Head blight *(Fusarium spp.)* resistance of wheat cultivars registered in Austria[1]

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Ährenfusariose-Resistenz von österreichischen Weizensorten

1. Introduction

The FAO of the United Nations estimated that about 25 % of the world's food crops are affected by mycotoxins each year (MANNON and JOHNSON, 1985). In developing countries inadequate storage conditions are the main cause for mycotoxin contamination. There exist mainly problems with *Aspergillus spp.* infections leading to aflatoxin accumulation. Under temperate climatic conditions especially *Fusarium spp.* and concomitant toxins are predominant (LEW, 1993).

The most important mycotoxins produced by *Fusarium* on small grain cereals and maize in Austria are deoxynivalenol (DON), moniliformin and zearalenone (ZON). More toxic *Fusarium* metabolites such as T2-toxin and fumonisins are produced by *Fusarium spp.* which play only a secondary role in Austria (LEW, 1993). The economic impact of *Fusarium* head blight (FHB) can be substantial. The presence of mycotoxins in cereals may have serious implications for crop and livestock producers, grain handlers as well as food and feed processors. Direct economic losses result from low crop yields, poor grain quality (baking quality and seed quality), reduced animal performance and reproductive capability, and increased disease incidence. In Austria the guidelines for maximum mycotoxin concentrations in small grain cereals are: 1) for DON: 500 ppb in *Triticum aestivum* L. and in *Secale cereale* L., and 750 ppb in *T. durum* Desf. and 2) for ZON: 60 ppb in cereals (ÖST. LEBENSMITTELBUCH, 1993). World-wide efforts are increasing to set legislatively regulated upper limits for toxin concentrations in food and feed. Additional economic losses due to *Fusarium* fungi originate from the cost of programs designed to moni-

Zusammenfassung

Im Rahmen eines Resistenzzüchtungsprogrammes gegen Ährenfusariose bei Weizen wurde die Resistenz von in Österreich registrierten Weizensorten und Linien in der Wertprüfung getestet. Nach künstlicher Inokulation wurden Krankheitsverlauf und Ernteverlust jedes Genotyps bestimmt. In diesem Beitrag werden dreijährige Ergebnisse präsentiert. Die Winterweizengenotypen mit dem höchsten Resistenzniveau in diesem Sortiment waren Martin, Livius, Karat, Extrem, Expert und Perlo. Kadett, Delos und Hans waren die meist resistenten Sommerweizensorten. Alle *Triticum durum* Genotypen waren sehr anfällig.

Schlagworte: Ährenfusariose, Resistenz, *Fusarium,* Weizen, Österreich.

Summary

Within the scope of a resistance breeding program against *Fusarium* head blight (FHB, scab) of wheat, the resistance of in Austria registered wheat cultivars and breeding lines in national list trials was tested. The wheat genotypes were artificially inoculated and disease development as well as yield loss were determined. The results of a three years' investigation are presented in this contribution. Based on visual observations the most resistant winter wheat genotypes were Martin, Livius, Karat, Extrem, Expert and Perlo. Of the investigated spring wheat cultivars Kadett, Delos and Hans showed the highest resistance level. All *Triticum durum* genotypes reacted very susceptible.

Key words: scab, resistance breeding, *Fusarium, Triticum,* Austria.

1 This work was supported by the Ministry of Agriculture and Forestry, Austria (research project nrs. L687/91 and L850/94).

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tor and regulate mycotoxin concentrations in crops to minimise health risks for humans and animals.

To date the cultivation of resistant varieties is the best solution to reduce mycotoxin contamination of cereals. Within the scope of a resistance breeding program against head blight of wheat, the resistance of in Austria registered wheat cultivars as well as the resistance of breeding lines in national list trials were tested. The wheat genotypes were artificially inoculated and the disease development as well as yield loss were evaluated. The results of a three years' investigation are presented in this contribution.

Table 1: Characteristics of the *Fusarium* inocula used in the field experiments described by species, source and colony forming units/mL^{-1} (- = not used)

Tabelle 1: Eigenschaften der verwendeten *Fusarium* Inokula: *Fusarium Spezies,* Herkunft des Isolates und Anzahl der lebenden Vermehrungseinheiten mL^{-1} (– = nicht verwendet)

Isolate	*Fusarium spp.*	Source	Colony Forming Units mL^{-1}		
			1992	1993	1994
91015	*F. culmorum*	*T. durum*	$22*10^4$	$23*10^4$	–
91031	*F. graminearum*	*T. durum*	$45*10^4$	$55*10^4$	–
91047	*F. graminearum*	*T. durum*	$51*10^4$	$45*10^4$	–
91401	*F. culmorum*	*T. aestivum*	$48*10^4$	$58*10^4$	$1*10^6$
A1	*F. graminearum*	*Zea mays*	–	–	$25*10^4$

2. Material and Methods

The experiments were carried out at the Experimental Station of the University of Agricultural Sciences in Großenzersdorf near Vienna. The head blight resistance of in Austria registered wheat cultivars and lines in official state trials was tested from 1992 to 1994. The investigated wheat genotypes are listed in table 4 (winter wheat, *T. aestivum*) and table 5 (spring wheat, *T. aestivum* and *T. durum*).

The characteristics of the inocula used for artificial inoculation are summarised in Table 1. Both *F. graminearum* and *F. culmorum* were used, isolated from either *T. durum*, *T. aestivum* or *Zeae mays* L.. All isolates were single spore isolates (LEMMENS et al., 1993), and long-term preservation was carried out with the soil storage method (see DHINGRA and SINCLAIR, 1985 and references therein). The inocula were prepared with the bubble breeding method (MESTERHAZY and ROWAISHED, 1977), except the inoculum of isolate 91401 in 1994 which was prepared on a mixture of wheat and oat kernels according to SNIJDERS and VAN EEUWIJK (1991). The latter inoculum consisted of macroconidia only, while the other inocula were mixtures of mycelium and macroconidia. The number of colony forming units mL^{-1} was determined as described by LEMMENS et al. (1993). If only macroconidia were present in the inoculum, they were counted with a Bürker-Türk counting chamber. The aggressiveness of the inocula was tested with the Petridish infection test before and after the field inoculation period (LEMMENS et al., 1993) and proved to remain constant (results not shown).

The description of the field trials of each year is summarised in table 2. The design of the field trials has been improved from year to year based on experience of the previous seasons. In 1993 and 1994 replicates were sown with about two weeks interval resulting in a few days difference

Table 2: Description of the experiments and experimental designs of the field experiments (WW, winter wheat; SW, spring wheat)

Tabelle 2: Beschreibung der Experimente und Versuchsanlagen in den einzelnen Prüfjahren (WW, Winterweizen; SW, Sommerweizen)

Year	Wheat Genotype	Number of Isolates	Humidity Control	Number of Replications	Experimental Design
1992	1 plot of 10 m^2 (main plot)	4 (subplot)	bunches covered after inoculation with bags for 24 hours	3, nested within 1 plot and inoculated on the same day	nested design: replications nested within the genotypes
1993	3 plots of 3 m^2 sown on 3 different days (main plot)	4 (subplot)	bunches covered after inoculation with bags for 24 hours	3, inoculated on 3 different days (SW: 2 replications only)	split-plot
1994	3 plots of 1 m^2 sown on 3 different days (main plot)	2 (subplot)	bunches with bags and mist irrigation and bunches with mist irrigation only (subplot)	3, inoculated on 3 different days (WW: 2 replications only)	split-plot

in flowering time. The wheat genotypes were always inoculated by spraying 20 mL of each *Fusarium* suspension on separate bunches of 20 to 25 wheat heads at anthesis. A control bunch was treated with distilled water (not in 1994). A high relative air humidity was provided either by covering the heads with a bag for 24 hours or by using a mist irrigation system (in 1994). In the latter case the crop was kept humid for 20 hours after inoculation by sprinkling every 15 minutes for 10 seconds.

Disease development was evaluated 4 to 5 times starting on the 10^{th} day after inoculation and repeated thereafter every fourth day. The percentage of diseased spikelets was estimated on a 0 (no symptoms) to 4 (100 % diseased) scale; between 0 and 1 disease symptoms were scored at one decimal exact, between 1 and 4 at half a unit. The area under the disease progress curve (AUDPC) was calculated for each genotype and subsequently standardised (SAUDPC) according to the following equation:

$$SAUDPC = 1 - AUDPC/AUDPC_{max}$$

in which $AUDPC_{max}$ is the maximum possible area calculated when on the 10^{th} day all spikelets were diseased. SAUDPC ranges from 1 (no disease symptoms) to 0 (completely diseased on the first evaluation date) (see LEMMENS et al., 1993). Out of each bunch 15 representative ears were harvested after ripening and the relative ear weight (REW) was determined in relation to ears from the non-inoculated control bunch (the REW is the weight of 15 diseased ears divided by the weight of 15 non-inoculated ears of the same genotype). In 1994 the 15 control ears were cut at random out of the non-inoculated part of the plot. In 1993 REW was not determined for the spring wheats.

The genotypes and the number of genotypes tested (see table 4 and 5) as well as the experimental design of the experiments (see table 2) differed from year to year. The trials of each year were analysed according to their experimental designs. The mean values of each genotype in each year were then analysed across years and a least square mean (LSM) was calculated for each genotype using the SAS-GLM procedure (SAS, 1989).

3. Results

The variance analysis tables of both the SAUDPC and the REW data of the investigated winter and spring wheat genotypes showed highly significant differences between genotypes and between the isolates in each year of testing (results not shown). The only exception was in 1994 when for the parameter REW no significant differences between genotypes were detected in the winter and in the spring wheat nursery. Usually the genotype by isolate interaction was significant, but the mean square values were low as compared to the mean square values of the main factors wheat genotypes and fungal isolates.

The variance analyses of both parameters SAUDPC and REW for the winter and spring wheat nursery across 3 years are illustrated in table 3A and table 3B, respectively. Significant effects of genotype and especially of the year of testing were determined. The results for the FHB resistance of the investigated winter and spring wheat genotypes are presented in table 4 and 5, respectively. A large continuous variability in resistance was detected, SAUDPC ranging from 0.90 (for the cultivars Karat, Livius and Martin) down to 0.59 (Contra) in the winter wheat nursery. Among the most resistant spring wheat genotypes were Kadett, Delos and Hans (SAUDPC of 0.88, 0.84 and 0.81, respectively). All *T. durum* cultivars reacted very susceptible. The correlation coefficient r between the LSM data of SAUDPC and of REW in the winter wheat and the spring wheat nursery was 0.80 and 0.84, respectively (for all r: probability < 0.1 %).

Table 3A: Variance analysis of the parameters SAUDPC and REW for the investigated winter wheat genotypes across 3 years
Tabelle 3A: Ergebnisse der Varianzanalyse für die Parameter SAUDPC und REW der untersuchten Winterweizengenotypen über alle drei Jahre

Source	SAUDPC			REW		
	DF	Mean square	F Value	DF	Mean square	F Value
Genotypes (G)	66	0,0137	2,06**	66	0,0130	1,68*
Years (Y)	2	0,6414	96,44***	2	0,7071	90,93***
Error (G*Y)	61	0,0067		61	0,0078	

Table 3B: Variance analysis of the parameters SAUDPC and REW for the investigated spring wheat genotypes across 3 years
Tabelle 3B: Ergebnisse der Varianzanalyse für die Parameter SAUDPC und REW der untersuchten Sommerweizengenotypen über alle drei Jahre

Source	SAUDPC			REW		
	DF	Mean square	F Value	DF	Mean square	F Value
Genotypes (G)	35	0,0282	4,64***	32	0,0166	5,67**
Years (Y)	2	0,4982	81,91***	1	0,2056	70,26***
Error (G*Y)	30	0,0061		11	0,0029	

Table 4: Head blight resistance (SAUDPC) and relative ear weight (REW) data of the investigated winter wheat genotypes
Tabelle 4: Gesamtmittelwerte für die einzelnen Prüfjahre und Least-Square-Mittelwerte (LSM) der SAUDPC und des REW über alle drei Jahre der untersuchten Winterweizensorten

Genotype	Origin	Country	SAUDPC				REW
			1992	1993	1994	LSM	LSM
81-F3-79*	INRA/Agri-Obtentions S.A.	F	0.78	0.98	0.94	0.90	0.81
Karat	Probstdorfer Saatzucht	A	0.79	0.94		0.90	0.71
Livius[1]	Saatbau Linz	A	0.81	0.93		0.90	0.78
Martin[1]	Probstdorfer Saatzucht	A	0.83	0.96	0.90	0.90	0.64
Expert[1]	Probstdorfer Saatzucht	A	0.76	0.96	0.92	0.88	0.77
Extrem	Probstdorfer Saatzucht	A	0.72	0.97	0.95	0.88	0.75
Perlo	Probstdorfer Saatzucht	A	0.84	0.89	0.90	0.88	0.67
Arina*	F.A.P. Zürich-Reckenholz	CH	0.72	0.94	0.92	0.86	0.72
SL 101/82-3B[2]	Saatbau Linz	A			0.92	0.86	0.68
SVP 72017*	CPRO-DLO Wageningen	NL	0.77	0.95	0.86	0.86	0.74
Agron	Saatbau Neuhof	A	0.90	0.90	0.74	0.85	0.72
Georg	Probstdorfer Saatzucht	A			0.91	0.85	0.71
Titus[1]	Saatbau Linz	A	0.79	0.89	0.87	0.85	0.70
Pokal[1]	Probstdorfer Saatzucht	A			0.90	0.84	0.65
Artus[1]	Saatbau Linz	A	0.79	0.81		0.83	0.64
Claudius	Saatbau Linz	A	0.65	0.94	0.91	0.83	0.70
Justus	Saatbau Linz	A	0.77	0.87	0.85	0.83	0.62
Amadeus	Probstdorfer Saatzucht	A	0.73	0.95	0.79	0.82	0.69
Dominus	Saatbau Linz	A			0.88	0.82	0.66
Erla Kolben	Kärntner Saatbaugenossenschaft	A			0.88	0.82	0.57
Julius[1]	Saatbau Linz	A	0.63	0.94		0.82	0.66
SL 109/85-6[2]	Saatbau Linz	A			0.88	0.82	0.64
Florian	Probstdorfer Saatzucht	A			0.87	0.81	0.53
P 6409.90[2]	Probstdorfer Saatzucht	A			0.87	0.81	0.59
Renan	Agri-Obtentions S.A.	F			0.87	0.81	0.56
Silvius	Saatbau Linz	A			0.87	0.81	0.75
Willi	Bundesversuchswirtschaft Wieselburg	A			0.87	0.81	0.62
Capo	Probstdorfer Saatzucht	A	0.67	0.86	0.86	0.80	0.62
Adam	Saatbau Neuhof	A	0.64	0.87		0.79	0.63
SE 246/91[2]	L.F.S. Edelhof	A			0.85	0.79	0.66
Heiduck[1]	Saatbau Neuhof	A	0.57	0.93		0.78	0.61
Leopold	Probstdorfer Saatzucht	A		0.85	0.86	0.78	0.55
SE 266/90[2]	L.F.S. Edelhof	A			0.84	0.78	0.52
Almari[2]	IHAR Radzików-ZDHAR Smolice	PL			0.83	0.77	0.55
Famulus[1]	Saatbau Linz	A	0.67	0.80		0.77	0.56
SL 59/81-24[2]	Saatbau Linz	A	0.54	0.93		0.77	0.63
Sorbas[1]	Saatzucht Fr. Strube	D	0.58	0.90		0.77	0.65
Josef	Probstdorfer Saatzucht	A			0.82	0.76	0.64
Regent[1]	Probstdorfer Saatzucht	A	0.63	0.82		0.76	0.62
Brutus	Saatbau Linz	A			0.81	0.75	0.54

Genotype	Origin	Country	SAUDPC				REW
			1992	1993	1994	LSM	LSM
Hai	Hilleshög	D	0.54	0.90	0.82	0.75	0.63
LS 3-1-92[2]	Saatzucht Piatti	A			0.81	0.75	0.58
P 9102/3.88[2]	Probstdorfer Saatzucht	A	0.52	0.92		0.75	0.60
Aron	Semundo Saatzucht	D			0.80	0.74	0.51
Herzog	Saatzucht Breun	D	0.47	0.89	0.85	0.74	0.60
Kontrast	Semundo Saatzucht	D			0.79	0.73	0.52
PA 1484[2]	Saatzucht Breun	D	0.55	0.83	0.81	0.73	0.58
Ikarus	Saatbau Linz	A	0.45	0.85	0.87	0.72	0.62
Lindos	Saatzucht Fr. Strube	D			0.78	0.72	0.59
P 5367.90[2]	Probstdorfer Saatzucht	A			0.78	0.72	0.54
SE 203/90[2]	L.F.S. Edelhof	A			0.78	0.72	0.51
Atlantis	Saatzucht Schweiger	D	0.43	0.87	0.82	0.71	0.54
Hubertus	Saatbau Linz	A	0.52	0.84	0.75	0.70	0.56
Profit	Saatzucht Toerring	D	0.41	0.87	0.83	0.70	0.60
ST 507[2]	Saatzucht Streng's Erben	D			0.76	0.70	0.50
SE 293/91[2]	L.F.S. Edelhof	A			0.75	0.69	0.57
Ferdinand	Saatzucht Piatti	A	0.46	0.80		0.66	0.46
P 2283.89[2]	Probstdorfer Saatzucht	A			0.72	0.66	0.56
Alidos	Semundo Saatzucht	D		0.74		0.65	0.55
Aurus	Probstdorfer Saatzucht	A		0.67	0.78	0.65	0.57
Citadel[1]	Zelder B.V.	NL	0.43	0.81		0.65	0.55
Konsul[1]	W. Weibull AB	S	0.49	0.68	0.77	0.65	0.55
Donau[1]	S.A. Florimond Desprez Veuve et Fils	F	0.49	0.73		0.64	0.50
Rektor	Saatzuchtwirtschaft Firlbeck	D	0.39	0.71	0.82	0.64	0.56
Magnus[1]	Saatbau Linz	A	0.49	0.69		0.62	0.48
Apollo	Saatzucht Breun	D	0.41	0.72	0.71	0.61	0.55
Contra	Saatzucht Breun	D			0.65	0.59	0.43
Mean			**0.62**	**0.86**	**0.83**		
LSD5			**0.05**	**0.11**	**0.10**	**0.13[3]**	**0.14[3]**

For each investigated genotype the mean value of SAUDPC of each year of investigation is presented as well as the Least Square Means (LSM) calculated across all years. For REW only the LSM across 3 years is shown. The genotypes were sorted in order of decreasing resistance according to the LSM for SAUDPC. (* = local control lines, [1] = genotypes not registered anymore in Austria, [2] = genotypes which were not registered in Austria after official trials, [3] = LSD5 for LSM over all three seasons)
Die Reihung wurde abnehmend nach dem LSM für SAUDPC vorgenommen. (* = Standard, [1] = Sorten, die in Österreich nicht mehr zugelassen sind, [2] = Genotypen, die in Österreich nach offizieller Prüfung nicht registriert wurden, [3] = LSD5 für LSM über alle drei Jahre)

Table 5: Head blight resistance (SAUDPC) and relative ear weight (REW) data of the investigated spring wheat genotypes
Tabelle 5: Gesamtmittelwerte für die einzelnen Prüfjahre und Least-Square-Mittelwerte (LSM) der SAUDPC und des REW über alle Prüfjahre der untersuchten Sommerweizensorten

Genotype	Origin	Country	SAUDPC				REW
			1992	1993	1994	LSM	LSM
Hope*	USDA-BPI Highmore	USA	0.82	0.98		0.94	0.95
Kadett	W. Weibull AB	S	0.76	0.92		0.88	0.79
Lutescens 62*	IPSR Norwich Saratov	RU	0.75	0.97	0.89	0.87	0.58
Sumey 3*	Suzhou Inst. Agricultural Science	China		0.99	0.95	0.87	0.69
Frontana*	Wheat Experimental Station Bage	BRA		0.98	0.94	0.86	0.65
Delos[1]	Saatzucht Fr. Strube	D	0.70	0.91		0.84	0.60
Hans	Bundesversuchswirtschaft Wieselburg	A	0.73	0.89	0.81	0.81	0.62
Michael	Saatzucht Bauer	D			0.87	0.80	0.53
Favorit	Saatzucht Engelen	D			0.87	0.80	0.49
Rubin	Kärntner Saatbaugenossenschaft	A			0.85	0.78	0.62
Turbo[1]	Saatenring von Rümker	D	0.69	0.88	0.78	0.78	0.59
Kärntner Früher	Kärntner Saatbaugenossenschaft	A			0.84	0.77	0,56
SE 213/91[2]	L.F.S. Edelhof	A			0.81	0.74	0.55
Star	F. von Lochow-Petkus	D	0.56	0.92	0.75	0.74	0.51
Erwin	L.F.S. Edelhof	A	0.45	0.91	0.83	0.73	0.53
Nandu	F. von Lochow-Petkus	D	0.56	0.89	0.74	0.73	0.54
W 44[2]	Bundesversuchswirtschaft Wieselburg	A			0.80	0.73	0.55
LP 2663.87[2]	F. von Lochow-Petkus	D			0.79	0.72	0.56
P 3033.88[2 $]	Probstdorfer Saatzucht	A		0.85		0.72	
Mephisto[1]	Saatenring von Rümker	D	0.44	0.95	0.75	0.71	0.50
Remus	Bayerische Pflanzenzuchtgesellschaft	D	0.48	0.87	0.79	0.71	0.46
SE 208/92[2]	L.F.S. Edelhof	A			0.78	0.71	0.59
Grandur[$]	Probstdorfer Saatzucht	A	0.49	0.79	0.83	0.70	0.57
SE 229/90[2]	L.F.S. Edelhof	A			0.77	0.70	0.49
Signadur[1 $]	Probstdorfer Saatzucht	A	0.48	0.81		0.68	0.50
Brillant[1]	Bundesversuchswirtschaft Wieselburg	A	0.42	0.79		0.64	0.40
P 8334.90[2 $]	Probstdorfer Saatzucht	A			0.71	0.64	0.45
P 3326.90[2 $]	Probstdorfer Saatzucht	A		0.75		0.62	
Topdur[$]	Probstdorfer Saatzucht	A			0.64	0.57	0.39
Bonadur[$]	Probstdorfer Saatzucht	A	0.29	0.71	0.69	0.56	0.40
Extradur[$]	Probstdorfer Saatzucht	A		0.66	0.66	0.56	0.46
Helidur[$]	Probstdorfer Saatzucht	A	0.25		0.75	0.56	0.45
Astrodur[$]	Probstdorfer Saatzucht	A	0.30	0.64	0.64	0.53	0.38
Goldur[1 $]	Probstdorfer Saatzucht	A	0.25	0.72		0.52	0.43
Semperdur[$]	Probstdorfer Saatzucht	A		0.54		0.41	
P 4725.89[2 $]	Probstdorfer Saatzucht	A	0.21			0.41	0.37
Mean			**0.51**	**0.84**	**0.79**		
LSD5			**0.05**	**0.15**	**0.10**	**0.13[3]**	**0.12[4]**

For each investigated genotype the mean value of SAUDPC of each year of investigation is presented as well as the Least Square Means (LSM) calculated across 3 years. For REW only the LSM across 2 years is presented (REW was not determined in 1993). The genotypes were sorted in order of decreasing resistance according to the LSM for SAUDPC. (* = local control lines, [$] = *T. durum*, [1] = genotypes not registered anymore in Austria, [2] = genotypes which were not registered in Austria after official trials, [3] = LSD5 for LSM over all three seasons, [4] = LSD5 for LSM over 1992 and 1994)
Die Reihung wurde abnehmend nach dem LSM für den SAUDPC vorgenommen. (* = Standard, [$] = *T. durum*, [1] = Sorten, die in Österreich nicht mehr zugelassen sind, [2] = Genotypen, die in Österreich nach offizieller Prüfung nicht registriert wurden, [3] = LSD5 für LSM über alle Prüfjahre, [4] = LSD5 für LSM von 1992 und 1994)

4. Discussion

The incidence of natural FHB epidemics on wheat is largely depending on ideal weather conditions (humidity and temperature) for infection and the epidemics occur erratic in time and over locations. For this reason artificial inoculation techniques are used for FHB investigations in order to have an equally distributed infection pressure across the field trials. Because the success of such inoculation techniques also depends on the climate, adverse weather conditions can interfere significantly with the field resistance tests. This was the case in 1992. The first week of the inoculation period in this year was extremely dry and hot, leading to a very low infection pressure after inoculation. The second part of the inoculation period was humid and cooler and those conditions were more appropriate for infection. For this reason the resistance of early flowering genotypes was highly overestimated. This is especially true for the cultivar Agron, which was apparently the best winter wheat genotype in 1992 (see SAUDPC data in table 4). However, further investigations showed that Agron is actually one of the most susceptible winter wheat cultivars tested (see table 4 in 1994).

The different designs of the trials during the three seasons reflect the progress in inoculation techniques. In 1992 the replications were nested within the same plot (all replications were inoculated on the same day), in 1993 and 1994 the replications were sown with about 2 weeks interval resulting in different flowering dates and hence different inoculation days of the same genotype. In this way the same genotype was inoculated under varying weather conditions resulting in a larger variability between the results of the replications of each genotype (see increase of LSD5 in 1993 and 1994 as compared to 1992 in table 4 and 5). However, possible adverse weather conditions at inoculation of one replication (such as e. g. low temperature during the night) are partly neutralised by the results of the other replications, resulting in a better estimation of the genotype's true resistance. It was observed that during days with a high solar radiation the temperature inside the bags rises above 40°C resulting in a lower infection success. Therefore from 1994 onwards the high humidity, necessary for successful artificial FHB inoculation, was applied with a computer controlled mist irrigation system and the data from this year are considered to be the most reliable.

As the experimental designs of the field trials varied from year to year, no pooled error for the variance analysis across 3 years was calculated, and the effects "genotype" and "year" were therefore tested against the genotype by year interaction mean square. The variance analysis of the parameters SAUDPC and REW for the investigated winter and spring wheat nurseries revealed that the factor „year" was highly significant and accounted for a major proportion of the variability. In the factor „year" not only the effect of the year of investigation is present but also the influence of the isolates, the number as well as the kind of which was varying during the three years of field experiments (see table 1). In this design the influence of the isolates cannot be separated from the factor „year". Studies of artificial FHB inoculations over years have shown highly significant differences between average infection severity in different years as well as significant genotype by year interactions (MESTERHAZY, 1987). For the latter reason it is necessary to repeat experiments over years in order to obtain reliable FHB resistance results.

Testing the FHB resistance of the registered wheat cultivars is an important initial step in solving the existing FHB problem in wheat in Austria. With the identification of the superior genotypes the average resistance level of wheat cultivars used in commercial production can be raised significantly in a short time mainly by avoiding growing very sensitive cultivars. In scab prone regions (for instance in areas with constant high relative air humidity) the cultivation of head blight tolerant cultivars identified in this study is recommended. It was not possible to find genotypes with a very high resistance level in the set tested here. This conclusion is also true for the existing Austrian breeding material investigated so far (to be reported elsewhere). From 1990 onwards foreign wheat genotypes were collected and tested, identifying a number of highly resistant genotypes (BUERSTMAYR et al., 1996). Most of this material is not adapted to our conditions, but they are very useful crossing partners, the resistance of which is now introgressed in locally adapted lines in cooperation with the Austrian wheat breeding industry.

List of abbreviations

A:	Austria
AUDPC:	area under the disease progress curve
BRA:	Brazil
CH:	Switzerland
DF:	degrees of freedom
DON:	deoxynivalenol
F:	France
FHB:	*Fusarium* head blight
D:	Germany

LSM:	least square mean
NL:	The Netherlands
PL:	Poland
REW:	relative ear weight
RU:	Russian Federation
S:	Sweden
SAUDPC:	standardised area under the disease progress curve
SW:	spring wheat
WW:	winter wheat
ZON:	zearalenone

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Acknowledgements

We wish to thank the co-operators for providing seeds, especially Mr. M. Oberforster (Federal Bureau and Research Centre for Agriculture Vienna, Austria), late Dr. L. Seibert and Dr. F. Löschenberger (Probstdorfer Saatzucht), Mr. A. Neumayer (Saatbau Linz) and Mr. K. Schulmeister (Saatzucht Edelhof).

We also wish to thank Mrs. G. Neuhold and Dr. O. Semenova for reading the manuscript.

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Eingelangt am 30. Oktober 1996
Angenommen am 25. November 1996