Sources of resistance to septoria speckled leaf blotch caused by *Septoria passerinii* in barley

H. Toubia-Rahme and B.J. Steffenson

Abstract: Septoria speckled leaf blotch (SSLB), incited by *Septoria passerinii*, has reemerged as one of the most serious foliar diseases of barley (*Hordeum vulgare*) in the Upper Midwest region of the United States over the last decade. The most cost-effective and environmentally safe method of preventing SSLB epidemics is through the use of resistant cultivars. Thus, the objective of this study was to investigate sources of resistance to *S. passerinii* in barley and to determine the reliability of greenhouse seedling tests for predicting the adult-plant reaction in the field. From a preliminary greenhouse screening of over 250 barley accessions, 78 lines were selected and subsequently evaluated at the seedling (greenhouse) and adult-plant (field) stages for reaction to *S. passerinii*. All of the major malting (*H. vulgare* 'Drummond', 'Excel', 'Foster', 'Lacey', 'Legacy', 'Morex', 'Stander', 'Conlon', and 'Robust') and feed (*H. vulgare* 'Bowman', 'Logan', and 'Royal') cultivars grown in or recommended for the Upper Midwest region of the United States were highly susceptible. Highly significant correlations were detected between the infection response of seedlings in the greenhouse and adult plants in the field. Twenty-nine accessions exhibited resistance at both the seedling and adult-plant stages. The resistant accessions identified in this study were from geographically diverse regions and will be valuable in developing barley cultivars with diverse and broad-based resistance to SSLB.

Key words: resistance to disease, *Hordeum vulgare*, *Septoria passerinii*, septoria speckled leaf blotch.

Résumé : Depuis une dizaine d'années, les taches septoriennes (TS), causées par le *Septoria passerinii*, sont réapparues en tant qu'une des plus importantes maladies foliaires de l'orge (*Hordeum vulgare*) dans le Haut Midwest des États-Unis. La méthode la plus rentable et respectueuse de l'environnement pour prévenir les épidémies de TS est l'utilisation de cultivars résistants. Ainsi, l'objectif de la présente étude était de rechercher dans l'orge des sources de résistance au *S. passerinii* et de déterminer la fiabilité des tests effectués en serre sur des semis pour prédire la réaction des plantes adultes au champ. À partir d'une sélection préliminaire en serre sur plus de 250 obtentions d'orge, 78 lignées furent sélectionnées et évaluées par la suite aux stade semis (en serre) et plante adulte (au champ) pour leur réaction au *S. passerinii*. Tous les principaux cultivars cultivés ou recommandés pour le Haut Midwest des États-Unis, qu'ils soient destinés à l'industrie brassicole (*H. vulgare* 'Drummond', 'Excel', 'Foster', 'Lacey', 'Legacy', 'Morex', 'Stander', 'Conlon' et 'Robust') ou à l'alimentation animale (*H. vulgare* 'Bowman', 'Logan' et 'Royal'), furent très sensibles. Des corrélations très significatives furent trouvées entre la réponse des semis à l'infection en serre et celle des plants adultes au champ. Vingt-neuf obtentions ont manifesté de la résistance aux stades semis et plant adulte. Les obtentions résistantes identifiées dans la présente étude provenaient de régions géographiques diverses et seront précieuses pour le développement de cultivars d'orge possédant de la résistance diversifiée et générale contre les TS.

Mots clés : résistance aux maladies, *Hordeum vulgare*, *Septoria passerinii*, taches septoriennes.

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Introduction

The fungi *Septoria passerinii* Sacc. and *Stagonospora avenae* Bisset f. sp. *triticea* T. Johnson (teleomorph: *Phaeosphaeria avenaria* (G.F. Weber) O. Eriksson f. sp. *triticea* T. Johnson) cause septoria speckled leaf blotch (SSLB) of barley (*Hordeum vulgare* L.). The pathogens survive on infected host debris and are spread mainly by rain-splashed pycnidiospores (Mathre 1997). In the Upper Midwest region of the United States, *S. passerinii* is the most common SSLB pathogen, although *Stagonospora avenae* f. sp. *triticea* is also frequently isolated from SSLB-infected barley tissue (Krupinsky and Steffenson 1999). Infection

and incubation periods for *S. passerinii* are longer than for other common foliar pathogens of barley such as *Puccinia* spp. (causing stem and leaf rust), *Pyrenophora teres* Drechs. (causing net blotch), and *Cochliobolus sativus* (Ito & Kuribayashi) Drechs. ex Dastur (causing spot blotch) (Mathre 1997). More than 48 h of continuous moisture is required for spore germination and leaf penetration by *S. passerinii* (Green and Dickson 1957). Moreover, the incubation period is 16 days or longer (Koble et al. 1959). These specific requirements largely explain why the disease is important only in years when moist conditions persist for extended periods. Septoria speckled leaf blotch was severe on barley during the 1950s in the north-central region of the United States and prairie provinces of Canada (Buchannon 1961; Green and Dickson 1957), causing up to 20% yield reduction (Green and Bendelow 1961). In recent years, SSLB (caused primarily by *S. passerinii*) has reemerged as one of the most important diseases of barley in the Upper Midwest region of the United States because of the increased use of minimum tillage and high rainfall during the growing season. Yield losses of 23%–38% due to *S. passerinii* infection were recently reported on barley (Toubia-Rahme and Steffenson 1999). In addition to markedly reducing yield, SSLB also reduces kernel plumpness and malt extract, which are important malt quality characters in barley (Green and Bendelow 1961). Although fungicides can be effective in reducing SSLB severity, the most cost-effective and environmentally safe method of preventing epidemics is through the use of resistant cultivars.

A number of barley lines resistant to *S. passerinii* have been reported in previous studies (Green and Dickson 1957; Rasmusson and Rogers 1963); however, none has been exploited in barley breeding programs. The incorporation of resistance to SSLB into adapted cultivars with the desired yield and quality characteristics has taken on greater urgency given the severe disease outbreaks that have occurred on barley in the United States over the past decade. This study was undertaken to reevaluate, in adult plants, the resistance of barley lines previously reported as resistant and to identify new sources of resistance in commercial cultivars and agronomically advanced midwestern breeding lines. Additionally, greenhouse tests were conducted to compare the reactions of seedlings with those of adult plants in the field.

Materials and methods

Plant materials

Over 250 barley accessions were evaluated for resistance to *S. passerinii* at the seedling stage during the 1998–1999 greenhouse season. The barley germplasm selected for screening included cultivars commonly grown in or recommended for the Upper Midwest region of the United States, older cultivars that were extensively cultivated in previous decades and (or) extensively used as parents in midwestern barley breeding programs, barley lines previously reported to carry resistance to *S. passerinii* (Banttari et al. 1975; Buchannon 1961; Green and Dickson 1957; Koble et al. 1959; Rasmusson and Rogers 1963), agronomically advanced midwestern breeding lines, and parental sets of various doubled-haploid (DH) populations used in molecular-mapping studies. Seeds were obtained from barley breeders and the National Small Grains Collection, Agricultural Research Service, US Department of Agriculture (Aberdeen, Idaho). From this preliminary evaluation, 78 lines were selected for replicated field and greenhouse tests in 1999 and 2000. Also included in this group were the resistant and susceptible controls of *H. vulgare* 'Atlas' (PI 539108) and 'Betzes' (PI 129430), respectively. Of the 78 accessions selected, 60 were resistant in the initial seedling test. The remaining 18 accessions were chosen because they are major malting and feed cultivars in the region, were reported resistant by other researchers but were susceptible in our preliminary study, or were one of the parental pairs of DH populations that exhibited a polymorphic reaction to the disease.

Fungal isolates

Our objective was to assess the general resistance of barley to a diverse collection of *S. passerinii* isolates. Since no distinct pathotypes have been reported in this fungus, we used a mixture of five isolates of *S. passerinii* collected from different locations in North Dakota in 1997. For long-term storage of the isolates, pycnidiospores were suspended in a 15% sterile glycerol solution and maintained at –80 °C as described by Krupinsky (1997). For inoculum production, the isolates were grown on yeast malt agar (Eyal et al. 1987) in plastic Petri dishes at 21 °C with a 12-h photoperiod (150–270 $\mu E \cdot m^{-2} \cdot s^{-1}$ supplied by cool-white fluorescent tubes). When pycnidia developed and sporulated, mass spore transfers were made by removing cirrhi from pycnidia with a sterile needle and transferring them to new yeast malt agar plates. After 4–5 days of incubation under the same conditions, pycnidia were harvested by flooding the surface of the plates with double-distilled water and scraping the agar surface with a rubber spatula. This suspension of pycnidia was homogenized for 30 s in a blender to release pycnidiospores and then filtered through four layers of cheesecloth. Tween® 20 (polyoxyethylene (20) sorbitan monolaurate) was added to the pycnidiospore suspension at a rate of 100 $\mu L \cdot L^{-1}$ to facilitate the uniform distribution and adsorption of inoculum onto the leaf surfaces. Inoculum consisted of a mixture of equal amounts of pycnidiospores produced by the five isolates of *S. passerinii*.

Field tests

The field study was conducted at Langdon, N.D., in 1999. The barley accessions were sown in hill plots (10–15 seeds per hill) spaced 0.3 m apart in paired rows with a four-row cone planter. Hill plots were planted with the interior two cones of the planter, while the outside two cones were set to plant a continuous row of a mixture of three highly susceptible six-rowed barley cultivars ('Foster' (PI 592758), 'Robust' (PI 476976), and 'Stander' (PI 564743)). The plants were uniformly inoculated with a pycinidiospore suspension of the five *S. passerinii* isolates (5×10^5 pycnidiospores/mL), applied at a rate of 48 $mL \cdot m^{-2}$, three times during the season, using a 1.2-m-long CO_2-pressurized aluminum spray boom (Fetch and Steffenson 1994; Nutter et al. 1985). The first inoculation was applied at the jointing stage (Zadoks GS 31–32; Zadoks et al. 1974), the second inoculation at the

boot stage (GS 41–43), and the third inoculation at the early heading stage (GS 51–52). Inoculations were made at or after sundown when conditions were conducive for heavy dew formation. An overhead misting system was used to maintain a high level of moisture in the leaf canopy and thereby promote disease development. Infection responses (IRs) were assessed on leaves (flag down to flag minus 4) of 15 randomly selected tillers per replicate between the soft- and hard-dough stages of development (GS 85–87). The IR scale used was patterned after the one developed for *Septoria tritici* Roberge in Desmaz. on wheat by Rosielle (1972): 0, immune (no visible symptoms); 1, highly resistant (no or only a few isolated and minute pycnidia, particularly in older leaf tissue; presence of hypersensitive flecks in younger leaf tissue); 2, resistant (pycnidia small and infrequent; some coalescing of lesions, but mainly towards the leaf tip and in older leaf tissue); 3, intermediate (pycnidia small to medium and infrequent; moderate coalescing of lesions towards the leaf tip, but also elsewhere on the leaf blade); 4, susceptible (pycnidia medium to large and fairly abundant; lesions coalescing considerably across the leaf blade); and 5, highly susceptible (pycnidia large and abundant; lesions coalescing extensively across the leaf blade). Infection responses 0, 1, and 2 and combinations thereof were considered indicative of resistance or a low IR. Infection responses 3, 4, and 5 and combinations thereof were considered indicative of susceptibility or a high IR. The plots were arranged in a randomized complete block design with two replicates.

Greenhouse tests

All entries included in the replicated field trial were also tested at the seedling stage in the greenhouse. Five seeds of each entry were sown in plastic pots (10 cm × 10 cm) filled with a commercial potting mixture (3:1 peat moss – perlite, *v*/*v*) (No. 1 Sunshine Mix, Fisons Horticulture, Inc., Vancouver, B.C.). Slow-release (14–14–14 N–P–K, 2 g per pot) and water-soluble (15–0–15 N–P–K, 536 ppm N rate) fertilizers were added at the time of planting. All seedlings were grown in a greenhouse at 20 ± 3 °C with 14 h of supplemental lighting (230–270 $\mu E \cdot m^{-2} \cdot s^{-1}$ supplied by 1000-W metal-halide lights). The experimental design was a randomized complete block with three replicates. Plants were inoculated at the two-leaf stage (10–12 days after planting) with a pycnidiospore suspension of the same five *S. passerinii* isolates (5×10^5 pycnidiospores/mL) at a rate of ~0.5 mL per plant, using an atomizer pressured by an air pump at 60 kPa. Inoculated seedlings were incubated at 21 °C (darkness) and 25 °C (light) for 72 h in chambers maintained near saturation by periodic misting from ultrasonic humidifiers. The first 40 h of incubation were in darkness followed by a photoperiod of 5 h (150–270 $\mu E \cdot m^{-2} \cdot s^{-1}$) for each of the next 2 days. Plants were allowed to dry off slowly before being transferred to the greenhouse under the same conditions previously described. Infection responses were assessed on the second leaves of seedlings 20 days after inoculation, using a 0–5 rating scale modified from Rosielle (1972): 0, immune (no visible symptoms); 1, highly resistant (presence of hypersensitive flecks); 2, resistant (very light pycnidial production and coalescing of lesions, mainly towards the leaf tip and edges); 3, intermediate (light pycnidial production and moderate coalescing of lesions, mostly towards the leaf tip, but also elsewhere on the leaf blade); 4, susceptible (moderate pycnidial production with lesions coalescing considerably across the leaf blade); and 5, highly susceptible (large and abundant pycnidia with lesions coalescing extensively across the leaf blade). Some accessions showed occasional to very light pycnidial production but extensive leaf necrosis. These lines were considered resistant based on their reduced pycnidial production. The criteria for classifying resistant and susceptible lines were the same as described in the field tests.

Statistical analyses

Data of IRs were subjected to analysis of variance, using Statistical Analysis System (SAS Institute, Inc., Cary, N.C.). Pearson's correlation coefficients (r) were computed to compare the reactions of seedlings in the greenhouse with those of adult plants in the field.

Results

Field tests

The level of SSLB in the field nursery was high based on the IR of the susceptible control 'Betzes' (IR = 5) and other susceptible lines (IR = 4–5). Septoria speckled leaf blotch symptoms were evident on leaves by GS 77–83, approximately 26 days after the first inoculation and 16 days after the last inoculation. Susceptible accessions exhibited typical SSLB symptoms of elongate, straw-colored lesions with many dark pycnidia. Differences in the IRs of barley accessions to *S. passerinii* were highly significant ($P < 0.0001$), whereas differences between replicates were not significant ($P = 0.13$). The rounded means and range of IRs of barley lines (including controls) are given in Table 1 (columns 3 and 7). All of the major malting ('Drummond', 'Excel', 'Foster', 'Lacey', 'Legacy', 'Morex', 'Stander', 'Conlon', and 'Robust') and feed ('Bowman', 'Logan', and 'Royal') cultivars grown in or recommended for the Upper Midwest region were susceptible or highly susceptible, exhibiting IRs of 4–5. In total, 37 lines were resistant to *S. passerinii* (IR = 1–2), while the remaining 41 accessions were susceptible (IR = 3–5). Parental pairs of DH populations that exhibited a polymorphic reaction to *S. passerinii* included 'Bowman' (*yd2*)/Cali-sib and 'Leger'/CIho 9831. 'Bowman' (*yd2*) and 'Leger' exhibited a high IR of 5, whereas Cali-sib and CIho 9831 exhibited a low IR of 1.

Greenhouse tests

All barley accessions tested in the replicated field trial were also evaluated at the seedling stage in the greenhouse. A high degree of variation in disease reaction was observed (Table 1, columns 4 and 8). Differences among lines were highly significant ($P < 0.0001$), whereas differences between replicates were not ($P = 0.43$). The resistant ('Atlas') and susceptible ('Betzes') controls exhibited low and high IRs of 1 and 5, respectively. Of the 78 accessions tested, 35 exhibited IRs of 1–2 and were considered resistant.

Twenty-nine lines exhibited resistance at both the seedling and adult-plant stages. Pedigree analysis was used to

Table 1. Infection responses of 78 barley accessions to *Septoria passerinii* at the adult and seedling stage in the field and greenhouse, respectively.

Line	Type	Infection response[a]	
		Field	Greenhouse
'Betzes'	2-row malting cultivar	5/5	5/5
'Bowman' (*yd2*)	2-row DH parent	5/5	5/5
'Conlon'	2-row malting cultivar	5/5	5/5
'Logan'	2-row feed cultivar	5/5	5/5
ND 17490	2-row breeding line	3/3	5/5
ND 16453	2-row breeding line	3/3	4/3–4
ND 16666	2-row breeding line	3/2–3	2/1–3
ND 17526	2-row breeding line	2/2	4/3–4
ND 17444	2-row breeding line	2/1–2	3/2–4
ND 16462	2-row breeding line	2/1–2	3/1–4
ND 17386	2-row breeding line	2/2	2/1–3
ND 15462	2-row breeding line	2/1–2	2/1–3
ND 16111	2-row breeding line	2/1–2	1/1–2
'Baronesse'	2-row feed cultivar	2/1–2	1/1
ND 16461	2-row breeding line	2/1–2	1/1
ND 16463	2-row breeding line	2/1–2	1/1
ND 15562	2-row breeding line	1/1	2/1–2
ND 16092	2-row breeding line	1/1	1/1
CIho 9831	2-row DH parent	1/1	1/0–1
'Robust'	6-row malting cultivar	5/5	5/5
'Royal'	6-row feed cultivar	5/5	5/5
'AC Hamilton'	6-row feed cultivar	5/4–5	5/5
'Foster'	6-row malting cultivar	5/4–5	5/5
'Leger'	6-row DH parent	5/4–5	5/5
ND 17163	6-row breeding line	5/4–5	5/5
ND 17186	6-row breeding line	5/4–5	5/5
ND 17218	6-row breeding line	5/4–5	5/5
ND 17220	6-row breeding line	5/4–5	4/4–5
ND 17241	6-row breeding line	5/4–5	4/4–5
'Drummond'	6-row malting cultivar	5/4–5	4/4
'Excel'	6-row malting cultivar	5/4–5	3/3
'Morex'	6-row malting cultivar	5/5	3/2–4
ND 17159	6-row breeding line	4/4	5/5
ND B112	6-row breeding line	4/4	5/5
'Stander'	6-row malting cultivar	4/4	5/4–5
'Legacy'	6-row malting cultivar	4/4	4/3–5
ND 17180	6-row breeding line	4/3–4	4/4
ND 17215	6-row breeding line	4/3–4	4/3–4
'Lacey'	6-row malting cultivar	4/4	3/3–4
ND 17232	6-row breeding line	4/4	3/2–3
ND 17210	6-row breeding line	3/3	5/5
ND 17224	6-row breeding line	3/3	4/4–5
ND 17238	6-row breeding line	3/2–3	4/4–5
ND 17239	6-row breeding line	3/3	4/3–5
CIho 4249-2	6-row landrace accession	3/2–3	4/3–5
ND 15629	6-row breeding line	3/2–3	4/3–5
ND 17209	6-row breeding line	3/2–3	4/3–4
ND 17216	6-row breeding line	3/2–3	3/3–4
ND 17214	6-row breeding line	3/3	2/1–4
ND 17174	6-row breeding line	3/3	2/1–3
ND 17213	6-row breeding line	3/3	2/1–3
CIho 4428	6-row landrace accession	3/2–3	2/1–3
'Flynn 1'	6-row feed cultivar	3/2–4	1/1
ND 15609	6-row breeding line	2/1–2	4/3–5
ND 17234	6-row breeding line	2/1–2	4/3–4
ND 17217	6-row breeding line	2/2	3/2–4
M68–128	6-row breeding line	2/2	2/1–3
'Atlas 54'	6-row malting cultivar	2/2	1/1–2
CIho 4940	6-row landrace accession	2/2	1/1–2
PC 11	6-row breeding line	2/2	1/1–2
'Belford'	6-row feed cultivar	2/2	1/1
'Glacier'	6-row feed barley	2/2	1/1
'Vaughn'	6-row feed cultivar	2/2	1/1
'Atlas'	6-row malting cultivar	2/1–2	1/1
'Bolron'	6-row feed cultivar	2/1–2	1/1
CIho 10644	6-row accession	2/1–2	1/1
'Feebar'	6-row feed barley	2/1–2	1/1
M65-167	6-row breeding line	2/1–2	1/1
ND 17242	6-row breeding line	2/1–2	1/1–2
ND 15630	6-row breeding line	1/1	4/1–5
ND 17231	6-row breeding line	1/1	3/2–4
ND 17243	6-row breeding line	1/1	2/1–3
CIho 4439	6-row landrace accession	1/1	1/1–2
ND 17223	6-row breeding line	1/1	1/1–2
Cali-sib	6-row DH parent	1/1	1/1
CIho 4780	6-row landrace accession	1/1	1/1
PC 84	6-row breeding line	1/1	1/1
SP 1	Unknown 6-row line	1/1	1/1

Note: Data are presented as rounded means and range. The range represents the lowest and highest infection responses observed on the barley lines.

[a]Infection response rated on a 0–5 scale (modified from Rosielle 1972), where 0, 1, and 2 are indicative of resistance, and 3, 4, and 5 of susceptibility.

postulate the probable source of resistance to SSLB in these accessions. Data of geographic origin were then obtained for these probable sources and the resistant accessions evaluated in the present study. This analysis revealed five geographically diverse origins for resistance to SSLB (Table 2). Fourteen accessions originated from North America (United States and the ICARDA–CIMMYT (International Centre for Agricultural Research in the Dry Areas – Centro Internacional de Mejoramiento de Maiz y Trigo) program in Mexico), one from South America (Bolivia), one from Europe (Germany), five from North Africa (Algeria and Egypt), and six from East Asia (China and Japan).

The correlation between the IRs of seedlings in the greenhouse and those exhibited by adult plants in the field was highly significant ($P < 0.0001$) with an r value of 0.72. Eight accessions (ND 15609, ND 15630, ND 16462, ND 17217, ND 17231, ND 17234, ND 17444, and ND 17526)

Table 2. Description, probable resistance donor, and origin of barley accessions with resistance to *Septoria passerinii*.

Line	CI or PI No.	Pedigree, selection, or description	Probable sources of resistance to *Septoria passerinii*[a]	Origin
'Atlas'	539108	Coast selection	'Coast'	United States
'Atlas 54'	9556	CI 9534/2* 'Atlas 46'	'Coast'	United States
'Baronesse'	568246	{[('Mentor'/'Minerva')/mutant of 'Vada']/[('Carlsberg'/'Union')/('Opavsky'/'Salle')/ 'Ricardo']} × ('Oriol'/6153 P40)	—	Germany
'Belford'	7060	'Beldi Giant'/'Horsford'	'Beldi Giant'	Algeria
'Bolron'	7123	'Bolivia'/'Chevron'	'Bolivia'	Bolivia
Cali-sib	—	LBIran/UNA8271//Gloria-sib/Come-sib	Gloria-sib/Come-sib	CIMMYT
CIho 4439	69551	Landrace	—	China
CIho 4780	70837	Landrace	—	China
CIho 4940	73702	Landrace	—	China
CIho 9831	197102	'Kaikei 8'/'Hosomugi 3'	—	Japan
CIho 10644	10644	'Feebar'/'Kindred'	'Mariout'	Egypt
'Feebar'	7260	'Peatland'/'Vaughn'	'Mariout'	Egypt
'Glacier'	6976	'Atlas'/'Vaughn'	'Mariout'	Egypt
'Vaughn'	1367	'Mariout'/'Leiorrhynchium' or 'Club Mariout'/'Lion'	'Mariout'	Egypt
M65-167	—	'Traill'/CIho 4780//'Traill'/Br 57602	CIho 4780	China
M68-128	—	'Cree'/3/M65-167	CIho 4780	China
ND 15462	—	ND 13082/ND 14760	Gloria-sib/Copal-sib	CIMMYT
ND 15562	—	ND 13890//ND 12567/'Azafran'	Gloria-sib/Copal-sib	CIMMYT
ND 16092	—	ND 13297/ND 14701	—	—
ND 16111	—	ND 13076/Q21861//ND 11853/3/ND 13836/ND 14760	Gloria-sib/Copal-sib	CIMMYT
ND 16461	—	ND 13296/ND 14760	Gloria-sib/Copal-sib	CIMMYT
ND 16463	—	ND 13296/ND 14760	Gloria-sib/Copal-sib	CIMMYT
ND 17386	—	'Logan'/ND 15562	Gloria-sib/Copal-sib	CIMMYT
ND 17223	—	ND 14156/ND 15608	Gloria-sib/Copal-sib	CIMMYT
ND 17242	—	ND 15964/ND 15608	Gloria-sib/Copal-sib	CIMMYT
ND 17243	—	ND 15964/ND 15608	Gloria-sib/Copal-sib	CIMMYT
SP 1	—	—	—	—
PC 11	584763	San Carlos//Gloria-sib/Come-sib/3/CI2325//BOY*2/3*Surb	Gloria-sib/Copal-sib	CIMMYT
PC 84	584764	Mola-sib/4/Brea-sib/DL70//Mozdosky/3/Nopal-sib/5/79W40762/6/Gloria-sib/Copal-sib	Gloria-sib/Copal-sib	CIMMYT

Note: A dash indicates unknown or unavailable data.

[a]These lines were reported to possess resistance to *S. passerinii* (Green and Dickson 1957; Rasmusson and Rogers 1963; J. Franckowiak, personal communication).

exhibiting low IRs (1–2) in the field gave high IRs (3–5) in the greenhouse. Another six lines (CIho 4428, 'Flynn 1', ND 16666, ND 17174, ND 17213, and ND 17214) exhibiting low IRs (1–2) in the greenhouse gave high IRs (3) in the field.

Discussion

The incorporation of resistance to SSLB into adapted cultivars with desired yield and quality characteristics has taken on greater urgency given the severe SSLB outbreaks that have occurred on barley in the Upper Midwest region since 1993 (Toubia-Rahme and Steffenson 1999). To determine whether resistance to SSLB might be already present in adapted germplasm, we screened cultivars commonly grown in or recommended for the Upper Midwest region, older cultivars that were extensively cultivated in previous decades and (or) extensively used as parents in midwestern barley breeding programs, and agronomically advanced midwestern breeding lines. Unfortunately, all of the major cultivars grown over the past 25 years were highly susceptible to SSLB. We did, however, identify sources of resistance in advanced midwestern breeding lines, particularly the North Dakota two-rowed barley improvement program. The resistance in most of these breeding lines was probably derived from Gloria-sib/Copal-sib, a series of sister lines developed by the ICARDA/CIMMYT barley breeding program in Mexico that exhibited resistance to *S. passerinii* under field conditions in North Dakota (J. Franckowiak, personal communication). We also confirmed the resistance of 'Atlas', 'Bolron', CIho 4439, CIho 4780, CIho 10644, 'Feebar', and 'Vaughn', which were previously reported to

have resistance to *S. passerinii* by other investigators (Banttari et al. 1975; Buchannon 1961; Green and Dickson 1957; Koble et al. 1959; Metcalfe et al. 1970; Rasmusson and Rogers 1963). All of these lines exhibited high levels of resistance at both growth stages to the North Dakota isolates of *S. passerinii* used in this study. Unfortunately, none are well adapted to the Upper Midwest growing region and will require extensive breeding efforts to recover resistance to SSLB in an agronomically suitable background.

Two accessions ('AC Hamilton' and CIho 4249-2) reported to be resistant to *S. passerinii* by Ho et al. (1995) and Rasmusson and Rogers (1963), respectively, were found to be susceptible at both growth stages in the present study. This lack of agreement with previous investigators may be due to the use of different pathogen isolates, seed stocks, and (or) different experimental conditions in the respective studies.

The DH parental pairs of 'Bowman' (*yd2*)/Cali-sib and 'Leger'/CIho 9831 exhibited a distinct polymorphic reaction to *S. passerinii*. Molecular marker maps have already been constructed on DH populations derived from these parents. The evaluation of these populations to *S. passerinii* will allow one to determine the number, chromosomal position, and effect of loci contributing to resistance to SSLB. These studies are currently in progress.

The reaction of accessions evaluated in the two seedling tests (i. e., the preliminary screening test including 250 lines and the one reported here with 78 selected accessions) were very similar. In most cases, accessions exhibited the same IR in the two tests or occasionally one consecutive IR unit lower or higher. The adult-plant reaction of the 78 selected accessions was tested in only one field season; however, the IRs were consistent between replicates in the field (a highly significant correlation ($P < 0.0001$) with an r value of 0.89). Several of the most resistant accessions identified in this study were used as parents in subsequent inheritance studies (e.g., 'Belford', Cali-sib, 'Feebar', CIho 4780, CIho 9831, and CIho 10644) or as resistant controls ('Baronesse', 'Feebar', and CIho 4780) in other SSLB experiments. All of them have consistently exhibited low IRs over several years of testing in the field (unpublished data).

Overall, a highly significant correlation was found between the reaction of seedling plants in the greenhouse and that of adult plants in the field. This indicates that seedling evaluations will, in general, be useful for selecting lines with resistance in adult plants in breeding applications. A few accessions did, however, exhibit distinctly different reactions to the pathogen at the two growth stages. This suggests the presence of genes that are effective at either the seedling or adult stage. Further investigations of these lines should be undertaken to substantiate this result.

The geographic origin of the probable resistance sources was quite diverse (Table 2). Resistance to SSLB was reported in barley accessions from North America (United States and the ICARDA/CIMMYT program in Mexico), South America (Bolivia), Europe (Germany), North Africa (Algeria and Egypt), and East Asia (China and Japan). These groups of accessions may possess different resistance genes, although this cannot be resolved with any certainty until the proper allelism tests are conducted. Studies are underway to determine the number, allelic relationship, and chromosomal position of genes for resistance to SSLB in several of the accessions tested in this study. This information will facilitate the efficient transfer of diverse and broad-based resistance to SSLB into adapted cultivars, thereby reducing the threat of this sporadic but damaging disease.

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