Danish Research Service for Plant and Soil Science
Research Centre for Plant Protection
Department of Plant Pathology
DK-2800 Lyngby
Department of Biometry and Informatics
DK-2800 Lyngby

Report no. 2067

Influence of cultural practices on incidence of take-all (*Gaeumannomyces graminis* var. *tritici*) in winter wheat and winter rye

Kulturtekniske faktorers indflydelse på angrebsgraden af goldfodsyge (Gaeumannomyces graminis *var.* triciti) *i vinterhvede og vinterrug*

LARS BØDKER, HELLFRIED SCHULZ and KRISTIAN KRISTENSEN

Summary

In the years 1978–86, 627 trials established with different purpose in winter wheat and winter rye were evaluated for the incidence of take-all (*Gaeumannomyces graminis* var. *tritici*).

The trials were very heterogeneous and the results of the statistical analyses can therefore only show general trends.

Information about cultural practices was collected and analysed by a general linear model procedure in SAS. For each factor with regard to cultural practice the attack of take-all was estimated and corrected to an adjusted mean per cent attack and in this way the effect of unbalance in data was minimized.

There was a significantly larger attack of take-all in winter wheat compared to winter rye.

In the period 1978–86 attack of take-all showed a declining tendency.

One of the six regions was found to have a higher attack than the rest of the country.

Four years with winter wheat or spring barley caused the largest attack of take-all. One year break from wheat and spring barley with a broad-leaved crop was sufficient to reduce disease severity to a significantly lower level. No difference between field peas and oilseed rape was detected. Two years with grass for seed production did not increase the disease severity.

There was a clear negative correlation between yield and disease severity in winter rye and to a lesser extent in winter wheat.

Key words: Take-all, *Gaeumannomyces graminis* var. *tritici*, winter wheat, winter rye, cultivation methods.

Resumé

I den niårige periode fra 1978–86 blev der ved Planteværnscentret bedømt for angreb af goldfodsyge (*Gaeumannomyces graminis* (Sacc.) v. Arx & Olivier var. *tritici* J. Walker) i 627 forsøg anlagt i vinterhvede og vinterrug med forskellige formål.

Forsøgsmaterialet er meget heterogent og re-

sultaterne af den statistiske bearbejdelse af det store talmateriale kan derfor kun anskueliggøre generelle tendenser.

Den statistiske analyse viste et signifikant højere angreb af goldfodsyge i vinterhvede i forhold til vinterrug. I begge afgrøder faldt angrebet over perioden 1978–86. I regionen Sønderjylland var angrebsniveauet af goldfodsyge markant højere end i resten af landet. Materialet viser, at angrebsgraden af goldfodsyge er stærkt afhængig af forfrugts- og sædskiftekombinationer. Angrebsgraden af goldfodsyge var størst efter fire år med vinterhvede eller vårbyg. I femte års hvedeafgrøder viste der sig endnu ingen »declineeffect«.

To år med frøgræs opformerede ikke goldfodsygesvampen. Et år med vårbyg eller vinterhvede er tilstrækkeligt til at opbygge et højt smittepotentiale i marken. Modsat vil ét år med tokimbladede afgrøder kunne reducere smittepotentialet til et signifikant lavere niveau. For tokimbladede afgrøder var der ingen forskel mellem ært og raps.

Der var en klar negativ sammenhæng mellem udbytteniveauet og angrebet af goldfodsyge i rug og en mindre udtalt sammenhæng i hvede.

Nøgleord: Goldfodsyge, *Gaeumannomyces graminis* var. *tritici,* vinterhvede, vinterrug, kulturforanstaltninger.

Introduction

Take-all caused by the soil borne fungus *Gaeumannomyces graminis* (Sacc.) v. Arx & Oliver var. *tritici* J. Walker is a severe disease of wheat (*Triticum aestivum* L.) and rye (*Secale cereale* L.). Chemical control of take-all using foliar or soil drench fungicides has not been effective in the past (1, 2, 15, 23) and breeding for resistant cultivars is difficult and of doubtful economic value (18, 24, 27).

Control of take-all, therefore, includes crop rotation (8, 19, 22, 39, 43, 45); not too high pH (7); proper use of chloride fertilizer (5, 6, 12); ammonium forms of nitrogen (39, 5); late sowing (25, 32, 39, 44) and a well prepared seedbed (11).

G. graminis attacks wheat and barley especially and to a minor extent rye and some grasses (3, 13, 16, 17, 24, 28, 41).

Most plants withstand mild root infections and appear symptomless. Severe take-all symptoms are most obvious near heading when plants appear stunted. Tillers are killed prematurely and their heads are distinctly bleached and sterile giving the symptom called whiteheads.

In such cases, yield can be reduced by more than 50% (36).

This study was initiated to determine the influence of cultural practices on incidence of the take-all fungus in winter wheat and winter rye.

Materials and methods

Hand-dug samples of tillers, from 627 different crop rotation and fungicide trials in winter wheat and winter rye over the period 1978–86, were assessed for severity of take-all.

In July, around growth stage 75 (Zadoks scale), about 100 individual shoots per plot were randomly collected. Roots were washed and bleached in 1.5% sodium hypochlorite solution for about one hour. The disease severity in each plot was assessed by scoring the per cent discoloured root mass. Scoring has been done by the same person all years. Information about location, soil type, tillage method, burning of straw, crop rotation, sowing-time and yield were each year collected from the farmers.

Statistical analyses were carried out using the general linear model procedure (31) with the following qualitative factors: year, region, cereal host, soil type, tillage method, burning og straw, crop rotation and sowing-time. Estimates for the disease severity for each factorlevel in the model is an adjusted mean value, where the means are corrected for unbalance in the data. The estimate

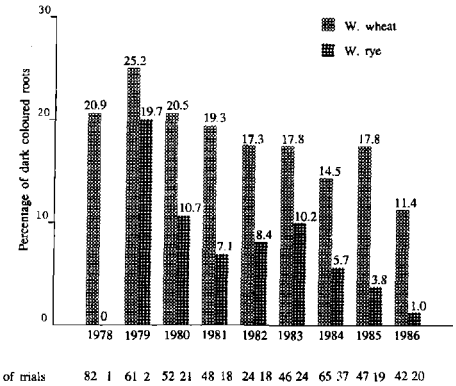

Fig. 1. Adjusted mean per cent attack of take-all in winter wheat and winter rye for the period 1978–86. 467 trials in winter wheat, 160 trials in winter rye.

Table 1. Significance table for the attack of take-all in winter wheat and winter rye in the years 1978–86, tested two by two (NS No significance, *P<=0.05, **P<=0.01, ***P<=0.001).

Winter wheat

	1978	1979	1980	1981	1982	1983	1984	1985	1986
1978		*	NS	NS	NS	NS	***	NS	***
1979			*	**	**	***	***	***	***
1980				NS	NS	NS	**	NS	***
1981					NS	NS	*	NS	***
1982						NS	NS	NS	*
1983							NS	NS	**
1984								NS	NS
1985									**
1986									

Winter rye

	1978	1979	1980	1981	1982	1983	1984	1985	1986
1978		*	NS	NS	NS	NS	NS	NS	NS
1979			NS	NS	NS	NS	NS	*	*
1980				NS	NS	NS	NS	*	**
1981						NS	NS	NS	NS
1982						NS	NS	NS	*
1983							NS	*	**
1984								NS	NS
1985									NS
1986									

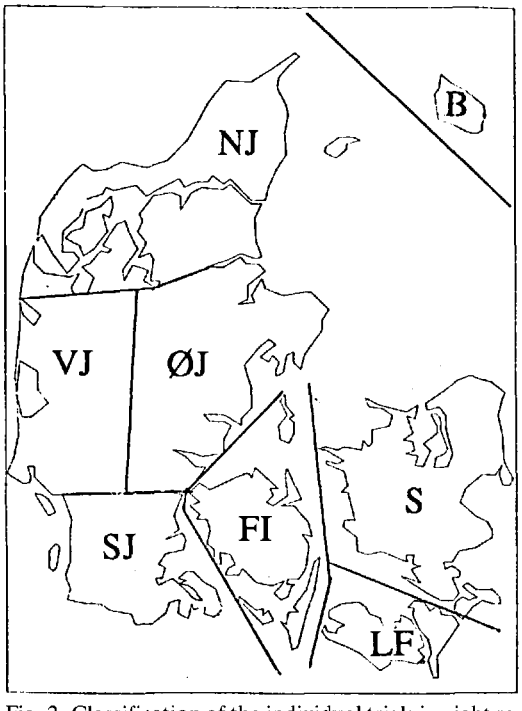

Fig. 2. Classification of the individual trials in eight regions NJ – Nordjylland, VJ – Vestjylland, ØJ – Østjylland, SJ – Sønderjylland, FI – Fyn and islands, SM – Sjælland and Møn, LF – Lolland-Falster and B – Bornholm.

of confidence is calculated by testing corrected adjusted mean values two by two using a t-test. The method takes into account the different number of observations for each factor and the additional variation caused by the adjustment.

Results

Year

Over the period 1978 to 1986, take-all in winter wheat has shown a slightly declining tendency. In winter rye the variation has been more pronounced (Fig. 1). In spite of this the number of significant differences was considerably higher for winter wheat than for winter rye (Table 1) probably because of the greater number of trials in winter wheat compared to winter rye.

Region

All the trials were classified in eight regions Nordjylland, Vestjylland, Østjylland, Sønderjylland, Fyn and the islands around Fyn, Sjælland and Møn, Lolland-Falster and Bornholm. Sønderjylland covers primarily the experimental station Rønhave on the island of Als (Fig. 2).

Table 2. Significance table for the attack of take-all in winter wheat for different combinations of previous crops in the period 1978–86, tested two by two (NS No significance, *P<=0.05, **P<=0.01, ***P<=0.001).

						WH SG SG	WH RA BA	WH RA WH	WH VE WH	WH PE WH	WH BA BE WH BA	WH BA	WH WH BA	WH WH RA	WH WH WH	WH BA BA BA	WH WH WH WH WH
WH	SG	SG					NS	NS	NS	NS	NS	NS	*	**	**	**	**
WH	RA	BA						NS	NS	NS	NS	*	**	***	***	***	***
WH	RA	WH							NS	NS	NS	NS	**	***	**	**	**
WH	VE	WH								NS	NS	NS	NS	NS	NS	NS	NS
WH	PE	WH									NS	NS	NS	*	*	*	**
WH	BA	BE	WH	BA								NS	NS	NS	NS	NS	NS
WH	BA	WH											NS	NS	NS	NS	NS
WH	WH	BA												NS	NS	NS	NS
WH	WH	RA													NS	NS	NS
WH	WH	WH														NS	NS
WH	BA	BA	BA	BA													NS
WH	WH	WH	WH	WH													

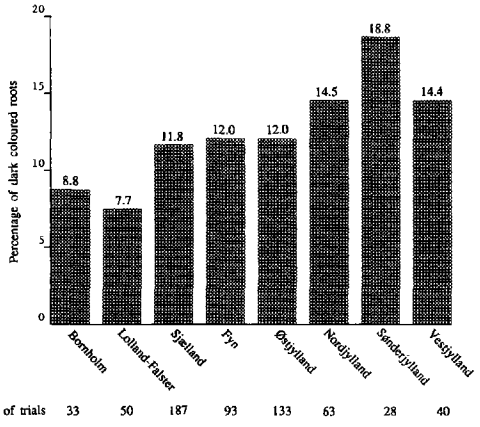

Fig. 3. Adjusted mean per cent attack of take-all in winter wheat and winter rye together in eight different regions over the period 1978–86. 627 trials.

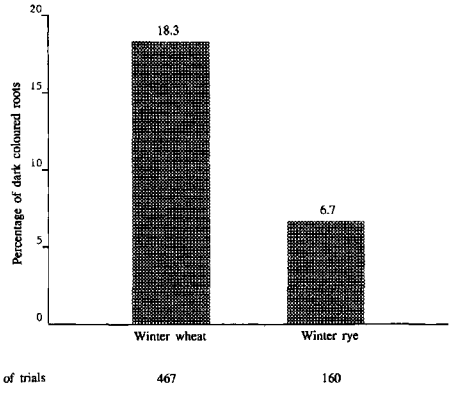

Fig. 4. Adjusted mean per cent attack of take-all in winter wheat and winter rye in the period 1978–86. 467 trials in winter wheat and 160 trials in winter rye.

The adjusted mean per cent attack of take-all in Sønderjylland for winter wheat and winter rye together was significantly higher than for the rest of the country (Fig. 3). The level of take-all in Nordjylland and Sønderjylland were significantly higher than the level in Lolland-Falster and Bornholm.

Cereal host

The statistical analyses included only trials in winter wheat and winter rye. There was a significantly (*P<=0.001) greater attack of take-all in winter wheat compared to winter rye (Fig. 4).

Crop rotation

Information concerning previous crops during a four years periode was registered for most of the trials. The 12 most common combinations of previous crops to winter wheat were tested (Fig. 5). The rotation winter wheat, spring barley, sugar beet, winter wheat is the most common in the region Lolland-Falster.

As expected the combination of four years monoculture with winter wheat or spring barley prior to winter wheat caused the highest attack of take-all. They were however not significantly different from combinations with winter wheat or barley the year before the winter wheat crop (Table 2).

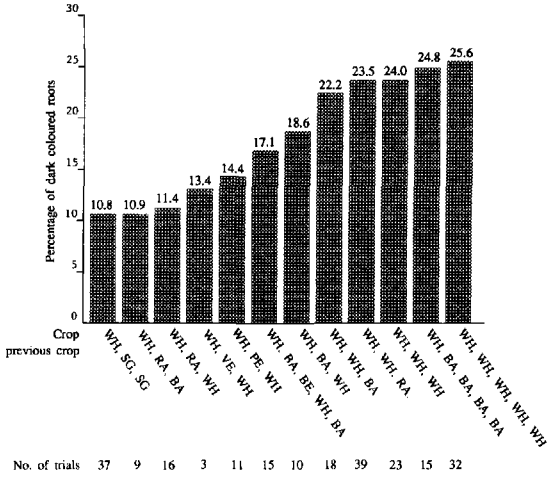

Fig. 5. Adjusted mean per cent attack of take-all in different combinations of previous crops to winter wheat in the period 1978–86. Ra-oilseed rape, SG-grass for seed production, WH-winter wheat, VE-vegetables, PE-peas, BA-spring barley, BE-sugar beets. 225 trials.

There was a significant difference in the incidence of take-all in winter wheat between field peas (*Pisum sativum L.*) or oil-seed rape (*Brassica napus L.*) and cereal monoculture used as previous crops (Fig. 5, Table 2). Two years with grass for seed production did not increase the severity of take-all in winter wheat.

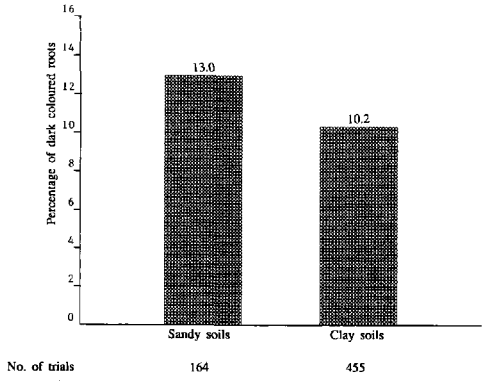

Fig. 6. Adjusted mean per cent attack of take-all in both winter wheat and winter rye on clay soils and sandy soils respectively over the period 1978–86. 164 trials on sandy soils, 455 trials on clay soils.

Soil type

Dividing the trials into those carried out on sandy soils and those on clay soils resulted in no significant difference in the adjusted mean per cent attack of take-all for the two soil types (Fig. 6).

Tillage

There was no effect of tillage on the severity of take-all in trials with conventional tillage including ploughing before sowing compared to trials with direct drilling (Fig. 7).

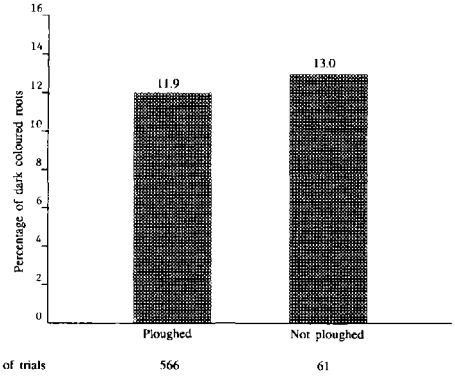

Fig. 7. Adjusted mean per cent attack of take-all in both winter wheat and winter rye by conventional ploughing and not ploughing respectively before sowing in autumn in the period 1978–86. 566 trials were ploughed and 61 trials were not ploughed.

Sowing-time

All the trials were classified in six groups according to the time of sowing (Fig. 8).

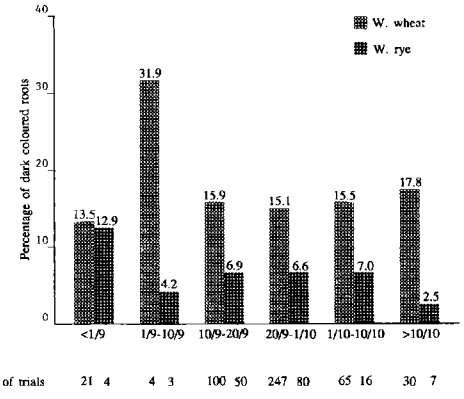

Fig. 8. Adjusted mean per cent attack of take-all in winter wheat and winter rye for different intervals in the time of sowing over the period 1978–86. 467 trials in winter wheat, 160 trials in winter rye.

With one exception there were no significant difference between the sowing dates for winter wheat. The significantly greater level (*p <=0.001) of take-all in the second interval (2/9 – 20/9) shall be considered with care due to the fact that there are only three trials (observations) behind the estimate.

There are no significant differences in the levels of take-all in winter rye for the different intervals of sowing-time.

Straw treatment

In the trials where the previous crop was a cereal crop the effect of burning straw before tillage was analysed. It was found that there was no effect on the level of take-all by burning the straw (Fig. 9).

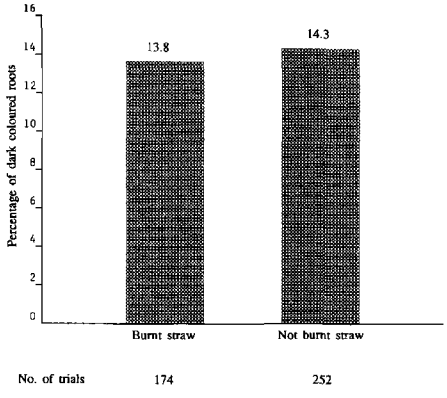

Fig. 9. Adjusted mean per cent attack of take-all where the straw have been burnt or not burnt before tillage for both winter wheat and winter rye over the period 1978–86. 174 trials where the straw have been burnt and 252 trials with no burning.

Grain yield

Grain yield with respect to disease severity is given in Fig. 10. There was a clear negative correlation between yield and disease severity (Fig. 10). There was only a small number of trials with severe attack of take-all.

In winter wheat a significant decline in grain yield was registrated when the darkcoloration increased from below 10% to 11–20% and from 11–20% to 21–30%. In winter rye there was only a significant difference in grain yield below 10% and above 30% dark coloured roots.

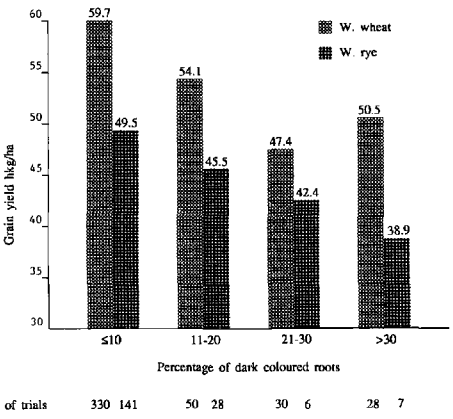

Fig. 10. Adjusted mean grain yield (hkg/ha) by different degree of dark coloured roots over the period 1978–86. 438 trials in winter wheat and 187 trials in winter rye.

Discussion and conclusion

The estimated values are calculated on the basis of very heterogeneous trials. There is, therefore, a great degree of uncertainty about the values for the adjusted mean per cent attack of take-all and the results of the statistical analyses can only show general trends.

The reason for the indicated decline of take-all in winter cereals over the nine year period 1978–86 is difficult to explain. A lot of information about the disease has been given to the farmers over the period and most farmers now take their precautions against the take-all disease.

The combination of biological, chemical and physical factors at different locations influences the expression of take-all (49). The variation between regions reflects mainly the variation in climatic conditions and the general inoculum potential. The significantly highest level of take-all was registered in the region Sønderjylland which primarily covers the experimental station Rønhave on the island of Als, which is an area with a traditionally high level of take-all.

The higher level of take-all in winter wheat than in winter rye was in agreement with several previous investigations (3, 13, 16, 17, 24, 28, 41).

Crop rotation is the oldest and still the most reliable way to reduce the inoculum potential. In Denmark, *Jensen* (15) confirmed the classic »take-all decline« phenomenon where the disease

severity in a cereal monoculture increased the first 2–4 years and then declined to a constant lower level. The yield was inversely proportional to the disease severity. The present results do not show any indication of a decline effect in the fifth crop of winter wheat (Fig. 5).

In crop rotations where field peas or oilseed rape were the previous crop to winter wheat, the disease severity is significantly lower than in fields where the previous crop was winter wheat or spring barley.

Two years with grass for seed production did not increase the disease severity in winter wheat in spite of the ability of ryegrass (*Lolium multiflorum* L. and *Lolium perenne* L.) (4, 34) timothy (*Phleum pratensis* L.) and meadow fescue (*Festuca pratensis* Huds.) (4) to be host for the take-all fungus. Several investigations in Northern Europe have shown a significant reduction in disease severity in winter wheat after a grass crop because of the natural content of antagonistic microorganisms in the soil (9, 33, 34, 38, 46, 47).

One year with winter wheat or spring barley is sufficient to build up inoculum to a high level, but one year break from winter wheat or spring barley with a broad-leaved crop is also sufficient to reduce the disease severity to a significantly lower level (Fig. 5).

No differences between field peas or oilseed rape as the previous crop to winter wheat were detected (Fig. 5). Danish assessment at Rønhave Research Station has shown a slightly higher level of take-all with field peas than spring rapeseed as the previous crop (*Jepsen,* pers.comm.).

A number of investigations have shown that take-all is generally most severe on lighter soils (11, 14, 28, 29, 30, 49). In the present study there are no significant differences between the adjusted mean per cent attack of take-all on sandy soils and clay soils but there was tendency in the same direction. The reason is probably the rough classification of the soils in the two groups.

Many reports from field studies all over the world show contradictory results concerning the effect of tillage methods (21, 48). In these trials only two tillage systems, direct drilling and conventional ploughing, were tested (Fig. 7). There were no significant differences between the two tillage systems probably because of several contradictory processes in the root zone.

Our studies cannot confirm the general conclusion of others (25, 32, 39, 44) that plants show a lower degree of infection when the sowing-time is delayed (Fig. 8).

Burning of straw and stubble before sowing in the autumn had no effect on the attack of take-all in the subsequent cereal crop (Fig. 9). Most of the infected crop debris is located in the rooting zone below the soil surface and is, therefore, not particularly affected by burning. Similar results were found by *Dueholm* and *Jørgensen* (10) and *Shipton* (35).

Regression analyses (26, 37, 40) indicate that an increase in the attack of take-all, decreased yield of winter wheat. *Stetter* (42) found that several fungi were able to discolour the roots of spring barley and 10 % of the isolated fungi from the roots were able to lower the yield at least by 20%. According to *Stetter* (pers. comm.) the yield of spring barley is not influenced if less than 20% of the roots are affected.

In spite of the relatively few trials with severe attack a clear relation between the grain yield and the severity of take-all was also found here (Fig. 10). Cereal monoculture of winter wheat and spring barley causes the highest attack of take-all (Fig. 5) and probably the lowest grain yield. In Fig. 10 it is not possible to distinguish between the reducing effect of physical and chemical factors resulting from cereal monoculture and the attack of take-all on the grain yield. Besides the general linear model is simplified and the means adjusted only for unbalance in data due to variation between region and soil type.

The study has shown a lot of uncertainty about the effect of cultural practices but nevertheless it shows clearly that the broad-leaved break crops field pea or oil-seed rape can reduce the disease severity in a following crop of winter wheat.

References

1. *Bateman, G. L.* 1980. Prospects for fungicidal control of take-all of wheat. Ann. appl. Biol. 96, 275-282.
2. *Bockus, W. W.* 1983. Effects of fall infection by *Gaeumannomyces graminis* var. *tritici* and triadimenol seed treatment on severity of take-all in winter wheat. Phytopathology 73, 540-543.
3. *Christensen, B. D.* 1967. Undersøgelser over goldfodsygesvampen *Ophiobolus graminis* (Sacc.) 1. Undersøgelse over virulensens variation, kornarternes modtagelighed og udbyttedepression ved smitte med *Ophiobolus graminis.* Tidsskr. Planteavl. 71, 64-69.

4. *Christensen, B. D.* 1968. Undersøgelser over goldfodsygesvampen *Ophiobolus gramnis* (Sacc.) III. Nogle græsarters modtagelighed samt deres evne til at overføre smitte af *Ophiobolus graminis*. Tidsskr. Planteavl. 72, 90-99.
5. *Christensen, N. W. & Brett, M.* 1985. Chloride liming effects on soil nitrogen form and take-all of wheat. Agron. J. 77, 157-163.
6. *Christensen, N. W., Powelsen, R. L. & Brett, M.* 1987. Epidemiology of wheat take-all as influenced by soil pH and temporal changes in inorganic soil N. Plant and Soil. 98, 221-230.
7. *Cook, R. J.* 1981. The effect of soil reaction and physical conditions. In Biology and Control of Take-all. *M. J. C. Asher* and *P. J. Shipton* (eds), Academic Press, London, p. 343-352.
8. *Cotterill. P. J. & Sivasithamparam, K.* 1988. Reduction of take-all inoculum by rotation with lupin, oats or field peas. J. Phytopath. 121, 125-134.
9. *Deacon, J. W.* 1973. Control of the take-all fungus by grass leys in intensive cereal cropping. Pl. Path. 22, 88-94.
10. *Dueholm, S. & Jørgensen, I.* 1974. Halmens indflydelse på kerneudbyttet og fodsyge ved ensidig korndyrkning 1967-1973. Statens Forsøgsvirksomhed i Plantekultur, Meddelelse nr. 1159.
11. *Glenn, O. F., Hainsworth, J. M., Parker, C. A. & Sivasithamparam, K.* 1987. Influence of the matric potential and soil compaction on the growth of the take-all fungus through soil. Trans. Br. mycol. Soc. 88, 83-89.
12. *Gutteridge, R. J., Bateman, G. L. & Hornby, D.* 1987. Comparison of the effects of spring applications of ammonium chloride and other nitrogen fertilizers on take-all in winter wheat. J. agric. Sci. 108, 567-572.
13. *Hornby, D.* 1975. Inoculum of the take-all fungus: Nature, measurement, distribution and survival. EPPO Bull. 5, 319-333.
14. *Hostrup, S. B.* 1972. Jordens efterbehandling ved ensidig korndyrkning. Tidsskr. Planteavl 76, 490-502.
15. *Jensen, A.* 1975. Danish experiments with cereals in monoculture. EPPO Bull. 5, 181-191.
16. *Jensen, H. P. & Jørgensen, J. H.* 1970. Studies on the take-all fungus, *Gaemannomyces graminis* III. Interactions between fungal isolates and cereal species and varieties. Kgl. Vet.- og Landbohøjsk. Årsskr. 1970, 210-220.
17. *Jensen, H. P. & Jørgensen, J. H.* 1973. Reaction of five cereal species to the take-all fungus (*Gaeumannomyces graminis*) in the field. Phytopath. Z. 78, 193-203.
18. *Jensen, H. P. & Jørgensen, J. H.* 1976. Screening of barley varieties for resistance to the take-all fungus, *Gaeumannomyces graminis*. Z. Pflanzenzüchtg. 76, 152-162.
19. *Jepsen, H. M.* 1976. Resultater fra sædskifte og kulturforsøg i forbindelse med ensidig korndyrkning. Statens Planteavlsmøde 1976, 49-58.
20. *Jepsen, H. M.* 1980. Afgrødevalg og dyrkningssystemer. Ugeskr. Jordbrug 125, 7-12.
21. *Kochs, H. J.* 1975. Prognosis, control and resistance. Z. PflKrankh. PflSchulz. 82, 57.
22. *Kollmorgan, J. F., Griffiths, J. B. & Walsgott, D. N.* 1983. The effects of various crops on the survival and carry-over of the wheat take-all fungus *Gaeumannomyces graminis* var. *tritici*. Pl. Path. 32, 73-77.
23. *Mathre, D. E., Johnston, R. H. & Engel, R.* 1986. Effects of seed treatment with triadimenol on severity of take-all of spring wheat caused by *Gaeumannomyces graminis* var. *graminis*. Pl. Dis. 70, 749-751.
24. *Nilsson, H. E.* 1969. Studies of root and foot rot diseases of cereals and grasses. Lantbrukshögskolans Annaler. 35, 275-807.
25. *Olsen, C. C.* 1984. Såtid og såmængde i vinterhvede og vinterbyg. Tidsskr. Planteavl. 88, 557-569.
26. *Olvång, H.* 1982. Sambandet mellan rotparasiter och stråsädesskörd i svenska växtföljdsförsök. Nordisk Planteværnskonference, København, 181-184.
27. *Penrose, L.* 1985. Evidence for resistance in wheat cultivars grown in sand culture to the take-all pathogen, *Gauemannomyces graminis* var. *tritici*. Ann. appl. Biol. 107, 105-108.
28. *Pedersen, P. N. & Jørgensen, J.* 1960. Knækkefodsygens og goldfodsygens afhængighed af sædskifte og andre dyrkningsfaktorer. Tidsskr. Planteavl. 64, 369-416.
29. *Petersen, H. I.* 1963. Landsomfattende undersøgelser over forekomst af fodsyge i kornmarker i 1961 og 1962. Ugeskr. Landmænd 31, 487-492.
30. *Rasmussen, K. J. & Olsen, C. C.* 1983. Jordbearbejdning og efterafgrøde ved bygdyrkning. I. Vækstbetingelser, jordfysiske målinger og udbytter ved ensidig byg og sædskifteforsøg. Tidsskr. Planteavl. 87, 193-215.
31. *SAS User's Guide* 1985. Statistics. Version 5 Edition. SAS Institute Inc. Cary, N. C. USA. 960 pp.
32. *Schulz, H.* 1970. Angreb af fodsyge (*Pseudocercosporella herpotrichoides* Fron og *Ophiobolus graminis* Sacc.) ved forskellige såtider, så- og kvælstofmængder i vinterrug og vinterhvede. Tidsskr. Planteavl 74, 412-418.

33. *Schulz, H.* 1980. Smitteforsøg i korn i væksthus med goldfodsygesvampen *Gaeumannomyces graminis* (Sacc.) von Arx et Olivier. Smittetidspunktets og smittemængdens betydning. Tidsskr. Planteavl 84, 257-263.
34. *Schulz, H.* 1981. Nogle rajgræssorters modtagelighed over for goldfodsyge (*Gaeumannomyces graminis* Sacc.) og deres evne til at overføre smitten til en efterfølgende bygafgrøde. Tidsskr. Planteavl 85, 93-96.
35. *Shipton, P. J.* 1972. Influence of stubble treatment and autumn application of nitrogen to stubbles on the subsequent incidence of take-all and eyespot. Pl. Path. 21, 147-155.
36. *Slope, D. B. & Cox, J.* 1964. Continuous wheat growing and the decline of take-all. Rothamsted Exp. stn. Rep. for 1963. 108 pp.
37. *Slope, D. B. & Etheridge, J.* 1971. Grain yield and incidence of take-all (*Ophiobolus graminis* Sacc.) in wheat grown in different crop sequences. Ann. appl. Biol. 67, 13-22.
38. *Slope, D. B., Salt, G. A., Brown, E. W. & Culleridge, R. J.* 1978. Occurence of *Phialophora graminicola* var. *graminicola* and *Gaeumannomyces graminis* var. *tritici* on roots of wheat in field crops. Ann. appl. Biol. 88, 239-246.
39. *Steinbrenner, K. & Höflich, G.* 1984. Einfluss acker- und planzenbaulicher Massnahmen auf den Befall des Getreides durch *Pseudocerosporella herpotrichoides* (Fron) Deighton und *Gaeumannomyces graminis* (Sacc.) Arx. et Olivier. Arch. Phytopathol. u. Pflanzenschutz, Berlin 20, 469-486.
40. *Steinbrenner, K. & Obenauf, U.* 1986. Untersuchungen zum Einfluss der Vorfrucht und Vorvorfrucht auf den Ertrag der Wintergetreidearten und den Befall durch *Gaeumannomyces graminis*. Arch. Acker-Pflanzenbau Bodenkd. Berlin 30, 773-779.
41. *Stetter, S.* 1973. Forskellige kornarters evne til at overføre goldfodsyge *(Gaeumannomyces graminis)* og knækkefodsyge *(Cercosporella herpotrichoides)* til vårhvede. Tidsskr. Planteavl 77, 568-572.
42. *Stetter, S.* 1975. Alteration of the fungal population by continued cereal growing. Z. Pflanzenkh. Pflanzenschutz 82, 54.
43. *Sturz, A. V. & Bernier, C. C.* 1985. Incidence of a »Take-All Like Fungus« recovered from the crowns, stems and roots of winter wheat grown in Manitoba. Can. Pl. Dis. Surv. 65, 53-55.
44. *Taylor, R. G., Jackson, T. L., Powelson, R. L. & Christensen, N. W.* 1983. Chloride, nitrogen form, lime, and planting date effects on take-all root rot of winter wheat. Pl. Dis. 67, 1116-1120.
45. *Walker, J.* 1975. Take-all disease of *Gramineae:* a review of recent work. Rev. of Pl. Path. 54, 113-144.
46. *Wong, P. T. W.* 1981. Biological control by cross-protection. In Biology and Control of Take-all. *M. J. C. Asher* and *P. J. Shipton* (eds), Academic Press, London p. 417-432.
47. *Yarham, D. J.* 1981. Practical aspects of epidemiology. In Biology and Control of Take-all. *M. J. C. Asher* and *P. J. Shipton* (eds), Academic Press, London, 343-384.
48. *Yarham, D. J. & Hirst, J. M.*. 1975. Disease in reduced cultivation and direct drilling systems. EPPO Bull. 5, 287-296.
49. *Zimmermann, A.* 1983. Wurzelfäule an Weizen durch *Gaeumannomyces graminis* var. *tritici* – Interaktionen zwischen Fruchtfolgestellung und bodenphysikalischen Parametern. Z. PflKrankh. PflSchutz. 90, 505-514.

Manuscript received 22 December 1989.