Resistance of Kentucky Bluegrass Cultivars to Necrotic Ring Spot
by Tom Hsiang and Gary A Chastagner

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Introduction

Patch diseases of turfgrass in North America are caused by a diverse group of pathogenic fungi. There are at least 19 different patch diseases (Couch, 1995) caused by both foliar and root infecting fungi. Several distinctly different soilborne ectotrophic ascomycetes infect the roots of turfgrass causing diseases that have similar symptoms. These diseases include spring dead spot of *Cynodon* species (Endo et al., 1985; Wadsworth and Young, 1960; Walker and Smith, 1972), take-all patch of *Agrostis* species (Gould et al., 1961; Walker, 1981), and summer patch and necrotic ring spot of *Poa* species (Chastagner et al., 1984; Jackson 1984; Smiley and Craven-Fowler, 1984; Worf et al., 1986).

Necrotic ring spot (NRS) is a relatively new disease of turfgrass. It has been reported to affect a number of different turfgrass species, but is especially destructive on Kentucky bluegrass (*Poa pratensis* L.) (Smiley et al., 1992; Worf et al., 1986), which is one of the most commonly used turf species in the temperate regions of North America. NRS was first suspected as being a new disease in North America when application of the fungicide triadimefon was unsuccessful in controlling a patch disease believed to be Fusarium blight (Worf, 1980). Fusarium blight, which was first reported in 1959 (Bean, 1966; Couch and Bedford, 1966), is a patch disease that occurs in mature stands of Kentucky bluegrass. Symptoms are small, pale, straw-coloured patches of turf a few cm in diameter that increase in size to form circular or ring-shaped patches of dead turf up to 100 cm in diameter (Couch and Bedford, 1966). *Fusarium roseum* (L.K.) amend. Snyd. & Hans. f.sp. *cerealis* "*Culmorum*" and *F. tricinctum* (Cda.) Snyd. & Hans. f.sp. *poa* were the most common foliar organisms isolated from disease samples and were, therefore, considered the causal agents of the disease (Couch and Bedford, 1966). However, *Fusarium* species could not always be isolated from diseased plants exhibiting patch symptoms which had generally been attributed to Fusarium blight (Worf et al., 1986).

Smiley and Craven-Fowler (1984) identified other organisms that were associated with turf exhibiting symptoms that generally had been attributed to Fusarium blight. They isolated two ectotrophic ascomycetes that were pathogenic to Kentucky bluegrass and both caused symptoms identical to Fusarium blight. There was initially some confusion as to the identification of the causal organisms, but they are now known as *Magnaporthe poae* Landschoot and Jackson, causal agent of summer patch (Landschoot and Jackson, 1989), and *Leptosphaeria korrae* Walker & Smith (=*Ophiosphaerella korrae* (J. Walker & A.M. Smith) Shoemaker & Babcock) (Walker & Smith 1972), the cause of NRS.

In addition to past problems with identification of the causal agent of NRS, there also has been some taxonomic controversy. Walker & Smith (1972) named this pathogen *Leptosphaeria korrae.* Shoemaker & Babcock (1989) subsequently transferred it to *Ophiosphaerella* based on descriptions of *Ophiosphaerella* Speg. as described by Walker in 1980. However, in that same article, Walker (1980) retained the genus *Leptosphaeria* for *L. korrae*. Recently, Tisserat et al. (1994) sequenced and analyzed the ITS1 region of both *Ophiosphaerella herpotricha* and *L. korrae* (which they called *O. korrae*) and found that the homology between ITS1 regions of these two was much greater than that between *L. korrae* and *L. maculans.* Thus, along with morphological evidence presented by Shoemaker & Babcock (1989), there is supportive molecular evidence to accept *L. korrae* as belonging to *Ophiosphaerella* or at least to the same genus as *O. herpotricha*. The question of taxonomic identity of *L. korrae* is still open, and requires further study.

Because of the difficulty in accurately identifying specific patch diseases based on field symptoms, much of the recent research on *L. korrae* has focused on improved methods of detection (Tisserat, 1988; Nameth et al., 1990; Tisserat et al., 1991; O'Gorman et al., 1994; Tisserat et al., 1994). However, there are many aspects of the ecology and epidemiology of *L. korrae* which are unknown. For example basic information on the source and spread of inoculum is still lacking. Although pseudothecia can be found on plants in the field and produced in culture (Hammer, 1988), the importance of ascospores in the spread of this disease is still unknown.

NRS is a very difficult disease to manage. Melvin and Vargas (1994) have recently shown that irrigation and fertilizer frequency can influence the incidence of NRS. Research on chemical management has demonstrated several fungicides that have efficacy against the pathogen. These chemicals include some benzimidazoles and demethylation-inhibiting fungicides. Effective control requires repeated annual applications (Chastagner and Hammer, 1987). Cultural practices that optimize turfgrass growing conditions and promote deep root development in the spring and fall are also commonly recommended as treatments that may minimize the damage caused by NRS (Chastagner and Byther, 1985; Couch, 1995).

Another method that potentially can be used to manage this disease is the use of NRS-resistant cultivars of Kentucky bluegrass. One of the problems facing sod growers, landscapers, homeowners and turf managers when selecting Kentucky bluegrass cultivars is the lack of a comprehensive evaluation of Kentucky bluegrass cultivars for NRS resistance. Equally important is the need to identify cultivars which are consistently found to be susceptible to NRS so their use can be minimized in areas where NRS problems are prevalent.

A recent review of patch disease management (Dernoedon, 1993) cites three studies in which Kentucky bluegrass cultivars were evaluated for NRS. Vargas (1994) lists five cultivars (Midnight, Monopoly, Able 1, Majestic, and America) that have been shown to be resistant in inoculated field trials, while Dernoeden (1994) indicates that Wabash, Vantage, I-13, and Adelphi have some resistance to NRS. In his recent book, Couch (1995) does not list any Kentucky bluegrass cultivars that are resistant to NRS.

In the past ten years, there have been many trials to evaluate the field resistance of Kentucky bluegrass to NRS. Some of these trials have depended upon natural inoculum to establish the disease, while others have been artificially inoculated in an effort to ensure a basic level of disease pressure. The objective of this paper is to review field trials in which the resistance of Kentucky bluegrass cultivars to NRS was tested. There is a need to compile and correlate results between trials to derive a single listing of NRS-resistant cultivars useful to turf managers.

Methods

We began by searching the literature for Kentucky bluegrass cultivar trials that included NRS disease evaluations. We also included data from turf field days and industry reports. Data were entered for every test as presented, except for those tests using nominal data (e.g. resistant vs. susceptible). These data were transformed to a numeric scale (0=resistant, 0.5=moderate, 1=susceptible). For any single cultivar to be included in our final analysis, it had to be represented in at least 3 different trials. This permitted better comparisons among trials, and likely increased the reliability of the assessments of cultivar resistance.

Correlation coefficients were calculated for all trials using PROC CORR in SAS® 6.04. These r-values were derived by correlating the ratings between any two sites of all cultivars shared by these two sites. This permitted comparisons of cultivars shared between trials, and also allowed for some analysis of the effects of artificial inoculation vs. natural inoculum in the different trials. Data within a site were ranked on a scale of 0 to 100 with 0 reflecting a lower level of susceptibility than 100. These ranks were then subjected to analysis of variance using PROC GLM in SAS® 6.04.

The reliability of using cultivars which were represented in 3 or more cultivar tests was assessed by performing the same analysis on cultivars that were represented in at least 5 tests. A coefficient of determination (r^2) was calculated between the rankings of cultivars present in both analyses.

Results

Data from 15 cultivar trials were evaluated (Table 1). Using data for only those cultivars that were represented in 3 or more tests, a total of 115 out of the 265 different cultivars of Kentucky bluegrass were used in our analysis (Table 2). Turf in 6 of the 15 trials was inoculated with *L. korrae*, whereas the remaining trials relied on natural inoculum (Table 1). Significant differences (p 0.05) were found in comparisons (Table 3) of uninoculated vs. uninoculated (r=0.46), uninoculated vs. inoculated (r=0.30), and inoculated vs. inoculated trials (r=0.46). Although none of the 115 cultivars of Kentucky bluegrass was totally resistant to NRS, cultivars clearly varied in their tolerance or resistance to this disease (Table 4). Overall disease rankings ranged from a high of 99.1 to a low of 33.0, with an LSD (p=0.05) of 30.6. The cultivars NE 80-88, Princeton 104 (=P-104), Washington, Alpine, Mystic, Joy, Miranda, Aldephi, Bristol, and Unique, which had the lowest mean susceptibility rankings, were significantly (p=0.05) more resistant than Barsweet, HV-97 (=Cocktail), Annika, Opal, BA 70-131, Amazon, BA 69-82 (=Fairfax), J-335, Sydsport or Trampas.

When using cultivars that were represented in 5 or more tests (73 cultivars), we found that the ranking results did not change significantly. The coefficient of determination between rankings of cultivars in the 3-cultivar analysis and the 5-cultivar analysis was 0.995.

Discussion

The lack of clear separation between the mean rankings of many cultivars listed in Table 4 and the high LSD value indicate that there is great variation between test results of different sites. This variation could arise from several sources. We examined all pair-wise correlations between inoculated vs. uninoculated trials and did not find that results from inoculated trials were more similar to each other (Table 3). Another source of variation might arise from potential differences in virulence of *L. korrae* in different geographic areas. Hammer (1988) found that there were strong differences in the virulence of three isolates of *L. korrae* that were tested at several different sites. However it has been found that isolates of *L. korrae* from across North America belong to a small number of clonal groups (Tisserat et al. 1991 & 1994), and that the different groups are very closely related to each other (Hsiang et al., unpublished data). The question of variation in results arising from artificially inoculated vs. natural inoculum in testing Kentucky bluegrass cultivar resistance to *L. korrae* needs further research.

One of the most effective and environmentally acceptable methods of managing a plant disease in general is through the use of genetically resistant cultivars. Turfgrass cultivars that vary in their disease susceptibility are often utilized in a mixture or a blend of turfgrass species are often used in an effort to avoid significant damages to turf from any single disease. Kentucky bluegrass is one of the most commonly utilized turfgrass species in the temperate regions of North America. Vargas (1994) states that to sustain a high level of quality, a cultivar of Kentucky bluegrass needs to be resistant to melting out (*Drechslera poae* Shoemaker), NRS, summer patch, and stripe smut (*Ustilago striiformis*) Westend. (Niessl.). However, all of these diseases do not necessarily occur in a given area. For example, NRS is relatively common on Kentucky bluegrass in certain areas of the Pacific Northwest, while summer patch has not yet been reported from this area (Jackson, 1993).

In areas where NRS is a problem, sod growers, hydroseeders, landscapers, turf managers, and homeowners commonly want to know what cultivars of Kentucky bluegrass are resistant to this disease. This is particularly important to sod growers where problems with NRS in recently sodded turf can result in a significant public relations problem that has, in some cases, engendered lawsuits or even forced sod producers out of business.

Our analysis of data from 15 field trials indicates that there are a number of cultivars of Kentucky bluegrass that have significantly higher levels of susceptibility to NRS than other cultivars. Furthermore, there was a strong correlation between rankings of cultivars represented in 3 or more tests compared to those represented in 5 or more tests, and this showed that the rankings were relatively stable across different tests. From our analysis, cultivars such as Barsweet, HV-97 (=Cocktail), Annika, Opal, BA 70-131, Amazon, BA 69-82 (=Fairfax), J-335, Sydsport, Trampas or other highly susceptible cultivars should probably not be utilized in sod or seed mixtures in areas where NRS is a likely problem. While there may be additional NRS-resistant or tolerant cultivars among the 150 cultivars that were not included in our analysis, additional testing of these cultivars would need to be conducted before they could be added to a recommended list.

It is difficult to determine the level of disease that is acceptable in developing a list of resistant cultivars. Our analysis indicates that the best cultivars had significantly lower levels of disease compared to the most highly susceptible cultivars. Among these, the top ten were: NE 80-88, Princeton 104 (=P-104), Washington, Alpine, Mystic, Joy, Miranda, Aldephi, Bristol, and Unique. It is possible that use of any of the top 10 or 20 cultivars would effectively minimize the potential for NRS. In Wisconsin, sod growers who changed their seed mixtures containing Ram I, Glade, Sydsport, and Baron, three of four of which are all in the more susceptible half of our rankings, to mixtures containing Midnight, Eclipse, and Adelphi, which are all in the least susceptible third of our rankings, greatly diminished their problems with NRS (Dernoeden, 1993).

In areas where NRS is a problem, the selection of cultivars of Kentucky bluegrass should be based on their tolerance to NRS, the local adaptability of the cultivar and its susceptibility to other locally important diseases. This assessment should aid in that selection.

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Table 1. Kentucky bluegrass cultivar trials used as data sources for a review of resistance to NRS.

Site[1]	Reference	Inoculated	Rating	Range
WI1	Worf et al., 1985	No	Resistant, moderate or susceptible (0, 0.5, 1)	0 - 1
MI2	Melvin et al., 1990	Yes	Percent area affected	0 - 23%
WA3	Chastagner et al. 1989	Yes	Plots affected / plots inoculated (9)	0 - 1
ID4	Brede & Williams, 1992	No	rating 1-9, 9=no disease	8.3 - 9
NY5	Fowler and Hummel, 1988 (mean 6/3+6/27)	Yes	Plots affected / plots inoculated (3)	0 - 0.67
KY6[2]	Vincelli and Powell, 1995	No	rating 0-5, 0=no damage, 5=50% damage	0 - 4.85
OR7	Chastagner, unpublished	Yes	Plots affected / plots inoculated (9)	0 - 1
PA8	Landschoot et al. 1991	No	Percent disease injury	0 - 40%
ID9	Anonymous, 1990	No	Rating 1-9, 9=no disease	5.6 - 9
ID10	Anonymous, 1991	No	Spots in a plot	0 - 3.7
ID11	Anonymous, 1994	No	Rating 1-9, 9=no disease	3.3 - 9
ID12[3]	Brede & Williams, 1994	No	% area affected 0-100	0 - 15.6
PA13[4]	Landschoot & Hoyland, 1992	No	Horsfall Barratt 1=0% 10=100%	1 - 7
WA14	Chastagner, unpublished	Yes	Plots affected / plots inoculated (9)	0 - 0.67
ON15	Hsiang, 1996	Yes	Plots affected / plots inoculated (5)	0.01 - 0.28

[1] WI = Wisconsin, MI - Michigan, WA = Washington, ID = Idaho, NY = New York, PA = Pennsylvania, OR = Oregon, United States, and ON = Ontario, Canada
[2] Earlier data from this trial were reported in Vincelli & Powell (1994)
[3] These are 1992/1993 data from these plots. Earlier data from this trial were reported in ID4 (Brede & Williams 1992)
[4] Earlier data from this trial were reported in Landschoot et al. (1991)

Table 2. Summary of necrotic ringspot ratings for 115 cultivars of Kentucky bluegrass evaluated at 15 test sites, with overall ranking.

Cultivar	TEST SITE(1)															
	WI1	MI2	WA3	ID4	NY5	KY6	OR7	PA8	ID9	ID10	ID11	ID12	PA13	WA14	ON15	rank(2)
No. cv in test	24	25	66	28	86	144	24	63	72	61	125	72	69	71	25	
A-34		0.23	0.75		0.33	1.00		1.0	8.9		6	0.3	4	0	0.28	69.1
ABBEY (=BA72-441)			1.00			0.00	0.29	0.0	8.2		7.3	0.3	2.33	0.44		57.3
ABLE 1		0.00	1.00			0.15		0.0	8.7		7.3	3.5	5	0.22		67.0
ADELPHI	0.0			9.0	0.00	0.15	0.14	0.0					1.33		0.01	42.1
ALPINE						0.70					8.0				0.05	35.2
AMAZON			1.00			2.50		40.0	7.1	2.0		3.3	5.33	0.11		89.2
AMERICA		0.05	1.00		0.00			2.7	8.8			0.4	1.33	0	0.08	56.2
ANNIKA			1.00						6.8			4.5		0.33		92.0
AQUILA		0.12	0.50					0.0	7.9			1.4				58.8
ASPEN			1.00		0.00	0.00		0.0	8.0		6.3	2.1	3.33	0		67.9
ASSET			0.80					0.0	9.0			0.5	3.67	0		49.6
BA 69-82 (=FAIRFAX)			1.00			3.85	0.89	0.0	7.3		3.5	7.4	3.33	0.11		87.1
BA 70-131						4.00	0.71				5.0					89.2
BA 70-242								0.0	9.0			3.5	1.67	0		50.4
BA 73-540 (=ALLURE?)			1.00				0.67	0.0	8.1		3.3	0.4	3.33	0		71.1
BANFF					0.00	0.30	0.50				7.7				0.07	48.4
BAR VB 1169						4.65				0.3	6.7					84.0
BAR VB 534			0.80					0.0	8.0			5.1	2.67	0.56		70.7
BAR VB 577								0.0	9.0			3.2	3.67	0		58.3
BARBLUE				8.7	0.67	1.00					8.3				0.03	56.9
BARCELONA (=BAR VB 1184)						3.35				0.3	7.7					69.6
BARMAX (=BAR VB 7037)						0.00				3.0	5.0					73.0
BARON	0.5	0.09	1.00		0.33	0.65		0.0	8.9	0.0	7.3	0.3	3	0.22	0.13	64.7
BARSWEET						4.85				3.7	4.3					99.1
BARTITIA						3.15				0.3	7.0					76.2
BARZAN			1.00						9.0	0.0	8.3	0.3		0		45.2
BELMONT (=798)						1.50				0.0	7.3				0.06	53.7
BLACKSBURG		0.15	1.00			2.15		0.0	8.9		7.3	2.0	2	0.44		66.7
BRISTOL		0.09	0.25		0.33		0.17	0.0	8.8			0.0	1.67	0		42.2
CHALLENGER		0.08	0.83		0.00	0.00		0.0	8.7		8.3	0.1	3.33	0		47.2
CHATEAU (=BA 72-500)			0.60				0.71	1.7	8.6			2.8	3	0		61.2
CHELSEA						2.30				0.3	6.0					82.0
CHERI		0.13	1.00		0.67	4.00		3.3	8.6			2.2	4.33	0	0.16	80.9
CLASSIC			0.00	9.0	0.00	1.30	0.00	0.0	8.9		6.7	1.1	1.67	0.11	0.05	49.7
COBALT						0.50				0.0	7.7					50.4
COMPACT			1.00						9.0			3.1		0.22		69.4
CONNI			1.00			0.35			8.9		7.7	0.4		0.44		58.7
COVENTRY (=BA 70-139)			1.00			3.15	0.63	1.7	7.1		5.0	4.2	3.33	0		78.7
CREST						0.15				0.0	6.7					55.3
CYNTHIA			1.00			2.50		0.0	7.1	0.0	6.3	15.6	1.33	0.11		75.7
DAWN			1.00			0.50		0.7	8.9		8.0	9.5	5	0.11		70.4
DESTINY			0.33	9.0		0.30			8.9	0.0	8.3	5.4		0.11		51.0
ECLIPSE	0.5	0.00	0.00	9.0	0.00	0.00	0.29	0.0	8.6		7.7	1.7	1.33	0.11	0.12	49.4
ESTATE (=BA 72-492)			0.67			3.65	0.75		7.9		4.7	2.0	2.67	0.11		69.4
EVB 13.703						1.00				0.0	6.3					69.0
EVB 13.863						0.00				0.0	5.7					59.2
FORTUNA						0.00				0.0	7.0					49.8
FREEDOM (=F-1872)			1.00			0.70			9.0	0.3	8.0	0.8		0	0.27	58.4
FYLKING				9.0	0.00	1.65									0.08	72.2
GEORGETOWN	1.0	0.21				1.15	0.57	0.0	8.8		7.7	3.3	4	0		67.6
GLADE	1.0	0.07	0.89	9.0	0.33	0.00	0.75	0.0	9.0		8.3	2.9	4.67	0		60.8
GNOME			1.00		0.00	0.00			8.7	0.0	7.3	0.0		0.33		59.3
HAGA	1.0		1.00		0.00	0.00		0.0	8.8	1.3	7.7	2.6	4.33	0		69.0

HARMONY			0.50		0.00			0.0	8.9			3.3	1.67	0.11		55.8
HOLIDAY					0.00			0.0					3			70.2
HUNTSVILLE			1.00			1.85			8.6			0.0		0		60.0
HV-97 (=COCKTAIL)			1.00					25.0	7.1			8.4	4.67	0.56		96.4
I-13	0.5				0.00								1			45.1
IKONE			0.80					13.3	7.6			10.0	4.33	0		76.5
J-229 (=NUBLUE)				9.0		0.00				0.3	6.7				0.07	62.7
J-335						3.85				0.3	6.3					86.4
J-386						1.00				0.0	7.0					62.4
J34-99				9.0		0.50					7.3					59.9
JOY								0.0	9.0			0.1	1.67	0		38.7
JULIA			0.00			3.15		20.0	8.0		6.3	7.1	3	0.67	0.08	73.4
K1-152			0.50		0.67			0.0	9.0			1.7	4	0		58.4
K3-178					0.00			0.0	9.0			0.4	4	0		56.0
KELLY (=BA 73-626)			1.00			0.00	0.57	0.0	8.9		7.3	0.0	2.33	0.11		52.2
KENBLUE		0.02			0.00	0.15		0.0	8.9	0.0	5.7	2.4	2	0.22		58.3
KWS PP 13-2						0.00				0.3	6.3					64.3
LIBERTY			0.75	8.9		0.15			9.0	0.0	6.7	0.6		0.22	0.05	51.3
LIMOUSINE				8.3		3.50					7.0				0.09	80.5
LIVINGSTON						0.00				0.7	6.3					65.1
LOFTS 1757			0.67					0.0	8.9			0.0	3.67	0.11	0.07	51.9
MAJESTIC	0.0			9.0	0.67			2.7					3.33			75.0
MARQUIS						0.85	0.75				7.7					62.8
MERION	0.0	0.03	0.00		0.00	0.85	0.00	0.0	9.0	0.3	5.3	1.0	3	0		49.5
MERIT	0.5	0.18	1.00		0.00	0.00	0.50	0.0	9.0	0.0	7.7	3.3	3	0.22		61.8
MIDNIGHT	0.0	0.00	0.50		0.00	0.00		0.0	7.7	0.3	8.3	7.7	3	0.22	0.07	56.6
MIRACLE						0.50				0.0	8.3					42.4
MIRANDA				9.0		0.00					8.0					42.0
MONOPOLY		0.00	0.33		0.33	0.00		0.0	9.0	0.0	6.7	0.8	1.67	0.11		46.7
MYSTIC	0.0	0.02	0.00		0.00			0.0	8.9			0.0	1.33	0		38.0
NASSAU	1.0		1.00		0.00	0.15		0.0	8.3		7.7	3.1	2.33	0	0.02	60.1
NE 80-47						3.70				0.0	6.0					79.4
NE 80-88			0.67						9.0			0.2		0		30.6
NUGGET				9.0	0.00	0.35									0.07	62.3
NUSTAR				9.0		0.00				0.0	8.0					46.9
OPAL (=WWAG 495)			1.00			3.70			5.6	2.0	4.3	12.0	4.33	0		90.0
PARADE		0.13			0.00			0.0	9.0			0.0	3	0.33		57.8
PARK	0.0						1.00			0.0						66.9
PLUSH					0.00			0.0					2			61.0
PRINCETON 104 (=P-104)			0.00						8.9		7.0	0.1		0	0.02	31.9
PST-CB1			1.00						9.0			1.1		0.22		63.5
RAM I	1.0	0.18	1.00		0.67	3.35	0.67	0.0	8.9	0.0	7.0	0.1	2.33	0.11		69.9
RUGBY		0.13	1.00		0.00			0.0	8.7			0.9	4	0.22		73.5
S.D. CERT.			0.50							0.0	7.0		2.67			46.9
SOMERSET			1.00		0.00			0.0	8.6			9.7	1.33	0		68.3
SOUTH DAKOTA								0.0	8.8			1.2		0.22		66.7
SR 2000						0.30				0.0	7.7					46.8
SUFFOLK (=A 239)			0.50	9.0	0.33	0.50		0.0	8.9	0.0	8.3	2.5	5	0.11		61.0
SYDSPORT	1.0	0.23	1.00	8.3	0.00		0.67	0.0	8.0			11.2	2.67	0.22	0.19	85.1
TENDOS			0.71						8.6			1.2		0.11		54.6
TOUCHDOWN					0.00	0.85		0.3			6.3		7		0.09	78.3
TRAMPAS	1.0				0.00	2.50					6.0					84.2
TRENTON		0.18	0.83		0.00	0.50		0.0	8.7		7.3	5.4	4.33	0		66.5
UNIQUE (=PST-C-76)						0.00				0.0	7.7					42.3
VANESSA				9.0	0.00			0.0					3			72.1
VICTA		0.11	1.00		0.00		0.57	0.0	7.1			0.6	2	0		62.6
WABASH	0.0		1.00		0.00	0.00		0.0	8.7			0.1	1.33	0		51.0
WASHINGTON						0.30				0.0	9.0					35.1
WELCOME		0.23	0.33		0.33			0.0	9.0			1.2	3	0.22		62.5
WWAG 468								0.0	7.6			5.6	1.67	0		65.1
WWAG 491			1.00					0.0	8.4			7.6	4	0		78.1

WWAG 496			0.75					0.0	8.3			5.6	4.33	0.11		72.7
LSD (p=0.05) (3)					1.35			8.4	1.8	1.1	1.9	ns	1.62		0.07	30.6

(1) Test site rating scales: WI1 - resistant (0), moderate (0.5), and susceptible (1); MI2, PA8, and ID12 - % area affected, diseased or injured; WA3, NY5, OR14, ON15, and ON16 - plots affected/plots inoculated; ID10 - No. of spots/plot; and PA13 - Horsfall Barratt 1=0% and 10=100%.

(2) To determine overall mean ranking, all data within a site were ranked from 0 to 100. All scales were synchronized so that 0 reflected a lower level of susceptibility than 100.

(3) LSD values are as reported from each test.

Table 3: Correlation coefficients for different studies on Kentucky bluegrass resistance to necrotic ring spot[1]

		UNINOCULATED SITES									INOCULATED SITES					
		ID4	ID9	ID10	ID11	ID12	KY6	PA8	PA13	WI1	MI2	NY5	ON15	OR7	WA3	WA14
UNINOCULATED	ID4	1.00	0.90	0.25	0.19	-0.87	-0.82	0.14	0.06	-0.56	-0.95	-0.03	-0.55	-0.51	-0.60	-0.63
	ID9	0.90	1.00	-0.72	0.59	-0.60	-0.59	-0.48	-0.13	0.04	0.03	0.29	0.14	-0.44	-0.25	-0.12
	ID10	0.25	-0.72	1.00	-0.59	0.31	0.35	0.81	0.70	0.38	-0.48	-0.36	0.37	-0.87	0.29	-0.42
	ID11	0.19	0.59	-0.59	1.00	-0.18	-0.56	-0.10	0.06	0.19	0.01	0.20	-0.18	-0.24	-0.03	0.11
	ID12	-0.87	-0.60	0.31	-0.18	1.00	0.36	0.23	0.17	0.25	0.17	-0.21	0.04	0.44	0.18	0.11
	KY6	-0.82	-0.59	0.35	-0.56	0.36	1.00	0.37	0.08	0.41	0.48	0.58	0.18	0.51	0.08	-0.00
	PA8	0.14	-0.48	0.81	-0.10	0.23	0.37	1.00	0.30	-0.30	0.03	0.45	-0.04	0.27	0.03	0.32
	PA13	0.06	-0.13	0.70	0.06	0.17	0.08	0.30	1.00	0.46	0.30	0.25	0.32	0.60	0.30	-0.00
	WI1	-0.56	0.04	0.38	0.19	0.25	0.41	-0.30	0.46	1.00	0.75	0.10	0.42	0.43	0.61	-0.05
INOC	MI2	-0.95	0.03	-0.48	0.01	0.17	0.48	0.03	0.30	0.75	1.00	0.27	0.88	0.62	0.43	0.08
	NY5	-0.03	0.29	-0.36	0.20	-0.21	0.58	0.45	0.25	0.10	0.27	1.00	0.28	0.38	-0.00	-0.13
	ON15	-0.55	0.14	0.37	-0.18	0.04	0.18	-0.04	0.32	0.42	0.88	0.28	1.00	0.77	0.41	-0.19
	OR7	-0.51	-0.44	-0.87	-0.24	0.44	0.51	0.27	0.60	0.43	0.62	0.38	0.77	1.00	0.77	-0.11
	WA3	-0.60	-0.25	0.29	-0.03	0.18	0.08	0.03	0.30	0.61	0.43	-0.00	0.41	0.77	1.00	0.02
	WA14	-0.63	-0.12	-0.42	0.11	0.11	-0.00	0.32	-0.00	-0.05	0.08	-0.13	-0.19	-0.11	0.02	1.00

[1] The code for sites is presented in Table 1. Correlation coefficients (r) were calculated by correlating ratings of all cultivars common to any pair of sites. The negative value for some correlations represents the use of inverse scales (e.g. highest value is greatest severity in some scales and lowest severity for other scales). The upper left quadrant represents uninoculated vs. uninoculated sites; lower left/upper right, uninoculated vs. inoculated; and lower right, inoculated vs inoculated.

Table 4. Overall disease ranking of the susceptibility of 115 cultivars of Kentucky bluegrass to necrotic ringspot from the most susceptible to the least susceptible. (This table is optional since the data was presented in Table 2. The value is that the isolates are placed in rank order)

Cultivar[1]	Rank[2]
BARSWEET	99.1
HV-97 (=COCKTAIL)	96.4
ANNIKA	92.0
OPAL (=WWAG 495)	90.0
BA 70-131	89.2
AMAZON	89.2
BA 69-82 (=FAIRFAX)	87.1
J-335	86.4
SYDSPORT	85.1
TRAMPAS	84.2
BAR VB 1169	84.0
CHELSEA	82.0
CHERI	80.9
LIMOUSINE	80.5
NE 80-47	79.4
COVENTRY (=BA 70-139)	78.7
TOUCHDOWN	78.3
WWAG 491	78.1
IKONE	76.5
BARTITIA	76.2
CYNTHIA	75.7
MAJESTIC	75.0
RUGBY	73.5
JULIA	73.4
BARMAX (=BAR VB 7037)	73.0
WWAG 496	72.7
FYLKING	72.2
VANESSA	72.1
BA 73-540 (=ALLURE?)	71.1
BAR VB 534	70.7
DAWN	70.4
HOLIDAY	70.2
RAM I	69.9
BARCELONA (=BAR VB 1184)	69.6
COMPACT	69.4
ESTATE (=BA 72-492)	69.4
A-34	69.1
EVB 13.703	69.0
HAGA	69.0
SOMERSET	68.3
ASPEN	67.9
GEORGETOWN	67.6
ABLE 1	67.0
PARK	66.9
SOUTH DAKOTA	66.7
BLACKSBURG	66.7
TRENTON	66.5
LIVINGSTON	65.1
WWAG 468	65.1
BARON	64.7
KWS PP 13-2	64.3
PST-CB1	63.5
MARQUIS	62.8
J-229 (=NUBLUE)	62.7
VICTA	62.6
WELCOME	62.5
J-386	62.4
NUGGET	62.3
MERIT	61.8
CHATEAU (=BA 72-500)	61.2
SUFFOLK (=A 239)	61.0
PLUSH	61.0
GLADE	60.8
NASSAU	60.1
HUNTSVILLE	60.0
J34-99	59.9
GNOME	59.3
EVB 13.863	59.2
AQUILA	58.8
CONNI	58.7
K1-152	58.4
FREEDOM (=F-1872)	58.4
KENBLUE	58.3
BAR VB 577	58.3
PARADE	57.8
ABBEY (=BA72-441)	57.3
BARBLUE	56.9
MIDNIGHT	56.6
AMERICA	56.2
K3-178	56.0
HARMONY	55.8
CREST	55.3
TENDOS	54.6
BELMONT (=798)	53.7
KELLY (=BA 73-626)	52.2
LOFTS 1757	51.9
LIBERTY	51.3
DESTINY	51.0
WABASH	51.0
COBALT	50.4
BA 70-242	50.4
FORTUNA	49.8
CLASSIC	49.7
ASSET	49.6
MERION	49.5
ECLIPSE	49.4
BANFF	48.4
CHALLENGER	47.2
NUSTAR	46.9
S.D. CERT.	46.9
SR 2000	46.8
MONOPOLY	46.7
BARZAN	45.2
I-13	45.1
MIRACLE	42.4
UNIQUE (=PST-C-76)	42.3
BRISTOL	42.2
ADELPHI	42.1
MIRANDA	42.0
JOY	38.7
MYSTIC	38.0
ALPINE	35.2
WASHINGTON	35.1
PRINCETON 104 (=P-104)	31.9
NE 80-88	30.6
LSD (p = 0.05)	30.6

[1] Cultivar equivalences were determined from listings in the trials examined
[2] To determine the overall ranking, all data were ranked within each trial from 0 to 100. All scales were synchronized so that 0 reflected a lower level of susceptibility than 100.