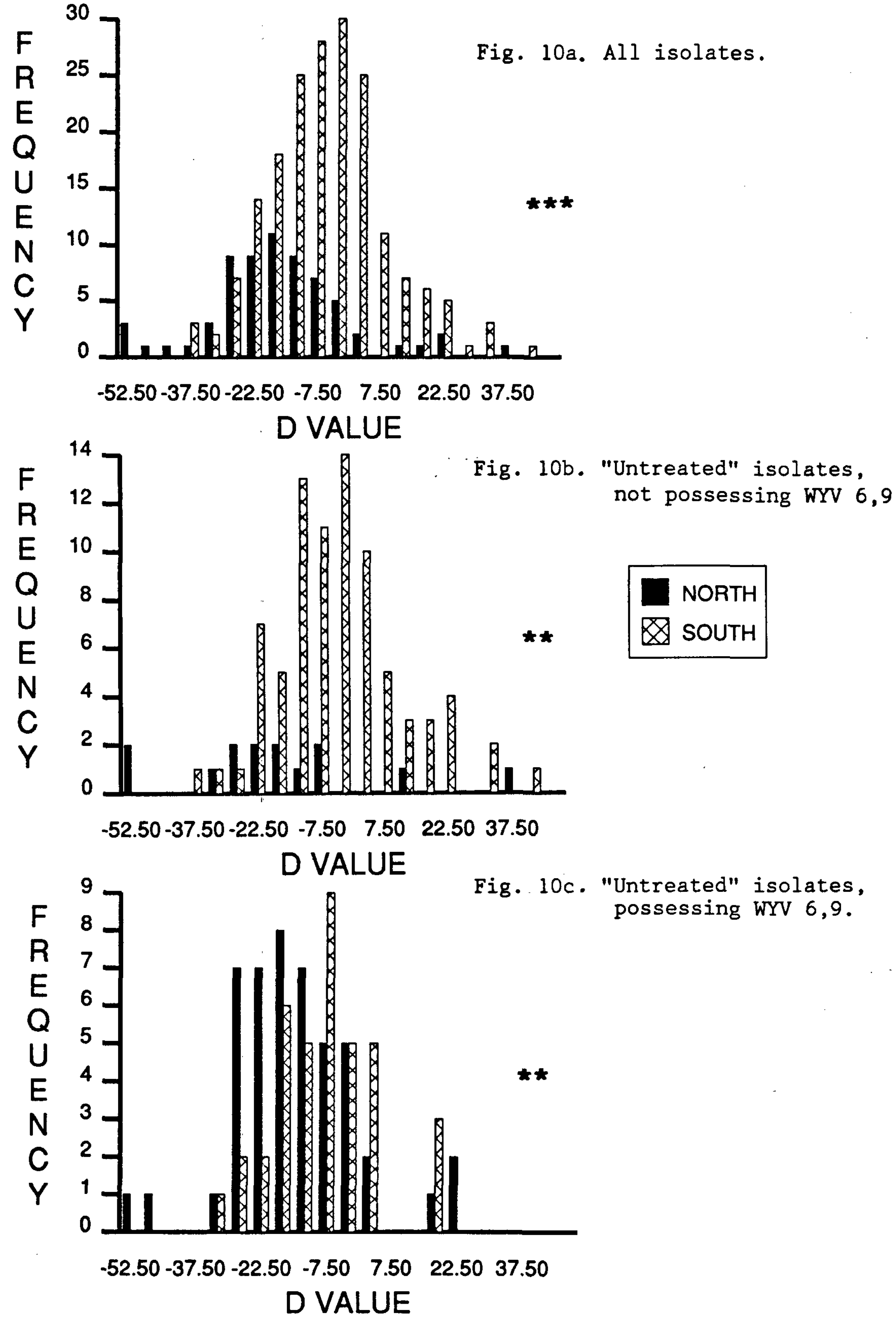
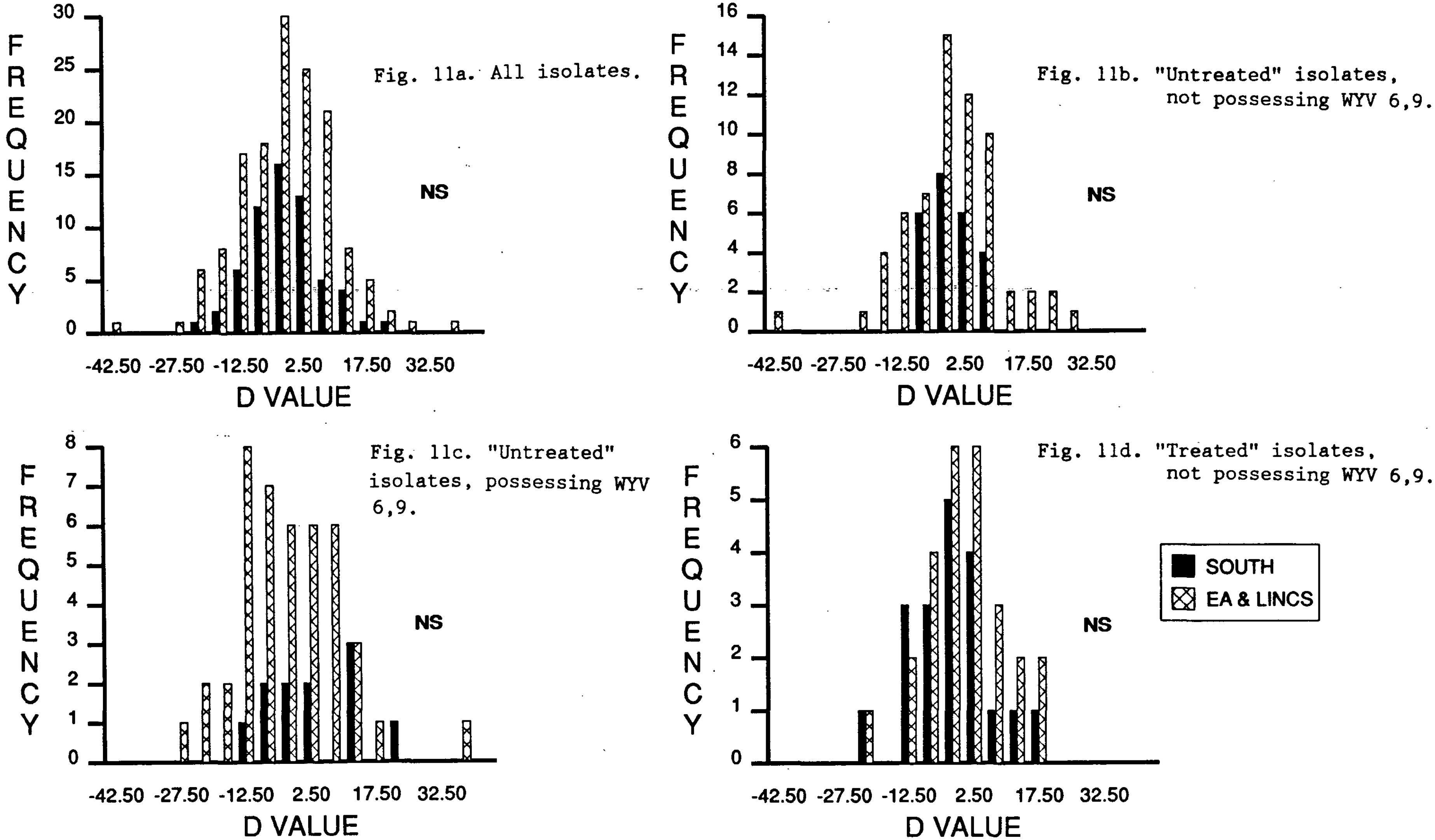


Fig. 9c. "Untreated" isolates, possessing WYV 6,9.

Figs 10a-c. Comparisons of D value frequency distributions between northern and southern isolates screened to fenpropimorph at 1/20th field rate. Median values significantly different (P⩽0.001)***, (P⩽0.01)**.



Figs 11a-d. Comparisons of D value frequency distributions between southern isolates excluding those from East Anglia and Lincolnshire and isolates from E. Anglia and Lincs. only, screened to triadimenol at 1/40th field rate. Median values not significantly different (P>0.05) NS.



Figs 12a-d. Comparisons of D value frequency distributions between southern isolates excluding those from East Anglia and Lincolnshire and isolates from E. Anglia and Lincs. only, screened to fenpropimorph at 1/20th field rate. Median values significantly different (P<0.05)*, or not (P>0.05) NS.

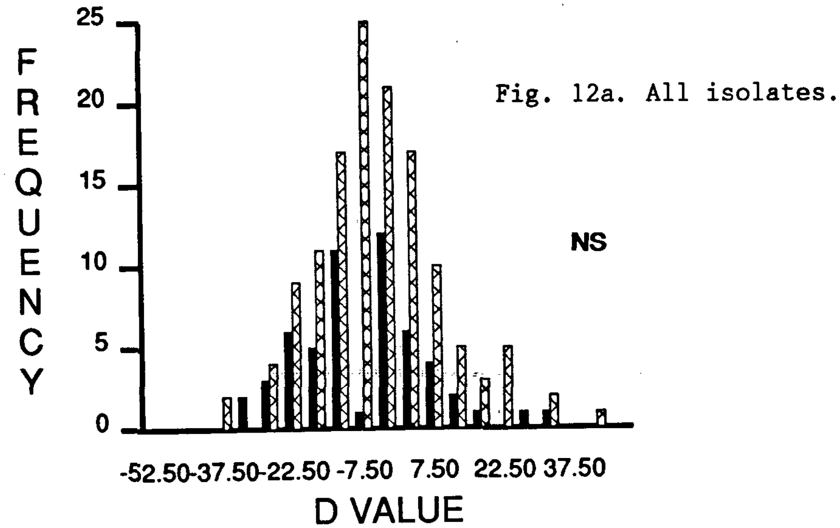


Fig. 12a. All isolates.

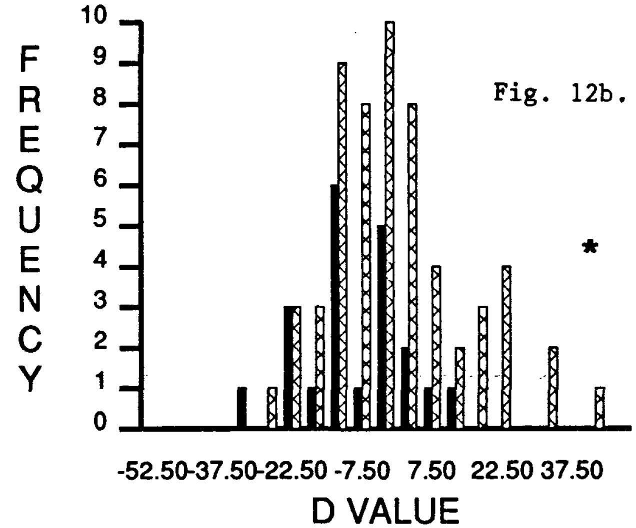


Fig. 12b. "Untreated" isolates, not possessing WYV 6,9.

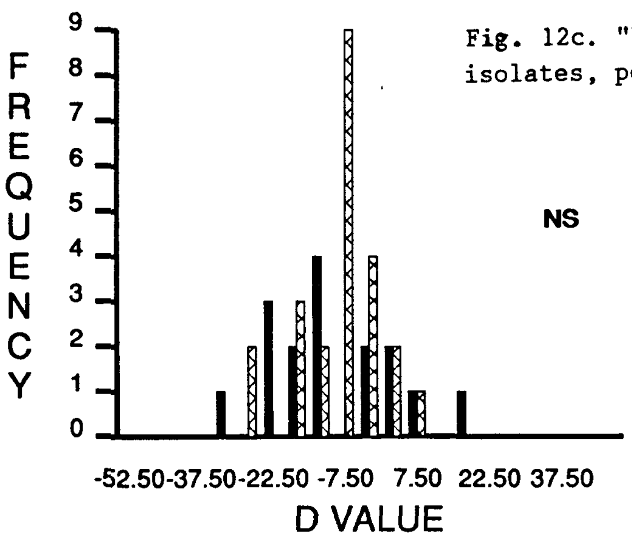


Fig. 12c. "Untreated" isolates, possessing WYV 6,9.

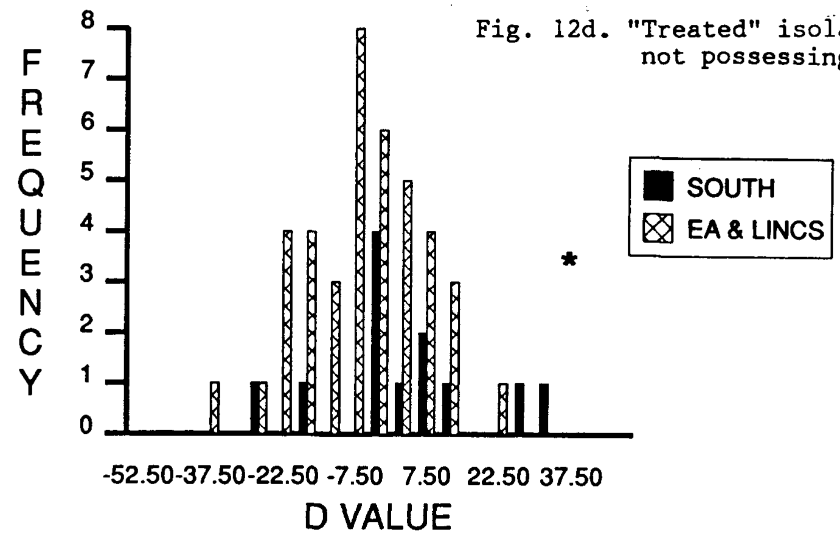


Fig. 12d. "Treated" isolates, not possessing WYV 6,9.

Figs 13a-d. Comparisons of D value frequency distributions between isolates with WYV 6,9 and without these virulence factors (WYV-6,9) for isolates screened to triadimenol at 1/40th field rate. Median values significantly different ($P \leqslant 0.05$)*, or not ($P > 0.05$) NS.

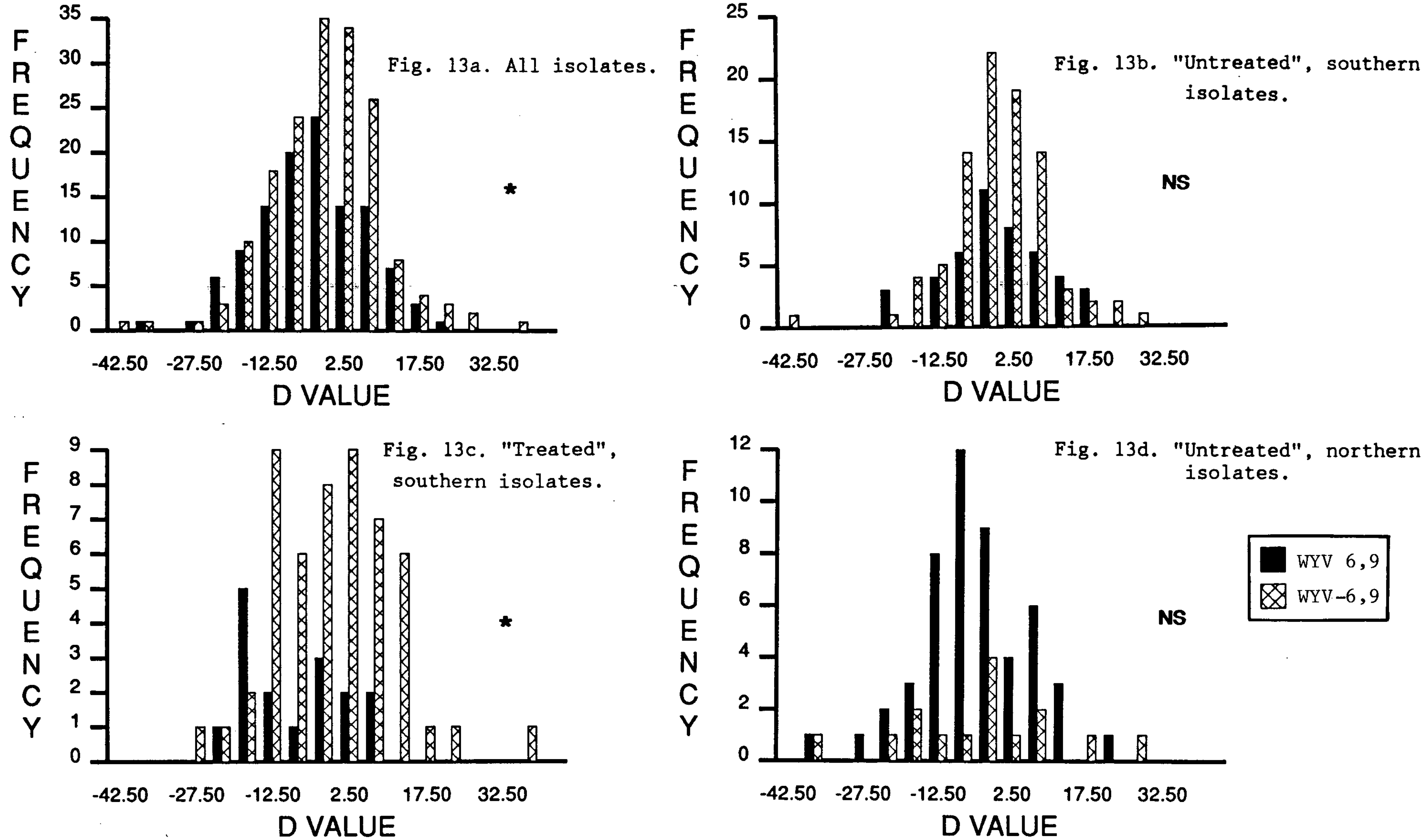


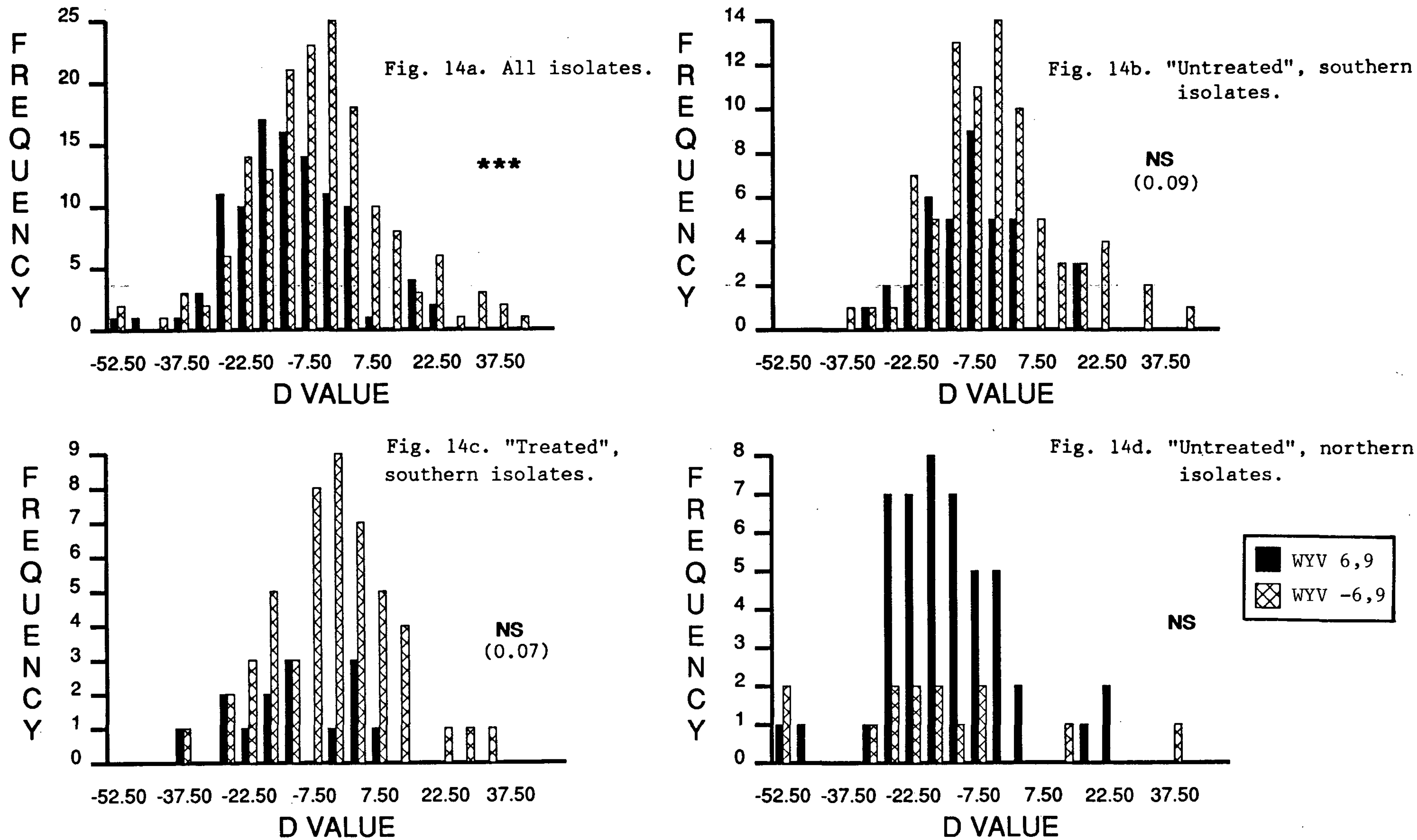
Fig. 13a. All isolates.

Fig. 13b. "Untreated", southern isolates.

Fig. 13c. "Treated", southern isolates.

Fig. 13d. "Untreated", northern isolates.

Figs 14a-d. Comparisons of D value frequency distributions between isolates with WYV 6,9 and without these virulence factors (WYV - 6,9) for isolates screened to fenpropimorph at 1/20th field rate. Median values significantly different ($P \leqslant 0.001$)***, or nearly significantly different ($P \leqslant 0.1$), or not significantly different ($P > 0.05$) NS.



Figs 15a- b. The performance of isolate WYR 90/20 compared to the control isolate WYR 83/62 when screened to fungicide at seven rates, as shown by uredia production as a % of the leaf area covered at nil fungicide rate. Vertical bars represent 95% confidence limits of the means.

Fig. 15a. Triadimenol applied at field and reduced rates

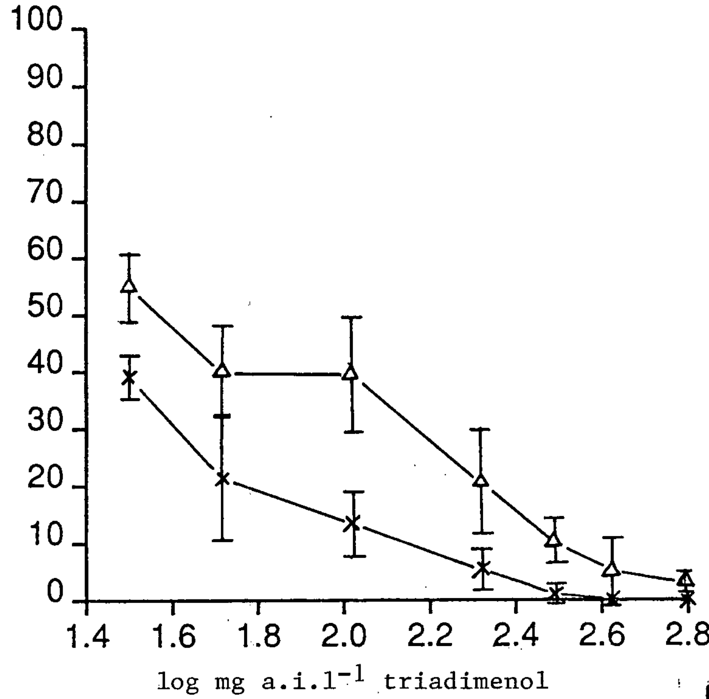


Fig. 15b. Fenpropimorph applied at field and reduced rates

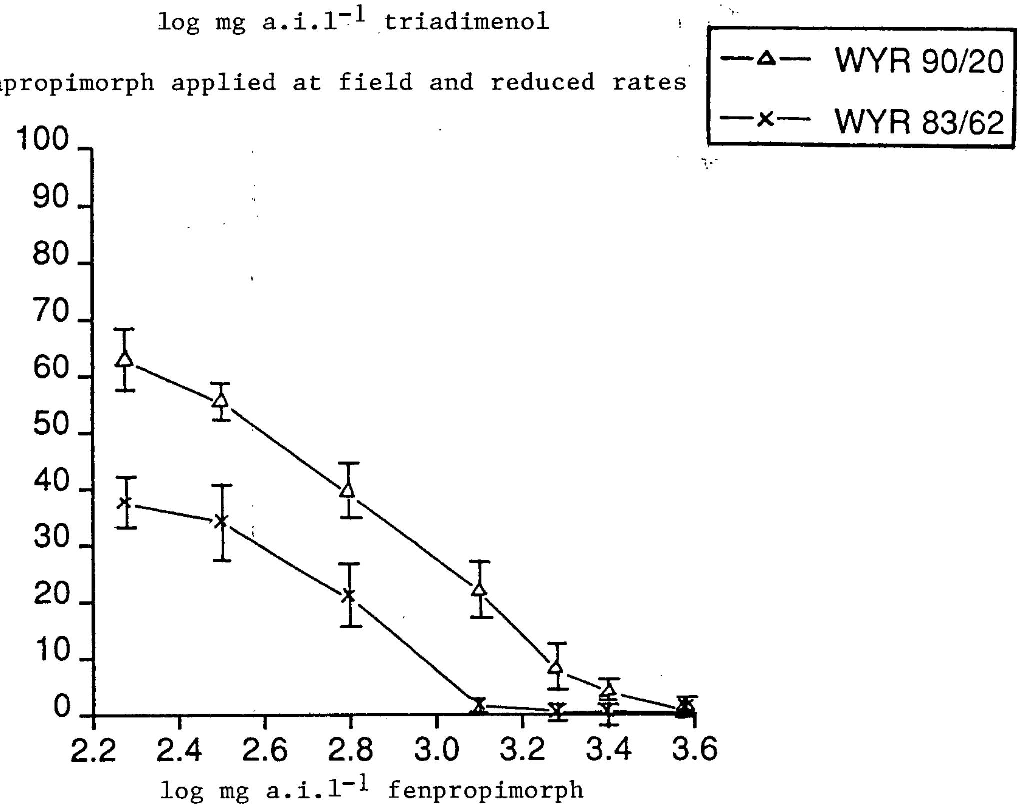


Fig. 16a. Diagrammatic representation of mean uredia production by isolate WYR 90/20 compared to the control isolate WYR 83/62 on first seedling leaves treated with field and reduced rates of triadimenol and a nil rate.

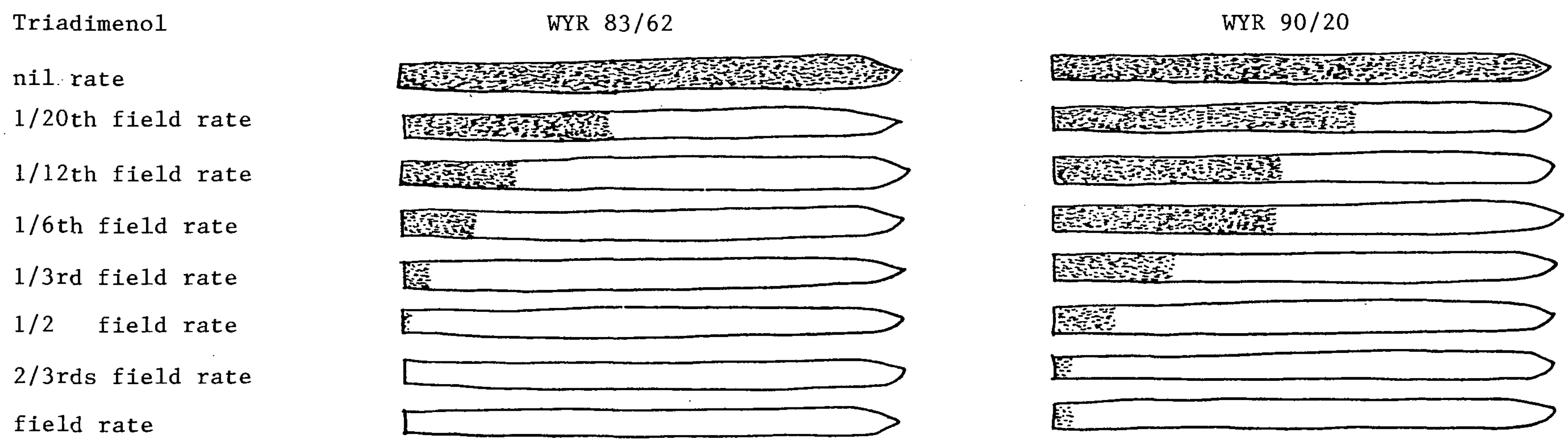
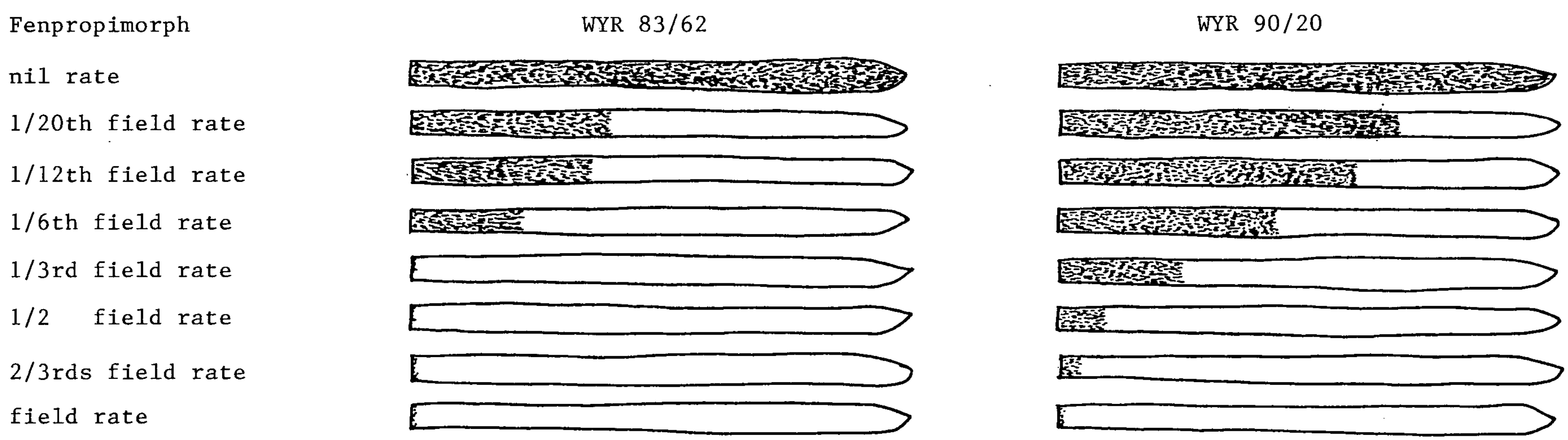


Fig. 16b. Diagrammatic representation of mean uredia production by isolate WYR 90/20 compared to the control isolate WYR 83/62 on first seedling leaves treated with field and reduced rates of fenpropimorph and a nil rate.



Appendix I

Source and virulence factors of wheat yellow rust isolates

Key: Fungicide applied in field; triazole (T), morpholine (M); other (O), no record (X), no fungicide (n)
Some information not available (-).

Year	Code	Source Cultivar	Location collected	Fungicide applied	Virulence factors
1960	330SS	-	-	n	-
1961	7xVi	-	-	n	-
1962	306SS	-	-	n	-
	2-150	-	-	n	-
1963	P631	-	-	n	-
1964	R54	-	-	n	-
1965	694SS	-	-	n	-
1966	P66/1	-	-	n	3
	P66/3	-	-	n	3,4
1969	3/55D	-	-	n	2,3,4
1970	P70/2	-	-	n	3,4,6
1971	P71/2	-	-	n	3,4
	71/493	Capta	Scotland	n	1,2,3,7
1972	P72/40	-	-	n	1,2,3
	P72/55	-	-	n	2,3,4,6
	P72/56	-	-	n	1,2,3,7
	72/415	Maris Ranger	Scotland	n	1,2,3,6
	72/852	Maris Ranger	Leics	n	(2),3,4,6
1975	75/27	-	-	n	2,3,4,14
	75/109	Kinsman	Shropshire	n	2,3,4,6
1976	76/71	Grenade	Scotland	n	1,2,3,13
	79/4	Maris Templar	Suffolk	n	1,2,3,14
1980	80/7	DU 1101	Norfolk	n	1,2,3
	80/16	Hobbit	Wiltshire	n	1,2,3,(6)
	80/29	DU 1210	Norfolk	n	1,2,3,4
	80/34	Maris Huntsman	Northumberland	n	1,2,3
1981	81/3	-	Lincs	n	1,2,3
	81/24	Copain	Scotland	n	1,2,3
1982	82/3	Virtue	Hampshire	TO	1,2,3
	82/8	Hustler	Scotland	n	1,2,3,(4),(7)
	82/16	Guardian	Worcestershire	n	1,2,3,6,(7)
1983	83/6	Brigand	Norfolk	n	2,3,4,6
	83/8	Brigand	Lincs	n	1,2,3
	83/10	Hammer	Oxon	n	1,2,3,9
	83/45	Brigand	Hampshire	n	1,2,3
	83/62	Longbow	Norfolk	n	1,2,3,6,13
1984	84/1	Brimstone	Lincs	n	1,2,3,4,6
	84/3	Longbow	Lincs	TO	1,2,3,6
	84/7	Longbow	Lincs	O	1,2,3,6
	84/11	Longbow	Lincs	MO	1,2,3,6
	84/12	Longbow	Humberside	n	1,2,3,6
1985	85/19	Stetson	Lincs	n	1,2,3,9
1986	86/4	Norman	Lincs	n	1,2,3,4,6
	86/5	Longbow	Northants	T	1,2,3,6
	86/12	Fervert	Scotland	n	1,2,3,4,6,7
1987	87/1	Norman	Scotland	MO	1,2,3,7
	87/2	Slejpner(?)	Scotland	MO	1,2,3,7
	87/4	Slejpner	Scotland	n	1,2,3,4,6

Source and virulence factors of wheat yellow rust isolates (continued)

Year	Code	Source Cultivar	Location collected	Fungicide applied	Virulence factors
1987	87/5	Norman	Norfolk	n	1,2,3,6
	87/7	Norman	Scotland	n	1,2,3,6
	87/9	Slejpner	Lincs	T	1,2,3,6
	87/10	Norman	Yorkshire	n	1,2,3,6
	87/11	Minion	Northants	T	1,2,3,6
	87/12	Longbow	Cambs	n	1,2,3,6
	87/13	Slejpner	Lincs	MO	1,2,3,9
	87/16	Longbow	Lincs	n	1,2,3,6
	87/21	0478/10/1	Scotland	n	2,3,4,6
	87/22	Stetson	Oxon	n	1,2,3,9
	87/28	Longbow	Norfolk	n	1,2,3,6
	87/31	Minaret	Lincs	TO	1,2,3,6
	87/33	Brimstone	Northumberland	n	1,2,3,4,6
1988	88/3	Slejpner	Lincs	n	1,2,3,4,6
	88/7	Slejpner	Essex	n	2,3,4,9
	88/8	Slejpner	Lincs	n	1,2,3,9
	88/11	Alexandria	Cambs	n	1,2,3,4,6
	88/16	Avalon	Northumberland	n	2,3,4,6,9
	88/21	Slejpner	Suffolk	n	2,3,4,9
	88/26	Slejpner	Cambs	M	1,2,3,9
	88/28	Slejpner	Cambs	TM	1,2,3,9
	88/30	Slejpner	Cambs	TM	1,2,3,9
	88/31	CWW 86/6	Scotland	n	2,3,4,6,9
	88/35	Hornet	Scotland	n	2,3,4,6,9
	88/36	CWW 86/4	Scotland	n	2,3,4,6,9
	88/37	Civic	Scotland	n	2,3,4,6,9
	88/61	NRPB 3023	Lincs	n	1,2,3,6
	88/63	Slejpner	Kent	M	2,3,4,9
	88/64	Slejpner	Lincs	TO	1,2,3,9
	88/65	Slejpner	Lincs	TO	2,3,4,9
	88/67	Brimstone	Cambs	n	1,2,3,4,6
	88/70	Avalon	Cambs	n	1,2,3,4,6
	88/75	Brock	Cambs	n	2,3,4,6,7
	88/76	Avalon	Scotland	n	1,2,3,4,6
	88/77	Brock	Scotland	n	2,3,4,6,7
	88/78	Riband	Scotland	n	1,2,3,4,6
	88/90	Slejpner	Lincs	TMO	1,2,3,9
	88/91	Apollo	Scotland	n	1,2,3,4,6,9
	88/92	Fortress	Scotland	n	1,2,3,4,6,9
	88/105	Mandate	Scotland	n	1,2,3,4,6,9
	88/106	Sniper	Scotland	n	1,2,3,6
	88/109	Fortress	Scotland	n	1,2,3,4,6,9
	88/123	Slejpner	Northumberland	TO	1,2,3,4,6,9
	88/126	Hornet	Cambs	n	1,2,3,6
	88/127	7732/16/1/7/4	Cambs	n	1,2,3,4,7
	88/128	Fortress	Scotland	n	1,2,3,4,6,9
	88/129	Apollo	Lincs	n	1,2,3,9
	88/130	Sniper	Cambs	n	(1),2,3,4,9
	88/131	Fortress	Cambs	n	1,2,3,4,6
	88/132	Mercia	Cambs	n	1,2,3,4,6
	88/134	Angler	Scotland	n	1,2,3,4,6,9
	88/140	Alexandria	Ireland	n	1,2,3,6
	88/141	Minaret	Ireland	n	1,2,3,6

Source and virulence factors of wheat yellow rust isolates (continued)

Year	Code	Source Cultivar	Location collected	Fungicide applied	Virulence factors
1988	88/143	CWW 87/1	Scotland	n	1,2,3,4,6,9
	88/144	Fortress	Scotland	n	1,2,3,4,6,9
	88/152	Fortress	Scotland	n	1,2,3,4,6,9
	88/162	Minaret	Northumberland	n	1,2,3,4,6
	88/163	Brock	Northumberland	n	2,3,4,6,7
	88/170	Apollo	Scotland	n	1,2,3,4,6,9
1989	89/2	Slejpner	Sussex	n	2,3,4,9
	89/5	Slejpner	Northumberland	n	1,2,3,4,6,9
	89/9	Hornet	Norfolk	n	2,3,4,9
	89/10	Hornet	Norfolk	n	2,3,4,9
	89/11	Slejpner	Suffolk	n	2,3,4,9
	89/16	Slejpner	Scotland	n	1,2,3,4,(6),9
	89/18	Riband	Cambs	n	2,3,4,9
	89/20	Mercia	Scotland	n	1,2,3,4,6,9
	89/22	Slejpner	Cambs	n	(1),2,3,4,9
	89/23	Slejpner	Bedfordshire	n	(1),2,3,4,9
	89/25	Hornet	Scotland	n	1,2,3,4,6,9
	89/30	Hornet	Lincs	n	1,2,3,4,9
	89/42	Fortress	Lincs	n	1,2,3,4,6,9
	89/43	Slejpner	Suffolk	TO	2,3,4,9
	89/44	Slejpner	Suffolk	n	2,3,4,9
	89/45	Mercia	Northumberland	n	1,2,3,4,6,9
	89/46	Slejpner	Cambs	n	2,3,4,9
	89/48	Gambit	Norfolk	n	2,3,4,9
	89/52	Hornet	Northants	O	1,2,3,4,6,9
	89/53	Slejpner	Sussex	n	2,3,4,9
	89/54	Hornet	Humberside	n	1,2,3,4,6,9
	89/59	Slejpner	Gloucestershire	n	2,3,4,9
	89/60	Apollo	S.Wales	n	1,2,3,4,6,9
	89/62	Fortress	Lincs	n	1,2,3,4,6,9
	89/63	Fortress	Cambs	n	1,2,3,4,6,9
	89/67	Hornet	Northumberland	n	1,2,3,4,6,9
	89/68	Slejpner	Suffolk	n	2,3,4,9
	89/70	Hornet	Cambs	n	(1),2,3,4,9
	89/71	Riband	Cambs	n	2,3,4,6
	89/77	Hornet	Oxford	n	1,2,3,4,6,9
	89/78	Hornet	Northumberland	n	1,2,3,4,6,9
	89/79	Riband	Northumberland	n	1,2,3,4,6,9
	89/80	Slejpner	Northumberland	n	1,2,3,4,6,9
	89/81	Fortress	Northumberland	n	1,2,3,4,6,9
	89/82	Riband	Norfolk	n	2,3,4,9
	89/88	Pastiche	Norfolk	n	2,3,4,9
	89/89	Riband	-	n	2,3,4,9
	89/90	Apostle	Norfolk	n	2,3,4,9
	89/91	Salvo (triticale)	Cambs	n	2,3,4,9
	89/93	Hornet	Cambs	n	2,3,4,9
	89/97	Mercia	Cambs	T	1,2,3,6,(7),9
	89/98	Hornet	Cambs	n	1,2,3,(4),6,9
	89/102	Slejpner	-	x	2,3,4,9

Source and virulence factors of wheat yellow rust isolates (continued)

Year	Code	Source Cultivar	Location collected	Fungicide applied	Virulence factors
1989	89/104	Mercia	Derby	n	2,3,4,9
	89/105	Hornet	Cambs	n	1,2,3,4,6,9
	89/106	Fortress	Cambs	n	1,2,3,4,6,9
	89/108	Hornet	Essex	n	1,2,3,4,6,9
	89/113	Hornet	Scotland	n	1,2,3,4,6,9
	89/115	Hornet	Gloucestershire	n	1,2,3,4,6,(7),(9)
	89/124	Slejpner	Devon	M	2,3,4,9
	89/125	Hornet	Isle of Wight	n	1,2,3,4,(6),9
	89/127	Hornet	Suffolk	TM	2,3,4,9
	89/132	Haven	Cambs	n	2,3,4,9
	89/134	Hornet	Avon	M	1,2,3,4,6,9
	89/140	Slejpner	Cambs	TM	2,3,4,9
	89/141	Mercia	Leics	O	1,2,3,9
	89/142	Hornet	Lincs	n	1,2,3,4,6,9
	89/143	Slejpner	Northumberland	TM	1,2,3,4,6,9
	89/144	Slejpner	Cambs	TM	2,3,4,9
	89/145	Fortress	Northants	n	1,2,3,4,6,9
	89/147	Slejpner	Essex	M	2,3,4,9
	89/149	Hornet	Suffolk	n	2,3,4,6,9
	89/150	Hornet	Cambs	n	1,2,3,6,7
	89/152	Hornet	Cambs	n	1,2,3,4,6,9
	89/154	Slejpner	Cambs	TM	2,3,4,9
	89/157	Hornet	Devon	n	1,2,3,4,6,9
	89/162	Hornet	Northumberland	n	1,2,3,4,6,9
	89/164	Haven	Cambs	n	1,2,3,4,6,9
	89/166	Slejpner	Shropshire	n	1,2,3,4,9
	89/170	Mercia	Cambs	n	2,3,4,9
	89/172	Hornet	Cambs	TM	1,2,3,4,6,9
	89/173	Urban	Norfolk	TO	1,2,3,6
	89/174	Brock	Cambs	n	2,3,4,9
	89/175	Rendezvous	Suffolk	n	(1),2,3,4,9
	89/176	Fortress	Kent	M	1,2,3,4,6,9
	89/177	Druid	Hampshire	n	2,3,4,9
	89/179	Mercia	Wilshire	n	2,3,4,9
	89/180	Apollo	N.Yorks	n	1,2,3,4,9
	89/181	Hornet	Humberside	TM	1,2,3,4,(6),9
	89/182	Camp Remy	Cambs	n	2,3,4,6,7,9
	89/187	Hornet	Kent	n	1,2,3,4,6,9
	89/188	Apollo	Yorkshire	n	2,3,4,9
	89/191	Beaver	Norfolk	n	1,2,3,4,6,9
	89/192	Haven	Yorkshire	n	1,2,3,4,6,9
	89/194	Haven	Northumberland	n	1,2,3,4,6,9
	89/195	Beaver	Northumberland	n	1,2,3,4,6,9
	89/196	Dean	Northumberland	n	1,2,3,4,6,9
	89/198	Hornet	Scotland	n	1,2,3,4,6,9
	89/200	Riband	Scotland	n	1,2,3,4,6,9
	89/201	Slejpner	Yorkshire	TMO	(1),2,3,4,9

Source and virulence factors of wheat yellow rust isolates (continued)

Year	Code	Source Cultivar	Location collected	Fungicide applied	Virulence factors
1989	89/202	Hornet	Suffolk	n	1,2,3,4,6,9
	89/203	CWW 88/2	Kent	n	1,2,3,4,6,9
	89/204	Hornet	Norfolk	n	1,2,3,4,6,9
	89/205	Brock	Norfolk	n	1,2,3,4,7,9
	89/207	Mercia	Cambs	n	2,3,4,9
	89/209	Mercia	Essex	n	2,3,4,9
	89/210	Parade	Gloucestershire	n	1,2,3,4,(6),9
	89/211	Apollo	Northumberland	n	1,2,3,4,6,9
	89/212	Haven	Northumberland	n	1,2,3,4,6,9
	89/213	Beaver	Northumberland	n	1,2,3,4,6,9
	89/214	Hornet	Northumberland	n	1,2,3,4,6,9
	89/216	Fortress	Cambs	n	1,2,3,4,6,9
	89/219	Apostle	Wiltshire	n	1,2,3,4,6,9
	89/220	Hornet	SE	n	1,2,3,4,6,9
	89/222	Galahad	Northumberland	n	1,2,3,4,6,9
	89/G1	Slejpner	Cambs	TMO	1,2,3,4,9
	89/G3	Slejpner	Cambs	TM	2,3,4,9
	89/G4	Slejpner	Cambs	M	2,3,4,9
	89/G5	Slejpner	Cambs	MO	2,3,4,9
	89/G6	Slejpner	Cambs	M	2,3,4,9
	89/G7	Slejpner	Cambs	M	2,3,4,9
	89/G8	Slejpner	Cambs	TMO	2,3,4,9
	89/G9	Slejpner	Cambs	TMO	2,3,4,9
	89/G10	Slejpner	Cambs	n	2,3,4,9
	89/G11	Slejpner	Cambs	TO	2,3,4,9
	89/G12	Slejpner	Cambs	n	2,3,4,9
	89/G15	Slejpner	Essex	X	2,3,4,9
1990	90/1	Riband	Lincs	n	2,3,4,9
	90/2	88-B111	Lincs	n	2,3,4,9
	90/3	Slejpner	Somerset	n	1,2,3,4,6,9
	90/7	Riband	Cambs	n	1,2,3,4,(6),9
	90/8	Mercia	Suffolk	n	1,2,3,4,6,9
	90/9	Slejpner	Cambs	T	2,3,4,9
	90/10	Hornet	Cambs	n	1,2,3,4,6,(7),9
	90/11	Hornet	Essex	M	2,3,4,9
	90/12	Haven	Lincs	n	2,3,4,9
	90/15	Carolus	Northants	n	1,2,3,9
	90/16	Beaver	Lincs	MO	1,2,3,4,6,9
	90/17	Haven	Lincs	MO	1,2,3,4,6,9
	90/18	Riband	Lincs	n	1,2,3,4,6,9
	90/20	Slejpner	Sussex	TO	2,3,4,9
	90/21	Riband	Kent	n	1,2,3,6
	90/22	Brock	Norfolk	n	2,3,4,7
	90/23	Fortress	Cambs	TO	1,2,3,4,6,9
	90/24	Fortress	Cambs	TO	1,2,3,4,6,9
	90/25	Slejpner	Bedfordshire	n	1,2,3,4,6,9
	90/26	Hornet	Bedfordshire	n	1,2,3,4,9
	90/27	Slejpner	Suffolk	n	2,3,4,9
	90/29	Hornet	Cambs	TMO	1,2,3,4,9

Source and virulence factors of wheat yellow rust isolates (continued)

Year	Code	Source Cultivar	Location collected	Fungicide applied	Virulence factors
1990	90/30	Riband	Cambs	x	1,2,3,4,6,9
	90/31	Hornet	Cambs	x	1,2,3,4,6,9
	90/32	Mercia	Cambs	n	2,3,4,9
	90/33	Apollo	Cambs	n	1,2,3,4,6,9
	90/34	Hornet	Scotland	n	1,2,3,4,6,9
	90/35	Jaguar	Kent	n	1,2,3,4,6,9
	90/36	Alexandria	Kent	TM	1,2,3,4,6,7,9
	90/37	Slejpner	Oxon	n	1,2,3,4,6,9
	90/38	ICI 6980/22/2/2	Scotland	n	1,2,3,4,6,9
	90/40	ICI 6980/22/2/1	Scotland	n	1,2,3,4,6,9
	90/41	Brock	Lincs	n	2,3,4,7
	90/42	Beaver	Lincs	TO	1,2,3,4,6,9
	90/43	Haven	Lincs	TO	1,2,3,4,6,7,9
	90/44	Haven	Cambs	n	1,2,3,4,6,9
	90/45	-	Cambs	n	1,2,3,4,6,9
	90/47	Apollo	Leics	n	1,2,3,9
	90/48	Apollo	Norfolk	O	1,2,3,4,7,9
	90/49	Apollo	Humberside	TMO	1,2,3,4,6,9
	90/50	Hornet	Northumberland	TMO	1,2,3,4,6,9
	90/51	Haven	Lincs	n	2,3,4,6,9
	90/52	Riband	Lincs	n	1,2,3,(9)
	90/53	Carolus	Leics	TM	1,2,3(4),9
	90/56	Hornet	Scotland	n	1,2,3,4,6,9
	90/57	ICI 16980/22/12/2	Scotland	n	1,2,3,4,6,9
	90/58	Haven	Scotland	n	1,2,3,4,6,9
	90/60	Hornet	Scotland	n	1,2,3,4,6,9
	90/62	Hornet	Shropshire	n	1,2,3,4,6,9
	90/63	Hornet	Norfolk	n	1,2,3,4,6,9
	90/64	<u>Aegilops cylindriam</u>	Norfolk	n	1,2,3,4,6,9
	90/65	Mara	Norfolk	n	1,2,3,9
	90/66	KU 9438	Norfolk	n	1,2,3,4,6,9
	90/67	KU 9178	Norfolk	n	1,2,3,4,6,9
	90/69	Hereward	Essex	n	1,2,3,4,6,9
	90/71	Haven	Essex	n	1,2,3,4,6,9
	90/75	Haven	Northumberland	n	1,2,3,4,6,9
	90/77	Talon	Scotland	n	1,2,3,4,6,9
	90/78	Beaver	Northumberland	n	1,2,3,4,6,9
	90/79	Slejpner	Suffolk	TM	1,2,3,4,9
	90/80	Talon	Lincs	n	1,2,3
	90/81	Slejpner	Lincs	TMO	-
	90/82	Slejpner	Lincs	O	-
	90/83	Haven	Scotland	n	1,2,3,4,6,9
	90/84	Apollo	Northumberland	n	1,2,3,4,6,9
	90/85	Haven	Scotland	n	1,2,3,4,6,9
	90/86	Axial	Northumberland	n	1,2,3,4,6,9
	90/87	Slejpner	Northumberland	n	1,2,3,4,6,9
	90/G1	Slejpner	Cambs	TO	1,2,3,4,9
	90/G2	Slejpner	Cambs	TO	1,2,3,4,9
	90/G3	Slejpner	Cambs	TO	1,2,3,4,9

Source and virulence factors of wheat yellow rust isolates (continued)

Year	Code	Source Cultivar	Location collected	Fungicide applied	Virulence factors
1990	90/G4	Slejpner	Cambs	n	1,2,3,4,9
	90/G5	Slejpner	Cambs	M	1,2,3,4,9
	90/G6	Slejpner	Cambs	TO	1,2,3,4,9
	90/G7	Slejpner	Cambs	TM	1,2,3,4,9
	90/G8	Slejpner	Cambs	TO	1,2,3,4,9
	90/G9	Slejpner	Cambs	TO	1,2,3,4,9
	90/G10	Slejpner	Cambs	TO	1,2,3,4,9
	90/G11	Hornet	Cambs	TO	-

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