ABSTRACT

TETTEH, ANTONIA YARBEH. Breeding for Resistance to Powdery Mildew Race 2W in Watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]. (Under the direction of Todd C. Wehner, Ph.D.)

Watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] is a major vegetable crop in the United States. Powdery mildew [*Podosphaera xanthii* (Castagne) Braun & Shishkoff (syn. *Sphaerotheca fuliginea auct. p.p.*)] is now a common disease of watermelon in the United States and other parts of the world. The disease is of great economic importance because it leads to loss in fruit yield and quality. The watermelon germplasm collection has not been screened for resistance to powdery mildew race 2W. It would be useful to obtain a source of resistance to powdery mildew for incorporation into commercial cultivars. The objectives of this study were 1) to develop an efficient and reliable method for screening for powdery mildew resistance; 2) to screen the USDA watermelon germplasm collection along with available cultivars for resistance to powdery mildew race 2W; 3) to determine the heritability and genetic variance estimates for resistance to powdery mildew race 2W. Two experiments were carried out for development of a method for screening for resistance to powdery mildew. In these experiments, effect of humidity, inoculum source and application method, and type of growth chamber on disease severity were tested. Consistent and significant differences in disease severity among four resistant and susceptible accessions were observed with the use of a spray of spore suspension of inoculum and when plants were maintained at normal greenhouse relative humidity. No supplementation of the relative humidity was required. The use of a special humidity chamber and maintenance of spores on either squash or watermelon plants did not have significant effects on disease severity. In the germplasm screening experiment the entire available U.S. Plant Introduction collection of

Citrullus Schrad. ex Eckl. & Zeyh. species was screened. Resistance was found in wild type accessions and was characterized by moderate to high variability. Eight of the 1,654 accessions and cultivars demonstrated high levels of resistance with low levels of phenotypic variability. Using data from the screening and retest studies, the most resistant accessions were PI 632755, PI 386015, PI 346082, PI 525082, PI 432337, PI 386024, and PI 269365 and PI 189225. Twenty-three accessions demonstrated uniform intermediate resistance. Inheritance of powdery mildew race 2W was studied in two accessions, PI 189225 and PI 270545. Two susceptible parent lines PI 269677 and 'Charleston Gray' were crossed with the resistant accessions. Parents, F_1, F_2 and backcross populations were evaluated in the greenhouse. Inheritance of resistance in PI 189225 was found to be multigenic, while in PI 270545, a major gene was found whose expression was more complex than that suggested by the single gene alone. No discrete phenotypic classes were observed in the segregating F_2 populations of any cross. Based on quantitative analyses, each resistant line contained at least two to three effective factors for powdery mildew resistance. Additive gene action was the most important component of variation in all three crosses. Dominance effects were not significant. Narrow sense heritability estimates for powdery mildew resistance was 0.62 for PI 189225 and 0.92 for PI 270545.

Breeding for Resistance to Powdery Mildew Race 2W in Watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai].

by
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DEDICATION

I dedicate the work and effort that have gone into this research project to my family and the good people of Ghana who supported my study with their love, goodwill, prayers and tax money.

BIOGRAPHY

Antonia Yarbeh Tetteh was born on December 25, 1964 in Zanzibar, Tanzania, to Christopher John Yarney of blessed memory and Virginia Dora Yarney both of Winneba, Ghana. After spending the first four years of her life in Zanzibar, her family moved back to Ghana. Antonia grew up in Winneba, where her father, who was then the Director of the Advanced Teacher Training College, Winneba, under his able administration, had established a farm to grow crops and raise livestock to feed the students of the College. She visited the farm with her father on weekends and this is where her love for plants began.

She attended Winneba Methodist Primary and Middle Schools from 1969 to 1976, and Winneba Secondary School from 1976 to 1981. She passed her G.C.E Ordinary Level Examination and moved on to Mfantsiman Girls Secondary School, Saltpond, for her Sixth Form education from 1981 to 1983. In 1984 she enrolled in Kwame Nkrumah University of Science and Technology, Kumasi, Ghana where she graduated in 1988 with B.Sc. Biochemistry major. She was awarded Canadian International Development Agency (CIDA) award in 1989 to pursue Master of Science degree in Food Science and Agricultural Chemistry in Macdonald campus of McGill University, Montreal, Canada. In McGill, Antonia worked with Professor Benjamin K. Simpson as her Advisor on 'Optimization Studies of Chitin Extraction from Crustacean Solid Wastes' for her M.Sc. research project.

Upon graduation in 1991, she went back to Ghana and took up a lecturer appointment at the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. During this period she taught many courses and did research in Food Science and Biochemistry. She attended many conferences and workshops in Africa and became a member of African

Women Scientists in Natural Resources Conservation and Management. In 2003, she got a grant to attend a 4-month training program in vegetable crop production at the Asian Vegetable Research and Development Center (AVRDC) in Arusha, Tanzania, where she earned a Diploma in Vegetable Crop Production.

Antonia's love for the people of Africa and the dire need to meet the challenges facing agriculture and food supply in Africa rekindled a strong desire in her to pursue a doctoral degree in horticultural science. In January 2005, she got enrolled in the Department of Horticultural Science, North Carolina State University, Raleigh, North Carolina for a Ph.D. program in plant breeding and genetics under the direction of Dr Todd C. Wehner. Her research project involved breeding for powdery mildew resistance in watermelon. In addition to working on watermelons, she obtained a state-of- the-art field and greenhouse training from Dr Wehner in cucumber and melon breeding and got the opportunity every year to interact with expertise from seed companies. She also took classes and labs in corn, cotton, small grains, peanut, soybean, tobacco, sweet potato, and turf grass breeding.

In the first year of her program in NC State, Antonia received International Fellowship from the Rosalind Nix Gilliatt Fund of the Association of American University Women (AAUW) to support her research and living. Her Ph.D. program was fully funded by Ghana Government Scholarship award.

Antonia found Dr Todd C. Wehner not only as an academic Advisor, but a mentor with a keen interest, love and goodwill for his students here and even after graduation. She received a lot of encouragement, direction and motivation and teamwork building skills from Dr Wehner through weekly meetings with him. While studying at NC State, she was initiated into an honor society of Pi Alpha Xi. However, due to her family responsibilities she could not take active part in the society's fall and spring fundraising plant sale.

Following the completion of her studies, Antonia will go back to Ghana to contribute the knowledge and expertise she has gained for the progress and development of agriculture in Africa. She dreams of the day when Africa will be food sufficient. Antonia is married to Isaac Tetteh and they have three wonderful children, Kweku, Esi and Araba.

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To God be the glory, great things He has done.

I express my sincere gratitude and appreciation to my major professor, Dr Todd C. Wehner for his guidance, advice and assistance during my graduate studies. I also thank him for the confidence he had in me at the beginning, to take me on a graduate student and believing that I would be able to carry on with this research work to completion.

Special thanks are due to my graduate committee members Dr William (Bill) Swallow, Dr Ralph Dean and Dr Gerald Holmes for their guidance, direction, ideas and advice during my coursework and their contributions, comments and helpful suggestions which were incorporated into the preparation of this dissertation. Great appreciation goes to my graduate representative, Dr Wendy Boss.

My gratitude and appreciation go to the good people of Ghana for their financial support and encouragement which have enabled me to pursue a graduate degree in the United States of America. I am very thankful to the Association of American University Women (AAUW) who supported the first year of my living and graduate work and enabled me to bring my family with me to the U.S. through the Rosalind Nix Gilliatt Fund.

My special thanks and admiration goes to Tammy Ellington for her love, wisdom, generosity and friendship. I also thank her for teaching me powdery mildew research techniques when I took over the powdery mildew project.

I thank the staff of the greenhouses of the Department of Horticultural Science, especially Mark Hardy, Wesley Turner, Brian McCall and Allen Gordon, who relentlessly worked with me in diverse ways to get my plants in the greenhouse healthy and pest-free. My appreciation goes to the staff of the Horticultural Crops Research Station at Clinton, North Carolina, for their technical assistance.

I am greatly indebted to my mother whose constant love, prayers and phone calls gave me the ability to carry on during the difficult times of my study. To my father of blessed memory, who inspired in me a perpetual gift of aiming high and trusting in God that my efforts will not be in vain, all I can say is I love you dad, and may God grant you a peaceful rest.

I thank Jiyoung Oh for her loving friendship and encouragement during the course of this work. I thank Rakesh Kumar, Adam Criswell, Lingli Lou and Adam Call for their friendship and help with greenhouse and fieldwork.

Gratitude and appreciation are hereby extended to the Faculty of Horticultural Science, especially Dr John Dole and Dr. Mary Peet for helping me in diverse ways. I thank Mr. Bill Jester for helping with extension outreach experience. I acknowledge the diverse ways in which Rachel McLaughlin helped me.

I thank my five sisters and brother in Ghana, who supported me with their love and prayers.

My highest gratitude goes to my husband and children, whose sacrifice, affection, patience, support and encouragement kept me working until the end of my study. I especially thank my son, Kweku, who in diverse ways helped at home so my research work could be done.

Finally, I am thankful to God, whose providence opened the way for me to come to America to pursue a program which is so relevant to the economy of Ghana and the whole of

Africa. Out of the abundance of His blessings, He gave me strength and fortitude, health and perseverance, wisdom and insight and all that I needed to complete this study according to His will. I ask Him to lead me in the path of increasing in knowledge and using it to serve humanity.

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GENERAL INTRODUCTION

WATERMELON BREEDING AND GENETICS OF RESISTANCE TO FUNGAL PATHOGENS

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Brief History of Watermelon Breeding

Watermelon [*Citrullus lanatus* (Thunb.) Matsum. and Nakai] is one of the twelve species of the family Cucurbitaceae cultivated by man. It is a major vegetable crop in the United States and other parts of the world and accounts for 6.8% of the world area devoted to vegetable crop production (FAO, 2002). Watermelon is grown in over 96 countries with China, Turkey, Iran and U.S. being the top four leading producers. In 2005, watermelon production in the U.S. was 1,669 metric tons with an average yield of 31,139 kg/ha and a dollar value of $313.5 million (U.S. Dept. of Agriculture, 2006). Watermelon is indigenous to tropical Africa where it grows wild (De Candolle, 1882) and is native to the sandy and dry areas of southern Africa, chiefly the Kalahari Desert (Bailey, 1949). It also grows wild in various parts of the western hemisphere, particularly in India (Pangalo, 1930, 1944, 1955; Peter, 1998) and in the Mediterranean area, particularly, Egypt and Iran.

Open Pollinated Varieties

For hundreds of years, watermelon breeding was concentrated on selection for desirable types in terms of flesh color, sweetness, and storage characteristics, however, in the late 19th and early 20th centuries, planned improvements in fruit quality began by public and private groups (Maynard et al., 2007). Some of the first few open pollinated cultivars which were released in the U.S. were ‘Angeleno’, ‘Chilean’ and ‘Kleckley Sweet’, ‘Florida Favorite’ and ‘Georgia Rattlesnake’ (Whitaker and Jagger, 1937). C.F. Andrus released ‘Congo’, ‘Fairfax’ and ‘Charleston Gray’, (Andrus, 1949, 1953, 1955). ‘Charleston Gray’, ‘Jubilee’ (J.M. Crall, University of Florida), ‘Crimson Sweet’, ‘Allsweet’ (C.V. Hall, Kansas

State University) and ‘Sugar Baby’ (M. Hardin, Geary, Okla.) were reported to be the most successful diploid and open-pollinated cultivars in the U.S. (Maynard et al., 2007). Charleston Gray has elongate fruit shape, gray rind, and red flesh, with anthracnose and Fusarium wilt resistance and good shipping qualities because of its strong rind texture. ‘Crimson Sweet’ is a 12-15 kg round fruit, has light green with dark green stripes, dark red flesh and fine texture. It is resistant to anthracnose and Fusarium wilt.

Triploid Seedless Watermelon

A very significant change in contemporary watermelon breeding is the development of seedless fruit. It began in 1938 with the discovery of effect of colchicine on doubling the ploidy level of chromosomes (Eigsti, 1938). Hitashi Kihara, a world-renowned plant geneticist later used colchicine to double the chromosome number of a female diploid ($2x=22$) parent to produce a tetraploid ($4x=44$). He produced triploid seedless watermelon in 1947 from a cross between a female tetraploid and a male diploid (Kihara, 1951). Kihara’s work became known outside of Japan in 1951 after World War II. In 1962, Eigsti produced a commercial triploid seedless watermelon ‘Tri-X-313’ which became commercially important after improving its germination ability and eliminating hard seeds from the fruit (Woodburn, 1999). The technique for producing seedless watermelon is now made easier (McQuiston and Wehner, 2005).

Hybrid Watermelon

Hybrid watermelons became popular when studies in the 1950s and 1960s showed that some heterosis is present in watermelon, though very small and not useful. Hybrid varieties are useful for combining traits inherited in a dominant fashion from two parents. In recent years, popular varieties for commercial production are almost all hybrids (Maynard, 2001). Hybrids are more popular because they provide exclusive opportunity for the seed company to control seed production of their cultivars. Two types of watermelon hybrids are produced: diploid hybrid and triploid hybrid. Diploid hybrid is the F_1 progeny from two inbred diploid parents and may be based on 'Allsweet', 'Crimson Sweet', 'Charleston Gray' or 'Sugar Baby' types. The most popular diploid hybrid varieties based on 'Allsweet' type are 'Sangria', 'Royal Sweet', 'Fiesta', 'Mardi Gras' and 'Regency'. Triploid hybrid is the F_1 progeny from a tetraploid maternal parent and a diploid pollen parent (Zhang, 2007). The most popular triploid hybrids are 'Tri-X-313', 'Summer Sweet 5244', 'Millionaire', 'Genesis' and 'Tri-X-Shadow'.

Breeding for Mini Watermelon

In the past two decades, there has been a growing demand in the U.S. for small fruit watermelons of 3 to 5 kg size known as ice box. Mini watermelons with size 1.5 to 3 kg are the newest watermelons in the marketplace. 'New Hampshire Midget' is the first mini watermelon released and was produced in 1951 by A.F. Yeager at the University of New Hampshire. This watermelon cultivar had a brittle rind which cracked easily, as were other mini watermelon cultivars. In 1986, J. M. Crall released cultivars 'Minilee' and 'Mickylee', which are now used as pollenizers in triploid seedless watermelon production. Xingping Zhang of Syngenta used a watermelon line from Asia to develop 'PureHeart' brand, a mini watermelon with thin rind, deep red seedless flesh, and an array of rind patterns (Zhang and Williams, 2004, 2006).

Genetics of Disease Resistance

Commercial watermelon varieties are susceptible to a number of pathogens and insect pests. Breeding for resistance to diseases became important at the beginning of the 20th century when Biffen (1907) discovered that a particular resistance to yellow rust in wheat was controlled by a single recessive gene. Today, many breeding programs consider incorporating resistance into cultivars without compensating for yield and quality of the product.

Resistance of a host cultivar may be specific or general. Specific resistance, also known as vertical resistance allows less or no disease development on the host compared to the susceptible control cultivar. A plot of an F_2 trait data usually shows a discontinuous variation. Inheritance of resistance is mostly Mendelian and is controlled by single dominant or recessive gene and follows the gene-for-gene theory (Flor 1942, 1956, 1971). Resistance based on single dominant genes are usually race-specific and often give complete protection, however, durability of such resistance is usually very short because it can be overcome by simple genetic changes in the pathogen (McDonald and Linde, 2002; Roberts and Caldwell, 1970; Skinnes, 2002).

General resistance allows less disease development than a susceptible cultivar by all genotypes of the pathogen. It is also called partial resistance. A plot of the F_2 data usually shows continuous distribution. Genetic basis of horizontal resistance may be additive, partially dominant or epistatic. This form of resistance is inherited as a quantitative trait and has been shown to be durable. Typical examples are the North American winter wheat cultivar ‘Knox’ which was shown to have effective resistance against powdery mildew for more than two decades of commercial production (Shaner, 1973; Lillemo and Skinnes, 2006) and continues to be resistant. Also the partial resistance in cultivar ‘Massey’ has remained effective over more than two decades (Liu et al., 2001).

The use of horizontal resistance in plant breeding has been limited because of the difficulty in detecting and selecting for it. The use of statistical models, gene number estimates and heritability of partial resistance provides useful information on the effectiveness of selection in populations derived from crosses involving partially resistant cultivars.

Genetics of Watermelon Resistance to Fungal Pathogens

In the U. S., fungal diseases are major production-limiting factor in the watermelon industry. The four most common fungal diseases and their causative agents are Fusarium wilt caused by *Fusarium oxysporum* Schlecht. (emend. Snyd. and Hans.) f. sp. *niveum* (E.F. Sm.); anthracnose caused by *Colleotrichum orbiculare* (Berk. & Mont.) Arx (syn. *C. lagenerium* (Pass.) Ellis & Halst.); gummy stem blight caused by *Didymella bryoniae* (Auersw.) Rehm.; and powdery mildew caused by *Podosphaera xanthii* (Castagne) U. Braun & N. Shish.

Comb. nov. [syn. *Sphaerotheca fuliginea auct. p.p.*]. The genetics of resistance in Fusarium wilt, anthracnose and gummy stem blight have been described and provide useful information for breeding cultivars (Guner and Wehner, 2003, 2004).

Resistance to anthracnose races 1 and 3 is controlled by a single dominant gene *Ar-1* (Layton, 1937). Sources of resistance to race 2 are the African Citron W-695, PI 512385, PI 189225, PI 271775, PI 271779, and PI 299379. The resistance in these lines is controlled by a single dominant gene *Ar-2-1* (Winstead et al., 1959).

Sources of resistance to Fusarium wilt is reported to be present in 'Quetzali' and 'Mickylee' for race 0, in 'Calhoun Gray' for races 0 and 1, and in PI 296341 and PI-272769 for races 0, 1 and 2 (Maynard, 2001) (Table 1). A single dominant gene *Fo-1* controls resistance to race 1 (Henderson et al., 1970). In PI 296341 and PI-272769, a recessive gene with some minor gene interactions is known to control all three races (Martyn and Netzer, 1991; Zhang and Rhodes, 1993).

Resistance to gummy stem blight was found in PI 189225 and PI 271778 and is governed by a single recessive gene, *db*, (Norton et al., 1986), PI 482238 and PI 526233 (Gusmini et al., 2005). The resistance in these lines was found to be quantitative.

In the past, powdery mildew was not a problem of watermelon as they were resistant to older races of *Podosphaera xanthii* present in the U.S. However in 1975, susceptibility to powdery mildew was found in the plant introduction accession, PI 269677 (Robinson and Provvidenti, 1975) and was found to be controlled by a single recessive gene *pm* (Robinson et al., 1975). In recent years, a new pathotype of powdery mildew has been damaging watermelon crops in the United States (Davis et al., 2001; Keinath, 2000; McGrath, 2001a).

Outbreaks of powdery mildew have been confirmed in the southeastern states, Oklahoma, Texas, Maryland, New York, Arizona and California. The disease is reported to be caused by two races of *Podosphaera xanthii* designated race 1W and race 2W and is responsible for low yields and quality loss (Davis et al., 2001; McGrath, 2001a). Following the evaluation of 590 (Robinson and Provvidenti, 1975) and 266 (Thomas et al., 2005) accessions of *C. lanatus* for their reaction to powdery mildew, the USDA-ARS Southern Regional Plant Introduction Station, Griffin, GA, has made new collections of 1,537 PI accessions of the *Citrullus* genus, necessitating screening for sources of resistance. Screening a total of 1,573 accessions of the watermelon collection, resistance to powdery mildew race 1W was found in PI 525088 which is inherited as a multigenic trait (Davis et al., 2002, 2007). There have been no reports of screening the watermelon germplasm collection for resistance to powdery mildew race 2W. It will be useful to screen the germplasm collection to find sources of resistance to powdery mildew race 2W for further incorporation into commercial cultivars.

Objectives

The objectives of this dissertation were 1) to develop an efficient and reliable method for screening for powdery mildew resistance; 2) to screen the USDA watermelon germplasm collection along with available cultivars and breeding lines for resistance to powdery mildew race 2W; 3) to determine the heritability and genetic variance estimates for resistance to powdery mildew race 2W.

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Zhang, X.P. 2007. US Patent No. 7,238,866 “Triploid Hybrid Watermelon Plants”.

Table 1. Watermelon cultivars with vertical resistance to Fusarium wilt caused by *Fusarium oxysporum* Schlecht. (emend. Snyd. and Hans.) f. sp. *niveum* (E.F. Sm.).

Cultigen	Race 0	Race1	Race2
‘Black Diamond’, ‘Sugar Baby’	S	S	S
‘Texas W5’,‘Quetzali, Mickylee’ ‘Charleston Gray’	R	S	S
‘Calhoun Gray’, ‘Summit’	R	R	S
PI 296341-FR, PI 271769	R	R	R

S=susceptible; R=resistant.

CHAPTER ONE

OVERVIEW OF GENES FOR FUNGAL DISEASE RESISTANCE IN WATERMELON

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Introduction

The use of resistant varieties as a means of controlling plant disease is simple, effective and economical. Since the middle of the 20th century, a large number of disease resistance genes along with improved horticultural characteristics have been incorporated into cultivated cucurbits (Sitterly, 1972). Commensurate with this advancement is the effort made by curators of genetic resource centers to search for sources of resistance in compatible lines. Cultivars with many disease resistance traits have replaced those with resistance to one disease.

Many diseases attack watermelon, of which fungal diseases form an important class. An important class of diseases is the fungal diseases. In the last two centuries, most of the watermelon cultivars developed in the U.S. have been derived from few lines, leading to a narrow genetic background of most of the cultivars and predisposing them to elevated susceptibility to pests and diseases (Levi et al., 2000, 2001a). In the U. S. four major fungal diseases attack watermelons and these are Fusarium wilt, gummy stem blight, anthracnose and in recent years, powdery mildew.

The watermelon genes were originally organized and summarized by Poole (1944). Lists of genes for watermelon have been published by Robinson et al. (1976), the Cucurbit Gene List Committee (1979, 1982, and 1987), Henderson (1991 and 1992), Rhodes and Zhang (1995), Rhodes and Dane (1999), and Guner and Wehner (2003, 2004). There are 170 total mutants, with 111 markers (protein or isozyme mutants, DNA (RFLP and RAPD) markers, and cloned genes), and 59 morphological and resistance mutants. The latter can be grouped into seed and seedling mutants, vine mutants, flower mutants, fruit mutants, and resistance mutants.

Although there are 59 genes reported to control morphological and resistance traits in watermelon, there have been no reports of linkage among them, other than correlations among traits not controlled by single genes (Navot et al., 1990). This is in contrast with other cucurbits such as cucumber (*Cucumis sativus* L.) and melon (*Cucumis melo* L.), where many linkages have been reported. In watermelon, the only linkages reported have been among the molecular markers.

This paper has the objective of reviewing the history of watermelon fungal diseases and sources of resistance.

Fusarium Wilt

Fusarium wilt of watermelon is a soilborne disease caused by the fungus *Fusarium oxysporum* Schlecht. (emend. Snyd. and Hans.) f. sp. n*iveum* (E.F. Sm.). The disease is a major problem in watermelon production in susceptible varieties. It was first described in the U.S. in Georgia and South Carolina by Smith (1894). It is now well-established throughout the watermelon-growing regions of the world (Martyn and Netzer, 1991; Zitter et al., 1996). The disease is manifested first as a temporary wilt of vines, which usually occurs during the hottest part of the day, with the wilt occurring more rapidly when the plant is under water stress or bearing fruit. The wilt progresses and affects more vines and the foliage becomes desiccated and necrotic and within 2-3 days, plants may die. Plants which survive become severely stunted and produce very scanty vine growth and poor fruit set.

Among all the control measures which have been used to control Fusarium wilt of watermelon, genetic resistance has consistently proven to be the most effective and efficient means of control (Elmstrom and Hopkins, 1981; Hopkins and Elmstrom, 1984). Orton (1907) released the first watermelon cultivar resistant to Fusarium wilt. Since then, many other resistant cultivars have been released, many of which have succumbed to new races of wilt over the years (Martyn and Netzer, 1991).

Presently, within the formae specialis *F. oxysporum* f. sp. *niveum* occurs in three races: races 0, 1 and 2 on the basis of their degree of aggressiveness on watermelon differential genotypes (Crall, 1963; Martyn, 1987, 1996; Martyn and Bruton, 1989; Netzer, 1976; Zhou and Everts, 2004). Race 0 was first detected in Florida in 1963 and causes wilt in susceptible watermelon cultivars with no wilt resistance genes and therefore, is of little economic importance. Race 1 causes severe wilt in susceptible cultivars and slight to moderate wilt on most cultivars that are considered resistant. It is the predominant race throughout commercial watermelon regions in the U.S. and world. Race 2 is highly aggressive and overcomes all currently known resistant cultivars. Much breeding efforts have produced cultivars with resistance to Fusarium wilt race 1. Race 2 was first observed in Israel in 1973 (Netzer, 1976; Netzer and Dishon, 1973) and in the U.S. in 1981 (Martyn, 1985, 1987). No commercial genotypes have high resistance to race 2; however, the wild plant introduction line from South Africa PI 296341, a *Citrullus lanatus* var. *citroides* has been selected for improved race 2 resistance. The improved line is designated PI-296341-FR (Martyn and Netzer, 1991) and is the only internationally acknowledged source of high resistance to all three races. Resistance in PI-296341-FR is described as being substantial but incomplete as occasionally, more than 5% of plants inoculated with race 2 die. A second PI line, PI-272769, is also reported to have resistance to race 2 (Maynard, 2001).

Sources of Resistance to Fusarium Wilt

Fusarium wilt resistance is found in the lines ‘Summit’ and Texas W5. Breeders have used these two lines as sources of resistance in ‘Dixielee’ and ‘Sugarlee’ (Elmstrom and Crall, 1979; 1981) and SSDL (small-seed Dixielee-type) (Crall et al., 1994). Another form of resistance is present in ‘Smokylee’ and ‘Calhoun Gray’ and these were combined with the resistance in Texas W75 to breed for ‘Charlee’ (Crall, 1990). ‘AU-Sweet Scarlet’ derives its resistance from ‘Crimson Sweet’, ‘Allsweet’, ‘Calhoun Gray’ and ‘W.R. Peacock’ (Norton et al., 1995). These lines contain resistance to races 0 and 1 (Table 1). Resistance to race 1 is controlled by a single dominant gene *Fo-1* (Henderson et al., 1970; Netzer and Weintall 1980). The corresponding susceptible gene is designated *fo-1* and is present in susceptible lines like ‘New Hampshire Midget’.

Resistance to race 2 in PI 296341-FR is thought to be a recessive gene in interactions with some minor genes (Martyn and Netzer, 1991; Zhang and Rhodes, 1993). A cross between PI 296341-FR and ‘New Hampshire Midget’, produced two linkage groups from the F_2 data: a 112.9 cM RAPD-based map consisting of 26 markers, while the F_3 data produced a 139 cM RAPD-based map consisting of 13 markers covering five linkage groups. Isozyme and SSR markers were unlinked. About 40% to 48% of the RAPD markers were significantly skewed from the expected 3:1 and 5:3 Mendelian segregation ratios in the F_2 and F_3

generations, respectively. In the backcross to the susceptible parent, 25.7% of the 179 markers were skewed away from the expected 1:1 ratio (at P=0.05) (Levi et al., 2001b).

Anthracnose

Anthracnose is a relatively common disease of the foliage and fruit of watermelon. It is caused by *Colletotrichum orbiculare* (Berk. & Mont.) Arx (syn. *C. lagenerium* (Pass.) Ellis & Halst.). The disease on watermelon is manifested as brown to black lesions. The margins of lesions on the leaves are typically irregular. Black spots appear on young fruits which result in abortion or malformation (Vakalounakis, 1996). Although control measures including use of eradicant fungicides, clean seed and crop rotation reduce the severity of the disease, control of the disease through the use of resistant varieties has been the ideal method. *Colletotrichum lagenarium* races 1, 2 and 3 are important in watermelon production (Sitterly, 1972).

Sources of Resistance to Anthracnose

The first anthracnose resistant varieties of watermelon to find wide acceptance were ‘Congo’, ‘Fairfax’ and ‘Charleston Gray’ (Andrus in 1949, 1953, 1955). These cultivars possessed resistance to races 1 and 3 were found to be controlled by a single dominant gene (Hall et al. 1960) symbolized, *Ar-1* (Layton, 1937).

Race 2 was identified in 1956 in North Carolina when the anthracnose resistant cultivars ‘Congo’, ‘Fairfax’ and ‘Charleston Gray’ became susceptible to a fungus which was indistinguishable by cultural and morphological characteristics to *C. lagenarium* (Goode, 1956, 1958) The three races could clearly be distinguished by four differential host reactions (Goode, 1958). These are Butternut squash which is immune to race 3 but susceptible to races 1 and 2, 'Charleston Gray' watermelon which is resistant to races 1 and 3 but highly susceptible to race 2, PI 163213 which is susceptible to race 1 and resistant to race 3, and the cucumber variety 'Model' which is highly susceptible to all three races. All watermelon varieties tested were susceptible to race 2.

Winstead et al. (1959) screened 350 plant introduction accessions for resistance to race 2 and found a citron line, W-695 which originated from South Africa to segregate for resistance to race 2. Preliminary inheritance studies showed that resistance to race 2 in this line was monogenic and dominant as the populations fitted the expected 3:1 and 1:1 resistant: susceptible ratios of the F_2 and backcross populations, respectively. However, a second inheritance study failed to produce the same results and no conclusion about the inheritance could be obtained.

New sources of resistance to anthracnose race 2 have since been found. These are PI 189225, PI 271775, PI 271778, PI 299379, PI 270550 and PI 203551 (Sowell et al.1980); Suvanprakon and Norton, 1980). However, Boyhan et al. (1994) and Love and Rhodes (1988) failed to observe the resistance reported in these plants in that their susceptibility to anthracnose race 2 was not significantly different from that of 'Crimson Sweet', the susceptible control. Two new sources of resistance to race 2 have since been reported. These are PI 512385 (Boyhan et al., 1994) and a *Citrullus colocynthis* line R309 (Love and Rhodes, 1991). Resistance to race 2 is governed by a single dominant gene *Ar-2-1* (Winstead et al., 1959) present in W695 citron, PI 189225, PI 271775, PI 271779, and PI 299379. The susceptible allele *ar-2-1* is present in 'Allsweet', 'Charleston Gray', and 'Florida Giant'; Resistance in the *Citrullus colocynthis* line R309 was found to be due to other dominant factors (Love and Rhodes, 1988, 1991; Sowell et al., 1980; Suvanprakorn and Norton, 1980; Winstead et al., 1959).

Gummy Stem Blight

Gummy stem blight, caused by *Didymella bryoniae* (Auersw.) Rehm [syn. *Mycosphaerella melonis* (Pass.) Chiu and Walker] and *Mycosphaerella citrullina* (C.O.Sm.) Gross. and its anamorph *Phoma cucurbitacearum* (Fr.:Fr.) Sacc. [syn *Aschochyta cucumis* Fautrey & Roum] (Keinath et al. 1995) is one of the most destructive diseases of watermelon (Sowell and Pointer, 1962). The pathogen is most common in southern U.S. and in subtropical and tropical areas of the world (Thomas, 1996). The disease is manifested on watermelons as circular, tan to dark brown spots which begin at the leaf margins, and enlarge rapidly until the entire leaf is blighted. Stem cankers and extensive defoliation also occur. Symptoms are also observed on cotyledons, hypocotyls and fruit (Maynard and Hopkins, 1999). Control of gummy stem blight through fungicide applications (Keinath, 1995, 2000) and good cultural practices (Keinath, 1996; Rankin, 1954) is difficult particularly during periods of frequent rainfall when relative humidity remains high for a long period (Gusmini et al., 2005) and concern over the development of resistance to fungicides by the fungus has also been expressed (Keinath and Zitter, 1998; Malathrakis and Vakalounakis, 1983).

Sources of Resistance to Gummy Stem Blight

The plant introduction accessions PI 189225 and PI 271778 have demonstrated high levels of resistance to *D. bryoniae* (Sowell, 1975; Sowell and Pointer, 1962). Norton (1979) reported that resistance in these lines is inherited as a single recessive gene *db*. These sources of resistance were used to produce ‘AU-Jubilant’, ‘AU-Producer’ (Norton, et al., 1986), ‘AU-Golden Producer’ (Norton et al., 1993) and ‘AU-Sweet Scarlet’ (Norton et al., 1995). New source of resistance were found in PI 482238 and PI 526233 (Gusmini et al., 2005) Resistance in these lines was found to be quantitative, and few effective factors were estimated to regulate it.

Powdery mildew

Powdery mildew on cucurbits is a disease of historical and economic importance worldwide. In the past, watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] was considered to be free of the disease (Křístková, 2000; Bertrand, 1991; Robinson and Provvidenti, 1975; Robinson et al., 1975; Sitterly, 1978). However, in recent years, powdery mildew has become an important disease of watermelon in the U.S. especially in the southeastern states, Texas, Oklahoma, Maryland, New York, Arizona and California. Powdery mildew on watermelon is caused by *Podosphaera xanthii* which occurs in two races, race 1W and race 2W, the difference determined using melon differentials (Davis et al., 2001; McGrath, 2001a). The disease is manifested as chlorotic spots on the leaves with or without mycelial and conidial development on leaves and stems. The affected plant parts become necrotic and dry up resulting in decreased plant canopy. A reduced canopy results in low yield, poor fruit quality and short storage life (Keinath and DuBose, 2004; McGrath and Thomas, 1996).

Sources of Resistance to Powdery Mildew

Watermelons were resistant to older races of *P. xanthii* present in the U.S. in the 1970s, but a single recessive gene *pm* (Robinson et al., 1975) for high susceptibility to powdery mildew was found in the plant introduction, PI 269677. Races 1W and 2W of powdery mildew are now present in the U.S., and cause a susceptible reaction in most cultivars. PI 269677 is highly susceptible to the new race. Recent screening of the USDA-ARS watermelon germplasm collection made up of 1,573 accessions revealed that eight accessions exhibited high levels of resistance, and another eighty-six demonstrated intermediate resistance to race 1W (Davis et al., 2007). Of these, PI 525088, a *Citrullus lanatus* var. *lanatus* line from Egypt was the most resistant. The inheritance of race 1W powdery mildew resistance in an F_2 population of PI 525088 x 'Black Diamond' was found to be multigenic (Davis et al., 2002). Thus it would be useful to study the number of effective factors controlling the multigenic inheritance of resistance in watermelon to powdery mildew race 1W.

At present, there is dearth of information on sources of resistance to powdery mildew race 2W. It would be useful to search for sources of resistance to race 2W. Finding sources of resistance will contribute to information regarding the genetics of resistance and lead to the development of inbred lines which can be used to develop powdery mildew resistant cultivars.

Conclusion

Most fungal diseases of watermelon can so far be controlled by using monogenic resistant cultivars. Emergence of new virulent races necessitates the search for new sources of resistance genes in related species and genera and also finding ways of making non-durable resistance genes durable. Application of molecular genetics research to enhance the identification and combination of minor and additive genes will provide understanding to the genetic basis of quantitative resistance.

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Table 1. Genes for fungal disease resistance in watermelon.

Gene	Character	References[z]	Supplemental references
Ar-1	Anthracnose resistance to races 1 and 3 of *Glomerella cingulata* var. o*rbiculare* (*Colletotrichum lagenarium*); *Ar-1* from 'Africa 8'*, "Africa 9'*, 'Africa 13'* and 'Charleston Gray'**; *ar-1* from 'Iowa Belle 487'* and N.C.9-2, N.C.11, and 'New Hampshire Midget'**.	Layton, 1937.	Hall et al., 1960; Robinson et al., 1976; Winstead et al., 1959.**
Ar-2-1	Anthracnose resistance to race 2 of *Colletotrichum lagenarium*; *Ar-2-1* from W695 citron* and PI 189225, PI 271775, PI 271779, and PI 299379**; *ar-2-1* from 'Allsweet', 'Charleston Gray', and 'Florida Giant'; resistance in *Citrullus colocynthis* is due to other dominant factors; resistance from R309***; susceptibility from 'new Hampshire Midget'.	Winstead et al., 1959.*	Love and Rhodes, 1988*** 1991; Sowell et al., 1980**; Suvanprakon and Norton, 1980.
db	Resistance to gummy stem blight caused by *Didymella bryoniae*; *db* from PI 189225; *Db* from "Charleston Gray'.	Norton, 1979.	Gusmini et al., 2005.
Fo-1	Fusarium wilt resistance to race 1; dominant gene for resistance to race 1 of *Fusarium oxysporum* f. sp. *niveum*; *Fo-1* from 'Calhoun Gray' and 'Suummit'; *fo-1* from 'New Hampshire Midget.'	Henderson et al., 1970.	Netzer and Weintall, 1980
pm	Powdery mildew susceptibility; susceptibility to *Sphaerotheca fuliginea* is recessive; *pm* from PI 269677; *Pm* from 'Sugar Baby' and most cultivars.	Robinson et al., 1975.	-

[z]Asterisks on cultigens and associated references indicate the source of information for each.

CHAPTER TWO

METHODS FOR SCREENING WATERMELON FOR RESISTANCE TO POWDERY MILDEW RACE 2W

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Abstract

Powdery mildew [*Podosphaera xanthii* (Castagne) Braun & Shishkoff (syn. *Sphaerotheca fuliginea auct. p.p.*)] has become an important disease of watermelon in the United States in recent years. The need to search for sources of resistance in the watermelon germplasm collection has necessitated the development of a reliable and efficient method of testing for resistance. The objective of this study was to develop a method for screening watermelons for resistance to *P. xanthii* race 2W, the race prevalent in southeastern U.S. Two experiments were run to determine the effect of humidity, inoculum application method and type of growth chamber on disease severity of resistant and susceptible accessions. The optimum time to carry out disease assessment was also studied. The best method for evaluating resistance to powdery mildew was determined by the combination of the factors which gave the widest range in disease severity between most susceptible and most resistant accessions. The best method was found to be made up of inoculation of seedlings with a spray of a spore suspension of inoculum and maintaining the inoculated seedlings at normal greenhouse temperature and relative humidity. A high relative humidity was not required for disease establishment. Maintenance of inoculum on squash or watermelon plants did not have a significant effect on disease severity. Rating leaves for disease severity was found to be more efficient as it gave more uniform ratings and contributed larger variances among accessions than stem ratings. Taking multiple ratings was useful in verifying disease progress, however larger significant differences between susceptible and resistant lines were observed when plants were rated on the third to fourth week after inoculation.

Introduction

Powdery mildew is an important disease of cucurbit crops worldwide. It is caused by *Podosphaera xanthii* (Castagne) Braun & Shishkoff (syn. *Sphaerotheca fuliginea auct. p.p.*) and *Golovinomyces cichoracearum s.l.* (D.C.) V.P. Heluta (syn*. Erysiphe cichoracearum auct. p.p*) (Jahn et al., 2002). In the past, watermelon was considered to be free of powdery mildew with the exception of few, isolated and mild cases of the disease (Ivanoff, 1957; Nagy, 1983; McLean, 1970; Robinson and Provvidenti, 1975). In recent years powdery mildew outbreaks have been reported in the U.S. and the disease has been confirmed in the southeastern states, Maryland, Texas, Oklahoma, Arizona, New York and California (Keinath, 2000; Davis et al 2001; McGrath et al. 2001a). In the U.S. only *P. xanthii* is known to affect watermelon.

Podosphaera xanthii is known to occur in several physiological races. These races are differentiated using melon differentials. In the U.S., two races of *P. xanthii*, races 1W and 2W have been identified on watermelon (Davis et al 2001; McGrath et al. 2001a; Davis et al., 2007). Powdery mildew is manifested as chlorotic spots on leaves with or without white mycelial and/or conidial development on leaves and stem. The disease results in moderate to severe damage to the foliage, as well as a reduction in yield (McGrath, 2001a; Davis et al., 2001). The disease is controlled with fungicides, however reports of resistance to the recommended fungicides, and the difficulty of fungicide application to underside of leaves necessitates a more efficient method of control (McGrath and Thomas, 1996; Keinath and Dubose, 2004). The use of disease resistant cultivars will offer economical and safe method to control the disease. The watermelon germplasm collection has been screened for powdery mildew race 1W and sources of resistance have been reported (Davis et al., 2007). So far no sources of resistance to powdery mildew race 2W have been reported.

In order to screen a large number of watermelon germplasm for resistance to powdery mildew, it is necessary to develop an efficient and reliable test. The method should permit screening of cultigens to obtain uniform data and efficient use of resources. Factors reported to influence colonization and sporulation of powdery mildew fungi are method of inoculation, source of inoculum (personal communication, Davis, 2005), inoculum density, relative humidity, and light intensity. Powdery mildew fungi multiply under high relative humidity, warm temperatures, low light, high fertility, and succulent plant growth. Moisture requirements for powdery mildew appear to be complex and contradictory (Butt, 1978). Yarwood (1939) reported that though high relative humidity is required, infection can occur at relative humidity below 50% and that free water on plant surfaces must be avoided.

Among inoculum application methods, a direct leaf-to-leaf contact (Walmsley-Woodard et al., 1979; Schepers, 1984), use of spreader plants (Ziv and Zitter, 1992), and dusting of plants with inoculum are some common methods (Moseman et al., 1965; Laws et al., 1982) though they are characterized by nonuniformity of spore deposition, deposition of clumps of spores, and inability to quantify the spores deposited on the healthy tissue. There are contradictory reports on harmful effects of suspending powdery mildew spores in water (Corner, 1935; Nicot et al., 2002). Various species of *Sphaerotheca*, *Blumeria*, and *Erysiphe* were reported to have failed to germinate or produced a short germtube when immersed in water. Other researchers have disputed the deleterious effect of water on powdery mildew conidia and have confirmed successful inoculation with spore suspensions on *B. graminis*

(Lumbruso et al., 1982), *S. fuliginea* and *E. cichoracearum* (Yarwood, 1978; Huggenberger et al., 1984), *E. pisi* (Reeser et al., 1983), *E. polygoni* (Searle, 1920) and *Leveillula taurica* (Diop-Bruckler and Molot, 1984).

Some researchers have observed that powdery mildew colonization on healthy plants was enhanced when the source of inoculum was from the same species than when the inoculum was maintained on a different species (communication).

With the advent of powdery mildew disease on watermelon in the U.S., a search for resistance genes for use in developing resistant breeding lines is underway (Davis et al., 2006b, 2007). A screening procedure requires the use of an efficient method that can distinguish among cultigens. There is little information on the effect of inoculum delivery methods and optimum environmental conditions required for disease establishment of *P. xanthii* race 2W is available.

Objective

The objective of this study was to develop an effective method for screening watermelon germplasm for resistance to powdery mildew race 2W.

Materials and Methods

Location and Germplasm

A powdery mildew disease test was conducted in the greenhouses of the Department of Horticultural Science, North Carolina State University, Raleigh, North Carolina, from 2004 to 2006. Two experiments were run: preliminary and main experiments. Greenhouse temperatures during the preliminary experiments ranged from 26 to 38^{o}C during the day and 13 to 19^{o}C at night. In the main experiment, greenhouse temperatures ranged from 30 to 37^{o}C during the day and 13 to 24^{o}C at night. *Citrullus* accessions and cultivar, hereafter collectively referred to as cultigens, were obtained from the Southern Regional Plant Introduction Station, USDA-ARS, Griffin, Georgia. In order to verify the presence of *P. xanthii* race 2W, ten melon differential genotypes were included in all experiments. These were 'Edisto 47', 'Iran H', MR 1, WMR 29, PI 124112, PI 313970, PI 414723, 'Topmark', 'PMR 45'and 'PMR 5'.

Inoculum

When breeding crops for resistance to a disease, it is important to know the species and races of the causative organism present in the locality because resistance genes are specific to the prevailing race (McCreight et al., 1987). A South Carolina isolate of *P. xanthii* race 2W was maintained in the greenhouse on plants of 'PMR 45' melon (*Cucumis melo* L.) from Hollar Seeds (Rocky Ford, Colorado) and 'Gray Zucchini' squash (*Cucurbita pepo* L.) from Seminis Vegetable Seeds (Woodland, California). This isolate was used for the study as *P. xanthii* race 2W is reported to be the predominant cause of damage to watermelons in the southeastern states (C.E. Thomas, communication, Jahn et al., 2002). A spore suspension was prepared by detaching heavily sporulating leaves and washing them with a spray of 100 ml of water and filtered through a double layer of cheesecloth. The suspension was diluted to a spore concentration of 4 x 10^{4} conidia ml^{-1}. This was freshly prepared as and when needed.

Preliminary Experiment

Powdery mildew disease severity on two cultigens, PI 244019 and ‘Calhoun Gray’ was evaluated in a factorial experiment with two types of growth chambers, three levels of humidity and two methods of inoculum application. Chambers were greenhouse benches with a frame covered on four sides with clear polyethylene, one with the top covered and one with the top uncovered. The humidity treatments consisted of zero, one, or two humidifiers in the chamber. Humidifiers were run for 24 hours a day throughout the study. Temperature and humidity were recorded with a hygrometer (Dickson Co., Addison, Illinois). Relative humidity in the chambers were recorded as follows: no top with no humidifier - 37% RH; no top with one humidifier - 45% RH; no top with two humidifiers - 54% RH; top with no humidifier - 40%RH; top with one humidifier - 94% RH; and top with two humidifiers - 96% RH.

The experiment was laid out in a split plot design with four replications and four plants per plot. Seeds were sown in 100 mm pots in 4P *Fafard* soilless *mix* (Conrad Fafard Incorporated, Massachusetts) and placed in the chambers for treatment. Pots were thinned to one plant each at full cotyledon stage and were fertilized weekly with 150 $mg \cdot kg^{-1}$ of Peters Professional 20-10-20 N-P-K (Scotts-Sierra Horticultural Products Company, Marysville, Ohio). Seedlings were inoculated once at the first to second true leaf stage using two methods of inoculum application: dusting with dry spores from heavily-sporulating ‘PMR 45’ melon leaves and spraying a spore suspension onto plant surfaces.

Disease Assessment

For studying the effect of chamber type on disease severity, plants were rated on cotyledon, stem and whole plant. Cotyledons and stem were used here because generally cotyledon tissue get more disease than leaf and stem and there is a weak but significant correlation between them (Davis et al., 2007). We decided to include the cotyledon for rating in order to be sure of a disease incidence occurring. To test the effect of inoculum application method and humidity ratings were done on leaves and stem. Plants were rated for disease severity using the 0-9 rating scale developed by Tetteh and Wehner (Unpublished). On this scale 0 = no symptoms; 1 = faint yellow speck on leaves; 2 = chlorotic lesions on leaves; 3 = chlorotic lesions covering 20% of leaves; 4 = first sign of active mycelium sporulation on leaves and stem; 5 = 2 to 3 healthy colonies of mycelium on leaves and stem; 6 = less than 20% mycelium coverage; 7 = 20-50% mycelium coverage; 8 =50-70% mycelium coverage with large necrotic areas; 9 = plant fully covered with powdery mycelium or plant dead (Tetteh and Wehner, unpublished).

Main Experiment

The experiment was factorial laid out in a split plot design with four replications of one plant per plot. Three humidity levels, four methods of inoculum application, and two cultigens were tested. Humidity levels were: a set of chambers with a humidifier running 24 hours for the first seven days after inoculation at 100% RH day and night, a set of chambers with overhead mist nozzles running for 24 hours for the first seven days after inoculation with 100% RH day and night, and a control treatment with no chamber and no humidity supplement at normal greenhouse relative humidity of 40-58% RH day and 70-72% RH night.

Two cultigens were evaluated: a resistant accession, PI 525082 which is a *C. lanatus* var. *citroides* from Egypt, and susceptible PI 269677 which is a *C. lanatus* var. *lanatus* from Belize. Seeding, irrigation, thinning and fertilization were done as in the preliminary experiments. Two inoculation methods were tested: dusting with heavily sporulating leaves with the aid of a paintbrush, and spraying with a conidial suspension of 4×10^4 conidia ml^{-1}. Two sources of inoculum were tested: conidia maintained on 'Gray Zucchini' squash (*Cucurbita maxima*), and conidia maintained on 'Charleston Gray' watermelon (*C. lanatus* var. *lanatus*). Seedlings were inoculated three times during the study, at 12 days after planting (one to two true leaf stage) and at 19 and 26 days after planting. After inoculation, seedlings were subjected to the various humidity treatments. Melon differentials were included to verify that race 2W of *P. xanthii* was present.

Powdery mildew severity on leaves and stem was rated on the 0-9 scale for four times at one-week interval beginning at the seedling stage when the highly susceptible line, PI 269677 was showing large masses of mycelium and at 40% coverage.

Data Analysis

Data from each experiment were summarized as means over replications. Analysis of variance was performed using PROC GLM, and differences in means identified using the LSD (SAS 9.1.3, SAS Institute, Cary, NC). The treatment combination which gave the widest range in disease severity between resistant and susceptible cultigens was chosen as the best method for evaluating powdery mildew race 2W resistance in watermelon.

Results and Discussion

Reaction of *Citrullus* accessions to *P. xanthii* race 2W infection was manifested in a wide range of symptoms spanning the whole rating scale of 0 to 9. Symptoms were characterized by presence or absence of chlorotic spots and masses of mycelium of various sizes on the leaves and stems. In all experiments the *P. xanthii* strain which was present was race 2 as defined by susceptibility to the melon differentials 'Iran H', 'Topmark', and 'PMR 45' and resistance to 'PMR 5', MR 1, PI 124112 and PI 313970 (McCreight, 2006; Pitrat et al., 1998).

Preliminary Experiment

Powdery mildew severity on two *Citrullus* cultigens grown in two different growth chambers, at three levels of humidity and two inoculum application methods were evaluated. Table 1 shows the effect of chamber type on disease severity of the cultigens. Generally there was no significant effect of chamber type on disease severity, except for the first cotyledon rating in which a slight effect ($P<0.05$) was observed. Mean final disease severity on cotyledons were both 8.4 for chamber with top and no top ($LSD_{.05}$=0.5), on stem was 6.3 and 6.5 for chamber with top and no top ($LSD_{.05}$=0.6), respectively, and on whole plant were 5.8 and 5.6 for chamber with top and no top ($LSD_{.05}$=0.5), respectively. A major difference among the chambers was the level of humidity, with the no top covering chamber having a lower relative humidity of 37-45% and chamber with top covering having humidity of 94-96%.

There was no significant effect of humidity on powdery mildew disease severity for leaf or whole plant rating (Table 2). However, a significant effect on stem rating was observed on the third week of rating whereby plants in chamber with two humidifiers had lower ($P<0.05$) rating than those maintained at no humidity or one humidity. Because humidity difference between the one humidifier chamber (45-94% RH) and the two humidifier chamber (54-96% RH) were in the same range the difference in the stem rating observed may be due to error in rating. Further testing of effect of humidity was necessary. Although many powdery mildew species require high humidity for colonization and sporulation, the strain of *P. xanthii* used in this experiment appears to be different in its humidity requirement from those reported to affect other cucurbits.

A significant effect ($P<0.01$) of method of inoculum application on disease severity was observed (Table 2). Plants that were inoculated by spraying a spore suspension had higher disease ratings than on plants inoculated by dusting. This observation may probably have been caused by nonuniform deposition of spores on the leaf surfaces, where some plants with the potential of being diseased may have received little or no inoculum and therefore showing less disease than expected. The effect of inoculum application method was therefore retested in the main experiment to verify this observation.

Table 2 shows a significant ($P<0.01$) cultigen effect with 'Calhoun Gray' demonstrating more susceptibility to *P. xanthii* than PI 244019. The differences were however not consistent across all the plant tissues rated. Only the leaf ratings were consistent.

Stem ratings were generally lower than leaf ratings. This was also true in race 1W studies (Davis et al., 2007). In this experiment, correlations between leaf and stem were stronger at early rating dates and gradually weakened at later rating dates (Table 5). Because leaves form a significant surface area of watermelon plants, leaf ratings are more important than stem rating.

Main Experiment

In the main experiment, three levels of humidity, in combination with four levels of inoculum application method and two cultigens were studied. Variation in disease severity ratings were found to be more pronounced at the fist and fourth rating dates than at the second and third rating dates (Table 3). Generally, inoculum application method did not have a significant effect on powdery mildew severity among the cultigens. When plants were inoculated by dusting or spraying, leaf mean disease severity rating increased from 2 to 5. Stem ratings were lower ranging from 2 to 4 (Table 3). Based on these findings, we concluded that either dusting or spraying of inoculum were both effective methods. In addition, it did not matter whether inoculum was increased on squash or watermelon. Leaf ratings had higher F values and lower coefficient of variation than stem ratings. For tests where it is important to have more precise data, it may be worthwhile to take ratings on both leaf and stem, and at multiple growth stages.

Humidity main effects were significant at all the rating dates for leaf and whole plant, but not for stem rating. Normal greenhouse humidity of 40 to 70% RH day/night produced the highest mean disease severity rating of 4.5 in the seedling stage and 5.5 in the adult plant stage for the leaf rating. The use of a humidifier gave mean disease severity ratings of 2.4 at the seedling stage and 5.6 at the adult plant stage. Again lower mean disease severity ratings were observed for the stem (Table 2). However, this humidity effect between humidifier and no humidifier disappeared as the disease progressed and plants matured. In contrast to these observations, use of overhead mist produced the lowest disease severity ratings, ranging from 0.5 to 4.5 (Table 3). These low ratings may probably have been caused by the presence of free water on stems and leaves and supports the finding of Yarwood (1939) that free water on the surface of the leaves reduces disease incidence. The observations made here supports the findings in the preliminary experiment that sporulation of *P. xanthii* race 2W was not affected by different levels of humidity of as low as 45% and as high as 100%.

PI 525082 and PI 269677 are widely disparate in their reaction to *P. xanthii* race 2W. In the main experiment, consistent and significant differences were observed in disease severity of these two accessions (Table 3). The combination of treatments which gave the widest range in disease severity between the two accessions was chosen as the most effective method of screening for resistance. The widest range in disease severity ratings between the most resistant and most susceptible cultigens occurred with either spraying plants with a spore suspension or dusting and when plants were maintained at normal greenhouse relative humidity (Table 4).

Conclusion

In our studies, the best method for evaluating powdery mildew resistance was to inoculate seedlings with a spray spore suspension and plants maintained at normal greenhouse temperature. It may be useful to treat plants in a growth chamber with added humidity in locations or seasons where ambient humidity is below 40%. Spores can be maintained either on squash or watermelon plants. We were able to raise more inoculum per plant using squash than watermelon. For large, preliminary tests, plants can be rated quickly at the seedling stage using just the disease incidence on leaves. For final tests, plants should be rated at later plant growth stages using both leaf and stem ratings.

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Table 1. Means for powdery mildew severity ratings of watermelon cultigens maintained in two types of growth chambers and rated at weekly intervals.

Chamber Type	Cotyledon Week1	Cotyledon Week2	Cotyledon Week3	Stem Week1	Stem Week2	Stem Week3	Plant Week1	Plant Week2	Plant Week3
No Top	0.9	5.0	8.4	1.3	4.9	6.3	1.0	5.0	5.8
Top	1.3	4.8	8.4	0.9	4.2	6.5	1.1	5.0	5.6
$LSD_{.05}$	0.4	0.7	0.5	0.3	0.7	0.5	0.3	0.7	0.7
F-value	11.6*	0.3^{ns}	0.1^{ns}	4.6^{ns}	4.5^{ns}	0.8^{ns}	0.5^{ns}	0.0^{ns}	0.6^{ns}
CV (%)	55	24	10	39	25	13	41	22	20

*indicates F ratio significant at 5% level; ns = not significant.

Table 2. Means for powdery mildew severity ratings of watermelon cultigens at multiple levels of humidity and inoculum application method rated at weekly intervals for the preliminary experiment.

Treatment	Leaf			Stem		Plant	
	Week1	Week2	Week3	Week2	Week3	Week2	Week3
Application Method							
Dust	3.5	5.7	7.0	1.7	2.5	5.0	5.8
Spray	3.6	6.0	7.2	3.4	3.7	5.7	6.4
$LSD_{.05}$	0.3	0.3	0.3	0.4	0.3	0.4	0.2
F-value	0.2^{ns}	3.4^{ns}	52.3**	68.9**	53.5**	32.2**	362.5**
Humidity							
None	3.7	5.8	6.9	2.7	3.4	5.5	6.1
One Humidifier	3.5	5.8	7.2	2.6	3.2	5.0	6.0
Two Humidifiers	3.5	6.0	7.2	2.4	2.7	5.5	6.2
$LSD_{.05}$	0.4	0.3	0.4	0.5	0.4	0.5	0.3
F-value	0.7^{ns}	0.8^{ns}	3.3^{ns}	1.1^{ns}	8.6*	1.7^{ns}	0.5^{ns}
Cultigen							
PI 244019	3.4	5.5	6.6	2.5	3.3	5.3	6.1
‘Calhoun Gray’	3.7	6.2	7.6	2.6	2.9	5.3	6.1
$LSD_{.05}$	0.3	0.3	0.3	0.4	0.3	0.4	0.3
F-value	4.1*	26.1**	56.2**	0.12^{ns}	8.03*	0.02^{ns}	0.04^{ns}
CV (%)	22	14	12	46	32	20	11

Table 2 (continued).

*,**indicates F value significant at 5 or 1% level, respectively; ns = not significant.

Table 3. Means for powdery mildew severity ratings of watermelon cultigens at multiple levels of humidity and inoculum application method rated at weekly intervals for main experiment.

Treatment	Leaf				Stem			
	Week1	Week2	Week3	Week4	Week1	Week2	Week3	Week4
Application Method								
Dust/Sq	2.6	3.8	4.6	5.2	1.8	2.9	3.6	4.3
Dust/Wm	2.6	3.7	4.5	5.2	2.7	1.8	3.5	4.2
Spray/Sq	2.4	3.6	4.6	5.2	2.8	1.7	3.5	4.2
Spray/Wm	2.4	3.7	4.5	5.2	2.8	1.7	3.5	4.4
$LSD_{.05}$	0.4	0.5	0.5	0.6	0.5	0.7	3.5	4.3
F-value	4.0*	1.3^{ns}	0.3^{ns}	0.3^{ns}	2.3^{ns}	1.5^{ns}	0.8^{ns}	0.3^{ns}
Humidity								
Humidifier	2.4	3.9	5.0	5.6	1.6	2.8	3.9	4.8
OverMist	0.5	2.4	3.5	4.5	0.3	1.7	2.6	3.7
None	4.5	4.9	5.2	5.5	3.5	3.8	4.1	4.5
$LSD_{.05}$	0.4	0.4	0.5	0.5	0.5	0.6	0.7	0.7
F ratio	1161.5**	94.7**	69.8**	52.9**	427.8**	97.8**	52.8**	22.8**
Cultigen								
PI 525082 (S)	2.1	1.7	1.6	1.6	1.1	0.8	0.6	0.6
PI 269677 (R)	8.4	7.1	7.8	7.8	6.9	5.2	5.7	4.0
$LSD_{.05}$	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5
F-value	143.3**	221.4**	265.9**	326.9**	101.7**	154.1**	160.8**	87.6**

Table 3 (continued).

Treatment	Leaf				Stem			
	Week1	Week2	Week3	Week4	Week1	Week2	Week3	Week4
CV (%)	42	30	25	21	50	37	33	43

*,**indicates F ratio significant at 5 or 1% level, respectively. ns = not significant; Sq = inoculum maintained on squash; Wm = inoculum maintained on watermelon; OverMist = Overhead mist. S = susceptible; R = resistant.

Table 4. Effect of inoculum application method and humidity on the range of powdery mildew severity ratings between most resistant (PI 525082) and most susceptible (PI 269677) watermelon accessions.

Treatment		Leaf				Stem			
	Inoculation/ Maintenance	Week1	Week2	Week3	Week4	Week1	Week2	Week3	Week4
Humidity	Dust/Squash	6.8	6.0	6.5	6.5	4.5	4.8	6.0	7.0
	Dust/Wm[y]	6.0	5.8	6.8	6.8	4.1	4.4	6.5	7.3
	Spray/Squash	7.0	5.8	6.3	6.8	4.5	5.2	5.2	7.3
	Spray/Wm	6.8	6.0	6.0	5.8	4.5	4.6	5.0	6.1
OverMist[z]	Dust/Squash	2.8	5.5	6.0	6.0	1.6	4.2	5.1	5.2
	Dust/Wm	2.0	4.0	5.8	6.5	1.7	3.0	4.5	5.0
	Spray/Squash	2.3	4.8	6.3	6.0	1.4	3.8	4.7	4.8
	Spray/Wm	2.3	4.8	6.3	6.0	1.4	3.8	4.7	4.8
None	Dust/Squash	5.3	6.3	5.5	5.0	4.7	5.6	4.5	4.7
	Dust/Wm	7.3	7.8	7.8	7.5	5.4	5.9	6.0	5.9
	Spray/Squash	7.8	7.8	8.0	7.8	5.7	5.7	5.7	5.6
	Spray/Wm	8.0	8.0	8.0	7.5	5.5	5.3	5.7	6.1

[z]OverMist = overhead mist; [y]Wm = watermelon.

Table 5. Correlations of traits at three rating dates for powdery mildew disease severity ratings on watermelons for main experiment.[z]

		Leaf			Stem			
		Week2	Week3	Week4	Week1	Week2	Week3	Week4
Leaf	Week1	0.84	0.73	0.65	0.97	0.82	0.71	0.56
	Week2		0.92	0.87	0.81	0.96	0.90	0.75
	Week3			0.96	0.68	0.89	0.97	0.84
	Week4				0.61	0.83	0.92	0.87
Stem	Week1					0.82	0.69	0.53
	Week2						0.88	0.74
	Week3							0.84

[z] Correlations above 0.50 are significant at the 0.01% level.

CHAPTER THREE

SCREENING THE WATERMELON GERMPLASM COLLECTION FOR RESISTANCE TO POWDERY MILDEW RACE 2W

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Abstract

Powdery mildew caused by *Podosphaera xanthii* has in recent times become a common disease of watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] in the United States. The disease can be controlled with fungicides. However, it is more economical and environmentally safe to use genetic resistance against this disease. This paper reports screening for sources of resistance to powdery mildew race 2W in the available U.S. Plant Introduction collection made of four *Citrullus* Schrad. ex. Eckl. & Zeyh. species, *Praecitrullus fistulosus* (Stocks) Pangalo species, including available cultivars. A total of 1,654 accessions were tested in the greenhouse using seven to ten replications. From that, 55 cultigens including the 45 most resistant and 10 checks were retested in greenhouse and field experiments. All accessions and cultivars showed signs of powdery mildew. Resistance was identified in the wild accessions and was characterized by moderate to high variability. Eight accessions showed high levels of resistance. Twenty-three accessions demonstrated intermediate resistance. Leaf and stem disease severity ratings were positively correlated (r=0.86, P=0.0001). Using data from the screening and retest studies, the most resistant accessions were PI 632755, PI 386015, PI 346082, PI 525082, PI 432337, PI 386024, and PI 269365 and PI 189225. The most susceptible accessions were PI 222775 and PI 269677. A large number of the resistant accessions originated from Nigeria and Zimbabwe.

Introduction

In the United States watermelon is a major vegetable crop. Major production states are Florida, California, Arizona, Texas, and Georgia. In 2005, the total production of watermelon in the U.S. was 1.7 million Mg, with a farm value of $410 million (U.S.D.A., 2006).

Powdery mildew is a fungal disease which affects a wide range of crops worldwide. On cucurbits, the disease is caused by *Podosphaera xanthii* (Castagne) Braun & Shishkoff [syn. *Sphaerotheca fuliginea auct. p.p.*] and *Golovinomyces cichoracearum s.l.* (D.C.) V.P. Heluta [syn. *Erysiphe cichoracearum auct. p.p*] (Jahn et al., 2002). In the U.S. only *P. xanthii* is known to affect watermelon. Presently, there are seven pathogenically distinct races of *P. xanthii* and these are differentiated using ten melon (*Cucumis melo* L.) differentials (McCreight et al., 1987; Pitrat et al., 1998; Hosoya et al., 1999). Recent work by McCreight (2006) showed that there may be as many as 28 races of *P. xanthii* on melon that include eight variants of race 1 and six variants of race 2.

In the past, watermelon was considered to be free of powdery mildew with the exception of few, isolated and mild cases of the disease (Ivanoff, 1957; Nagy, 1983; McLean, 1970; Robinson and Provvidenti, 1975). In recent years powdery mildew outbreaks have been reported in the U.S. and the disease has been confirmed in the southeastern states, Maryland, Texas, Oklahoma, Arizona, New York and California (Keinath, 2000; Davis et al 2001; McGrath et al. 2001a). In the U.S. only *P. xanthii* is known to affect watermelon.

In the U.S., two races of *P. xanthii*, races 1W and 2W have been identified on watermelon (Davis et al.,2001; McGrath et al., 2001a; Davis et al., 2007). Watermelon now gets disease symptoms when inoculated with the race from melon having the same pattern as melon race 2, so we have used the designation *P. xanthii* race 2W in accordance with the nomenclature developed by Davis et al. (2007).

Powdery mildew is manifested as chlorotic spots on leaves with or without white mycelial and/or conidial development on leaves and stem. In some highly susceptible lines the petioles and stem show water-soaked areas in addition to these symptoms (Davis et al., 2006b).

The consequences of powdery mildew on watermelon are reduced plant canopy and a reduction in yield caused by reduced fruit size and number of fruit per plant. The few fruits which remain develop sunscald due to reduced canopy, have poor fruit quality and flavor and a shorter storage life (Keinath and Dubose, 2004; McGrath and Thomas, 1996).

Powdery mildew on watermelon is controlled with fungicides, however there have been reports of resistance to the recommended fungicides, especially the strobilurins and myclobutanil in southeastern U.S. (McGrath et al., 1996). Moreover, there are reports of chlorothalonil injury to watermelons (Holmes et al., 2002). Adequate disease control often requires the use of systemic fungicides as spray application to the underside of leaves is difficult (McGrath and Thomas, 1996). Effective control of powdery mildew on watermelon is achieved with alternating preventative applications of mancozeb with azoxystrobin (Keinath and Dubose, 2004).

The most effective and safe method to control powdery mildew in watermelon is to use resistant cultivars. So far, there is no commercial cultivar of watermelon carrying resistance to powdery mildew.

Since the evaluation of 590 (Robinson and Provvidenti (1975) and 266 (Thomas et al., 2005) accessions of *C. lanatus* for their reaction to powdery mildew, the USDA-ARS Southern Regional Plant Introduction Station at Griffin, GA, has been expanded to 1,537 PI accessions of *Citrullus*, making it possible to search a wider diversity of germplasm. Davis et al., (2006a) reported of screening of accessions for powdery mildew race 1W, which led to the release of a resistant selection PI 525088-PMR. However, little information is available on resistance of *Citrullus* to powdery mildew race 2W.

Objective

The objective of this research was to evaluate the entire U.S. Plant Introduction collection of *Citrullus* along with U.S. watermelon cultivars, totaling 1,654 accessions for resistance to powdery mildew race 2W.

Materials and Methods

Germplasm

A powdery mildew screening experiment was conducted in the greenhouses of the Department of Horticultural Science, North Carolina State University, during the spring, summer, and winter seasons of 2005 to 2006. A total of 1,654 watermelon accessions belonging to the genus *Citrullus* (Schrad. ex. Eckl. & Zeyh.) and *Praecitrullus fistulosus* (Stocks) Pangalo species were evaluated. These accessions were made up of 1,613 plant introduction accessions and 41 cultivars and breeding lines, hereafter referred to collectively as cultigens. The plant introduction accessions were obtained from the Plant Genetic Resources Conservation Unit, Southern Regional Plant Introduction Station, USDA-ARS, Griffin, GA. The cultigens originated from 72 countries, with the greatest numbers collected from Turkey, the former Yugoslavia, Zimbabwe, India, P.R. P.R. China, Spain and Zambia (Table 1).

Inoculum

A *P. xanthii* race 2W isolate which originated from infected commercial watermelon field in South Carolina was maintained on cantaloupe (*Cucumis melo*) 'PMR 45' and squash (*Cucurbita maxima*) 'Gray Zucchini' plants in the greenhouse. Inoculum was prepared from freshly sporulating leaves of diseased 'Gray Zucchini' plants. In an earlier study (Tetteh et al., unpublished), it had been established that the source of *P. xanthii* inoculum used to infect *Citrullus* did not affect the disease severity of *P. xanthii* on watermelon. (Tetteh et al., unpublished). Squash plants were used because they provided a high quantity of inoculum. A spore suspension was prepared by detaching heavily sporulating leaves and washing them with a spray of 100 ml of water and filtered through a double layer of cheesecloth. The suspension was diluted to a spore concentration of 4×10^4 conidia ml^{-1}. This was freshly prepared as and when needed.

Germplasm screening

Greenhouse Test

Seeds of all accessions were sown in 10 cm pots in 4P *Fafard* soilless media (Conrad Fafard Incorporated, Massachusetts, U.S.A.) and placed on benches in a greenhouse set at 24/32^{o}C and 40/70% RH day/night. The experiment was a randomized complete block design with seven to twelve replications of single-plant plots. Plants were fertilized weekly with 150 mg·kg^{-1} Peters Professional 20-10-20 N-P-K (Scotts Sierra Horticultural Products Company, Marysville, OH). Seedlings were inoculated at 12, 19, and 26 days after seeding, with the first inoculation timed to the 1 to 2 true-leaf stage. Inoculation was done by spraying each seedling with the spore suspension. Seedlings were maintained at normal greenhouse temperature and relative humidity. Spreader plants were placed between rows as additional source of powdery mildew infection (Ziv and Zitter, 1992). PI 269677 was used as a susceptible control. In order to verify the race of *P. xanthii* race 2, ten melon differentials were included in the experiment. These were 'Edisto 47', 'Iran H', MR 1, WMR 29, PI 124112, PI 313970, PI 414723, and 'PMR 5' which originated from various sources and were increased in the greenhouses of the Department of Horticultural Science, North Carolina State University, Raleigh, NC, by controlled self pollination. The other two melon differentials, 'Topmark' and 'PMR 45' were obtained from Hollar Seeds (Rocky Ford, Colorado).

Following the greenhouse germplasm screening experiment, those cultigens which were not represented in at least four replications were replanted and tested again. We termed this a 'Missing' experiment. The experiment was a randomized complete block design with eight replications. Seeding, thinning, inoculation and rating were done as before. Data from this experiment were pooled with the germplasm screening and analyzed.

Disease Assessment

Powdery mildew on watermelon was rated as disease incidence and severity at two times, at two and four weeks after inoculation. Disease severity was rated separately on the leaves and stem on individual plant, using a 0-9 rating scale (Tetteh and Wehner, unpublished) where 0 = no symptoms; 1 = faint yellow speck on leaves; 2 = chlorotic lesions on leaves only; 3 = chlorotic lesions covering 20% of leaves; 4 = first sign of active mycelium sporulation on leaves and stem; 5 = 2 to 3 healthy colonies of mycelium on leaves and stem; 6 = less than 20% mycelium coverage; 7 = 20-50% mycelium coverage; 8 =50-70% mycelium coverage with large necrotic areas; 9 = plant fully covered with powdery mycelium or plant dead. Total plant disease severity was calculated by averaging leaf and stem ratings. Accessions were classified into three classes based on their total plant disease rating of at least six replicates in the pooled germplasm screening and six replicates in the retest experiments: resistant when they had a total plant rating of ≤3; intermediate when rating was 3.1–4; susceptible when disease rating was ≥ 4.1.

Germplasm Retest

Greenhouse Retest

A germplasm retest was run in the greenhouse and field to verify the reaction of the resistant cultigens and cultivars from the germplasm screening. A total of 55 cultigens were chosen, made of 45 resistant and 10 check cultivars. The 45 cultigens were chosen from the first 70 PI accessions with the lowest total plant rating and chosen to represent a wide geographical diversity. Ten countries and five species and subspecies (*C. lanatus var. lanatus*, *C. lanatus* var. *citroides*, *C colocynthis*, *C. rehmii* and *P. fistulosus*. were present. The experiment in greenhouse was a randomized complete block design with 4 replications each of single-plant plots and they were inoculated and rated as in the first experiment. Final disease severity rating was used in data analysis.

Field Retest

Field retest was conducted at the Horticultural Crops Research Station, Clinton, North Carolina, during the summer season of 2006. The 45 cultigens chosen were planted in a randomized complete block design with four replications of three-plant plots. Seeds were planted on raised shaped beds covered with black plastic mulch in rows 3m apart center to center. Plots were 1.2m long, and were planted with nine seeds and thinned to a uniform stand of 3 plants per plot. Recommended horticultural practices were used. Melon differentials, 'Iran H', 'Top Mark', 'PMR 45', PMR 5 and 'MR1'were planted in the front and rear of each row of 18 plots to verify the race of *P. xanthii* present on the field. Rows were interplanted with squash that had heavy sporulation of *P. xanthii* race 2W as spreader plants (Ziv and Zitter, 1992) and also inoculated with the spore suspension as before. Individual plants were rated on the 0-9 scale.

Data Analysis

Data were summarized as means over replications for each study. Analysis of variance and correlation analysis were done with PROC GLM and PROC CORR of SAS 9.1.3 statistical package (SAS Institute, Cary, NC). In the germplasm screening experiment, total plant disease severity was calculated as the average of final leaf and stem ratings. In the retest study, total plant disease severity was calculated as the average of final greenhouse and field ratings of leaf and stem.

Results and Discussion

Germplasm Screening

In all experiments the *P. xanthii* strain which was present was race 2 as defined by susceptibility to the melon differentials 'Iran H', 'Topmark', and 'PMR 45' and resistance to 'PMR 5', MR 1, PI 124112 and PI 313970 (McCreight, 2006; Pitrat et al., 1998). Susceptibility of watermelon demonstrated that it was race 2W (race 2 which infects watermelon).

Powdery mildew race 2W was characterized by a wide range of reactions. Symptoms ranged from little sporulation to 100% coverage of mycelia on the plant; no blotching to moderate yellowing of many leaves; and no detectable water-soaked petioles to fully water-soaked petioles. A large number of the PI accessions (93%) had total plant disease severity rating of >4, which means at least 20 % mycelium coverage on leaves and stem. Seven percent of the cultigens demonstrated resistant and intermediate resistant reaction to *P. xanthii*. Table 2 shows a list of the 111 PI accessions having total plant disease severity rating of ≤4, which represent resistant and intermediate accessions. The complete list of disease severity rating of 1,647 cultigens is presented in Appendix Table1. Out of the 1,654 cultigens, seven were lost due to nonviable seeds.

When accessions were ranked for resistance by their total plant disease severity rating seventy-two PI accessions had ratings ≤3.0 (Table 2). This number reduced to 53 accessions when ranked by the leaf rating. Disease severity ratings of the stem were lower than that of total plant. Within the resistant category, all accessions which had total plant disease severity ratings of ≤3.0 also had stem ratings of ≤ 3.0. All PI accessions that showed leaf resistance also demonstrated stem resistance. However, out of the thirty-eight accessions which showed intermediate resistance based on disease severity of total plant, 28 of them had stem resistance.

In the retest (Table 3), seven PI accessions were classified as resistant (PI 632755, PI 386015, PI 346082, PI 525082, PI 432337, PI 386024, and PI 269365). These accessions were rated resistant in the germplasm screening. The decrease in number of resistant accessions in the retest may be due to disease escapes and misclassification. Twenty-three accessions which were classified as resistant in the germplasm screening showed intermediate resistance in the retest (PI 482283, PI 494532, PI 482319, PI 270545, PI 482286, PI 500354, PI 560010, PI 251244, PI 560003, PI 186489, PI 482326, PI 482338, PI 482259, PI 307608, PI 500334, PI 500329, PI 500331, PI 482307, PI 494531, PI 560020, PI 560024 and PI 560006). Fifteen accessions which were rated as resistant in the germplasm screening were susceptible in the retest. Combining data from the pooled germplasm screening and retest, the accessions which were found to be most resistant are PI 632755, PI 386015, PI 346082, PI 525082, PI 432337, PI 386024, and PI 269365 and PI 189225. We noted that PI 386015, PI 525082 and PI 270545 which have commercially useful resistance to powdery mildew race 1W (Davis et al., 2007) demonstrated resistance to race 2W. PI 189225 is reported to possess resistance to gummy stem blight (Sowell and Pointer, 1962; Gusmini et al., 2005) and anthracnose (Sowell et al., 1980; Winstead et al., 1959) is among the sixty accessions most resistant to race 2W. It was not included in the retest however it was present in the 'missing experiment' and was represented by 10 replications. We therefore decided to include it in the resistant accessions. All watermelon cultivars were found to be susceptible to powdery mildew race 2W.

Variability of Resistance within PI Accessions

Majority of the PI accessions were heterogeneous for powdery mildew resistance with standard deviations ranging from 0 to 70% of the mean and an average of 35%. Individual replicates in some resistant accessions had ratings ranging from 0 to 8. Accessions are usually open pollinated so this reaction was not unexpected. Although variable, they carried useful resistance for breeding purposes. Variability in susceptibility within accessions and cultivars was lower. Final disease severity ratings among the highly susceptible accessions varied from 6-9 in all experiments. These observations were true for race 1W also (Davis et al., 2007).

Correlation of Leaf and Stem Disease Severity Ratings

Correlation analysis of the disease severity ratings of leaf and stem of all 1,654 cultigens was carried out. There was strong and positive correlation between leaf and stem ratings ($r=0.86$; $P=0.0001$). As expected, correlations between leaf and stem ratings were also positive and strong for both greenhouse ($r=0.94$; $P=0.0001$) and field ($r=0.84$; $P=0.0001$) retests. Though stem had lower disease severity ratings than leaves, the high correlation suggests that resistance in stem and leaf are controlled by the same gene. This observation was also true for race 1W (Davis et al., 2007).

Resistance to P. xanthii Race 2W in the Genus Citrullus and P. fistulosus Species

Five species of watermelon were evaluated for their reaction to *P. xanthii* race 2W. Table 4 shows the percentage of resistant and intermediate cultigens within each species. A large percentage of *C. lanatus* var. *citroides* (37%) and *C. colocynthis* (17%) were present in the 30 most resistant accessions. Fewer resistant accessions were represented by *P. fistulosus* and *C. colocynthis*.

The results of these experiments show that most of the resistant PI accessions originated from Africa. Twenty-three percent of the resistant accessions came from Zimbabwe while 3% came from Nigeria. The total available U.S. *Citrullus* PI collection has 9.5% of the accessions originating from Zimbabwe and 2.9% from Nigeria.

From the screening and retest experiments, two resistant accessions, PI 189225 from Zaire and PI 270545 from Sudan two countries were selected for development of inbred lines for more uniform resistant reaction and for determination of inheritance of resistance to powdery mildew race 2W.

Conclusion

The studies presented here have demonstrated that resistance to powdery mildew race 2W is present in the germplasm collection. A few accessions which had resistance to race

2W also had some resistance to race 1W. Among the 1,654 *Citrullus* PIs and cultivars tested, 22 *C. lanatus* var. *citroides* demonstrated resistance to powdery mildew race 2W. For breeding purposes, *C. lanatus* var. *lanatus* (2n=2x=22) PI accessions are preferred because of their close proximity to the cultivated watermelon. Crossing of species within *Citrullus* genus produces viable F_1 hybrids while crosses between *P. fistulosus* (2n=2x=24)and *Citrullus* do not produce fruit (Navot and Zamir, 1987).*C. lanatus* var. *citroides*, which is considered to be the wild progenitor of the cultivated watermelon as evidenced by isozyme similarities (Navot and Zamir, 1987; Jarret et al., 1997) and DNA polymorphism (Levi et al., 2000) represent an important source of powdery mildew resistant genes though they do not have the desirable horticultural characteristics of *C. lanatus* var. *lanatus*.

Identification of powdery mildew races are based on the differential reactions of melons to the pathotypes. Although to date there are no formally released *Citrullus* species for powdery mildew differentials, based on the results of our study, we propose that the highly susceptible PI 269677 accession be used as a *Citrullus* powdery mildew race 2W differential.

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Table 1. Countries of origin for the 1,654 watermelon cultigens tested for powdery mildew race 2W resistance.

Seed Source	Number of cultigens	Seed source	Number of cultigens	Seed source	Number of cultigen
Afghanistan	26	Gabon	1	Maldives	17
Algeria	3	Ghana	15	Mali	12
Angola	1	Greece	6	Mauritania	1
Argentina	1	Guatemala	4	Mexico	8
Belize	6	Honduras	1	Moldova	1
Bolivia	4	Hungary	12	Morocco	1
Botswana	16	India	51	Namibia	3
Brazil	3	Iran	40	Nigeria	48
Bulgaria	1	Iraq	3	Pakistan	26
Cameroon	2	Israel	8	Paraguay	3
Chad	4	Italy	3	Philippines	7
Chile	1	Japan	15	Portugal	2
P.R. China	72	Jordan	2	Russia	5
Cuba	1	Kazakhstan	1	Senegal	1
Cyprus	1	Kenya	3	Somalia	8
Egypt	21	South Korea	26	South Africa	9
El Salvador	1	Lebanon	9	Soviet Union	7
Ethiopia	11	Liberia	2	Spain	76

Table 1 (continued).

Seed Source	Number of cultigens	Seed source	Number of cultigens	Seed source	Number of cultigen
Sudan	6	Ukraine	6	Yugoslavia	184
Syria	31	United States	36	Zaire	10
Taiwan	2	Unknown	2	Zambia	68
Thailand	1	Uruguay	1	Zimbabwe	157
Tunisia	2	Uzbekistan	6	Cultivars	41
Turkey	309	Venezuela	6	**Total**	**1,654**

Table 2. Ranking of the mean disease severity rating of PI accessions of *Citrullus* and *Praecitrullus* species in the germplasm screening study having resistant and intermediate resistant reactions to *P. xanthii* race 2W.[z]

		Mean disease severity rating (0-9 scale)[y]					
Rank	Cultigen	Rep No	Total plant	Leaf	Stem	Species[x]	Seed source
1	PI 386015	6	0.5	0.7	0.2	O	Iran
2	PI 386021	4	0.5	1.0	0.0	O	Iran
3	PI 346082	5	0.6	1.0	0.2	O	Afghanistan
4	PI 482326	6	0.9	1.5	0.3	T	Zimbabwe
5	Grif 14202	6	1.3	1.5	1.0	O	India
6	PI 386024	9	1.4	1.9	0.8	O	Iran
7	PI 482307	7	1.4	2.0	0.7	T	Zimbabwe
8	PI 482311	7	1.6	2.1	1.0	T	Zimbabwe
9	PI 560020	7	1.6	2.1	1.0	L	Nigeria
10	PI 386016	9	1.8	2.1	1.4	O	Iran
11	PI 482307	6	1.8	2.2	1.3	T	Zimbabwe
12	PI 494531	7	1.9	2.3	1.4	L	Nigeria
13	PI 432337	6	1.9	2.7	1.0	O	Cyprus
14	PI 186489	6	1.9	2.3	1.5	L	Nigeria
15	PI 500354	7	1.9	2.4	1.4	T	Zambia
16	PI 560005	7	1.9	2.4	1.4	L	Nigeria
17	PI 482288	6	1.9	2.5	1.3	L	Zimbabwe

Table 2 (continued).

		Mean disease severity rating (0-9 scale)[y]					
Rank	Cultigen	Rep No	Total plant	Leaf	Stem	Species[x]	Seed source
18	PI 482302	8	2.0	2.5	1.4	T	Zimbabwe
19	PI 482298	6	2.0	2.5	1.5	T	Zimbabwe
20	PI 525082	8	2.0	2.6	1.4	O	Egypt
21	PI 482282	7	2.0	2.7	1.3	T	Zimbabwe
22	PI 500329	6	2.0	2.8	1.2	L	Zambia
23	PI 560003	7	2.1	3.0	1.1	L	Nigeria
24	PI 482286	5	2.1	2.8	1.4	T	Zimbabwe
25	PI 542616	8	2.1	2.9	1.3	O	Algeria
26	PI 251244	6	2.2	2.3	2.0	F	India
27	PI 482338	8	2.2	2.8	1.5	T	Zimbabwe
28	PI 482322	7	2.2	3.0	1.4	T	Zimbabwe
29	PI 482341	7	2.2	3.0	1.4	L	Zimbabwe
30	PI 307608	8	2.3	2.9	1.6	L	Nigeria
31	PI 386025	9	2.3	2.7	1.9	O	Iran
32	PI 482259	7	2.4	2.6	2.1	T	Zimbabwe
33	PI 482361	7	2.4	2.7	2.0	T	Zimbabwe
34	PI 560024	6	2.4	3.0	1.7	L	Nigeria
35	PI 560010	9	2.4	3.0	1.7	L	Nigeria

Table 2 (continued).

		Mean disease severity rating (0-9 scale)[y]					
Rank	Cultigen	Rep No	Total plant	Leaf	Stem	Species[x]	Seed source
36	PI 500332	7	2.4	3.0	1.7	T	Zambia
37	PI 500331	7	2.4	3.0	1.7	T	Zambia
38	PI 482318	7	2.4	3.0	1.7	L	Zimbabwe
39	PI 225557	7	2.4	3.0	1.7	L	Zimbabwe
40	PI 269365	6	2.4	2.8	2.0	O	Afghanistan
41	PI 482299	7	2.4	2.9	1.9	T	Zimbabwe
42	PI 381752	6	2.5	2.7	2.2	F	India
43	PI 494528	7	2.5	2.9	2.0	L	Nigeria
44	PI 482321	6	2.5	3.2	1.7	T	Zimbabwe
45	PI 326516	7	2.5	2.9	2.1	L	Ghana
46	PI 482319	7	2.5	3.4	1.6	T	Zimbabwe
47	PI 560006	7	2.6	3.0	2.1	L	Nigeria
48	PI 540911	7	2.6	2.9	2.3	F	Unknown
49	PI 220778	8	2.6	2.9	2.3	O	Afghanistan
50	PI 500303	7	2.6	2.6	2.6	T	Zambia
51	PI 381750	6	2.6	2.7	2.5	F	India
52	PI 482283	6	2.6	3.2	2.0	T	Zimbabwe
53	PI 482377	6	2.6	3.2	2.0	L	Zimbabwe

Table 2 (continued).

			Mean disease severity rating (0-9 scale)[y]				
Rank	Cultigen	Rep No	Total plant	Leaf	Stem	Species[x]	Seed source
54	PI 500334	4	2.7	2.8	2.5	T	Zambia
55	PI 386026	7	2.7	3.0	2.3	O	Iran
56	PI 560023	7	2.7	3.3	2.0	L	Nigeria
57	PI 560002	7	2.7	3.9	1.4	L	Nigeria
58	PI 189225	10	2.7	3.1	2.2	T	Zaire
59	PI 494532	7	2.7	3.4	2.0	L	Nigeria
60	PI 596696	7	2.7	3.7	1.7	T	South Africa
61	PI 388770	6	2.8	3.2	2.3	O	Morocco
62	PI 500312	6	2.8	3.3	2.2	L	Zambia
63	PI 482277	6	2.8	3.3	2.3	T	Zimbabwe
64	PI 270545	7	2.9	3.6	2.1	L	Sudan
65	PI 482246	7	2.9	3.6	2.1	T	Zimbabwe
66	PI 560019	6	2.9	3.8	2.0	L	Nigeria
69	PI 632755	7	2.9	3.1	2.7	R	Namibia
70	PI 500327	7	3.0	3.6	2.3	L	Zambia
71	PI 482355	7	3.0	3.3	2.7	T	Zimbabwe
72	Grif 5596	7	3.0	3.3	2.7	L	India
73	PI 482336	2	3.0	4.0	2.0	T	Zimbabwe

Table 2 (continued).

		Mean disease severity rating (0-9 scale)[y]					
Rank	Cultigen	Rep No	Total plant	Leaf	Stem	Species[x]	Seed source
74	PI 482360	5	3.1	3.8	2.4	L	Zimbabwe
75	PI 595203	6	3.1	3.2	3.0	L	United States
76	PI 532726	7	3.1	3.6	2.6	L	Zimbabwe
77	PI 560001	7	3.1	3.6	2.6	L	Nigeria
78	PI 532722	7	3.2	3.3	3.0	L	Zaire
79	PI 500302	6	3.2	3.8	2.5	L	Zambia
80	PI 482262	6	3.2	3.8	2.5	L	Zimbabwe
81	PI 560011	7	3.2	4.0	2.3	L	Nigeria
82	PI 560014	7	3.2	4.0	2.3	L	Nigeria
83	PI 459074	7	3.2	3.7	2.6	L	Botswana
84	PI 559997	7	3.2	3.7	2.6	L	Nigeria
85	PI 525084	6	3.2	3.7	2.7	L	Egypt
86	PI 482308	7	3.2	3.7	2.7	T	Zimbabwe
87	PI 549161	7	3.2	3.7	2.7	O	Chad
88	PI 512828	6	3.3	3.3	3.2	L	Spain
89	PI 559994	6	3.3	3.7	2.8	L	Nigeria
90	PI 532730	7	3.3	3.9	2.6	L	Zimbabwe
91	PI 560008	7	3.3	3.9	2.6	L	Nigeria

Table 2 (continued).

			Mean disease severity rating (0-9 scale)[y]				
Rank	Cultigen	Rep No	Total plant	Leaf	Stem	Species[x]	Seed source
92	PI 500345	6	3.3	3.8	2.8	L	Zambia
93	PI 500318	7	3.3	3.9	2.7	L	Zambia
94	PI 482368	7	3.3	4.0	2.6	L	Zimbabwe
95	PI 381743	7	3.4	4.0	2.7	F	India
96	PI 482257	7	3.4	4.0	2.7	T	Zimbabwe
97	PI 254738	7	3.4	4.0	2.7	L	Senegal
98	PI 249009	7	3.4	3.9	2.9	L	Nigeria
99	PI 482312	7	3.5	3.9	3.0	T	Zimbabwe
100	PI 381748	7	3.5	4.0	2.9	F	India
101	PI 560004	7	3.5	4.0	2.9	L	Nigeria
102	PI 482273	6	3.5	3.8	3.2	T	Zimbabwe
103	PI 485583	7	3.5	4.0	3.0	T	Botswana
104	PI 482276	7	3.7	4.0	3.3	T	Zimbabwe
105	PI 386019	9	3.7	4.0	3.3	O	Iran
106	PI 525081	7	3.7	4.0	3.4	T	Egypt
107	PI 482372	7	3.8	4.0	3.6	L	Zimbabwe
108	Grif 5602	7	3.9	4.0	3.7	F	India
109	PI 306782	7	3.9	4.0	3.7	L	Nigeria

110	PI 500307	7	4.0	4.0	3.9	L	Zambia
111	PI 250145	7	4.0	4.0	4.0	F	Pakistan

[z] Table represents pooled data from greenhouse screening and missing experiments.
[y]PI accessions were classified into resistant, intermediate, or susceptible classes based on their total plant mean disease severity rating from at least six replicates.
Table 2 (continued).
Accessions were resistant if their total plant mean disease severity rating was ≤3.0; intermediate if 3.1 to 4; susceptible if ≥4.1.
[x]L = *Citrullus lanatus* var. *lanatus*; T = *Citrullus lanatus* var. *citroides*; O = *Citrullus colocynthis*; R = *Citrullus rehmii*; F = *Praecitrullus fistulosus*.

Table 3. Ranking of the mean disease severity rating of at least six replicates of *Citrullus* and *Praecitrullus* species in the retest for resistance to *Podosphaera xanthii* race 2W.

Rank	Cultigen	Mean disease severity rating on the 0-9 scale[z]				
		Total plant	Leaf	Stem	SDL[y]	SDS[x]
1	PI 632755	0.6	0.8	0.4	0.0	0.0
2	PI 386015	1.1	1.6	0.7	0.5	0.5
3	PI 346082	1.5	2.1	0.9	0.0	0.6
4	PI 525082	1.7	2.4	1.0	1.5	1.3
5	PI 432337	1.8	2.4	1.2	0.6	0.5
6	PI 386024	2.1	2.6	1.6	0.0	0.5
7	PI 269365	2.4	3.3	1.5	1.0	0.6
8	PI 482283	3.2	4.0	2.4	1.0	1.0
9	PI 494532	3.4	4.5	2.3	1.0	1.0
10	PI 482319	3.5	4.8	2.2	0.5	1.3
11	PI 270545	3.5	4.0	3.0	0.6	0.0
12	PI 482246	3.6	4.9	2.3	0.5	0.6
13	PI 500354	3.6	4.9	2.4	1.6	0.5
14	PI 560010	3.7	4.6	2.7	0.5	1.0
15	PI 251244	3.7	4.6	2.8	0.5	1.7
16	PI 186489	3.7	4.8	2.6	1.3	1.3
17	PI 482326	3.7	4.6	2.8	1.0	1.4
18	PI 560003	3.7	4.8	2.7	0.8	1.4

Table 3 (continued).

Cultigen		Total plant	Leaf	Stem	SDL[y]	SDS[x]
19	PI 482338	3.8	5.1	2.4	1.0	0.6
20	PI 482259	3.8	5.0	2.6	0.5	0.6
21	PI 307608	3.8	4.4	3.2	0.7	0.0
22	PI 500334	3.9	5.0	2.7	0.6	0.8
23	PI 500329	3.9	5.1	2.6	1.0	1.4
24	PI 500331	3.9	4.5	3.3	0.6	1.7
25	PI 482307	3.9	5.1	2.7	1.0	0.5
26	PI 494531	4.0	4.9	3.2	0.6	1.0
27	PI 560020	4.0	5.0	3.0	0.5	0.0
28	PI 560024	4.0	5.0	3.0	1.5	1.0
29	PI 560006	4.0	4.7	3.3	0.0	1.0
30	PI 482302	4.1	5.6	2.5	1.0	0.8
31	PI 560005	4.1	4.9	3.3	1.0	0.6
32	PI 482311	4.1	5.5	2.7	1.0	0.0
33	PI 482377	4.1	5.3	3.0	0.6	0.6
34	PI 482361	4.3	5.4	3.2	1.0	0.6
35	PI 560023	4.4	5.6	3.2	0.5	0.5
36	PI 482341	4.4	5.5	3.4	0.8	1.0

Table 3 (continued).

Cultigen		Total plant	Leaf	Stem	SDL[y]	SDS[x]
37	PI 482318	4.6	5.6	3.5	1.7	1.3
38	PI 482322	4.6	5.7	3.5	0.0	2.8
39	PI 494528	4.6	5.3	4.0	0.6	1.0
40	PI 482298	4.7	5.6	3.7	0.8	1.0
41	PI 381750	4.9	5.9	3.8	1.9	0.5
42	PI 225557	4.9	5.9	3.9	0.6	0.6
43	PI 540911	4.9	5.9	3.9	1.0	1.9
44	PI 482286	5.0	6.0	4.0	0.0	0.7
Checks						
'Tastigold'		5.6	6.6	4.5	0.5	1.0
'Charleston Gray'		5.6	7.0	4.3	1.0	0.6
'Hopi Red Flesh'		5.9	7.3	4.5	1.0	0.6
'Florida Favorite'		5.9	7.0	4.8	1.2	0.6
'Charlee'		6.0	7.0	5.1	0.5	0.6
'Peacock Shipper'		5.7	6.9	4.6	1.0	1.0
'Navajo Sweet'		6.6	7.6	5.6	0.8	1.3
'Chubby Gray'		6.7	7.5	6.0	1.0	0.6
'Moon & Stars'		6.7	7.6	5.9	1.5	0.6

Table 3 (continued).

Cultigen	Total plant	Leaf	Stem	SDL[y]	SDS[x]
Susceptible control					
PI 269677	7.0	7.9	6.1	1.2	1.2

[z]PI accessions were classified into resistant, intermediate, or susceptible classes based on their total plant mean disease severity rating from at least six replicates. Accessions were resistant if their total plant mean disease severity rating was ≤3.0; intermediate if 3.1 to 4; susceptible if ≥4.1. One cultivar was lost due to nonviable seeds.
[y]SDL = standard deviation of leaf rating; [x]SDS = standard deviation of stem rating.

Table 4. Number and percentage of resistant and intermediate resistant accessions within species.

Species	No. of resistant accessions[z]	% of all resistant accessions[y]	Species as % of PI collection
C. lanatus var. *lanatus*	12	40	88.9
C. lanatus var. *citroides*	11	37	7.9
C. colocynthis	5	17	1.2
C. rehmii	1	3	
P. fistulosus	1	3	1.8
Total	30	100	99.8

[z]Number of accessions within species which had total plant disease severity rating of ≤4.0 on the 0-9 scale.
[y]Percentage of resistant and intermediate resistant accessions totaling 30.

CHAPTER FOUR

HERITABILITY AND GENETIC VARIANCE ESTIMATES FOR RESISTANCE TO POWDERY MILDEW RACE 2W IN WATERMELON [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]

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Abstract

Powdery mildew caused by *Podosphaera xanthii* (Castagne) Braun & Shishkoff [syn. *Sphaerotheca fuliginea* auct. p.p.] has in recent years become a common disease of watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] in the United States. Two watermelon accessions, PI 189225 and PI 270545 have exhibited high levels of resistance to powdery mildew in field and greenhouse trials. In this study, the inheritance of resistance to powdery mildew race 2W in three crosses involving PI 198225 and PI 270545 as resistant parents with two susceptible watermelon lines was studied. Parents, F_1, F_2 and backcross populations were evaluated in the greenhouse. Based on both qualitative and quantitative analyses, the inheritance in PI 189225 was found to be multigenic, while in PI 270545, a major gene was found whose expression was more complex than that suggested by the single gene alone. No discrete phenotypic classes were observed in the segregating F_2 populations of any cross. Each of the resistant lines contained more than one effective factor with at least two to three genes segregating for resistance. The genetic parameters contributing to resistance were estimated by a mean separation analysis procedure. Additive gene action was the most important component of variation in all three crosses. Dominance effects were not significant. Narrow sense heritability estimates for powdery mildew resistance was 0.62 for PI 189225 and 0.92 for PI 270545. We also report on genetic linkage (significant departure from independent segregation) between leaves and stem resistance to powdery mildew with a map distance of 0 to 0.94cM.

Introduction

Powdery mildew disease is a production limiting factor of cucurbit crops worldwide requiring the need for fungicide application (Davis et al., 2007). In the past, powdery mildew on watermelons was not of major economic importance as few and isolated cases of the disease were reported (Ivanoff, 1957; Nagy, 1983; McLean, 1970; Robinson and Provvidenti, 1975; Bertrand, 1991). However, since the mid-nineties, a new pathotype of powdery mildew has been damaging watermelon crops in the U.S. (Davis et al., 2001, Keinath, 2000; McGrath, 2001a) and the disease is now prevalent in the major watermelon producing states.

Powdery mildew is caused by *Podosphaera xanthii* (Castagne) Braun & Shishkoff (syn. *Sphaerotheca fuliginea* auct. p.p.) and *Golovinomyces cichoracearum s.l.* (D.C.) V.P. Heluta (syn. *Erysiphe cichoracearum* auct. p.p.) (Jahn et al., 2002). In the U.S. only *P. xanthii* is known to affect watermelon and races 1W and 2W have been identified on watermelon (Davis et al. 2001; McGrath, 2001a). It is manifested as chlorotic spots on leaves with or without white mycelial and/or conidial development on leaves and stem. The disease results in moderate to severe damage to the foliage and a reduction in yield and quality of fruit (McGrath, 2001a; Davis et al., 2001). Chemical control is possible but adds expense to crop production costs. The use of resistant cultivars is economical and an environmentally safe means of controlling the disease. However, to date no commercial cultivars of watermelon are available.

Screening the U.S. *Citrullus* germplasm collection for resistance to powdery mildew race 2W, Tetteh and Wehner (unpublished) reported of accessions which possess good levels of resistance. Two of the accessions are PI 189225 is a *C. lanatus* var. *citroides* line whose resistance is characterized by slow development of chlorotic spots without mycelial or conidial development. PI 270545 is a *C. lanatus* var. *lanatus* with intermediate resistance and exhibits slow mildewing with few chlorotic spots at the adult plant stage. The inheritance of resistance to powdery mildew race 1W in PI 525088 was determined to be multigenic (Davis et al., 2002).

Objective

The objective of this research was to determine the inheritance of resistance to *P. xanthii* race 2W in the watermelon accessions, PI 189225 and PI 270545.

Materials and Methods

Location and Germplasm

All tests were conducted at the greenhouses of the Department of Horticultural Science, North Carolina Sate University. The susceptible parents for the genetic study were PI 269677 and 'Charleston Gray'. PI 269677 was originally collected as cultivar Excel from Belize. It was the only accession of *Citrullus lanatus* out of 590 tested that was susceptible to powdery mildew (Robinson and Provvidenti, 1975). The inheritance of susceptibility to *P. xanthii* in PI 269677 was reported to be a single recessive gene, named *pm* (Robinson et al., 1975). 'Charleston Gray No. 133' is a selection from 'Charleston Gray' (No. 51-27).

'Charleston Gray' was developed by C.F. Andrus (Andrus, 1955) at the Southeastern Vegetable Breeding Lab, Charleston, South Carolina in 1954 with the following pedigree: (((Africa 8 x Iowa Belle) x Garrisson) x Garrison) x (Hawkesbury x Leesburg) x Garrison. 'Charleston Gray No. 133' was released in 1961 by Stevenson in India as a selection from Charleston Gray having improved resistance to Fusarium wilt and a thinner rind. Like 'Charleston Gray', it is resistant to anthracnose and sunburn.

The resistant parents were PI 189225 and PI 270545. In addition to powdery mildew resistance, PI 189225 is resistant to gummy stem blight (Sowell and Pointer, 1962; Gusmini et al., 2005) and anthracnose (Sowell et al., 1980; Winstead et al., 1959). PI 270545 has intermediate resistance to powdery mildew race 2W (Tetteh et al., unpublished) and also demonstrates intermediate resistance to powdery mildew race 1W (Davis et al., 2007). The resistant accessions were selected and self-pollinated to the S_2 generation in the greenhouses of the Department of Horticultural Science, North Carolina State University.

Crosses

Three families of resistant by susceptible lines were produced from the following crosses: PI 189225 x 'Charleston Gray', PI 189225 X PI 269677 and PI 270545 x PI 269677. The F_1, F_2, and backcross generations (BC_1P_b = F_1 x resistant parent and BC_1P_a = F_1 x susceptible parent) were produced. The experiment had 20 plants of each parent, 40 plants of the F_1, 200 plants of the F_2, and 60 plants of each backcross. The seeds were planted in two sets, each containing half of each population to spread the workload and reduce the risk of loss of populations in the advent of unfavorable environmental circumstances or disease epidemics at one location.

Experimental Procedure

Seeds were sown in 100 mm pots in 4P *Fafard* soilless mix (Conrad Fafard Incorporated, Massachusetts, U.S.) and placed on benches in the greenhouse running at 26-38^{o}C (day) and 13-19^{o}C (night). Plots were irrigated as needed. Pots were thinned to one plant each at full cotyledon stage and were fertilized weekly with 150 $mg \cdot kg^{-1}$ of Peters Professional 20-10-20 N-P-K (Scotts-Sierra Horticultural Products Company, Marysville, Ohio). Plants of 'PMR 45' melon (*Cucumis melo* L.) from Hollar Seeds were included in each experiment to verify that race 2W rather than 1W of *P. xanthii* was present.

Inoculum and Inoculation Procedure

Podosphaera xanthii race 2W inoculum which originated from infected commercial watermelon plants in South Carolina was maintained on 'PMR 45' melon and ‘Gray Zucchini’ squash (*Cucurbita pepo* L.*)* plants from Seminis Vegetable Seeds (Woodland, CA) in the greenhouse. A spore suspension was prepared by detaching three to four average size heavily sporulating leaves and washing them with 100ml of water using a hand-pumped sprayer. The suspension was filtered through a double layer of cheesecloth and diluted to a spore concentration of 4×10^{4} conidia ml^{-1}. A fresh spore suspension was prepared for each inoculation day. Seedlings were inoculated three times, at one week intervals beginning at the first- to second-true leaf stage by spraying the spore suspension onto plant surfaces using a hand-pumped sprayer. Seedlings were maintained under normal greenhouse conditions of 37 -70% RH and 24 to 38^{o}C night/day.

Disease Assessment

Individual plants were rated for disease severity on the leaves and stem when disease symptoms appeared. In powdery mildew of watermelon leaf ratings are more important than stem as mycelium development on leaves is more that on stem (Tetteh et al., unpublished-a), however, our rating scale allowed a quantitative assessment of total disease on plant as mycelium on stem was always accompanied by a more extensive leaf damage. The final leaf rating was used for analyses of inheritance and genetic variance estimation. Both leaf and stem data were used for test of linkage between leaf and stem resistance traits. Disease severity ratings were done two times at 16 and 30 days after inoculation by using the 0 to 9 scale developed by Tetteh and Wehner, (unpublished) where 0 = no symptoms; 1 = faint yellow speck on leaves; 2 = chlorotic lesions on leaves; 3 = chlorotic lesions covering 20% of leaves; 4 = first sign of active mycelium sporulation on leaves and stem; 5 = 2 to 3 healthy colonies of mycelium on leaves and stem; 6 = less than 20% mycelium coverage; 7 = 20-50% mycelium coverage; 8 =50-70% mycelium coverage with large necrotic areas; 9 = plant fully covered with powdery mycelium or plant dead. Individual plants in each generation were classified into resistant, intermediate, or susceptible classifications based on their final disease severity rating: resistant if the final leaf rating was ≤3.0; intermediate if 3.1-4; susceptible if ≥4.1.

Data analysis

Distributions of the F_2 populations were tested for normality using Shapiro-Wilk's statistic (Shapiro and Wilk, 1965) in PROC UNIVARIATE procedure of SAS-STAT. Chi-square analyses were carried out to test the goodness-of-fit (Ramsey and Schafer, 1997) for the observed segregation with that of expected segregation for a single gene hypothesis at the 95% confidence level using the SASGENE 1.2 program (Liu et al., 1997). The F_2 disease severity data was plotted against the frequency distribution and based on these results resistance to powdery mildew in watermelon was analyzed as a quantitative trait.

The variance components, phenotypic (P), environmental (E), genotypic (G) and additive (A) variances in each generation were estimated using Warner (1952) and Wright's (1968) formula:

$$\sigma^2 (P) = \sigma^2 (F_2)$$

$$\sigma^2 (G) = \sigma^2 (P) - \sigma^2 (E)$$

$$\sigma^2 (E) = \frac{\sigma^2 (P_a) + \sigma^2 (P_b) + [2\, \sigma^2 (F_1)]}{4}$$

$$\sigma^2 (A) = [2\, \sigma^2 (F_2)] - [\sigma^2 (BC_1P_a) + \sigma^2 (BC_1P_b)]$$

Narrow sense heritability estimates were calculated using the ratio of additive variances to phenotypic variance. A quantitative estimate for the minimum number of effective factors controlling powdery mildew resistance was determined using the methods of Lande, (1981), Mather and Jinks (1982) and Wright (1968).

Lande`s method I:
$$\frac{\left[\mu(P_b) - \mu(P_b)\right]^2}{8 \times \left\{\sigma^2(F_2) - \frac{\sigma^2(P_a) + \sigma^2(P_b) + \left[2 \times \sigma^2(F_1)\right]}{4}\right\}}$$

Lande`s method II: $$\frac{[\mu(P_b)-\mu(P_a)]^2}{8\times\left\{\left[2x\sigma^2(F_2)\right]-\left[\sigma^2(BC_1P_a)+\sigma^2(BC_1P_b)\right]\right\}}$$

Lande`s method III: $$\frac{[\mu(P_b)-\mu(P_a)]^2}{\left\{8\times\left[\sigma^2(BC_1P_b)+\sigma^2(BC_1P_a)-\sigma^2(F_1)\right]\right\}-\frac{\left[\sigma^2(P_b)+\sigma^2(P_a)\right]}{2}}$$

Mather`s method: $$\frac{\frac{[\mu(P_b)-\mu(P_a)]^2}{2}}{\left[2\times\sigma^2(F_2)\right]-\left[\sigma^2(BC_1P_b)+\sigma^2(BC_1P_a)\right]}$$

Wright`s method: $$\frac{[\mu(P_b)-\mu(P_a)]^2\times\left\{1.5-\left[2\times\frac{\mu(F_1)-\mu(P_a)}{\mu(P_b)-\mu(P_a)}\times\left(1-\frac{\mu(F_1)-\mu(P_a)}{\mu(P_b)-\mu(P_a)}\right)\right]\right\}}{8\times\left\{\sigma^2(F_2)-\frac{\sigma^2(P_a)+\sigma^2(P_b)+\left[2\times\sigma^2(F_1)\right]}{4}\right\}}$$

The general assumptions for the estimation of number of effective factors are that no linkage exists between the loci involved, the effects of all loci are equal, and all genes for resistance are in a single parent, there is no dominance and no epistasis. The genetic parameters, *m* (mid-parent), *a* (additive component) and *d* (dominance component) were estimated using Hayman’s mean separation analysis procedure (Hayman, 1958; Gamble, 1962). Fisher’s t-test was used to test the hypotheses that the estimates are significantly different from zero.

The possible gain from selection per cycle was predicted for selection intensities of 5%, 10% and 20% using the formula: $h_n^2 \times \sqrt{\sigma^2(P)}$ multiplied by *k*, the selection differential in standard deviation units (Hallauer and Miranda, 1988). Statistical analysis for quantitative traits was carried out using SASQuant statistical package (Gusmini et al., 2007).

Results and Discussion

Powdery mildew development was good throughout the period of the study. Both susceptible parents, 'Charleston Gray' and PI 269677 reached a severity rating of 8 to 9 on the 0-9 rating scale by the last rating date. Disease severity of the F_2 lines covered the whole range of the 0-9 rating scale.

Discrete classes were not observed within the F_2 segregating population of any of the crosses (Fig. 1). A test of normality (Shapiro-Wilk's test) revealed that normal distribution did not occur in the F_2 population of any of the crosses. The results of the test are, for PI 189225 x 'Charleston Gray': W =0.94 and Pr < W of <0.0001; for PI 189225 x PI 269677: W =0.92 and Pr < W of <0.0001; and for PI 270545 x PI 269677: W =0.88 and Pr < W of <0.0001. The data were analyzed in both Mendelian and quantitative approach.

Test of linkage between leaf and stem resistance

Having screened the F_2 and backcross families for leaf and stem reaction to powdery mildew, we examined the possible linkage relationship between the two resistance traits for the three crosses. Each pairwise combination of genes was subjected to chi-square test for independent segregation of the traits l. Table 1 shows a linkage analysis of leaf and stem resistance to *P. xanthii* in watermelon. Low numbers of plants with stem susceptibility and leaf resistance and the opposite of high stem resistance and leaf susceptibility were observed. Leaf and stem resistance exhibited significant ($P << 0.0001$) co-segregation for powdery mildew resistance. For PI 189225 x 'Charleston Gray', the map distance between the two traits was calculated as 9.4 ± 2.7 cM for the F_2 and 5.7 ±3.2 cM for the backcross; for PI 189225 x PI 269677 the map distance was 8.3 ± 2.3 cM for F_2 and 5.5 ± 3.1 cM for the backcross; and for PI 270545 x PI 269677 the map distance was 0.0 for the F_2 and 5.1 ± 4.2 cM for the backcross indicating linkage between leaf and stem resistance. Leaf and stem resistance could be controlled by the same gene. However, the small distances observed could probably be due to experimental error or to lack of sensitivity of our rating scale to measure disease severity accurately. The data indicates linkage between leaf and stem resistance. Co-segregation of genes for leaf and stem resistance was not unexpected as a previous screening for powdery mildew race 2W resistance data revealed a strong and positive correlation (r= 0.86, P=0.0001) between the two traits (Tetteh and Wehner, unpublished). In screening for race 1W resistance in watermelons, Davis et al. (2007) also reported of a strong but weak correlation (r=0.64, P=0.001) between leaf and stem ratings. Host genes conferring resistance to leaf and stem may be tightly linked due to their evolution as gene clusters or possibly one gene may protect against leaf and stem infection.

Test for single gene

The expected segregation ratio for the inheritance of resistance to powdery mildew as a single gene were not observed in the F_2 generations of both crosses involving PI 189225 (Table 2). The lack of fit to the single gene hypothesis suggests that powdery mildew resistance in PI 189225 could be inherited as a quantitative trait. However, the recovery of a 1:1 segregation ratio in the backcross to the susceptible parent and 1:0 in the backcross to the resistant parent of the PI 189225 x 'Charleston Gray' cross suggest the likely presence of a single gene for resistance. The lack of normal distribution in the F_2 suggests that if a single gene is present, then its expression is modified by environmental effects or by minor genes. In the cross between PI 270545 and PI 269677 both the F_2 and backcross segregation data produced the expected ratios for a single recessive gene. The F_2 segregation data supported a 3 susceptible:1 resistant: ratio. The BC_1P_a population also supported the expected ratio for a single recessive gene hypothesis showing a 1 susceptible: 0 resistant ratio (Table 2).The BC_1P_b population segregated 1 susceptible:1 resistant ratio consistent with the presence of a single recessive gene. We propose naming this resistance gene in PI 270545 powdery mildew race 2W resistance, with the symbol *pmr*, in conformance with the gene nomenclatural rules for Cucurbitaceae (Cucurbit Gene List Committee, 1982).

Quantitative Analysis

The lack of fit to the single gene hypothesis and absence of discrete phenotypic F_2 distribution in the segregation population of both crosses suggest that resistance to powdery mildew race 2W in these lines may be controlled by quantitative factors. Quantitative analysis of the two individual populations of PI 189225 and the pooled population involves calculation of genetic variance estimates, heritabilities, number of effective factors, gene action and genetic gain.

Genetic variance estimates were consistent across families. Genetic variance was larger than environmental variance (Table 3) in both PI 189225 crosses and additive genetic variance formed a larger component of the genetic variance estimate with very little dominance effects. In the PI 270545 cross, environmental variance was large (3.24) and close to genetic variance (3.67). All the genetic variance was contributed by additive effects, with absence of dominance effect. A negative estimate for dominance effect in this population was observed. Robinson et al. (1955) reported that negative estimates should be considered equal to zero, but should be reported. The lack of dominance confirms the quantitative nature of the genes controlling resistance in PI 270545. Although in this population a single gene was found to control resistance of powdery mildew (Table 2) the distribution of the F_2 data was strongly skewed toward susceptibility (Fig. 1). This distribution pattern suggests the presence of a single gene either under strong environmental effects or the expression of the single gene is regulated by modifying genes.

Heritability estimates obtained for the three crosses were generally high. As would be expected, broad sense heritability estimates based on the variance components of the F_2 population was larger than the narrow sense estimates. This was true for the cross involving PI 189225, but not for PI 275045 (Table 3). The highest narrow sense heritability estimate of 0.92 was obtained for the cross involving PI 270545 x PI 269677, while the cross between PI

189225 x ‘Charleston Gray’ and PI 189225 x PI 269677 gave lower estimates of 0.64 and 0.59 respectively. These high heritability estimates indicate that selection for individuals containing high numbers of resistance genes should not be difficult. Likewise a heritability of 0.62 in the PI 189225 cross should lead to selection of individuals with enhanced resistance to powdery mildew. The larger value of narrow sense heritability in PI 270545 cross indicates that the single gene present in this line may be the largest factor controlling resistance, while other unknown minor genes may regulate its expression.

The minimum number of effective factors conferring resistance to powdery mildew in each cross is given in Table 3. Quantitative estimates of gene number for PI 189225 ranged between 1and 7 with a mean of 2.5, indicating that at least two genes govern powdery mildew resistance in this line. For PI 270545, quantitative estimates showed a range of effective factors between 1 and 6, with a mean of 2.9, indicating that at least 3 genes govern powdery mildew resistance.

The estimates for genetic parameters for all three crosses are presented in Table 4. Estimate for m were significant for all crosses. Only the additive components were significant. Dominance components were not important. All additive by additive, additive by dominance and dominance by dominance components were not significant. The analysis showed that for all three crosses, selection could lead to a gain of two or more points (on a nine-point scale) in PI 189225 and a gain of at least three points in PI 270545 per generation under the selection limit of 20% commonly used in recurrent selection programs.

Bjarko and Line (1988) working with the number of genes controlling leaf rust resistance reported that presence of linkage, dominance, or unequal effects at different loci will result in underestimation of the actual number of segregating genes present, while the presence of epistasis may cause either an overestimation or an underestimation of the actual number of segregating genes. In most cases, these formulas give a conservative estimate of the number of genes involved (Milus and Line, 1986; Luke et al., 1975; Skovmand et al., 1975, Wright, 1968). For example, the methods used to calculate the number of effective factors are based on Wright's formula which essentially estimates the gene number by dividing the square of the genotypic range by the genotypic variance. Because this method uses the parental difference as a measure of genotypic range, it often underestimates the number of genes. Other methods which use the phenotypic range as a measure of the genotypic range also tend to overestimate the number of genes (Bjarko and Line, 1988). In our study Mather's formula consistently gave higher number of effective factors. We concluded that upper and lower ranges of the methods used here provide reasonable estimates of the number of segregating resistance genes.

Conclusions

The study showed that resistance of leaf and stem to powdery mildew are linked. Because leaves make up the most significant surface are of watermelon plants, breeding for leaf resistance appears to be more important than stem. Stems had a smaller amount of mycelia than leaves probably by virtue of the nature of the tissue rather than the presence of resistance genes. We found that evaluating resistance to powdery mildew by using stem ratings may be misleading as many susceptible plants had low stem ratings.

Resistance to powdery mildew race 2W in PI 189225 and PI 270545 was inherited as a quantitative trait. Quantitative analyses demonstrated that at least two to three effective factors control resistance in PI 189225. In PI 270545 at least three effective factors were found, one of which was expressed as a major gene with the other two or more factors possibly acting as modifying genes. Narrow sense heritability and additive gene action exhibited in the three crosses suggest that incorporation of powdery mildew resistance in other cultivars should be feasible in environments which favor powdery mildew development.

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Table 1. Linkage analysis of leaf and stem resistance reaction to *P. xanthii* race 2W.[z]

	N	Susceptible		Resistance		Expected ratio[y]	$\bullet^{2}$	P-value	rf[x]	SE[w]
		Leaf	Stem	Leaf	Stem					
PI 189225 x ‘Charleston Gray’										
F_2	131	82	2	17	30	9:3:3:1	82.1	0.00**	0.094	0.027
BC_v	53	20	1	2	30	1:1:1:1	45.5	0.00**	0.057	0.032
PI 189225 x PI 269677										
F_2	160	88	2	22	47	9:3:3:1	66.2	0.00**	0.083	0.023
BC_v	55	10	0	3	42	1:1:1:1	81.2	0.00**	0.055	0.031
PI 270545 x PI 269677										
F_2	191	127	12	0	52	9:3:3:1	189.7	0.00**	0.000	0.000
BC_v	59	51	3	0	5	1:1:1:1	119.6	0.00**	0.119	0.029

*Prob with indicates gene pair might be linked
[z]On the 0-9 rating scale, plants were classified as resistant if their final plant leaf mean disease severity rating was ≤3.0; intermediate if 3.1-4; susceptible if ≥4.1
[y]Expcted ratio was the hypothesized segregation ratio for the generation.
[x]rf is the recombination fraction.
[w]SE is the standard error.
[v]BC_a is the backcross to the susceptible parent

Table 2. Single locus goodness-of-fit test for powdery mildew race 2W resistance in watermelon.[z]

Generation	Total	Susceptible	Resistant + Intermediate	Expected ratio[y]	χ^2	df	P-value
PI 189225 x 'Charleston Gray'							
P_a[x]	20	20	0				
P_b[w]	20	0	20				
F_1	12	3	9				
F_2	131	47	84	3:1	8.27	1	0.004*
BC_1P_a	53	32	21	1:0			
BC_1P_b	56	10	46	1:1	23.14	1	0.0001**
PI 189225 x PI 269677							
P_a[x]	20	20	0				
P_b[w]	20	0	20				
F_1	28	12	16				
F_2	160	70	90	3:1	80.73	1	0.000*
BC_1P_a	55	45	10	1:0			
BC_1P_b	51	11	40	1:1	16.49	1	0.000*
PI 270545 x PI 269677							
P_a[x]	20	20	0				
P_b[w]	20	0	20				
F_1	36	25	11				

Table 2 (continued).

Generation	Total	Susceptible	Resistant + Intermediate	Expected ratio[y]	χ^2	df	P-value
F_2	191	139	52	3:1	0.50	1	0.47
BC_1P_a	59	54	5	1:0			
BC_1P_b	59	26	33	1:1	0.83	1	0.36
Stem resistance							
PI 189225 x 'Charleston Gray'							
P_a[x]	20	0	20				
P_b[w]	20	20	0				
F_1	12	11	1				
F_2	131	32	99	3:1	178.88	1	0.00
BC_1P_a	53	22	31	1:0			
BC_1P_b	56	1	55	1:1	52.07	1	0.001
PI 189225 x PI 269677							
P_a[x]	20	0	20				
P_b[w]	20	20	0				
F_1	28	23	5				
F_2	160	110	49	3:1	2.87	1	0.09
BC_1P_a	55	13	42	1:0			
BC_1P_b	51	45	6	1:1	15.29	1	0.00
PI 270545 x PI 269677							

Table 2 (continued).

Generation	Total	Susceptible	Resistant + Intermediate	Expected ratio[y]	χ^2	df	P-value
P_a[x]	20	20	0				
P_b[w]	20	0	20				
F_1	36	23	13				
F_2	191	127	64	3:1	7.37	1	0.003
BC_1P_a	59	51	8				
BC_1P_b	59	19	40	1:1	7.47	1	0.006

[z]On the 0-9 rating scale, plants were classified as resistant if their final plant leaf mean disease severity rating was ≤3.0; intermediate if 3.1-4; susceptible if ≥4.1
[y]Expected ratio was the hypothesized segregation ratio for single gene inheritance.
[x]P_a was the susceptible parent.
[w]P_b was the resistant parent.

Table 3. Variance and heritability estimates for the three watermelon crosses evaluated for resistance to powdery mildew race 2W.[z]

(a) Phenotypic variances of the generations

Family	$\sigma^2(P_a)$	$\sigma^2(P_b)$	$\sigma^2(F_1)$	$\sigma^2(F_2)$	$\sigma^2(BC_1P_a)$	$\sigma^2(BC_1P_b)$
PI 189225 x ‘CH Gray’[1]	0.27	0.21	1.77	5.71	4.15	3.61
PI 189225 x PI 269677	0.12	0.50	1.11	7.07	5.47	4.46
PI 270545 x PI 269677	0.00	0.36	6.30	6.91	3.64	3.81

(b) Variance and heritability estimates

Family	$\sigma^2(P)^x$	$\sigma^2(E)^w$	$\sigma^2(G)^v$	$\sigma^2(A)^u$	$H^2_B{}^t$	$h^2_n{}^s$
PI 189225 x ‘CH Gray’	5.71	1.00	4.71	3.66	0.82	0.64
PI 189225 x PI 269677	7.07	0.71	6.36	4.20	0.90	0.59
PI 270545 x PI 269677	6.91	3.24	3.67	6.36	0.53	0.92

(c) Estimates of number of effective factors and predicted gain from selection under three selection intensities

	Effective factors						Gain[r]		
Family	W[q]	M[p]	L1[o]	L2[n]	L3[m]	Mean	5%	10%	20%
PI 189225 x ‘CH Gray’	1.2	6.0	1.2	1.5	1.0	2.2	3.2	2.7	2.1
PI 189225 x PI 269677	1.4	8.5	1.4	2.1	1.0	2.9	3.3	2.8	2.2
PI 270545 x PI 269677	1.7	3.9	1.7	1.0	6.4	2.9	5.0	4.3	3.4

[z]On the 0-9 rating scale, plants were classified as resistant if their final plant leaf mean disease severity rating was ≤30; intermediate if 31-4; susceptible if ≥4.
[y]F_2 Bartlett’s χ^2 =1.08; P-value = 0.61.
[x]$\sigma^2(P) = \sigma^2(F_2)$ = phenotypic variance

Table 3 (continued).

$^{w}\sigma^2(E) = \frac{\sigma^2(P_a) + \sigma^2(P_b) + \left[2\sigma^2(F_1)\right]}{4}$ = environmental variance

$^{v}\sigma^2(G) = \sigma^2(P) - \sigma^2(E) =$ genetic variance

$^{u}\sigma^2(A) = \left[2\sigma^2(F_2)\right] - \left[\sigma^2(BC_1P_a) + \sigma^2(BC_1P_b)\right]$ = additive variance

$^{t}H^2_B$ = broad-sense heritability

$^{s}h^2_n$ = narrow-sense heritability

^{r}Gain from selection = k x $h_n^{\,2} \times \sqrt{\sigma^2(P)}$

$$^{q}W = \text{Wright's method: } \frac{\left[\mu(P_b) - \mu(P_a)\right]^2 \times \left\{1.5 - \left[2 \times \frac{\mu(F_1) - \mu(P_a)}{\mu(P_b) - \mu(P_a)} \times \left(1 - \frac{\mu(F_1) - \mu(P_a)}{\mu(P_b) - \mu(P_a)}\right)\right]\right\}}{8 \times \left\{\sigma^2(F_2) - \frac{\sigma^2(P_a) + \sigma^2(P_b) + \left[2 \times \sigma^2(F_1)\right]}{4}\right\}}$$

$$^{p}M = \text{Mather's method: } \frac{\frac{\left[\mu(P_b) - \mu(P_a)\right]^2}{2}}{\left[2 \times \sigma^2(F_2)\right] - \left[\sigma^2(BC_1P_b) + \sigma^2(BC_1P_a)\right]}$$

$$^{o}L1 = \text{Lande's method I: } \frac{\left[\mu(P_b) - \mu(P_b)\right]^2}{8 \times \left\{\sigma^2(F_2) - \frac{\sigma^2(P_a) + \sigma^2(P_b) + \left[2 \times \sigma^2(F_1)\right]}{4}\right\}}$$

$$^{n}L2 = \text{Lande's method II: } \frac{\left[\mu(P_b) - \mu(P_a)\right]^2}{8 \times \left\{\left[2x\sigma^2(F_2)\right] - \left[\sigma^2(BC_1P_a) + \sigma^2(BC_1P_b)\right]\right\}}$$

$$^{m}L3 = \text{Lande's method III: } \frac{\left[\mu(P_b) - \mu(P_a)\right]^2}{\left\{8 \times \left[\sigma^2(BC_1P_b) + \sigma^2(BC_1P_a) - \sigma^2(F_1)\right]\right\} - \frac{\left[\sigma^2(P_b) + \sigma^2(P_a)\right]}{2}}$$

^{l}CH Gray = 'Charleston Gray'

Table 4. Estimates of the genetic components of variance among the generation means of three crosses of powdery mildew race 2W resistant *Citrullus* lines.[z]

	PI 189225 x 'CH Gray'		PI 189225 x PI 269677		PI 270545 x PI 269677	
	Estimate[v]	P-value	Estimate	P-value	Estimate	P-value
m[y]	3.50 ± 0.30	0.00	4.20 ± 0.30	0.00	6.08 ± 0.27	0.00
a[x]	3.04 ± 0.58	0.00	4.31 ± 0.86	0.00	3.44 ± 0.70	0.00
d[w]	1.02 ± 3.39	0.76	1.82 ± 3.70	0.93	-0.19 ± 3.40	0.95

[z]On the 0-9 rating scale, plants were classified as resistant if their final plant leaf mean disease severity rating was ≤30; intermediate if 31-4; susceptible if ≥4.

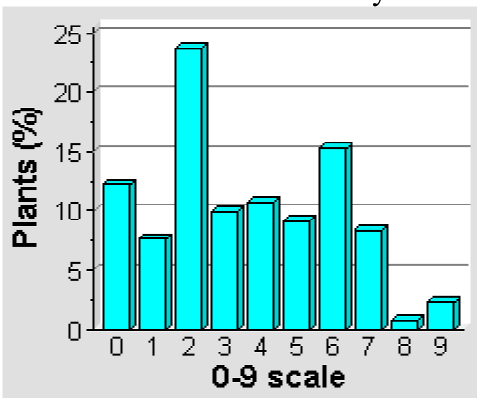
[y] $m = \mu_{F_2}$

[x] $a = \mu_{B_1} - \mu_{B_2}$; B_1=BC_1P_a; B_2=BC_1P_b

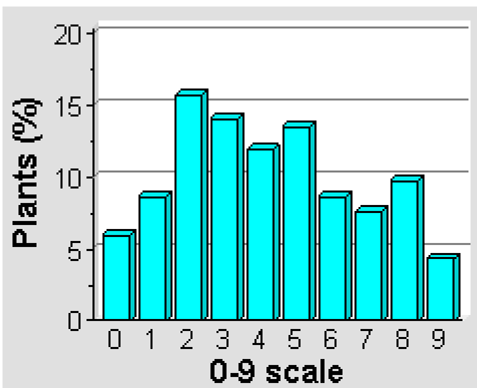
[w]$d = -\frac{\mu_{P_1}}{2} - \frac{\mu_{P_2}}{2} + \mu_{F_1} - (4\mu_{F_2}) + \left[2(\mu_{B_1} + \mu_{B_2})\right]$

[v]SASQuant tests the hypothesis that the estimates are significantly different from zero by performing Fisher's *t*-test.

PI 189225 x ‘Charleston Gray’



PI 189225 x PI 269677



PI 270545 x PI 269677

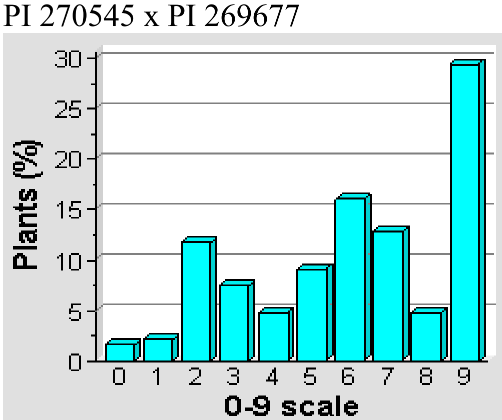


Fig. 1. Distribution of frequencies for final powdery mildew severity of F_2 lines of the families PI 189225 x ‘Charleston Gray’, PI 189225 x PI 269677 and PI 270545 x PI 269677.

GENERAL SUMMARY

The studies presented in this dissertation are contributions to the knowledge of sources of resistance and the understanding of the nature of resistance to powdery mildew race 2W in watermelon.

We developed an efficient method for screening for resistance to powdery mildew in watermelon. The method was made up of inoculation of seedlings with a spray of a spore suspension of inoculum of *P. xanthii* and maintaining inoculated seedlings at normal greenhouse temperature and relative humidity. A high relative humidity was not required for disease establishment. Maintenance of inoculum on squash or watermelon plants did not affect the disease pattern of race 2W. Race 2 was the only race detected in all experiments. Rating the leaves for disease severity was found to be more efficient as it gave more uniform ratings and contributed larger variances among accessions than stem ratings. Taking multiple ratings was useful in verifying disease progress, however rating at the third to fourth week after inoculation produced larger significant differences among accessions. This final powdery mildew rating was enough for analyses. This method was found to be efficient as it produced consistent and significant differences among resistant and susceptible lines.

The entire available U.S. Plant introduction accessions and available cultivars, made up of 1,654 cultigens were screened for resistance to race 2W.The results of the screening and retest revealed that eight accessions had high levels of resistance and seventy-eight accessions demonstrated intermediate resistance. Resistance was characterized by low disease severity of between 0 and 3 on a 0-9 rating scale. Resistant accessions were more heterogeneous than susceptible accessions. Leaf and stem ratings were found to be highly and significantly ($P<0.0001$) correlated. A large percentage of resistant accessions originated from Zimbabwe and Nigeria. Linkage analysis showed a significant departure from independent segregation between leaves and stem resistance to powdery mildew with a map distance of 0 to 0.94cM.

Two watermelon accessions, PI 189225 and PI 270545 were selected for studying the inheritance of powdery mildew resistance. Three families were generated from the crosses: PI 189225 x ‘Charleston Gray’, PI 189225 x PI 269677, and PI 270545 x PI 269677. Parents, F_1, F_2 and backcross populations were evaluated in the greenhouse. Inheritance in PI 189225 was found to be multigenic, while in PI 270545, a major gene was found. No discrete phenotypic classes were observed in the segregating F_2 populations of any cross. Based on quantitative analyses, each resistant line contained at least two to three genes for powdery mildew resistance. The genetic parameters contributing to resistance were estimated by a mean separation analysis procedure. Additive gene action was the most important component of variation in all three crosses. Dominance effects were not significant. Narrow sense heritability estimates for powdery mildew resistance was 0.62 for PI 189225 and 0.92 for PI 270545. In these two lines, a predicted genetic gain of at least two points per generation on the zero to nine point scale.

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APPENDICES

Appendix Table 1. Ranking of mean final disease severity ratings of *Citrullus* species and *Praecitrullus* species PI accessions and cultivars.[z]

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
PI accessions								
1	PI 386015	Iran	6	0.7	0.2	1.0	0.4	O
2	PI 386021	Iran	4	1.0	0.0	1.2	0.0	O
3	PI 346082	Afghanistan	5	1.0	0.2	1.0	0.4	O
4	PI 482326	Zimbabwe	6	1.5	0.3	1.4	0.8	T
5	Grif 14202	India	6	1.5	1.0	1.6	1.7	O
6	PI 386024	Iran	9	1.9	0.8	1.5	1.4	O
7	PI 482307	Zimbabwe	7	2.0	0.7	1.7	1.0	T
8	PI 482324	Zimbabwe	3	2.0	1.3	1.0	1.2	T
9	PI 386016	Iran	9	2.1	1.4	2.0	1.9	O
10	PI 482311	Zimbabwe	7	2.1	1.0	2.7	1.7	T
11	PI 560020	Nigeria	7	2.1	1.0	1.2	1.4	L
12	PI 482307	Zimbabwe	6	2.2	1.3	2.0	2.0	T
13	PI 494531	Nigeria	7	2.3	1.4	2.4	1.8	L
14	PI 186489	Nigeria	6	2.3	1.5	1.2	2.1	L
15	PI 251244	India	6	2.3	2.0	2.3	2.8	F
16	PI 500354	Zambia	7	2.4	1.4	2.5	2.0	T

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale^{y}					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD^{x} Leaf	SD Stem	Species
17	PI 560005	Nigeria	7	2.4	1.4	2.1	1.9	L
18	PI 482288	Zimbabwe	6	2.5	1.3	1.0	0.8	L
19	PI 482302	Zimbabwe	8	2.5	1.4	1.3	1.3	T
20	PI 482298	Zimbabwe	6	2.5	1.5	2.2	2.1	T
21	PI 482259	Zimbabwe	7	2.6	2.1	2.3	2.0	T
22	PI 500303	Zambia	7	2.6	2.6	3.4	3.2	T
23	PI 525082	Egypt	8	2.6	1.4	2.0	1.6	O
24	PI 432337	Cyprus	6	2.7	1.0	2.5	2.0	O
25	PI 386025	Iran	9	2.7	1.9	2.6	2.6	O
26	PI 381752	India	6	2.7	2.2	3.7	3.7	F
27	PI 381750	India	6	2.7	2.5	2.3	2.4	F
28	PI 482282	Zimbabwe	7	2.7	1.3	2.5	2.0	T
29	PI 482361	Zimbabwe	7	2.7	2.0	2.9	3.3	T
30	PI 482338	Zimbabwe	8	2.8	1.5	2.0	1.7	T
31	PI 500334	Zambia	4	2.8	2.5	3.4	2.9	T
32	PI 482286	Zimbabwe	5	2.8	1.4	1.9	2.2	T
33	PI 500329	Zambia	6	2.8	1.2	2.4	1.2	L
34	PI 269365	Afghanistan	6	2.8	2.0	2.6	2.6	O

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
35	PI 482299	Zimbabwe	7	2.9	1.9	2.5	2.0	T
36	PI 494528	Nigeria	7	2.9	2.0	2.1	1.9	L
37	PI 326516	Ghana	7	2.9	2.1	3.0	3.2	L
38	PI 540911	Unknown	7	2.9	2.3	1.8	1.9	F
39	PI 542616	Algeria	8	2.9	1.3	2.5	1.8	O
40	PI 307608	Nigeria	8	2.9	1.6	1.6	1.4	L
41	PI 220778	Afghanistan	8	2.9	2.3	3.1	3.4	O
42	PI 560003	Nigeria	7	3.0	1.1	2.7	1.2	L
43	PI 482322	Zimbabwe	7	3.0	1.4	1.0	0.8	T
44	PI 482341	Zimbabwe	7	3.0	1.4	2.3	1.4	L
45	PI 560024	Nigeria	6	3.0	1.7	1.8	1.6	L
46	PI 560010	Nigeria	9	3.0	1.7	1.9	1.5	L
47	PI 500332	Zambia	7	3.0	1.7	2.8	1.8	T
48	PI 500331	Zambia	7	3.0	1.7	2.7	1.8	T
49	PI 482318	Zimbabwe	7	3.0	1.7	2.7	2.1	L
50	PI 225557	Zimbabwe	7	3.0	1.7	1.4	1.8	L
51	PI 596692	South Africa	1	3.0	2.0	-	-	T
52	PI 560006	Nigeria	7	3.0	2.1	2.9	2.2	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
53	PI 386014	Iran	4	3.0	2.3	4.1	4.5	O
54	PI 386026	Iran	7	3.0	2.3	3.9	3.5	O
55	PI 189225	Zaire	9	3.1	2.2	1.9	2.3	T
56	PI 632755	Namibia	7	3.1	2.7	3.1	3.5	R
57	PI 482321	Zimbabwe	6	3.2	1.7	2.5	1.9	T
58	PI 482283	Zimbabwe	6	3.2	2.0	2.8	2.6	T
59	PI 482377	Zimbabwe	6	3.2	2.0	1.7	1.8	L
60	PI 388770	Morocco	6	3.2	2.3	3.9	3.8	O
61	PI 595203	United States	6	3.2	3.0	2.8	3.5	L
62	PI 560023	Nigeria	7	3.3	2.0	2.2	1.9	L
63	PI 482355	Zimbabwe	7	3.3	2.7	2.3	3.5	T
64	Grif 5596	India	7	3.3	2.7	2.4	2.4	L
65	PI 532722	Zaire	7	3.3	3.0	3.9	3.7	L
66	PI 500312	Zambia	6	3.3	2.2	2.0	1.9	L
67	PI 482277	Zimbabwe	6	3.3	2.3	2.1	2.7	T
68	PI 512828	Spain	6	3.3	3.2	3.0	3.5	L
69	PI 482319	Zimbabwe	7	3.4	1.6	2.2	1.7	T
70	PI 494532	Nigeria	7	3.4	2.0	2.1	1.8	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
71	PI 596679	South Africa	2	3.5	3.5	0.7	0.7	T
72	PI 270545	Sudan	7	3.6	2.1	2.8	3.1	L
73	PI 482246	Zimbabwe	7	3.6	2.1	3.1	2.4	T
74	PI 500327	Zambia	7	3.6	2.3	2.1	1.8	L
75	PI 532726	Zimbabwe	7	3.6	2.6	3.5	3.6	L
76	PI 560001	Nigeria	7	3.6	2.6	3.0	3.5	L
77	PI 525084	Egypt	6	3.7	2.7	2.5	2.2	L
78	PI 559994	Nigeria	6	3.7	2.8	3.5	3.4	L
79	PI 596696	South Africa	7	3.7	1.7	2.4	1.8	T
80	PI 459074	Botswana	7	3.7	2.6	2.3	2.4	L
81	PI 559997	Nigeria	7	3.7	2.6	2.8	2.4	L
82	PI 482308	Zimbabwe	7	3.7	2.7	2.9	3.1	T
83	PI 549161	Chad	7	3.7	2.7	2.0	3.3	O
84	PI 482360	Zimbabwe	5	3.8	2.4	1.6	1.5	L
85	PI 560019	Nigeria	6	3.8	2.0	2.3	1.7	L
86	PI 500302	Zambia	6	3.8	2.5	3.1	2.6	L
87	PI 482262	Zimbabwe	6	3.8	2.5	2.3	1.6	L
88	PI 500345	Zambia	6	3.8	2.8	1.9	3.3	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
89	PI 482273	Zimbabwe	6	3.8	3.2	1.9	2.1	T
90	PI 560002	Nigeria	7	3.9	1.4	1.9	1.7	L
91	PI 532730	Zimbabwe	7	3.9	2.6	2.4	1.9	L
92	PI 560008	Nigeria	7	3.9	2.6	2.3	1.6	L
93	PI 500318	Zambia	7	3.9	2.7	2.9	2.4	L
94	PI 249009	Nigeria	7	3.9	2.9	2.8	2.4	L
95	PI 482312	Zimbabwe	7	3.9	3.0	2.5	2.5	T
96	PI 482336	Zimbabwe	2	4.0	2.0	1.4	0.0	T
97	PI 560011	Nigeria	7	4.0	2.3	1.7	2.0	L
98	PI 560014	Nigeria	7	4.0	2.3	2.8	1.8	L
99	PI 482368	Zimbabwe	7	4.0	2.6	2.0	2.2	L
100	PI 381743	India	7	4.0	2.7	3.0	3.3	F
101	PI 482257	Zimbabwe	7	4.0	2.7	2.6	3.0	T
102	PI 254738	Senegal	7	4.0	2.7	1.3	1.3	L
103	PI 381748	India	7	4.0	2.9	2.6	2.7	F
104	PI 560004	Nigeria	7	4.0	2.9	3.1	2.3	L
105	PI 485583	Botswana	7	4.0	3.0	2.6	3.2	T
106	PI 482276	Zimbabwe	7	4.0	3.3	2.4	2.8	T

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
107	PI 386019	Iran	9	4.0	3.3	3.2	3.6	O
108	PI 525081	Egypt	7	4.0	3.4	2.8	3.0	T
109	PI 482372	Zimbabwe	7	4.0	3.6	0.8	1.6	L
110	Grif 5602	India	7	4.0	3.7	4.0	4.4	F
111	PI 306782	Nigeria	7	4.0	3.7	2.0	2.8	L
112	PI 500307	Zambia	7	4.0	3.9	2.8	3.9	L
113	PI 250145	Pakistan	7	4.0	4.0	3.7	3.9	F
114	PI 386018	Iran	5	4.0	4.2	4.1	4.5	O
115	PI 560000	Nigeria	7	4.1	2.1	1.2	1.2	L
116	PI 500323	Zambia	7	4.1	2.6	2.3	2.0	L
117	PI 482328	Zimbabwe	7	4.1	2.9	2.4	3.0	L
118	PI 482247	Zimbabwe	7	4.1	3.0	2.7	2.3	L
119	PI 249008	Nigeria	7	4.1	3.1	2.8	3.1	L
120	PI 505584	Zambia	7	4.1	3.1	2.5	2.9	L
121	PI 560017	Nigeria	7	4.1	3.3	2.9	3.2	L
122	PI 482264	Zimbabwe	6	4.2	2.5	2.5	1.2	L
123	PI 482249	Zimbabwe	6	4.2	3.0	1.7	2.1	L
124	PI 482333	Zimbabwe	5	4.2	3.6	3.0	3.4	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
125	PI 560018	Nigeria	8	4.3	4.1	2.7	2.8	L
126	PI 482252	Zimbabwe	7	4.3	2.7	1.8	2.1	T
127	PI 482278	Zimbabwe	7	4.3	3.0	1.5	1.7	L
128	PI 482364	Zimbabwe	7	4.3	3.0	2.3	2.8	L
129	PI 500328	Zambia	7	4.3	3.0	1.7	1.9	L
130	PI 381731	India	6	4.3	2.2	2.1	1.8	L
131	PI 254737	Senegal	6	4.3	2.5	2.3	1.8	L
132	PI 482258	Zimbabwe	6	4.3	3.2	1.0	1.5	L
133	PI 482248	Zimbabwe	6	4.3	3.2	2.3	2.6	L
134	PI 271749	Afghanistan	6	4.3	3.3	3.3	3.2	L
135	PI 254742	Senegal	6	4.3	3.5	3.0	3.2	L
136	PI 279461	Japan	6	4.3	3.5	2.6	3.2	L
137	PI 560016	Nigeria	6	4.3	3.7	3.1	3.2	L
138	PI 532659	Zimbabwe	6	4.3	3.8	2.9	3.3	L
139	PI 254744	Senegal	5	4.4	3.4	3.4	3.6	T
140	PI 482300	Zimbabwe	5	4.4	3.4	2.7	2.1	T
141	PI 374216	Afghanistan	10	4.4	3.5	3.5	4.0	O
142	PI 532733	Zimbabwe	7	4.4	2.4	2.7	2.4	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
143	PI 505587	Zambia	7	4.4	3.0	1.5	1.5	L
144	PI 505588	Zambia	7	4.4	3.1	1.5	1.5	L
145	PI 306367	Angola	7	4.4	3.6	1.0	1.3	L
146	PI 560012	Nigeria	7	4.4	4.1	2.2	2.8	L
147	PI 559999	Nigeria	6	4.5	2.8	3.2	2.3	L
148	PI 271985	Somalia	6	4.5	3.0	1.5	1.4	L
149	Grif 14201	India	4	4.5	3.0	2.4	2.2	O
150	PI 507869	Hungary	6	4.5	3.2	1.6	1.8	L
151	PI 381755	India	6	4.5	3.5	2.3	2.4	F
152	PI 494530	Nigeria	6	4.5	3.7	1.9	3.1	L
153	PI 381720	India	4	4.5	4.3	2.5	3.0	L
154	PI 500349	Zambia	6	4.5	4.5	2.1	3.0	L
155	PI 246559	Senegal	7	4.6	2.7	2.6	1.7	L
156	PI 278014	Turkey	7	4.6	3.0	1.1	1.9	L
157	PI 185635	Ghana	7	4.6	3.3	2.2	1.8	L
158	PI 381746	India	7	4.6	3.3	2.5	3.0	F
159	PI 164248	Liberia	7	4.6	3.4	1.7	2.1	L
160	PI 449332	India	7	4.6	3.6	2.4	2.1	F

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
161	PI 221430	Iran	7	4.6	3.6	1.9	1.8	L
162	PI 381725	India	7	4.6	4.1	2.7	3.0	L
163	PI 299378	South Africa	7	4.6	4.4	3.2	3.4	T
164	PI 185636	Ghana	5	4.6	3.4	2.7	2.1	L
165	PI 177328	Turkey	5	4.6	3.4	1.1	1.5	L
166	PI 536544	India	5	4.6	4.2	2.9	3.5	F
167	PI 532664	Zimbabwe	5	4.6	4.2	1.1	1.6	T
168	PI 500308	Zambia	6	4.7	2.2	1.4	1.2	T
169	PI 500338	Zambia	6	4.7	2.8	2.3	1.9	L
170	PI 299379	South Africa	6	4.7	3.0	2.3	1.8	T
171	PI 525086	Egypt	6	4.7	3.2	2.5	2.5	L
172	PI 534590	Syria	6	4.7	3.3	2.9	2.0	L
173	PI 482329	Zimbabwe	6	4.7	3.7	2.5	2.7	L
174	PI 247398	Greece	7	4.7	2.7	2.0	1.5	L
175	PI 381737	India	7	4.7	2.9	1.1	1.6	L
176	PI 482265	Zimbabwe	7	4.7	3.4	2.9	2.9	T
177	PI 526239	Zimbabwe	7	4.7	3.4	2.6	3.1	L
178	PI 532738	Zaire	7	4.7	3.7	2.4	2.9	T

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
179	PI 500342	Zambia	7	4.7	3.9	2.8	3.8	L
180	PI 500316	Zambia	7	4.7	3.9	3.0	3.1	L
181	PI 482269	Zimbabwe	7	4.7	4.0	3.0	3.7	L
182	PI 381753	India	7	4.7	4.1	2.9	3.1	F
183	PI 482348	Zimbabwe	7	4.7	4.3	2.3	2.7	L
184	PI 381742	India	7	4.7	4.3	3.2	3.5	F
185	PI 525088	Egypt	7	4.7	4.4	2.9	3.5	L
186	PI 169241	Turkey	5	4.8	3.4	2.0	1.1	L
187	PI 482271	Zimbabwe	5	4.8	3.8	1.5	3.1	L
188	PI 482292	Zimbabwe	5	4.8	4.0	2.2	3.7	L
189	PI 482370	Zimbabwe	5	4.8	4.4	1.8	1.3	L
190	PI 482250	Zimbabwe	6	4.8	3.5	1.7	1.9	L
191	PI 500324	Zambia	6	4.8	3.5	2.8	2.0	L
192	PI 534533	Syria	6	4.8	3.5	3.1	3.1	L
193	PI 278006	Turkey	6	4.8	3.7	1.7	1.6	L
194	PI 482317	Zimbabwe	6	4.8	4.3	3.2	3.3	L
195	PI 181936	Syria	7	4.9	3.3	1.3	1.5	L
196	PI 494527	Nigeria	7	4.9	3.4	2.2	2.1	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
197	PI 186975	Ghana	7	4.9	3.4	2.4	2.9	L
198	PI 505595	Zambia	7	4.9	3.6	2.5	3.0	L
199	PI 525083	Egypt	7	4.9	3.6	3.2	4.0	T
200	PI 532732	Zimbabwe	7	4.9	3.7	3.4	3.8	L
201	PI 222776	Iran	7	4.9	3.9	2.8	2.7	L
202	PI 271467	India	7	4.9	4.1	2.7	2.9	F
203	PI 183125	India	7	4.9	4.1	2.3	2.3	L
204	PI 271468	India	1	5.0	3.0	-	-	L
205	PI 248178	Zaire	5	5.0	3.4	3.1	3.6	L
206	PI 549159	Mauritania	7	5.0	3.4	1.2	0.8	L
207	PI 482376	Zimbabwe	6	5.0	3.5	1.7	1.8	L
208	PI 596666	South Africa	7	5.0	3.6	1.9	2.3	T
209	PI 559993	Nigeria	7	5.0	3.6	1.9	1.4	L
210	PI 505585	Zambia	7	5.0	3.6	2.8	3.1	L
211	PI 210017	India	5	5.0	3.6	2.2	2.6	L
212	PI 500336	Zambia	6	5.0	3.7	1.8	2.0	L
213	PI 223764	Afghanistan	6	5.0	3.8	2.1	1.6	L
214	PI 217522	Pakistan	6	5.0	3.8	3.1	3.1	F

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
215	PI 457916	Brazil	7	5.0	3.9	3.0	2.9	L
216	PI 482375	Zimbabwe	6	5.0	4.0	1.9	2.2	L
217	PI 381749	India	6	5.0	4.0	2.1	2.8	F
218	PI 559995	Nigeria	7	5.0	4.0	2.4	1.6	L
219	PI 534593	Syria	6	5.0	4.0	1.5	2.0	L
220	PI 275628	Pakistan	7	5.0	4.4	1.8	2.9	L
221	PI 227202	Japan	6	5.0	4.5	3.8	3.8	L
222	PI 540917	Unknown	7	5.0	4.6	2.5	3.4	F
223	Grif 5601	India	5	5.0	5.0	3.2	3.2	F
224	PI 217938	Pakistan	6	5.0	5.8	2.6	2.6	F
225	PI 596668	South Africa	7	5.1	3.9	3.0	3.4	T
226	PI 296335	South Africa	7	5.1	3.9	2.4	3.0	T
227	PI 482274	Zimbabwe	7	5.1	3.9	2.0	2.9	L
228	PI 186490	Nigeria	7	5.1	4.0	3.4	3.8	L
229	PI 482366	Zimbabwe	7	5.1	4.0	2.0	2.7	L
230	PI 560015	Nigeria	7	5.1	4.1	2.5	1.9	L
231	PI 368527	Yugoslavia	7	5.1	4.7	3.4	3.5	L
232	PI 381717	India	6	5.2	3.8	1.7	1.8	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
233	PI 500355	Zambia	6	5.2	3.8	1.5	1.6	T
234	PI 482343	Zimbabwe	6	5.2	4.5	2.4	2.7	L
235	PI 525090	Egypt	6	5.2	4.7	4.3	4.1	L
236	PI 482350	Zimbabwe	5	5.2	3.4	2.4	1.7	L
237	PI 179875	India	5	5.2	4.6	2.9	3.4	L
238	PI 381740	India	5	5.2	4.6	3.4	3.2	L
239	PI 277983	Turkey	9	5.2	3.8	2.6	2.0	L
240	PI 500335	Zambia	7	5.3	3.1	2.8	2.2	L
241	PI 278022	Turkey	7	5.3	3.6	2.1	2.1	L
242	PI 500337	Zambia	7	5.3	3.6	2.1	2.8	L
243	PI 526234	Zimbabwe	7	5.3	3.6	2.4	3.0	L
244	PI 526237	Zimbabwe	7	5.3	3.9	2.1	2.4	L
245	PI 482334	Zimbabwe	7	5.3	4.0	2.4	3.1	T
246	PI 560009	Nigeria	7	5.3	4.1	1.3	1.1	L
247	PI 482359	Zimbabwe	7	5.3	4.1	1.3	1.2	L
248	PI 441722	Brazil	7	5.3	4.3	2.5	3.5	L
249	PI 532723	Zimbabwe	7	5.3	4.3	1.6	2.3	L
250	PI 482304	Zimbabwe	7	5.3	4.3	2.1	2.7	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y]					
			No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
251	PI 482316	Zimbabwe	7	5.3	4.4	2.1	2.4	T
252	PI 500314	Zambia	7	5.3	4.4	1.1	1.9	L
253	PI 500344	Zambia	7	5.3	4.6	2.6	2.7	L
254	PI 482374	Zimbabwe	7	5.3	4.7	3.4	3.5	L
255	PI 512854	Spain	7	5.3	4.7	2.3	2.4	T
256	PI 482294	Zimbabwe	7	5.3	4.9	1.9	1.9	L
257	PI 629105	United States	7	5.3	5.1	2.4	3.0	L
258	PI 500301	Zambia	6	5.3	3.2	2.0	2.0	L
259	PI 296339	South Africa	3	5.3	3.3	3.5	4.9	T
260	PI 500341	Zambia	6	5.3	3.5	0.8	1.0	L
261	PI 244019	South Africa	6	5.3	3.5	2.7	3.5	T
262	PI 273480	Ethiopia	3	5.3	3.7	2.5	2.3	L
263	PI 270143	India	6	5.3	3.8	2.3	3.0	L
264	PI 169300	Turkey	6	5.3	4.2	1.5	1.5	L
265	PI 505604	Zambia	6	5.3	4.2	3.2	3.9	L
266	PI 180426	India	5	5.4	3.4	2.7	1.5	L
267	PI 244018	South Africa	5	5.4	3.8	2.3	3.6	T
268	PI 200732	El Salvador	5	5.4	4.0	1.9	2.2	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
269	PI 172803	Turkey	5	5.4	4.2	1.1	1.6	L
270	PI 172799	Turkey	5	5.4	5.0	3.8	4.3	L
271	PI 319237	Japan	5	5.4	5.4	3.8	3.8	L
272	PI 178874	Turkey	7	5.4	2.9	1.5	1.7	L
273	PI 512385	Spain	7	5.4	3.7	1.7	1.6	T
274	PI 179877	India	7	5.4	4.3	3.2	3.4	L
275	PI 482381	Zimbabwe	7	5.4	4.4	2.9	3.3	L
276	PI 482362	Zimbabwe	7	5.4	4.4	1.9	2.6	L
277	PI 526235	Zimbabwe	7	5.4	4.7	2.7	3.4	L
278	PI 179660	India	7	5.4	4.9	3.6	4.0	L
279	PI 182932	India	6	5.5	3.7	2.9	2.3	L
280	PI 494529	Nigeria	6	5.5	3.8	2.6	1.5	L
281	PI 276445	Jordan	6	5.5	3.8	2.0	1.6	L
282	PI 507860	Hungary	6	5.5	4.2	2.3	2.9	L
283	PI 500352	Zambia	6	5.5	4.2	1.2	2.6	L
284	PI 271778	South Africa	6	5.5	4.7	2.4	3.0	L
285	PI 482346	Zimbabwe	6	5.5	4.7	1.9	2.7	L
286	PI 583809	United States	4	5.5	4.8	1.7	1.7	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
287	PI 485580	Botswana	6	5.5	4.8	3.1	2.9	T
288	PI 288522	India	7	5.6	3.9	2.5	3.0	L
289	PI 482297	Zimbabwe	7	5.6	4.1	2.1	2.4	L
290	PI 559992	Nigeria	7	5.6	4.1	1.4	1.2	L
291	PI 278057	Turkey	7	5.6	4.3	1.3	2.0	L
292	PI 426625	Pakistan	7	5.6	4.6	2.1	2.2	L
293	PI 182935	India	7	5.6	4.7	1.0	1.3	L
294	PI 482314	Zimbabwe	7	5.6	4.9	2.6	3.3	L
295	PI 175656	Turkey	7	5.6	4.9	2.9	2.8	L
296	PI 532817	P.R. China	7	5.6	4.9	2.4	2.8	L
297	PI 595202	United States	7	5.6	5.1	2.1	2.6	L
298	PI 508444	Korea	7	5.6	5.1	3.6	4.1	L
299	PI 183398	India	7	5.6	5.1	3.6	3.3	L
300	PI 274794	Pakistan	7	5.6	5.3	3.3	3.4	L
301	PI 512399	Spain	7	5.6	5.4	2.7	3.3	L
302	PI 482315	Zimbabwe	5	5.6	2.8	1.9	1.8	T
303	PI 296332	South Africa	5	5.6	4.0	2.7	3.1	L
304	PI 169263	Turkey	5	5.6	4.8	3.5	3.2	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
305	PI 357695	Yugoslavia	5	5.6	5.4	2.8	3.5	L
306	PI 271363	India	8	5.6	4.9	2.9	3.6	F
307	PI 482379	Zimbabwe	6	5.7	4.0	2.7	3.2	T
308	PI 534599	Syria	6	5.7	4.3	1.9	1.8	L
309	PI 560013	Nigeria	6	5.7	4.5	1.4	1.0	L
310	PI 195927	Ethiopia	6	5.7	4.7	2.8	3.5	O
311	PI 482275	Zimbabwe	6	5.7	4.7	3.0	3.6	L
312	PI 482335	Zimbabwe	6	5.7	5.2	3.1	3.5	T
313	PI 357663	Yugoslavia	6	5.7	5.3	2.7	3.4	L
314	PI 512388	Spain	6	5.7	4.3	1.9	1.8	L
315	PI 164687	India	6	5.7	4.5	1.4	1.0	L
316	PI 234605	United States	7	5.7	3.9	1.7	1.9	L
317	PI 525087	Egypt	7	5.7	4.0	2.2	1.7	L
318	PI 212596	Afghanistan	7	5.7	4.1	1.6	2.6	L
319	PI 490376	Mali	7	5.7	4.1	2.9	3.0	L
320	PI 174104	Turkey	7	5.7	4.3	1.1	1.0	L
321	PI 534530	Syria	7	5.7	4.4	3.0	3.0	L
322	PI 180275	India	7	5.7	4.6	2.6	3.4	F

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale^{y}					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD^{x} Leaf	SD Stem	Species
323	PI 181938	Syria	7	5.7	4.6	2.1	2.3	L
324	PI 189318	Nigeria	7	5.7	4.7	1.0	1.3	L
325	PI 381734	India	7	5.7	5.1	1.6	2.3	L
326	PI 174812	India	7	5.7	6.1	3.5	3.8	F
327	PI 482279	Zimbabwe	4	5.8	2.8	3.2	2.2	T
328	PI 296337	South Africa	8	5.8	4.0	2.0	2.4	T
329	PI 278010	Turkey	5	5.8	4.2	2.4	3.0	L
330	PI 629103	United States	5	5.8	4.2	2.2	1.6	L
331	PI 181868	Syria	5	5.8	4.8	2.6	2.9	L
332	PI 277279	India	6	5.8	3.5	1.7	3.0	L
333	PI 357698	Yugoslavia	6	5.8	3.8	2.4	2.4	L
334	PI 278046	Turkey	6	5.8	3.8	3.1	2.1	L
335	PI 482373	Zimbabwe	6	5.8	4.5	0.8	0.5	L
336	PI 505589	Zambia	6	5.8	4.7	2.0	2.4	L
337	PI 195928	Ethiopia	6	5.8	4.7	1.9	2.4	L
338	PI 254623	Sudan	6	5.8	4.8	3.1	3.7	L
339	PI 485581	Botswana	6	5.8	5.0	2.2	2.6	T

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
340	PI 277984	Turkey	6	5.8	5.2	2.1	2.7	L
341	PI 482339	Zimbabwe	7	5.9	4.3	1.8	2.1	L
342	PI 254622	Sudan	7	5.9	4.3	2.0	2.7	L
343	PI 183299	India	7	5.9	4.3	1.7	1.7	L
344	PI 192938	P.R. China	7	5.9	4.4	2.0	2.4	L
345	PI 164639	India	7	5.9	4.6	2.2	2.4	L
346	PI 368515	Yugoslavia	7	5.9	4.6	2.2	3.4	L
347	PI 482378	Zimbabwe	7	5.9	4.7	2.3	2.7	L
348	PI 277982	Turkey	7	5.9	4.7	1.9	2.1	L
349	PI 600950	United States	7	5.9	4.7	2.3	2.6	L
350	PI 482345	Zimbabwe	7	5.9	4.9	2.1	2.8	L
351	PI 482357	Zimbabwe	7	5.9	5.0	2.0	4.0	L
352	PI 482337	Zimbabwe	7	5.9	5.0	3.4	4.0	L
353	PI 596669	South Africa	7	5.9	5.0	2.8	3.6	T
354	PI 459075	Botswana	7	5.9	5.1	3.1	3.7	L
355	PI 534597	Syria	7	5.9	5.3	2.2	2.2	L
356	PI 482353	Zimbabwe	7	5.9	5.4	3.0	3.4	L
357	PI 532819	P.R. China	7	5.9	5.6	2.5	3.3	T

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
358	PI 500317	Zambia	7	5.9	6.0	2.7	3.5	L
359	PI 184800	Nigeria	6	6.0	3.5	2.1	1.2	L
360	PI 175654	Turkey	7	6.0	3.7	2.1	1.7	L
361	PI 278051	Turkey	6	6.0	4.0	1.4	1.5	L
362	PI 167219	Turkey	7	6.0	4.3	1.8	2.4	L
363	PI 596665	South Africa	7	6.0	4.3	3.1	2.3	L
364	PI 270525	Israel	5	6.0	4.4	2.3	3.0	L
365	PI 600790	United States	5	6.0	4.4	1.4	0.9	L
366	PI 482253	Zimbabwe	5	6.0	4.4	2.0	2.9	L
367	PI 204689	Turkey	4	6.0	4.5	1.8	1.0	L
368	PI 278044	Turkey	7	6.0	4.6	3.2	3.4	L
369	PI 270524	Israel	6	6.0	4.7	3.2	3.2	L
370	PI 260733	Sudan	7	6.0	4.7	1.8	2.6	L
371	PI 207473	Afghanistan	8	6.0	4.8	2.3	2.3	L
372	PI 179884	India	6	6.0	4.8	2.2	2.4	L
373	PI 482303	Zimbabwe	6	6.0	4.8	2.1	1.9	L
374	PI 381754	India	7	6.0	4.9	2.5	3.2	F
375	PI 167045	Turkey	7	6.0	4.9	2.2	2.5	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
			Mean disease severity on a 0-9 scale[y]					
376	PI 500333	Zambia	7	6.0	4.9	2.0	2.7	L
377	PI 271984	Somalia	7	6.0	4.9	2.3	2.4	L
378	PI 275631	India	7	6.0	5.0	1.2	1.9	L
379	PI 169242	Turkey	6	6.0	5.0	1.5	2.2	L
380	PI 271774	South Africa	5	6.0	5.0	3.7	3.2	L
381	PI 526233	Zimbabwe	7	6.0	5.0	1.8	2.1	L
382	PI 249559	Thailand	7	6.0	5.0	1.8	2.2	L
383	PI 179240	Turkey	7	6.0	5.1	2.4	3.3	L
384	PI 534583	Syria	7	6.0	5.1	2.3	2.2	L
385	PI 278043	Turkey	6	6.0	5.2	2.1	2.2	L
386	PI 167026	Turkey	5	6.0	5.2	2.5	2.9	L
387	PI 277974	Turkey	7	6.0	5.3	1.0	2.2	L
388	PI 629107	United States	7	6.0	5.3	1.9	2.8	L
389	PI 560901	P.R. China	6	6.0	5.3	3.3	3.4	L
390	PI 482330	Zimbabwe	4	6.0	5.5	2.4	2.5	L
391	PI 482263	Zimbabwe	6	6.0	5.5	2.5	2.7	L
392	PI 181935	Syria	7	6.0	5.6	2.3	2.6	L
393	PI 512381	Spain	5	6.0	6.6	2.4	3.3	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
394	PI 169249	Turkey	8	6.1	5.3	1.7	1.8	L
395	PI 234603	United States	7	6.1	3.9	2.0	2.6	L
396	PI 537274	Pakistan	7	6.1	4.1	2.0	2.7	L
397	PI 482365	Zimbabwe	7	6.1	4.1	2.1	2.5	L
398	PI 255662	Afghanistan	7	6.1	4.3	0.7	1.0	L
399	PI 560007	Nigeria	7	6.1	4.4	3.1	2.9	L
400	PI 532624	Zimbabwe	7	6.1	4.4	1.7	1.5	T
401	PI 537269	Pakistan	7	6.1	4.4	1.5	1.9	L
402	PI 251515	Iran	7	6.1	4.6	2.0	2.8	L
403	PI 169245	Turkey	7	6.1	4.7	1.8	2.4	L
404	PI 296341	South Africa	7	6.1	4.7	1.1	0.5	T
405	PI 179878	India	7	6.1	4.7	2.3	2.4	L
406	PI 180276	India	7	6.1	4.9	1.7	2.4	L
407	PI 549163	Chad	7	6.1	4.9	1.6	2.0	L
408	PI 368503	Yugoslavia	7	6.1	5.0	2.7	3.2	L
409	PI 482325	Zimbabwe	7	6.1	5.0	1.8	2.0	L
410	PI 381700	India	7	6.1	5.0	1.6	2.7	L
411	PI 247399	Greece	7	6.1	5.0	2.3	3.1	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
412	PI 500353	Zambia	7	6.1	5.4	2.3	3.7	L
413	PI 274795	Pakistan	7	6.1	5.6	1.1	2.4	L
414	PI 612145	United States	7	6.1	5.6	1.8	2.4	L
415	PI 612471	Korea	7	6.1	5.6	2.5	2.8	L
416	PI 482342	Zimbabwe	7	6.1	5.7	2.0	3.5	T
417	PI 593358	P.R. China	7	6.1	6.3	1.6	1.9	L
418	PI 534594	Syria	6	6.2	4.0	1.7	3.0	L
419	PI 193964	Ethiopia	6	6.2	4.3	2.3	2.9	L
420	PI 227205	Japan	6	6.2	4.3	2.2	2.8	L
421	PI 277971	Turkey	6	6.2	4.3	2.2	2.8	L
422	PI 164636	India	6	6.2	4.3	1.8	2.7	L
423	PI 500319	Zambia	6	6.2	4.5	2.5	3.1	L
424	PI 278015	Turkey	6	6.2	4.5	1.2	0.8	L
425	PI 534595	Syria	6	6.2	4.7	3.2	2.9	L
426	PI 534535	Syria	6	6.2	4.7	1.7	2.4	L
427	PI 612458	Korea	6	6.2	4.8	2.4	3.4	L
428	PI 418762	Afghanistan	6	6.2	5.2	3.4	3.4	L
429	PI 500320	Zambia	6	6.2	5.5	2.4	2.9	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
430	PI 534591	Syria	6	6.2	5.7	1.8	2.0	L
431	PI 500350	Zambia	6	6.2	5.7	3.0	3.3	L
432	PI 482363	Zimbabwe	6	6.2	5.8	2.6	2.8	L
433	PI 220779	Afghanistan	5	6.2	4.4	2.3	2.6	L
434	PI 500306	Zambia	5	6.2	4.6	1.1	3.0	L
435	PI 535947	Cameroon	5	6.2	4.8	2.6	2.9	L
436	PI 331106	Uruguay	5	6.2	5.2	1.9	2.3	L
437	PI 600792	United States	5	6.2	5.8	3.6	3.7	L
438	PI 271773	South Africa	5	6.2	6.2	1.3	2.9	T
439	PI 183300	India	7	6.3	4.4	1.6	2.5	L
440	PI 482367	Zimbabwe	7	6.3	4.7	3.4	2.7	L
441	PI 228238	Israel	7	6.3	4.9	2.5	2.6	L
442	PI 164247	Liberia	7	6.3	4.9	2.8	3.3	L
443	PI 542119	Botswana	7	6.3	5.0	2.4	3.0	T
444	PI 596662	South Africa	7	6.3	5.1	2.1	2.7	T
445	PI 233556	Japan	7	6.3	5.1	2.0	2.9	L
446	PI 271777	South Africa	7	6.3	5.3	1.9	2.8	L
447	PI 526231	Zimbabwe	7	6.3	5.4	1.4	1.6	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
448	PI 270548	Ghana	7	6.3	5.6	1.6	2.8	L
449	PI 266025	Venezuela	7	6.3	5.7	2.4	3.2	L
450	PI 482347	Zimbabwe	7	6.3	5.7	1.9	2.9	L
451	PI 512383	Spain	7	6.3	5.9	3.3	3.4	L
452	PI 378616	Zaire	7	6.3	6.0	2.3	3.1	L
453	PI 163204	India	7	6.3	6.3	2.3	1.9	L
454	PI 226445	Israel	6	6.3	4.2	0.5	1.6	L
455	PI 596667	South Africa	6	6.3	4.5	2.1	2.9	T
456	PI 183124	India	6	6.3	4.7	2.4	3.7	L
457	PI 346787	United States	6	6.3	4.7	2.8	3.6	L
458	PI 482270	Zimbabwe	6	6.3	4.8	2.0	2.5	L
459	PI 212983	India	6	6.3	5.5	1.2	1.2	L
460	Grif 5598	India	6	6.3	5.5	2.3	2.3	L
461	PI 512342	Spain	6	6.3	5.7	2.0	2.7	L
462	PI 172797	Turkey	6	6.3	5.7	2.0	2.9	L
463	PI 254431	Lebanon	6	6.3	5.7	1.5	2.7	L
464	PI 306366	Taiwan	6	6.3	6.2	4.2	4.4	L
465	PI 271466	India	6	6.3	6.3	2.0	2.4	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
466	PI 179234	Turkey	6	6.3	6.5	3.6	4.0	L
467	PI 266015	Venezuela	8	6.4	5.5	2.7	3.2	L
468	PI 169262	Turkey	5	6.4	4.4	1.5	1.9	L
469	PI 254429	Lebanon	5	6.4	4.6	2.7	3.0	L
470	PI 177330	Syria	10	6.4	4.8	1.5	0.6	L
471	PI 379243	Yugoslavia	5	6.4	5.2	2.2	2.9	T
472	PI 525099	Italy	5	6.4	5.4	1.8	3.0	L
473	PI 381739	India	7	6.4	4.4	1.4	2.4	L
474	PI 278048	Turkey	7	6.4	4.4	1.9	1.8	L
475	PI 164709	India	7	6.4	4.4	1.1	1.3	L
476	PI 491265	Zimbabwe	7	6.4	4.6	1.6	2.4	L
477	PI 482327	Zimbabwe	7	6.4	4.7	1.4	2.1	L
478	PI 169279	Turkey	7	6.4	4.7	1.6	2.4	L
479	PI 482305	Zimbabwe	7	6.4	4.7	1.8	2.1	L
480	PI 629108	United States	7	6.4	4.9	2.0	2.2	L
481	PI 164543	India	7	6.4	5.0	1.6	2.2	L
482	PI 212094	Afghanistan	7	6.4	5.0	1.5	2.2	L
483	PI 505586	Zambia	7	6.4	5.1	1.4	2.1	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
484	PI 482267	Zimbabwe	7	6.4	5.4	3.0	3.0	L
485	PI 596676	South Africa	7	6.4	5.4	2.6	3.2	L
486	PI 275632	India	7	6.4	5.4	1.5	1.6	L
487	PI 179880	India	7	6.4	5.4	1.6	2.1	L
488	PI 482313	Zimbabwe	7	6.4	5.6	2.4	2.9	L
489	PI 500346	Zambia	7	6.4	5.6	2.3	3.5	L
490	PI 381736	India	7	6.4	5.7	1.4	1.9	L
491	PI 381716	India	7	6.4	5.7	2.0	2.4	L
492	PI 381701	India	7	6.4	5.9	2.0	2.2	L
493	PI 385964	Kenya	7	6.4	6.0	2.0	3.1	L
494	PI 176499	Turkey	7	6.4	6.0	3.0	3.9	L
495	PI 537271	Pakistan	7	6.4	6.0	2.3	2.4	L
496	PI 505591	Zambia	7	6.4	6.1	2.4	3.2	L
497	PI 593352	P.R. China	7	6.4	6.1	2.4	3.2	L
498	PI 217937	Pakistan	7	6.4	6.3	3.0	3.3	L
499	PI 525094	Egypt	7	6.4	6.6	2.2	2.3	L
500	PI 487476	Israel	7	6.4	6.7	1.7	2.1	L
501	PI 169244	Turkey	6	6.5	4.7	1.9	2.7	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
502	PI 534587	Syria	6	6.5	4.8	0.8	1.6	L
503	PI 357754	Yugoslavia	6	6.5	5.2	2.1	2.3	L
504	PI 278007	Turkey	6	6.5	5.2	1.8	2.0	L
505	PI 164633	India	6	6.5	5.2	1.5	2.0	L
506	PI 381714	India	6	6.5	5.2	1.5	2.0	L
507	PI 326515	Ghana	6	6.5	5.3	3.6	3.4	L
508	PI 500348	Zambia	6	6.5	5.3	1.2	2.4	L
509	PI 357707	Yugoslavia	6	6.5	6.0	2.0	2.8	L
510	PI 164804	India	6	6.5	6.0	1.5	2.4	L
511	PI 279459	Japan	6	6.5	6.2	3.6	3.6	L
512	PI 278001	Turkey	6	6.5	7.5	3.3	3.7	L
513	PI 181740	Lebanon	7	6.6	4.7	0.5	0.8	L
514	PI 482251	Zimbabwe	7	6.6	4.9	2.5	3.0	L
515	PI 278013	Turkey	7	6.6	5.0	1.4	1.9	L
516	PI 277970	Turkey	7	6.6	5.1	1.3	3.0	L
517	PI 254739	Senegal	7	6.6	5.3	1.5	1.9	L
518	PI 179885	India	7	6.6	5.3	1.5	1.9	L
519	PI 193490	Ethiopia	7	6.6	5.3	1.7	1.9	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
520	PI 525085	Egypt	7	6.6	5.4	1.4	2.0	L
521	PI 344395	Iran	7	6.6	5.6	1.9	2.6	L
522	PI 180427	India	7	6.6	5.6	1.5	1.9	L
523	PI 279460	Japan	7	6.6	6.0	2.2	3.3	L
524	PI 435991	P.R. China	7	6.6	6.0	3.3	4.0	L
525	PI 482352	Zimbabwe	7	6.6	6.0	1.8	3.4	L
526	PI 470249	Indonesia	7	6.6	6.0	1.9	3.0	L
527	PI 512392	Spain	7	6.6	6.1	3.1	3.3	L
528	PI 482281	Zimbabwe	7	6.6	6.3	2.6	3.0	L
529	PI 271775	South Africa	7	6.6	6.3	1.8	2.1	L
530	PI 482310	Zimbabwe	7	6.6	6.4	3.5	3.6	L
531	PI 482268	Zimbabwe	7	6.6	6.6	2.0	3.0	L
532	PI 176495	Turkey	7	6.6	6.6	3.0	3.3	L
533	PI 169266	Turkey	7	6.6	6.7	1.9	2.9	L
534	PI 271988	Somalia	10	6.6	4.8	1.3	2.3	L
535	PI 532668	Zimbabwe	5	6.6	5.2	1.1	0.4	T
536	PI 169243	Turkey	5	6.6	5.4	0.9	2.2	L
537	PI 512375	Spain	5	6.6	5.8	2.4	3.3	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
538	PI 254430	Lebanon	5	6.6	6.0	0.9	1.7	L
539	PI 295848	South Africa	5	6.6	6.0	1.7	1.7	L
540	PI 271986	Somalia	5	6.6	6.4	3.2	4.0	L
541	PI 379251	Yugoslavia	6	6.7	3.3	1.8	1.0	L
542	PI 381696	India	6	6.7	4.3	1.9	1.8	L
543	PI 534585	Syria	6	6.7	4.8	1.6	2.3	L
544	PI 227206	Japan	6	6.7	4.8	1.9	2.4	L
545	PI 189316	Nigeria	6	6.7	5.2	0.8	1.9	L
546	PI 307749	Philippines	6	6.7	5.2	2.9	3.5	L
547	PI 276444	Jordan	6	6.7	5.3	2.1	2.3	L
548	PI 357753	Yugoslavia	6	6.7	5.5	3.4	3.3	L
549	PI 494816	Zambia	6	6.7	5.7	1.5	2.7	L
550	PI 357675	Yugoslavia	6	6.7	5.8	1.5	1.8	L
551	PI 508443	Korea	9	6.7	5.9	1.3	1.8	L
552	PI 357672	Yugoslavia	6	6.7	6.0	1.6	2.4	L
553	PI 227203	Japan	6	6.7	6.0	2.4	3.0	L
554	PI 177322	Turkey	6	6.7	6.0	2.1	2.4	L
555	PI 169267	Turkey	6	6.7	6.2	3.5	3.6	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
556	PI 507858	Hungary	6	6.7	6.2	3.4	3.4	L
557	PI 270145	Greece	6	6.7	6.3	2.9	3.6	L
558	PI 299563	South Africa	7	6.7	4.3	1.0	1.9	L
559	PI 629101	P.R. China	7	6.7	4.6	1.3	2.1	L
560	PI 525096	Egypt	7	6.7	4.6	2.2	2.2	L
561	PI 381698	India	7	6.7	4.7	2.0	2.4	L
562	PI 278004	Turkey	7	6.7	5.0	1.3	2.3	L
563	PI 274785	India	7	6.7	5.1	1.9	3.1	L
564	PI 482371	Zimbabwe	7	6.7	5.3	1.6	2.6	L
565	PI 526238	Zimbabwe	7	6.7	5.4	1.3	1.6	L
566	PI 505935	Zambia	7	6.7	5.4	1.0	2.6	L
567	PI 458738	Paraguay	7	6.7	5.4	2.0	2.5	L
568	PI 277973	Turkey	7	6.7	5.6	2.4	3.2	L
569	PI 482272	Zimbabwe	7	6.7	5.7	2.4	3.1	L
570	PI 482309	Zimbabwe	7	6.7	5.7	1.7	3.0	T
571	PI 173670	Turkey	7	6.7	5.7	1.6	1.9	L
572	PI 173669	Turkey	7	6.7	5.7	3.2	3.1	L
573	PI 505594	Zambia	7	6.7	5.7	1.8	2.4	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
574	PI 189317	Nigeria	7	6.7	5.7	2.1	2.5	L
575	PI 512405	Spain	7	6.7	5.7	1.4	2.8	L
576	PI 593349	P.R. China	7	6.7	5.7	2.2	3.1	L
577	Grif 1730	P.R. China	7	6.7	5.9	1.4	1.5	L
578	PI 505592	Zambia	7	6.7	5.9	2.7	3.0	L
579	PI 179242	Iraq	7	6.7	5.9	2.4	2.8	L
580	PI 537471	Spain	7	6.7	5.9	2.5	2.9	L
581	PI 278009	Turkey	7	6.7	5.9	1.0	1.7	L
582	PI 512395	Spain	7	6.7	5.9	1.3	1.5	L
583	PI 288232	Egypt	7	6.7	5.9	1.9	2.3	L
584	PI 512833	Spain	7	6.7	5.9	2.4	2.5	L
585	PI 482296	Zimbabwe	7	6.7	6.0	1.8	2.1	L
586	PI 482344	Zimbabwe	7	6.7	6.0	2.8	3.3	L
587	PI 476328	Soviet Union	7	6.7	6.0	3.1	3.1	L
588	PI 254428	Lebanon	7	6.7	6.1	1.5	1.6	L
589	PI 526232	Zimbabwe	7	6.7	6.3	2.1	2.6	L
590	PI 379225	Yugoslavia	7	6.7	6.3	1.6	1.7	L
591	PI 165451	Mexico	7	6.7	6.4	2.4	3.6	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
592	PI 482380	Zimbabwe	7	6.7	6.4	3.3	3.6	L
593	PI 596677	South Africa	7	6.7	6.4	2.2	2.6	T
594	PI 494819	Zambia	7	6.7	6.7	1.3	2.1	L
595	PI 357658	Yugoslavia	7	6.7	6.9	1.9	2.9	L
596	PI 379231	Yugoslavia	7	6.7	6.9	2.4	3.1	L
597	PI 219906	Afghanistan	7	6.7	7.4	1.5	2.8	L
598	PI 183023	India	4	6.8	4.3	2.5	2.2	L
599	PI 179883	India	5	6.8	4.6	1.3	0.9	L
600	PI 229806	United States	5	6.8	4.8	2.2	2.9	L
601	PI 179662	India	5	6.8	5.2	1.1	1.5	L
602	PI 482284	Zimbabwe	5	6.8	5.6	2.2	1.9	L
603	PI 482354	Zimbabwe	5	6.8	5.8	1.5	1.8	L
604	PI 344066	Turkey	5	6.8	6.0	3.8	3.7	L
605	PI 179661	India	5	6.8	6.8	1.8	2.0	L
606	PI 226459	Iran	6	6.8	4.5	0.8	1.5	L
607	PI 248774	Namibia	6	6.8	5.3	2.0	3.4	T
608	PI 183218	Egypt	6	6.8	5.5	2.1	2.9	L
609	PI 314178	Soviet Union	6	6.8	5.5	3.5	3.3	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
610	PI 164665	India	6	6.8	6.0	1.3	2.4	L
611	PI 593377	P.R. China	6	6.8	6.3	1.3	2.1	L
612	PI 470248	Indonesia	6	6.8	6.3	1.2	2.3	L
613	PI 211013	Afghanistan	6	6.8	6.3	1.5	2.1	L
614	PI 368528	Yugoslavia	6	6.8	6.5	2.7	2.8	L
615	PI 182933	India	6	6.8	6.5	2.4	2.3	L
616	PI 227204	Japan	6	6.8	6.5	2.0	3.2	L
617	PI 381715	India	6	6.8	6.7	1.6	2.1	L
618	PI 296334	South Africa	6	6.8	6.8	1.3	1.8	T
619	PI 176912	Turkey	6	6.8	6.8	2.6	3.7	L
620	PI 207472	Afghanistan	6	6.8	6.8	2.3	3.4	L
621	PI 212209	Greece	6	6.8	6.8	1.0	1.8	L
622	PI 500321	Zambia	6	6.8	7.3	2.0	2.6	L
623	PI 368513	Yugoslavia	7	6.9	4.1	2.1	3.1	L
624	PI 612474	Korea	7	6.9	4.6	1.8	3.0	L
625	PI 482255	Zimbabwe	7	6.9	5.4	2.0	2.8	L
626	PI 525095	Egypt	7	6.9	5.4	1.8	2.0	L
627	PI 494815	Zambia	7	6.9	5.4	1.9	2.7	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
628	PI 464872	P.R. China	7	6.9	5.6	1.8	2.7	L
629	PI 482320	Zimbabwe	7	6.9	5.6	1.2	1.9	L
630	PI 593348	P.R. China	7	6.9	5.6	1.1	1.4	L
631	PI 254743	Senegal	7	6.9	5.6	2.0	2.1	L
632	PI 279456	Japan	7	6.9	5.7	2.3	2.8	L
633	PI 211850	Iran	7	6.9	5.7	1.7	2.4	L
634	PI 288317	India	7	6.9	5.7	1.3	2.3	L
635	PI 482306	Zimbabwe	7	6.9	5.7	1.3	2.8	L
636	PI 176905	Turkey	7	6.9	5.9	1.9	2.6	L
637	PI 381708	India	7	6.9	5.9	1.8	2.3	L
638	PI 500309	Zambia	7	6.9	6.0	1.6	2.5	L
639	PI 482340	Zimbabwe	7	6.9	6.0	1.9	3.1	L
640	PI 164146	India	7	6.9	6.1	2.0	2.7	L
641	PI 512343	Spain	7	6.9	6.4	2.5	3.3	L
642	PI 512366	Spain	7	6.9	6.4	3.1	3.3	L
643	PI 388021	India	7	6.9	6.6	0.7	1.9	L
644	PI 482331	Zimbabwe	7	6.9	6.6	1.8	2.3	T
645	PI 596670	South Africa	7	6.9	6.7	2.0	2.4	T

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
646	PI 500310	Zambia	7	6.9	6.7	1.7	2.5	L
647	PI 507867	Hungary	7	6.9	6.9	1.5	2.0	L
648	PI 368530	Yugoslavia	7	6.9	6.9	2.3	2.9	L
649	PI 169277	Turkey	8	6.9	5.8	2.9	2.9	L
650	PI 357682	Yugoslavia	8	6.9	6.0	1.5	2.1	L
651	PI 632751	Namibia	2	7.0	4.0	1.4	1.4	L
652	PI 255137	South Africa	3	7.0	5.0	1.0	0.0	T
653	PI 596682	South Africa	1	7.0	5.0	-	-	T
654	PI 183022	India	5	7.0	5.0	1.2	0.7	L
655	PI 271767	South Africa	1	7.0	5.0	-	-	T
656	PI 226506	Iran	6	7.0	5.2	1.4	1.0	L
657	PI 534596	Syria	6	7.0	5.2	1.5	2.6	L
658	PI 169286	Turkey	7	7.0	5.3	1.3	1.7	L
659	PI 179241	Iraq	7	7.0	5.3	1.3	3.2	L
660	PI 169233	Turkey	6	7.0	5.3	0.9	2.6	L
661	PI 208740	Cuba	6	7.0	5.5	1.9	2.9	L
662	PI 512394	Spain	7	7.0	5.6	1.9	3.3	L
663	PI 277972	Turkey	7	7.0	5.6	2.0	2.8	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
664	PI 431579	India	7	7.0	5.7	1.5	2.5	L
665	PI 482266	Zimbabwe	7	7.0	5.7	1.5	2.5	L
666	PI 223765	Afghanistan	7	7.0	5.7	2.4	2.8	L
667	PI 593384	P.R. China	7	7.0	5.7	1.3	2.9	L
668	PI 217939	Pakistan	7	7.0	5.7	2.5	3.4	L
669	PI 172800	Turkey	7	7.0	5.7	1.0	2.4	L
670	PI 279458	Japan	8	7.0	5.8	1.1	1.5	L
671	PI 307750	Philippines	6	7.0	5.8	2.7	3.0	L
672	PI 534584	Syria	6	7.0	5.8	1.4	1.8	L
673	PI 420320	Italy	7	7.0	5.9	2.1	3.1	L
674	PI 596671	South Africa	7	7.0	5.9	1.2	1.7	T
675	PI 307748	Philippines	7	7.0	5.9	1.2	2.2	L
676	PI 357740	Yugoslavia	7	7.0	6.0	1.9	2.2	L
677	PI 179886	India	7	7.0	6.0	2.8	3.3	L
678	PI 182175	Turkey	7	7.0	6.0	3.2	3.3	L
679	PI 502318	Uzbekistan	7	7.0	6.0	2.0	3.0	L
680	PI 629102	United States	6	7.0	6.0	1.1	2.8	L
681	PI 536450	Maldives	7	7.0	6.0	2.1	2.9	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
682	PI 490382	Mali	6	7.0	6.0	0.0	1.7	L
683	Grif 12336	P.R. China	7	7.0	6.1	3.1	3.3	L
684	PI 270140	India	7	7.0	6.1	1.5	2.0	L
685	PI 536446	Maldives	7	7.0	6.1	2.4	2.6	L
686	PI 512364	Spain	7	7.0	6.1	1.7	2.0	L
687	PI 482295	Zimbabwe	6	7.0	6.2	1.3	1.8	L
688	PI 537277	Pakistan	5	7.0	6.2	2.3	2.7	O
689	PI 512379	Spain	5	7.0	6.2	1.2	1.6	L
690	PI 176498	Turkey	7	7.0	6.3	1.7	2.6	L
691	PI 169255	Turkey	7	7.0	6.3	1.2	2.8	L
692	PI 525097	Egypt	7	7.0	6.3	2.0	2.2	L
693	PI 368494	Yugoslavia	7	7.0	6.3	1.3	1.5	L
694	PI 169290	Turkey	7	7.0	6.3	1.9	2.4	L
695	PI 278016	Turkey	6	7.0	6.3	1.3	2.4	L
696	PI 176489	Turkey	6	7.0	6.3	2.2	3.3	L
697	PI 271779	South Africa	5	7.0	6.4	1.4	2.6	T
698	PI 476324	Soviet Union	5	7.0	6.4	1.2	1.9	L
699	PI 167222	Turkey	7	7.0	6.4	1.6	2.5	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
700	PI 427298	India	7	7.0	6.4	2.3	3.4	F
701	PI 271752	Ghana	6	7.0	6.5	1.7	2.9	L
702	PI 381747	India	5	7.0	6.6	2.1	2.9	F
703	PI 357693	Yugoslavia	5	7.0	6.6	1.2	2.3	L
704	PI 211011	Afghanistan	6	7.0	6.7	2.6	3.6	L
705	PI 532813	P.R. China	7	7.0	6.7	2.5	3.1	L
706	PI 537266	Pakistan	7	7.0	6.7	1.6	2.1	L
707	PI 612461	Korea	7	7.0	6.7	1.4	2.2	L
708	PI 593346	P.R. China	5	7.0	6.8	3.9	3.9	L
709	PI 593381	P.R. China	6	7.0	6.8	2.2	2.6	L
710	PI 593368	P.R. China	5	7.0	7.0	0.7	1.4	L
711	PI 542118	Botswana	2	7.0	7.0	2.8	2.8	T
712	PI 254736	Senegal	7	7.0	7.1	3.3	3.5	L
713	PI 593388	P.R. China	6	7.0	7.2	1.8	2.2	L
714	PI 475746	Paraguay	6	7.0	7.3	0.0	2.9	L
715	PI 357742	Yugoslavia	1	7.0	9.0	-	-	L
716	PI 500304	Zambia	8	7.1	5.8	1.0	1.4	L
717	PI 295842	South Africa	7	7.1	5.1	2.0	1.1	T

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
718	PI 525093	Egypt	7	7.1	5.1	1.6	2.0	L
719	PI 482293	Zimbabwe	7	7.1	5.3	2.5	3.4	T
720	PI 593344	P.R. China	7	7.1	5.3	0.9	1.8	L
721	PI 222710	Iran	7	7.1	5.6	0.9	1.6	L
722	PI 222711	Iran	7	7.1	5.7	1.6	2.5	L
723	PI 163202	India	7	7.1	5.7	2.0	2.1	L
724	PI 481871	Sudan	7	7.1	5.7	1.5	2.4	L
725	PI 222137	Algeria	7	7.1	5.9	1.1	2.3	L
726	PI 182183	Turkey	7	7.1	5.9	1.7	1.7	L
727	PI 534598	Syria	7	7.1	6.0	0.9	2.1	L
728	PI 525098	Egypt	7	7.1	6.0	1.7	2.4	L
729	PI 378615	Zaire	7	7.1	6.1	1.8	2.3	L
730	PI 368510	Yugoslavia	7	7.1	6.1	1.1	2.3	L
731	PI 537273	Pakistan	7	7.1	6.1	1.5	2.0	L
732	PI 181741	Lebanon	7	7.1	6.1	1.8	2.3	L
733	PI 173668	Turkey	7	7.1	6.3	1.6	2.0	L
734	PI 164708	India	7	7.1	6.4	1.6	1.8	L
735	PI 632752	United States	7	7.1	6.4	1.2	1.8	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
			Mean disease severity on a 0-9 scale[y]					
736	PI 381712	India	7	7.1	6.4	1.3	2.0	L
737	PI 222715	Iran	7	7.1	6.4	1.7	2.5	L
738	PI 171582	Turkey	7	7.1	6.4	2.9	3.3	L
739	PI 277989	Turkey	7	7.1	6.4	1.6	1.8	L
740	PI 612457	Korea	7	7.1	6.6	1.8	2.6	L
741	Grif 1734	P.R. China	7	7.1	6.6	1.5	2.4	L
742	PI 211917	Iran	7	7.1	6.6	2.4	2.9	L
743	PI 345543	Ukraine	7	7.1	6.6	1.9	2.6	L
744	PI 482256	Zimbabwe	7	7.1	6.7	1.7	2.4	L
745	PI 163574	Guatemala	7	7.1	6.7	3.2	3.4	L
746	PI 482351	Zimbabwe	7	7.1	6.7	2.0	2.4	L
747	PI 357721	Yugoslavia	7	7.1	6.9	2.0	2.9	L
748	PI 368504	Yugoslavia	7	7.1	7.0	1.2	2.0	L
749	Grif 14199	India	7	7.1	7.1	1.5	2.3	L
750	PI 169251	Turkey	6	7.2	4.2	1.7	1.2	L
751	PI 181937	Syria	6	7.2	5.2	1.9	2.0	L
752	PI 612463	Korea	6	7.2	5.8	1.6	2.6	L
753	PI 490386	Mali	6	7.2	5.8	1.7	2.6	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
754	PI 512401	Spain	6	7.2	6.0	2.5	3.5	L
755	PI 177326	Turkey	6	7.2	6.0	0.8	2.1	L
756	PI 536463	Maldives	6	7.2	6.0	1.3	2.4	L
757	PI 216029	India	6	7.2	6.2	0.8	1.8	L
758	PI 357685	Yugoslavia	6	7.2	6.2	1.0	1.6	L
759	PI 482289	Zimbabwe	6	7.2	6.2	2.1	2.3	L
760	Grif 5597	India	6	7.2	6.3	1.3	2.7	L
761	PI 438675	Mexico	6	7.2	6.5	1.3	2.7	L
762	PI 381694	India	6	7.2	6.7	3.1	3.5	L
763	PI 526236	Zimbabwe	6	7.2	7.0	2.2	2.5	L
764	PI 381722	India	6	7.2	7.2	2.1	2.1	L
765	PI 500305	Zambia	6	7.2	7.3	1.6	2.6	L
766	PI 593340	P.R. China	6	7.2	7.8	1.6	1.8	L
767	Grif 12335	P.R. China	6	7.2	8.0	1.3	2.0	L
768	Grif 5599	India	5	7.2	4.6	0.4	0.9	L
769	PI 181743	Lebanon	5	7.2	5.2	1.1	2.5	L
770	PI 177331	Syria	5	7.2	5.4	1.8	2.5	L
771	PI 512362	Spain	5	7.2	6.0	1.1	1.7	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
772	PI 556995	United States	5	7.2	6.0	1.8	3.0	L
773	PI 357738	Yugoslavia	5	7.2	6.2	1.8	2.7	L
774	PI 379230	Yugoslavia	5	7.2	6.4	2.0	3.6	L
775	PI 534588	Syria	5	7.2	6.6	1.1	2.2	L
776	PI 612470	Korea	5	7.2	6.6	1.1	2.2	L
777	PI 169289	Turkey	5	7.2	6.6	1.1	2.6	L
778	Grif 1728	P.R. China	5	7.2	6.8	1.1	2.3	L
779	PI 596656	South Africa	5	7.2	6.8	2.0	3.0	T
780	PI 512377	Spain	4	7.3	5.8	1.5	2.5	L
781	PI 357678	Yugoslavia	8	7.3	6.0	2.1	2.1	L
782	PI 490379	Mali	8	7.3	6.6	1.8	2.0	L
783	PI 271770	South Africa	4	7.3	6.8	2.1	2.6	T
784	PI 176921	Turkey	7	7.3	5.4	1.5	1.8	L
785	PI 502319	Uzbekistan	7	7.3	5.6	1.4	1.8	L
786	PI 193963	Ethiopia	7	7.3	5.6	1.3	1.9	L
787	PI 271981	Somalia	7	7.3	5.6	2.5	2.8	L
788	PI 612472	Korea	7	7.3	5.7	0.8	1.8	L
789	PI 381721	India	7	7.3	5.9	0.5	1.6	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
790	PI 378617	Zaire	7	7.3	5.9	0.8	1.6	L
791	PI 482349	Zimbabwe	7	7.3	5.9	1.8	3.2	L
792	PI 438674	Mexico	7	7.3	5.9	1.0	2.3	L
793	PI 169256	Turkey	7	7.3	6.0	1.7	2.9	L
794	PI 379237	Yugoslavia	7	7.3	6.0	2.1	2.2	L
795	PI 379254	Yugoslavia	7	7.3	6.0	1.4	2.1	L
796	PI 269464	Pakistan	7	7.3	6.0	1.5	2.4	L
797	PI 482285	Zimbabwe	7	7.3	6.1	1.5	2.3	L
798	PI 512339	Spain	7	7.3	6.1	1.6	2.3	L
799	PI 593341	P.R. China	7	7.3	6.1	1.3	2.3	L
800	PI 593370	P.R. China	7	7.3	6.1	2.1	3.0	L
801	PI 482287	Zimbabwe	7	7.3	6.1	2.8	3.8	L
802	PI 169254	Turkey	7	7.3	6.1	1.4	2.0	L
803	PI 270549	Ghana	7	7.3	6.3	1.6	2.6	L
804	PI 500343	Zambia	7	7.3	6.3	1.9	2.2	L
805	PI 593355	P.R. China	7	7.3	6.3	2.1	2.8	L
806	PI 593347	P.R. China	7	7.3	6.3	1.1	2.2	L
807	PI 169278	Turkey	7	7.3	6.4	1.4	2.5	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
808	PI 270550	Ghana	7	7.3	6.4	1.7	2.6	L
809	PI 482323	Zimbabwe	7	7.3	6.4	0.8	1.9	L
810	PI 632753	United States	7	7.3	6.4	1.9	2.8	L
811	PI 278041	Turkey	7	7.3	6.6	1.0	2.3	L
812	PI 222778	Iran	7	7.3	6.6	1.4	2.4	L
813	PI 595218	United States	7	7.3	6.6	1.7	2.3	L
814	PI 169252	Turkey	7	7.3	6.6	1.4	1.9	L
815	PI 612469	Korea	7	7.3	6.6	1.7	2.4	L
816	PI 458739	Paraguay	7	7.3	6.7	2.2	3.2	L
817	PI 164634	India	7	7.3	6.7	1.3	2.1	L
818	PI 508446	Korea	7	7.3	6.7	1.3	2.4	L
819	Grif 1733	P.R. China	7	7.3	6.7	1.7	2.4	L
820	PI 242906	Afghanistan	7	7.3	6.7	1.5	2.2	L
821	PI 525091	Egypt	7	7.3	6.9	1.4	2.0	L
822	PI 357702	Yugoslavia	7	7.3	6.9	1.0	1.7	L
823	PI 512345	Spain	7	7.3	6.9	3.3	3.4	L
824	PI 177329	Turkey	7	7.3	6.9	2.9	3.4	L
825	PI 593350	P.R. China	7	7.3	7.0	0.8	2.0	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
826	Grif 1731	P.R. China	7	7.3	7.1	1.9	2.0	L
827	PI 182178	Turkey	7	7.3	7.1	3.3	3.5	L
828	PI 379228	Yugoslavia	7	7.3	7.3	2.5	3.1	L
829	PI 593386	P.R. China	7	7.3	7.3	1.8	2.4	L
830	PI 357734	Yugoslavia	7	7.3	8.4	2.1	1.5	L
831	PI 593380	P.R. China	6	7.3	5.7	0.8	1.6	L
832	PI 273479	Ethiopia	6	7.3	5.7	0.5	1.6	L
833	PI 325248	Soviet Union	6	7.3	5.7	1.6	3.7	L
834	PI 415095	Honduras	6	7.3	6.0	1.4	2.4	L
835	PI 270306	Philippines	6	7.3	6.0	1.9	2.4	L
836	PI 494820	Zambia	6	7.3	6.0	1.5	2.4	L
837	PI 277987	Turkey	6	7.3	6.0	1.6	2.4	L
838	Grif 5600	India	6	7.3	6.2	1.0	2.4	L
839	PI 207471	Afghanistan	3	7.3	6.3	1.5	2.3	L
840	PI 169261	Turkey	6	7.3	6.3	0.8	2.1	L
841	PI 381706	India	6	7.3	6.5	1.6	2.2	L
842	PI 270551	Ghana	6	7.3	6.7	0.8	2.0	L
843	PI 512348	Spain	6	7.3	6.7	1.8	2.7	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
844	PI 543209	Bolivia	6	7.3	6.8	1.9	2.9	L
845	PI 612466	Korea	6	7.3	7.0	2.3	3.3	L
847	PI 200733	Guatemala	6	7.3	7.0	1.6	2.8	L
848	PI 593390	P.R. China	6	7.3	7.0	2.9	3.3	L
849	PI 179879	India	6	7.3	7.0	1.0	1.7	L
850	PI 612460	Korea	6	7.3	7.2	2.3	2.4	L
851	PI 278056	Turkey	6	7.3	7.3	0.8	2.0	L
852	PI 500315	Zambia	6	7.3	7.3	1.9	2.7	L
853	PI 279462	Japan	6	7.3	7.5	1.6	2.5	L
854	PI 164685	India	6	7.3	7.5	1.5	2.3	L
855	PI 175659	Turkey	6	7.3	7.5	2.7	2.5	L
856	PI 381713	India	8	7.4	6.1	1.6	2.8	L
857	PI 534531	Syria	5	7.4	5.6	0.5	0.9	L
858	PI 270546	Ghana	5	7.4	5.6	2.1	3.3	L
859	PI 183673	Turkey	5	7.4	5.6	0.5	0.9	L
860	PI 278050	Turkey	5	7.4	5.6	1.8	3.3	L
861	PI 183123	India	5	7.4	5.8	1.1	1.8	L
862	PI 370432	Yugoslavia	10	7.4	6.0	1.4	1.6	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
863	PI 164550	India	5	7.4	6.0	1.1	2.8	L
864	PI 512390	Spain	5	7.4	6.2	2.3	3.3	L
865	PI 270144	Greece	5	7.4	6.4	1.5	1.9	L
866	PI 505590	Zambia	5	7.4	6.6	1.8	2.5	L
867	PI 357673	Yugoslavia	5	7.4	6.8	2.6	3.2	L
868	PI 381718	India	5	7.4	7.2	2.3	2.5	L
869	PI 179236	Turkey	5	7.4	7.2	1.7	2.5	L
870	PI 164570	India	5	7.4	7.4	0.9	2.2	L
871	PI 278055	Turkey	5	7.4	7.4	2.1	3.6	L
872	PI 368512	Yugoslavia	5	7.4	7.4	1.1	2.2	L
873	PI 596658	South Africa	7	7.4	4.9	0.5	0.9	T
874	PI 271983	Somalia	7	7.4	5.6	2.1	2.8	L
875	PI 532810	P.R. China	7	7.4	5.9	1.4	2.3	L
876	PI 500347	Zambia	7	7.4	5.9	1.6	2.3	L
877	PI 255139	South Africa	7	7.4	6.0	1.3	3.3	L
878	PI 556994	United States	7	7.4	6.0	1.0	1.0	L
879	PI 525100	Italy	7	7.4	6.0	1.8	2.2	L
880	PI 277997	Turkey	7	7.4	6.1	1.8	2.5	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
881	PI 277986	Turkey	7	7.4	6.3	1.9	2.6	L
882	PI 536459	Maldives	7	7.4	6.3	1.0	1.9	L
883	PI 512347	Spain	7	7.4	6.4	1.3	2.5	L
884	PI 593376	P.R. China	7	7.4	6.4	1.4	2.5	L
885	PI 487458	Venezuela	7	7.4	6.4	1.0	2.0	L
886	PI 271987	Somalia	7	7.4	6.4	1.6	2.5	L
887	PI 254735	Senegal	7	7.4	6.4	1.0	1.8	L
888	PI 612459	Korea	7	7.4	6.4	1.3	1.9	L
889	PI 476329	Soviet Union	7	7.4	6.6	1.5	2.3	L
890	PI 165002	Turkey	7	7.4	6.6	1.1	1.6	L
891	PI 357659	Yugoslavia	7	7.4	6.6	1.1	2.3	L
892	PI 277994	Turkey	7	7.4	6.7	1.1	2.2	L
893	PI 381695	India	7	7.4	6.9	1.4	2.2	L
894	PI 244017	South Africa	7	7.4	6.9	1.8	3.1	L
895	PI 612465	Korea	7	7.4	6.9	1.3	2.5	L
896	PI 368511	Yugoslavia	7	7.4	6.9	1.4	2.0	L
897	PI 249010	Nigeria	7	7.4	6.9	1.6	2.0	L
898	PI 612464	Korea	7	7.4	7.0	1.3	1.9	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
899	PI 278020	Turkey	7	7.4	7.0	1.5	1.9	L
900	PI 169260	Turkey	7	7.4	7.1	1.3	2.0	L
901	PI 537468	Spain	7	7.4	7.1	1.7	2.3	L
902	PI 357716	Yugoslavia	7	7.4	7.3	1.1	1.7	L
903	PI 345545	Ukraine	7	7.4	7.3	3.3	3.4	L
904	PI 246029	Chile	7	7.4	7.4	1.4	1.8	L
905	PI 357694	Yugoslavia	7	7.4	7.9	1.1	2.0	L
906	PI 534532	Syria	9	7.4	5.3	0.9	1.8	L
907	PI 307609	Nigeria	9	7.4	6.9	2.2	2.9	L
908	PI 542121	Botswana	2	7.5	5.0	0.7	0.0	L
909	PI 482291	Zimbabwe	6	7.5	5.7	1.0	2.1	L
910	PI 295850	South Africa	6	7.5	5.7	1.2	1.6	T
911	PI 470247	Indonesia	6	7.5	5.7	2.1	3.3	L
912	PI 357709	Yugoslavia	6	7.5	6.0	1.2	2.4	L
913	PI 490378	Mali	6	7.5	6.0	1.0	2.1	L
914	PI 183126	India	6	7.5	6.0	1.5	2.4	L
915	PI 357703	Yugoslavia	6	7.5	6.2	1.8	2.3	L
916	PI 593371	P.R. China	6	7.5	6.2	1.0	2.3	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
917	PI 479704	United States	8	7.5	6.3	1.8	2.7	L
918	PI 512382	Spain	6	7.5	6.3	2.1	3.3	L
919	PI 175665	Turkey	6	7.5	6.3	1.2	2.4	L
920	PI 271750	Ghana	6	7.5	6.3	1.0	2.4	L
921	PI 482280	Zimbabwe	6	7.5	6.5	1.2	2.2	L
922	PI 177321	Turkey	6	7.5	6.5	1.9	2.9	L
923	PI 368514	Yugoslavia	6	7.5	6.5	2.1	2.9	L
924	PI 512400	Spain	6	7.5	6.8	1.6	2.6	L
925	PI 169282	Turkey	6	7.5	6.8	1.2	2.4	L
926	PI 542115	Botswana	6	7.5	6.8	1.5	1.8	L
927	PI 278033	Turkey	6	7.5	6.8	1.5	2.6	L
928	PI 482261	Zimbabwe	6	7.5	7.0	0.8	2.2	T
929	PI 222184	Afghanistan	6	7.5	7.0	1.4	2.2	L
930	PI 357728	Yugoslavia	6	7.5	7.0	1.2	2.2	L
931	PI 169268	Turkey	6	7.5	7.0	1.5	2.2	L
932	PI 270141	India	6	7.5	7.0	1.8	2.2	L
933	PI 179876	India	6	7.5	7.2	1.6	2.0	L
934	PI 512331	P.R. China	6	7.5	7.2	1.5	2.0	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
935	PI 174107	Turkey	6	7.5	7.2	1.5	2.0	L
936	PI 368493	Yugoslavia	6	7.5	7.2	1.8	2.2	L
937	PI 629110	United States	6	7.5	7.3	1.5	2.0	L
938	PI 169287	Turkey	6	7.5	7.3	1.4	2.0	L
939	PI 296342	South Africa	2	7.5	7.5	2.1	2.1	T
940	PI 379250	Yugoslavia	6	7.5	7.8	1.4	1.3	L
941	PI 193965	Ethiopia	6	7.5	8.3	1.2	1.6	L
942	PI 512363	Spain	7	7.6	5.4	1.1	1.8	L
943	PI 629104	Syria	7	7.6	5.7	1.3	1.5	L
944	PI 525089	Egypt	7	7.6	5.7	1.0	1.7	L
945	PI 438677	Mexico	7	7.6	5.9	1.1	1.6	L
946	PI 368522	Yugoslavia	7	7.6	6.0	1.3	2.2	L
947	PI 512393	Spain	7	7.6	6.0	0.8	1.4	L
948	PI 482254	Zimbabwe	7	7.6	6.1	1.4	2.0	L
949	PI 169250	Turkey	7	7.6	6.1	1.1	2.9	L
950	PI 381697	India	7	7.6	6.1	1.3	2.2	L
951	PI 596659	South Africa	7	7.6	6.3	1.8	2.8	T
952	PI 370018	India	7	7.6	6.6	1.4	1.9	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y]					
			No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
953	PI 169293	Turkey	7	7.6	6.6	0.8	2.1	L
954	PI 632754	Bulgaria	7	7.6	6.6	2.0	3.2	L
955	PI 593357	P.R. China	7	7.6	6.7	1.5	2.2	L
956	PI 271982	Somalia	7	7.6	6.7	1.5	3.1	L
957	PI 254624	Sudan	7	7.6	6.7	1.4	2.4	L
958	PI 518611	Soviet Union	7	7.6	6.7	1.4	2.1	L
959	PI 381719	India	7	7.6	6.9	1.5	2.9	L
960	PI 171587	Turkey	7	7.6	6.9	1.4	2.7	L
961	PI 379223	Yugoslavia	7	7.6	6.9	1.1	2.0	L
962	PI 595200	United States	7	7.6	6.9	2.1	2.7	L
963	PI 470246	Indonesia	7	7.6	7.0	1.8	1.9	L
964	PI 169280	Turkey	7	7.6	7.0	1.1	1.9	L
965	PI 536452	Maldives	7	7.6	7.0	1.5	2.6	L
966	PI 165024	Turkey	7	7.6	7.0	1.1	2.0	L
967	PI 250146	Pakistan	7	7.6	7.1	1.0	1.9	L
968	PI 494821	Zambia	7	7.6	7.1	1.8	1.9	L
969	PI 269678	Belize	7	7.6	7.1	1.0	2.3	L
970	PI 253174	Yugoslavia	7	7.6	7.1	2.7	3.5	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
			Mean disease severity on a 0-9 scale[y]					
971	PI 593375	P.R. China	7	7.6	7.3	2.3	3.1	L
972	PI 593383	P.R. China	7	7.6	7.3	1.5	2.4	L
973	PI 277977	Turkey	7	7.6	7.3	1.5	2.2	L
974	PI 357719	Yugoslavia	7	7.6	7.4	1.4	2.0	L
975	PI 381728	India	7	7.6	7.4	1.1	2.0	L
976	PI 357700	Yugoslavia	7	7.6	7.6	1.0	1.9	L
977	PI 505593	Zambia	7	7.6	7.6	1.1	2.0	L
978	PI 179235	Turkey	7	7.6	7.6	1.8	2.7	L
979	PI 172805	Turkey	7	7.6	7.9	1.0	2.0	L
980	PI 507866	Hungary	7	7.6	7.9	2.2	2.0	L
981	PI 278021	Turkey	5	7.6	4.0	1.7	3.4	L
982	PI 542116	Botswana	5	7.6	5.6	1.1	0.9	L
983	PI 512371	Spain	5	7.6	6.0	0.9	1.9	L
984	PI 277981	Turkey	5	7.6	6.0	1.7	2.0	L
985	PI 296384	Iran	5	7.6	6.0	0.5	1.0	L
986	PI 593361	P.R. China	5	7.6	6.4	0.9	2.4	L
987	PI 164539	India	5	7.6	6.6	1.3	2.2	L
988	PI 476326	Soviet Union	5	7.6	6.6	1.1	2.2	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
989	PI 278011	Turkey	5	7.6	6.8	1.3	2.3	L
990	PI 176488	Turkey	5	7.6	7.0	1.1	2.0	L
991	PI 476327	Uzbekistan	5	7.6	7.0	1.3	2.8	L
992	PI 435282	Iraq	5	7.6	7.4	1.9	2.2	L
993	PI 195771	Guatemala	5	7.6	7.6	1.3	1.9	L
994	PI 430615	P.R. China	5	7.6	8.0	0.9	1.4	L
995	PI 381741	India	8	7.6	5.8	1.2	1.4	L
996	PI 612462	Korea	8	7.6	6.0	1.1	1.5	L
997	PI 512398	Spain	8	7.6	6.5	1.5	1.7	L
998	PI 532669	Zimbabwe	6	7.7	5.5	1.2	1.0	T
999	PI 532809	P.R. China	6	7.7	6.2	1.2	1.6	L
1000	PI 278005	Turkey	6	7.7	6.2	1.0	2.6	L
1001	PI 176914	Turkey	6	7.7	6.3	1.6	2.2	L
1002	PI 175660	Turkey	6	7.7	6.3	1.2	2.1	L
1003	PI 357691	Yugoslavia	6	7.7	6.5	1.0	2.2	L
1004	PI 179232	Turkey	6	7.7	6.7	1.0	2.0	L
1005	PI 357712	Yugoslavia	6	7.7	6.8	1.0	1.7	L
1006	PI 271751	Ghana	6	7.7	6.8	1.2	2.4	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1007	PI 482260	Zimbabwe	6	7.7	6.8	1.6	2.4	L
1008	PI 177323	Turkey	6	7.7	6.8	1.2	1.3	L
1009	PI 357705	Yugoslavia	6	7.7	7.0	2.0	2.5	L
1010	PI 182180	Turkey	6	7.7	7.0	1.2	2.2	L
1011	PI 240532	Iran	6	7.7	7.0	1.0	2.2	L
1012	PI 536451	Maldives	6	7.7	7.0	1.8	2.2	L
1013	PI 165523	India	6	7.7	7.0	1.6	2.5	L
1014	PI 593360	P.R. China	6	7.7	7.2	1.0	2.2	L
1015	PI 593351	P.R. China	6	7.7	7.2	1.5	2.0	L
1016	PI 537270	Pakistan	6	7.7	7.3	1.0	1.4	L
1017	PI 612473	Korea	6	7.7	7.5	1.5	1.8	L
1018	PI 381733	India	6	7.7	7.5	1.6	2.3	L
1019	PI 269466	Pakistan	6	7.7	7.7	1.0	1.6	L
1020	PI 512349	Spain	6	7.7	7.7	2.4	3.3	L
1021	PI 269681	Belize	6	7.7	7.7	2.4	3.3	L
1022	PI 270307	Philippines	7	7.7	5.6	1.8	2.9	L
1023	PI 532666	Zimbabwe	7	7.7	5.9	2.1	2.5	T
1024	PI 277990	Turkey	7	7.7	5.9	1.5	2.2	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1025	PI 314236	Soviet Union	7	7.7	5.9	1.0	2.3	L
1026	PI 629109	United States	7	7.7	5.9	0.8	2.0	L
1027	PI 518606	Russian	7	7.7	6.0	1.8	2.2	L
1028	PI 278062	Turkey	7	7.7	6.1	1.0	2.0	L
1029	PI 277998	Turkey	7	7.7	6.1	1.1	2.0	L
1030	PI 186974	Ghana	7	7.7	6.1	1.4	2.5	L
1031	PI 512373	Spain	7	7.7	6.1	0.8	2.0	L
1032	PI 278052	Turkey	7	7.7	6.1	1.1	2.0	L
1033	PI 512358	Spain	7	7.7	6.1	1.1	2.0	L
1034	PI 593343	P.R. China	7	7.7	6.3	1.0	1.9	L
1035	PI 368529	Yugoslavia	7	7.7	6.4	1.0	1.9	L
1036	PI 512387	Spain	7	7.7	6.4	1.0	1.9	L
1037	PI 278047	Turkey	7	7.7	6.4	1.5	2.4	L
1038	PI 536448	Maldives	7	7.7	6.4	1.1	2.0	L
1039	PI 296343	South Africa	7	7.7	6.4	1.5	2.5	T
1040	PI 222712	Iran	7	7.7	6.4	1.4	2.7	L
1041	PI 175653	Turkey	7	7.7	6.6	1.5	2.3	L
1042	PI 211851	Iran	7	7.7	6.6	1.3	2.0	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1043	PI 512376	Spain	7	7.7	6.7	1.3	2.1	L
1044	PI 442826	Brazil	7	7.7	6.7	1.4	2.2	L
1045	PI 518609	Russian	7	7.7	6.7	1.5	2.1	L
1046	PI 368502	Yugoslavia	7	7.7	6.9	1.0	2.0	L
1047	PI 381699	India	7	7.7	6.9	1.4	2.2	L
1048	PI 381711	India	7	7.7	6.9	1.5	3.1	L
1049	PI 379224	Yugoslavia	7	7.7	7.0	1.1	1.9	L
1050	PI 490383	Mali	7	7.7	7.0	1.1	1.7	L
1051	PI 278037	Turkey	7	7.7	7.1	2.2	2.7	L
1052	PI 435085	P.R. China	7	7.7	7.1	1.0	1.9	L
1053	PI 177320	Turkey	7	7.7	7.1	2.2	2.7	L
1054	PI 278042	Turkey	7	7.7	7.3	1.0	1.8	L
1055	PI 490375	Mali	7	7.7	7.3	1.7	2.1	L
1056	PI 212287	Afghanistan	7	7.7	7.3	2.6	3.4	L
1057	PI 490385	Mali	7	7.7	7.4	1.4	2.0	L
1058	PI 176918	Turkey	7	7.7	7.4	2.2	2.4	L
1059	PI 172789	Turkey	7	7.7	7.6	2.4	3.0	L
1060	PI 344301	Turkey	7	7.7	7.7	1.0	1.9	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1061	PI 512384	Spain	7	7.7	7.9	1.5	1.6	L
1062	PI 211849	Iran	7	7.7	8.0	2.2	2.6	L
1063	PI 537467	Spain	7	7.7	8.0	1.1	1.7	L
1064	PI 593369	P.R. China	7	7.7	8.3	1.0	1.3	L
1065	PI 165448	Mexico	4	7.8	6.0	1.5	2.0	L
1066	PI 532667	Zimbabwe	8	7.8	6.4	0.9	1.8	T
1067	PI 508445	Korea	8	7.8	6.5	1.4	2.7	L
1068	PI 175662	Turkey	5	7.8	6.0	1.1	1.7	L
1069	PI 171584	Turkey	5	7.8	6.4	1.8	2.5	L
1070	PI 278027	Turkey	5	7.8	6.4	1.1	2.4	L
1071	PI 593366	P.R. China	5	7.8	6.6	1.1	2.2	L
1072	PI 169257	Turkey	5	7.8	7.0	1.3	2.0	L
1073	PI 512406	Spain	5	7.8	7.0	1.8	2.8	L
1074	PI 500313	Zambia	5	7.8	7.2	1.3	2.5	L
1075	PI 172802	Turkey	5	7.8	7.4	1.3	2.2	L
1076	PI 600902	United States	5	7.8	7.6	1.6	1.9	L
1077	PI 500340	Zambia	5	7.8	7.8	1.8	1.8	L
1078	PI 534534	Syria	6	7.8	6.2	1.2	2.2	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	No. of rep.	Mean disease severity on a 0-9 scale[y] Leaf	Stem	SD[x] Leaf	SD Stem	Species
1079	PI 502317	Uzbekistan	6	7.8	6.3	1.0	2.1	L
1080	PI 176922	Turkey	6	7.8	6.5	1.6	2.0	L
1081	PI 392291	Kenya	6	7.8	6.5	1.2	2.0	L
1082	Grif 5595	India	6	7.8	6.5	1.0	2.2	L
1083	PI 537465	Spain	6	7.8	6.7	1.0	1.9	L
1084	PI 293765	Soviet Union	6	7.8	6.7	1.0	1.9	L
1085	PI 532818	P.R. China	6	7.8	6.7	1.2	2.1	L
1086	PI 163572	Guatemala	6	7.8	6.7	1.2	1.9	L
1087	PI 314148	Soviet Union	6	7.8	6.8	1.3	2.6	L
1088	PI 612468	Korea	6	7.8	6.8	1.6	2.6	L
1089	PI 174098	Turkey	6	7.8	6.8	2.0	2.6	L
1090	PI 368523	Yugoslavia	6	7.8	6.8	1.0	2.6	L
1091	PI 229605	Iran	6	7.8	6.8	1.3	1.8	L
1092	PI 368500	Yugoslavia	6	7.8	6.8	1.6	2.4	L
1093	PI 169264	Turkey	6	7.8	6.8	1.0	1.8	L
1094	PI 593387	P.R. China	6	7.8	7.0	1.5	2.3	L
1095	PI 222714	Iran	6	7.8	7.0	1.0	2.2	L
1096	PI 549162	Chad	6	7.8	7.0	1.3	2.2	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1097	PI 164737	India	6	7.8	7.0	1.2	2.2	L
1098	PI 357725	Yugoslavia	6	7.8	7.0	1.0	2.2	L
1099	PI 612467	Korea	6	7.8	7.2	2.0	3.0	L
1100	PI 179243	Turkey	6	7.8	7.2	1.3	2.0	L
1101	PI 381705	India	6	7.8	7.2	1.3	2.2	L
1102	PI 487459	Venezuela	6	7.8	7.2	1.0	2.0	L
1103	PI 278030	Turkey	6	7.8	7.3	1.3	2.0	L
1104	PI 214316	India	6	7.8	7.3	1.9	2.9	L
1105	PI 164474	India	6	7.8	7.3	1.3	2.6	L
1106	PI 507859	Hungary	6	7.8	7.3	1.3	2.6	L
1107	PI 273481	Ethiopia	6	7.8	7.5	1.3	2.3	L
1108	PI 357677	Yugoslavia	6	7.8	7.5	1.3	2.3	L
1109	PI 345544	Ukraine	6	7.8	7.5	1.0	2.0	L
1110	PI 219907	Afghanistan	6	7.8	7.7	1.9	2.2	L
1111	PI 608047	United States	6	7.8	7.7	1.0	2.1	L
1112	PI 271769	South Africa	6	7.8	7.8	2.0	2.9	T
1113	PI 278061	Turkey	6	7.8	7.8	1.3	2.0	L
1114	PI 319236	Japan	6	7.8	8.0	1.3	1.7	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1115	PI 368509	Yugoslavia	6	7.8	8.0	1.3	1.7	L
1116	PI 176494	Turkey	7	7.9	5.6	0.9	1.6	L
1117	PI 534592	Syria	7	7.9	5.7	1.1	1.8	L
1118	PI 277992	Turkey	7	7.9	6.0	0.9	1.5	L
1119	PI 536460	Maldives	7	7.9	6.1	0.9	2.0	L
1120	PI 512365	Spain	7	7.9	6.1	1.5	2.0	L
1121	PI 219691	Pakistan	7	7.9	6.3	0.9	2.1	L
1122	PI 593364	P.R. China	7	7.9	6.4	1.1	1.8	L
1123	PI 381751	India	7	7.9	6.4	1.1	1.9	F
1124	PI 542617	Algeria	7	7.9	6.6	1.2	2.4	L
1125	PI 536455	Maldives	7	7.9	6.6	1.2	2.7	L
1126	PI 169281	Turkey	7	7.9	6.7	1.6	2.9	L
1127	PI 593379	P.R. China	7	7.9	6.7	1.2	2.1	L
1128	PI 593365	P.R. China	7	7.9	6.7	1.2	2.2	L
1129	PI 536453	Maldives	7	7.9	6.9	1.6	2.0	L
1130	PI 180277	India	7	7.9	7.0	1.1	2.1	L
1131	PI 173888	India	7	7.9	7.0	1.2	2.6	L
1132	PI 169258	Turkey	7	7.9	7.0	1.5	1.9	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1133	PI 512389	Spain	7	7.9	7.0	1.7	2.6	L
1134	PI 537472	Spain	7	7.9	7.0	1.2	2.0	L
1135	PI 502316	Uzbekistan	7	7.9	7.0	1.1	1.5	L
1136	PI 543210	Bolivia	7	7.9	7.0	1.2	2.0	L
1137	PI 169237	Turkey	7	7.9	7.0	1.9	2.6	L
1138	PI 357656	Yugoslavia	7	7.9	7.0	1.1	2.0	L
1139	PI 266028	Venezuela	7	7.9	7.1	1.2	2.3	L
1140	PI 438673	Mexico	7	7.9	7.1	1.1	2.4	L
1141	PI 182934	India	7	7.9	7.1	0.9	1.9	L
1142	PI 561122	P.R. China	7	7.9	7.3	1.1	2.1	L
1143	PI 176916	Turkey	7	7.9	7.3	1.1	2.1	L
1144	PI 596675	South Africa	7	7.9	7.3	1.2	1.7	T
1145	PI 518610	Russian	7	7.9	7.3	1.5	2.4	L
1146	PI 278040	Turkey	7	7.9	7.4	1.2	2.0	L
1147	PI 183399	India	7	7.9	7.4	1.5	2.1	L
1148	PI 180278	India	7	7.9	7.6	1.7	1.9	L
1149	PI 629106	United States	7	7.9	7.6	1.2	1.9	L
1150	PI 167124	Turkey	7	7.9	7.6	1.2	1.8	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1151	PI 381704	India	7	7.9	7.6	1.9	2.5	L
1152	PI 532816	P.R. China	7	7.9	7.7	1.3	1.7	L
1153	PI 357720	Yugoslavia	7	7.9	7.7	0.9	1.9	L
1154	PI 543212	Bolivia	7	7.9	7.7	1.2	1.9	L
1155	PI 512386	Spain	7	7.9	7.7	1.2	2.2	L
1156	PI 270522	Israel	7	7.9	7.9	1.5	1.6	L
1157	PI 508441	Korea	7	7.9	7.9	1.1	2.0	L
1158	PI 629111	United States	7	7.9	7.9	1.2	1.5	L
1159	PI 169291	Turkey	7	7.9	8.1	0.9	1.6	L
1160	PI 357696	Yugoslavia	7	7.9	8.3	1.1	1.3	L
1161	PI 357660	Yugoslavia	7	7.9	8.4	1.6	1.5	L
1162	PI 176491	Turkey	7	7.9	8.7	1.1	0.8	L
1163	PI 512332	P.R. China	9	7.9	7.2	1.4	1.9	L
1164	PI 190050	Yugoslavia	8	8.0	5.9	0.9	2.1	L
1165	PI 559996	Nigeria	6	8.0	6.0	0.6	1.5	L
1166	PI 370431	Yugoslavia	7	8.0	6.1	1.0	2.0	L
1167	PI 536461	Maldives	7	8.0	6.1	0.8	2.0	L
1168	PI 164655	India	6	8.0	6.2	1.1	2.2	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1169	PI 176497	Turkey	5	8.0	6.2	1.0	1.8	L
1170	PI 176911	Turkey	5	8.0	6.2	1.0	1.8	L
1171	PI 255136	South Africa	6	8.0	6.3	1.7	3.1	T
1172	PI 357743	Yugoslavia	5	8.0	6.4	1.2	2.4	L
1173	PI 277979	Turkey	7	8.0	6.4	1.0	2.5	L
1174	PI 270565	South Africa	6	8.0	6.5	1.1	2.0	L
1175	PI 534589	Syria	6	8.0	6.5	1.1	2.0	L
1176	PI 536458	Maldives	6	8.0	6.5	1.1	2.8	L
1177	PI 512396	Spain	6	8.0	6.5	0.9	2.0	L
1178	PI 357739	Yugoslavia	2	8.0	6.5	1.4	3.5	L
1179	PI 176908	Turkey	6	8.0	6.5	0.9	2.0	L
1180	PI 593345	P.R. China	7	8.0	6.6	1.3	2.4	L
1181	PI 277991	Turkey	7	8.0	6.6	1.2	2.4	L
1182	PI 169246	Turkey	7	8.0	6.6	1.2	1.8	L
1183	PI 512407	Spain	8	8.0	6.6	1.1	2.1	L
1184	PI 368497	Yugoslavia	7	8.0	6.7	1.0	2.2	L
1185	PI 181744	Lebanon	7	8.0	6.7	1.2	2.1	L
1186	PI 319212	Egypt	7	8.0	6.7	1.3	3.0	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
			Mean disease severity on a 0-9 scale[y]					
1187	PI 278008	Turkey	7	8.0	6.7	1.0	2.1	L
1188	PI 195562	Ethiopia	8	8.0	6.8	1.2	2.1	L
1189	PI 600951	United States	5	8.0	6.8	1.0	2.0	L
1190	PI 357668	Yugoslavia	6	8.0	6.8	0.9	2.4	L
1191	PI 512397	Spain	6	8.0	6.8	1.1	2.4	L
1192	PI 357674	Yugoslavia	6	8.0	6.8	1.1	2.4	L
1193	PI 593385	P.R. China	7	8.0	6.9	1.2	2.0	L
1194	PI 174106	Turkey	7	8.0	6.9	0.8	2.0	L
1195	PI 269676	Belize	7	8.0	6.9	1.2	2.1	L
1196	Grif 1729	P.R. China	6	8.0	7.0	1.1	2.2	L
1197	PI 381707	India	7	8.0	7.0	1.3	2.1	L
1198	PI 179238	Turkey	6	8.0	7.0	0.9	2.2	L
1199	PI 172794	Turkey	6	8.0	7.0	0.9	1.7	L
1200	PI 490377	Mali	5	8.0	7.0	1.4	2.8	L
1201	PI 507868	Hungary	4	8.0	7.0	1.4	2.3	L
1202	PI 169248	Turkey	7	8.0	7.0	0.8	1.9	L
1203	PI 214044	India	7	8.0	7.1	1.3	2.0	L
1204	PI 169259	Turkey	7	8.0	7.1	0.8	1.7	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1205	PI 537275	Pakistan	7	8.0	7.1	1.0	1.9	L
1206	PI 176490	Turkey	7	8.0	7.1	1.3	2.5	L
1207	PI 379242	Yugoslavia	7	8.0	7.1	1.3	1.9	L
1208	PI 532814	P.R. China	7	8.0	7.1	1.0	2.3	L
1209	PI 169240	Turkey	7	8.0	7.1	1.3	2.3	L
1210	PI 536462	Maldives	7	8.0	7.1	1.2	2.5	L
1211	PI 368506	Yugoslavia	6	8.0	7.2	0.9	2.0	L
1212	PI 512352	Spain	6	8.0	7.2	1.7	3.0	L
1213	PI 183217	Egypt	5	8.0	7.2	0.7	2.0	L
1214	PI 482290	Zimbabwe	5	8.0	7.2	1.2	2.0	L
1215	PI 537461	Spain	5	8.0	7.2	0.7	2.5	L
1216	PI 506439	Moldova	7	8.0	7.3	1.0	2.1	L
1217	PI 212288	Afghanistan	7	8.0	7.3	1.2	1.9	L
1218	PI 169299	Turkey	7	8.0	7.3	1.8	2.2	L
1219	PI 593389	P.R. China	5	8.0	7.4	1.4	2.2	L
1220	PI 277976	Turkey	5	8.0	7.4	1.0	2.2	L
1221	PI 269679	Belize	7	8.0	7.4	1.0	2.0	L
1222	PI 357741	Yugoslavia	7	8.0	7.4	1.0	2.0	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1223	PI 561138	Kazakhstan	7	8.0	7.4	1.0	2.0	L
1224	PI 269465	Pakistan	7	8.0	7.4	1.2	1.6	L
1225	PI 293766	Soviet Union	7	8.0	7.4	1.3	2.1	L
1226	PI 537268	Pakistan	7	8.0	7.4	0.8	2.0	L
1227	PI 277995	Turkey	7	8.0	7.4	1.0	1.8	L
1228	PI 197416	Ethiopia	7	8.0	7.4	1.4	2.0	L
1229	PI 226634	Iran	6	8.0	7.5	1.5	2.3	L
1230	PI 378612	Zaire	6	8.0	7.5	1.7	2.3	L
1231	PI 593356	P.R. China	6	8.0	7.5	1.3	1.8	L
1232	PI 229604	Iran	6	8.0	7.5	1.7	2.3	L
1233	PI 169269	Turkey	7	8.0	7.6	1.0	1.9	L
1234	PI 254741	Senegal	7	8.0	7.6	1.3	1.9	L
1235	PI 512356	Spain	7	8.0	7.6	1.0	1.9	L
1236	PI 368508	Yugoslavia	5	8.0	7.6	1.7	1.9	L
1237	PI 270562	South Africa	8	8.0	7.6	1.7	1.9	T
1238	PI 277975	Turkey	6	8.0	7.7	1.1	2.1	L
1239	PI 277978	Turkey	6	8.0	7.7	1.3	2.1	L
1240	PI 507865	Hungary	6	8.0	7.7	1.1	2.1	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1241	PI 379226	Yugoslavia	6	8.0	7.7	1.1	1.6	L
1242	PI 203551	United States	7	8.0	7.7	1.0	1.7	L
1243	PI 254740	Senegal	7	8.0	7.7	1.5	2.2	L
1244	PI 182176	Turkey	5	8.0	7.8	1.4	1.8	L
1245	PI 536464	Maldives	5	8.0	7.8	1.0	1.8	L
1246	PI 169276	Turkey	6	8.0	7.8	0.9	1.8	L
1247	PI 357657	Yugoslavia	6	8.0	7.8	1.7	2.9	L
1248	PI 306365	Taiwan	6	8.0	7.8	1.3	1.8	L
1249	PI 600896	United States	7	8.0	7.9	1.7	2.0	L
1250	PI 179882	India	7	8.0	7.9	1.0	2.0	L
1251	PI 278012	Turkey	7	8.0	7.9	1.0	2.0	L
1252	PI 512367	Spain	4	8.0	8.0	1.2	2.0	L
1253	PI 357723	Yugoslavia	6	8.0	8.0	1.1	1.7	L
1254	PI 314655	Soviet Union	6	8.0	8.0	0.9	1.7	L
1255	PI 357679	Yugoslavia	5	8.0	8.0	1.0	2.2	L
1256	PI 368525	Yugoslavia	7	8.0	8.0	1.5	1.7	L
1257	PI 536449	Maldives	7	8.0	8.0	1.9	1.7	L
1258	PI 278032	Turkey	7	8.0	8.1	1.0	1.6	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1259	PI 226460	Iran	5	8.0	8.4	1.0	1.3	L
1260	PI 596691	South Africa	1	8.0	9.0	-	-	T
1261	PI 278002	Turkey	6	8.0	9.0	1.1	0.0	L
1262	PI 357730	Yugoslavia	9	8.1	7.8	1.1	1.9	L
1263	PI 518612	Soviet Union	8	8.1	7.5	1.1	2.1	L
1264	PI 169239	Turkey	7	8.1	6.6	0.9	1.8	L
1265	PI 512404	Spain	7	8.1	6.7	1.2	2.4	L
1266	PI 536457	Maldives	7	8.1	6.7	0.9	2.1	L
1267	PI 266027	Venezuela	7	8.1	6.9	1.2	2.0	L
1268	PI 435990	P.R. China	7	8.1	6.9	0.9	2.0	L
1269	PI 596653	South Africa	7	8.1	7.0	0.9	1.9	T
1270	PI 174103	Turkey	7	8.1	7.0	1.5	2.6	L
1271	PI 164977	Turkey	7	8.1	7.0	1.2	2.0	L
1272	PI 535948	Cameroon	7	8.1	7.3	1.2	2.1	L
1273	PI 178876	Turkey	7	8.1	7.3	1.1	1.6	L
1274	PI 161373	Korea	7	8.1	7.3	0.9	1.9	L
1275	PI 278054	Turkey	7	8.1	7.3	0.9	2.1	L
1276	PI 169295	Turkey	7	8.1	7.3	1.1	2.1	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1277	PI 379238	Yugoslavia	7	8.1	7.3	0.9	1.7	L
1278	PI 357727	Yugoslavia	7	8.1	7.4	1.2	2.1	L
1279	PI 379246	Yugoslavia	7	8.1	7.4	1.2	2.3	L
1280	PI 357684	Yugoslavia	7	8.1	7.4	1.2	2.0	L
1281	PI 379255	Yugoslavia	7	8.1	7.6	0.9	1.9	L
1282	PI 357750	Yugoslavia	7	8.1	7.6	0.9	1.9	L
1283	PI 169270	Turkey	7	8.1	7.6	1.2	2.1	L
1284	PI 537265	Pakistan	7	8.1	7.6	0.9	2.0	L
1285	PI 177324	Turkey	7	8.1	7.7	0.9	1.7	L
1286	PI 357669	Yugoslavia	7	8.1	7.7	0.9	1.7	L
1287	PI 167126	Turkey	7	8.1	7.7	1.2	2.2	L
1288	PI 381709	India	7	8.1	7.9	1.1	2.0	L
1289	PI 357718	Yugoslavia	7	8.1	7.9	0.9	2.0	L
1290	PI 169234	Turkey	7	8.1	7.9	1.1	2.0	L
1291	PI 270309	Philippines	7	8.1	7.9	1.1	2.0	L
1292	PI 178877	Turkey	7	8.1	7.9	0.9	2.0	L
1293	PI 502315	Ukraine	7	8.1	8.0	1.1	1.7	L
1294	PI 169283	Turkey	7	8.1	8.0	1.6	2.6	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y]					
			No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1295	PI 162667	Argentina	7	8.1	8.0	1.1	1.7	L
1296	PI 537276	Pakistan	7	8.1	8.1	1.2	1.6	L
1297	PI 379257	Yugoslavia	7	8.1	8.1	1.1	1.6	L
1298	PI 357671	Yugoslavia	7	8.1	8.3	1.2	1.3	L
1299	PI 357747	Yugoslavia	7	8.1	8.3	1.5	1.9	L
1300	PI 290855	United States	7	8.1	8.4	0.9	1.5	L
1301	PI 171586	Turkey	7	8.1	8.4	1.2	1.5	L
1302	PI 357681	Yugoslavia	7	8.1	8.4	1.1	1.5	L
1303	PI 164992	Turkey	7	8.1	8.4	1.6	1.5	L
1304	PI 512351	Spain	7	8.1	8.4	1.1	1.5	L
1305	PI 595201	United States	6	8.2	5.7	1.2	2.1	L
1306	PI 379247	Yugoslavia	6	8.2	6.2	1.6	2.6	L
1307	PI 344298	Turkey	6	8.2	6.8	1.0	2.4	L
1308	PI 179237	Turkey	6	8.2	6.8	1.0	2.4	L
1309	PI 169288	Turkey	6	8.2	7.2	1.0	2.0	L
1310	PI 357670	Yugoslavia	6	8.2	7.3	1.0	2.0	L
1311	PI 164748	India	6	8.2	7.3	1.3	2.0	L
1312	PI 278017	Turkey	6	8.2	7.3	1.0	2.7	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1313	PI 507864	Hungary	6	8.2	7.5	1.0	2.3	L
1314	PI 357680	Yugoslavia	6	8.2	7.5	1.3	1.8	L
1315	PI 612475	Korea	6	8.2	7.7	1.3	2.1	L
1316	PI 271776	South Africa	6	8.2	7.7	1.0	1.6	L
1317	PI 277985	Turkey	6	8.2	7.7	1.0	2.1	L
1318	PI 178870	Turkey	6	8.2	7.7	1.2	1.5	L
1319	PI 512341	Spain	6	8.2	7.7	1.3	2.1	L
1320	PI 512353	Spain	6	8.2	7.7	1.0	2.1	L
1321	PI 357729	Yugoslavia	6	8.2	7.8	1.3	1.8	L
1322	PI 172804	Turkey	6	8.2	7.8	1.0	2.0	L
1323	PI 164998	Turkey	6	8.2	7.8	1.0	1.8	L
1324	PI 357688	Yugoslavia	6	8.2	8.0	1.0	1.7	L
1325	PI 175650	Turkey	6	8.2	8.0	1.3	1.7	L
1326	PI 536454	Maldives	6	8.2	8.2	1.3	2.0	L
1327	PI 176913	Turkey	6	8.2	8.3	1.0	1.6	L
1328	PI 357667	Yugoslavia	6	8.2	8.7	1.3	0.8	L
1329	PI 370423	Yugoslavia	5	8.2	6.8	0.8	2.0	L
1330	PI 274035	South Africa	5	8.2	6.8	1.1	2.0	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
			Mean disease severity on a 0-9 scale[y]					
1331	PI 171583	Turkey	5	8.2	6.8	1.1	1.5	L
1332	PI 534586	Syria	5	8.2	7.0	1.1	2.0	L
1333	PI 179233	Turkey	5	8.2	7.2	1.3	2.7	L
1334	PI 357746	Yugoslavia	5	8.2	7.4	1.1	2.2	L
1335	PI 171581	Turkey	5	8.2	7.6	0.8	1.9	L
1336	PI 357697	Yugoslavia	5	8.2	7.8	1.1	1.8	L
1337	PI 438676	Mexico	5	8.2	8.0	1.3	2.2	L
1338	PI 379253	Yugoslavia	5	8.2	8.0	0.8	1.7	L
1339	PI 357704	Yugoslavia	5	8.2	8.2	0.8	1.3	L
1340	PI 379241	Yugoslavia	5	8.2	8.2	0.8	1.8	L
1341	PI 179239	Turkey	5	8.2	8.4	1.1	1.3	L
1342	PI 169238	Turkey	5	8.2	8.4	1.8	1.3	L
1343	PI 357711	Yugoslavia	5	8.2	9.0	1.1	0.0	L
1344	PI 175651	Turkey	5	8.2	9.0	1.1	0.0	L
1345	PI 368505	Yugoslavia	9	8.2	6.2	0.8	1.9	L
1346	PI 229686	Iran	9	8.2	7.7	1.0	1.7	L
1347	PI 357737	Yugoslavia	8	8.3	6.5	1.4	1.7	L
1348	PI 179881	India	4	8.3	6.5	1.0	1.9	T

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1349	PI 512374	Spain	8	8.3	6.5	0.7	1.7	L
1350	PI 532811	P.R. China	4	8.3	6.8	1.0	1.7	L
1351	PI 211915	Iran	8	8.3	7.9	0.7	1.2	L
1352	PI 167059	Turkey	7	8.3	7.0	1.0	2.5	L
1353	PI 270523	Israel	7	8.3	7.0	0.8	1.9	L
1354	PI 537470	Spain	7	8.3	7.1	0.8	1.9	L
1355	PI 172801	Turkey	7	8.3	7.1	0.8	1.9	L
1356	PI 169235	Turkey	7	8.3	7.3	1.0	2.1	L
1357	PI 172793	Turkey	7	8.3	7.3	1.0	2.1	L
1358	PI 368524	Yugoslavia	7	8.3	7.3	1.0	2.1	L
1359	PI 169253	Turkey	7	8.3	7.3	1.5	2.2	L
1360	PI 212289	Afghanistan	7	8.3	7.3	1.0	2.1	L
1361	PI 278024	Turkey	7	8.3	7.4	1.0	2.0	L
1362	PI 278029	Turkey	7	8.3	7.4	1.0	2.0	L
1363	PI 518608	Russian	7	8.3	7.4	0.8	2.0	L
1364	PI 357689	Yugoslavia	7	8.3	7.6	1.3	1.9	L
1365	PI 379222	Yugoslavia	7	8.3	7.7	1.0	1.9	L
1366	PI 177325	Turkey	7	8.3	7.7	1.3	1.7	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1367	PI 357701	Yugoslavia	7	8.3	7.7	1.0	2.4	L
1368	PI 306364	Gabon	7	8.3	7.9	1.0	2.0	L
1369	PI 192937	P.R. China	7	8.3	7.9	0.8	2.0	L
1370	PI 379252	Yugoslavia	7	8.3	7.9	0.8	2.0	L
1371	PI 169272	Turkey	7	8.3	7.9	1.0	1.5	L
1372	PI 490381	Mali	7	8.3	7.9	1.3	1.6	L
1373	PI 278031	Turkey	7	8.3	7.9	0.8	2.0	L
1374	PI 357732	Yugoslavia	7	8.3	7.9	1.0	2.0	L
1375	PI 357676	Yugoslavia	7	8.3	8.0	1.1	1.7	L
1376	PI 381723	India	7	8.3	8.0	1.0	1.7	L
1377	PI 370422	Yugoslavia	7	8.3	8.0	1.3	1.9	L
1378	PI 211852	Iran	7	8.3	8.0	1.0	1.7	L
1379	PI 176485	Turkey	7	8.3	8.1	1.3	1.6	L
1380	PI 379256	Yugoslavia	7	8.3	8.1	1.0	1.5	L
1381	PI 277993	Turkey	7	8.3	8.1	1.0	1.6	L
1382	PI 212208	Greece	7	8.3	8.3	1.0	1.3	L
1383	PI 368498	Yugoslavia	7	8.3	8.3	1.0	1.3	L
1384	PI 163203	India	7	8.3	8.4	1.0	1.5	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1385	PI 507861	Hungary	7	8.3	8.4	1.0	1.5	L
1386	PI 537473	Spain	7	8.3	8.4	1.0	1.5	L
1387	PI 537267	Pakistan	7	8.3	8.4	1.0	1.5	L
1388	PI 176915	Turkey	7	8.3	8.6	1.0	1.1	L
1389	PI 277996	Turkey	7	8.3	8.6	1.3	1.1	L
1390	PI 379236	Yugoslavia	7	8.3	8.6	1.0	1.1	L
1391	PI 357726	Yugoslavia	6	8.3	6.7	0.8	2.7	L
1392	PI 379227	Yugoslavia	6	8.3	6.8	1.0	2.4	L
1393	PI 542120	Botswana	3	8.3	7.0	1.2	2.0	L
1394	PI 167125	Turkey	6	8.3	7.2	0.8	2.0	L
1395	PI 169296	Turkey	6	8.3	7.2	0.8	2.0	L
1396	PI 163205	India	6	8.3	7.3	1.0	2.7	L
1397	PI 169265	Turkey	6	8.3	7.3	0.5	1.9	L
1398	PI 182181	Turkey	6	8.3	7.5	1.0	2.3	L
1399	PI 277988	Turkey	6	8.3	7.5	1.0	2.3	L
1400	PI 357731	Yugoslavia	6	8.3	7.7	0.5	2.1	L
1401	PI 512369	Spain	6	8.3	7.7	1.0	2.1	L
1402	PI 176910	Turkey	6	8.3	7.7	0.8	2.1	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
3	PI 177327	Turkey	3	8.3	7.7	1.2	2.3	L
1404	PI 172788	Turkey	6	8.3	7.8	1.0	1.8	L
1405	PI 176906	Turkey	6	8.3	7.8	1.0	1.8	L
1406	PI 176487	Turkey	6	8.3	7.8	1.0	1.8	L
1407	PI 344300	Turkey	6	8.3	7.8	0.8	1.8	L
1408	PI 490384	Mali	6	8.3	8.0	1.0	1.7	L
1409	PI 357722	Yugoslavia	6	8.3	8.3	1.0	1.6	L
1410	PI 357713	Yugoslavia	6	8.3	8.3	1.0	1.6	L
1411	PI 357699	Yugoslavia	6	8.3	8.3	1.0	1.6	L
1412	PI 172787	Turkey	6	8.3	8.3	1.2	1.6	L
1413	PI 512344	Spain	6	8.3	8.3	1.0	1.6	L
1414	PI 166993	Turkey	6	8.3	8.3	1.0	1.6	L
1415	PI 379245	Yugoslavia	6	8.3	8.3	1.0	1.6	L
1416	PI 274561	Portugal	6	8.3	8.3	1.0	1.6	L
1417	PI 476325	Ukraine	6	8.3	8.3	1.0	1.6	L
1418	PI 512370	Spain	6	8.3	8.5	0.8	1.2	L
1419	PI 271747	Afghanistan	6	8.3	8.5	1.0	1.2	L
1420	PI 172790	Turkey	6	8.3	8.7	1.0	0.8	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	No. of rep.	Mean disease severity on a 0-9 scale[y] Leaf	Stem	SD[x] Leaf	SD Stem	Species
1421	PI 512359	Spain	6	8.3	9.0	1.0	0.0	L
1422	PI 105445	Turkey	6	8.3	9.0	1.0	0.0	L
1423	PI 512350	Spain	8	8.4	8.0	0.9	1.9	L
1424	PI 357683	Yugoslavia	5	8.4	6.6	0.9	2.2	L
1425	PI 176496	Turkey	5	8.4	6.6	0.9	2.2	L
1426	PI 278026	Turkey	5	8.4	7.6	0.9	1.9	L
1427	PI 175658	Turkey	5	8.4	7.6	0.9	1.9	L
1428	PI 169294	Turkey	5	8.4	7.6	0.9	1.9	L
1429	PI 251796	Yugoslavia	5	8.4	8.0	0.5	1.7	L
1430	PI 169292	Turkey	5	8.4	8.2	0.9	1.8	L
1431	PI 319235	Japan	5	8.4	8.4	0.9	1.3	L
1432	PI 171392	South Africa	5	8.4	8.4	0.9	1.3	L
1433	PI 357710	Yugoslavia	5	8.4	8.6	0.9	0.9	L
1434	PI 169275	Turkey	5	8.4	9.0	0.9	0.0	L
1435	PI 512391	Spain	7	8.4	7.0	0.8	1.9	L
1436	PI 357664	Yugoslavia	7	8.4	7.0	1.1	2.6	L
1437	PI 185030	Turkey	7	8.4	7.4	0.8	2.0	L
1438	PI 370434	Yugoslavia	7	8.4	7.4	0.8	2.0	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1439	PI 178872	Turkey	7	8.4	7.6	1.0	1.9	L
1440	PI 370015	India	7	8.4	7.7	1.1	1.9	L
1441	PI 182177	Turkey	7	8.4	7.7	1.5	2.4	L
1442	PI 177318	Turkey	7	8.4	7.7	1.0	1.7	L
1443	PI 178871	Turkey	7	8.4	7.9	1.0	2.0	L
1444	PI 507862	Hungary	7	8.4	7.9	0.8	2.0	L
1445	PI 278019	Turkey	7	8.4	7.9	1.0	1.6	L
1446	PI 174108	Turkey	7	8.4	7.9	1.0	2.0	L
1447	PI 368501	Yugoslavia	7	8.4	8.0	1.0	1.7	L
1448	PI 269680	Belize	7	8.4	8.0	1.0	1.9	L
1449	PI 357752	Yugoslavia	7	8.4	8.0	0.8	1.7	L
1450	PI 181742	Lebanon	7	8.4	8.1	1.0	1.6	L
1451	PI 357661	Yugoslavia	7	8.4	8.1	0.8	1.5	L
1452	PI 174100	Turkey	7	8.4	8.1	1.0	1.6	L
1453	PI 368507	Yugoslavia	7	8.4	8.1	0.8	1.6	L
1454	PI 277999	Turkey	7	8.4	8.3	1.1	1.9	L
1455	PI 357744	Yugoslavia	7	8.4	8.4	0.8	1.5	L
1456	PI 378613	Zaire	7	8.4	8.4	1.0	1.5	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1457	PI 370426	Yugoslavia	7	8.4	8.4	1.0	1.0	L
1458	PI 379233	Yugoslavia	7	8.4	8.4	1.0	1.5	L
1459	PI 543211	Bolivia	7	8.4	8.4	1.1	1.5	L
1460	PI 379240	Yugoslavia	7	8.4	8.6	1.0	1.1	L
1461	PI 176909	Turkey	7	8.4	8.7	1.0	0.8	L
1462	PI 357736	Yugoslavia	7	8.4	9.0	0.8	0.0	L
1463	PI 176919	Turkey	7	8.4	9.0	1.0	0.0	L
1464	PI 274034	South Africa	2	8.5	7.0	0.7	2.8	L
1465	PI 595219	United States	8	8.5	7.0	0.8	1.8	L
1466	PI 542114	Botswana	6	8.5	7.2	0.8	2.0	T
1467	PI 169271	Turkey	6	8.5	7.5	0.8	2.0	L
1468	PI 381703	India	6	8.5	7.7	0.8	2.1	L
1469	PI 176486	Turkey	6	8.5	7.7	0.8	2.1	L
1470	PI 378611	Zaire	6	8.5	7.7	0.5	2.1	L
1471	PI 500311	Zambia	6	8.5	7.7	0.8	2.1	L
1472	PI 169232	Turkey	8	8.5	7.8	1.4	1.0	L
1473	PI 172786	Turkey	6	8.5	7.8	0.8	1.8	L
1474	PI 357733	Yugoslavia	6	8.5	7.8	0.5	1.8	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1475	PI 512340	Spain	6	8.5	7.8	0.8	1.8	L
1476	PI 512403	Spain	6	8.5	7.8	0.8	1.8	L
1477	PI 357662	Yugoslavia	6	8.5	8.0	0.8	1.7	L
1478	PI 278034	Turkey	8	8.5	8.0	0.9	1.9	L
1479	PI 278028	Turkey	6	8.5	8.0	0.8	1.7	L
1480	PI 175661	Turkey	8	8.5	8.1	0.9	1.6	L
1481	PI 228237	Israel	6	8.5	8.2	0.8	1.3	L
1482	PI 600903	United States	6	8.5	8.3	1.2	1.6	L
1483	PI 368516	Yugoslavia	6	8.5	8.3	0.8	1.6	L
1484	PI 593363	P.R. China	6	8.5	8.3	0.8	1.2	L
1485	PI 271771	South Africa	4	8.5	8.5	1.0	1.0	T
1486	PI 172798	Turkey	8	8.5	8.5	0.9	0.9	L
1487	PI 357708	Yugoslavia	6	8.5	8.5	0.8	1.2	L
1488	PI 174101	Turkey	6	8.5	9.0	0.8	0.0	L
1489	PI 476330	Soviet Union	6	8.5	9.0	0.8	0.0	L
1490	PI 368520	Yugoslavia	7	8.6	6.7	0.8	2.1	L
1491	PI 171579	Turkey	7	8.6	7.3	0.5	2.1	L
1492	PI 278053	Turkey	7	8.6	7.4	0.8	2.0	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y]					
			No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1493	PI 370428	Yugoslavia	7	8.6	7.6	0.8	1.8	L
1494	PI 379235	Yugoslavia	7	8.6	7.6	0.8	1.9	L
1495	PI 169247	Turkey	7	8.6	7.7	0.8	1.7	L
1496	PI 270308	Philippines	7	8.6	7.9	0.8	2.0	L
1497	PI 537299	Uzbekistan	7	8.6	7.9	0.8	2.0	L
1498	PI 234287	Portugal	7	8.6	7.9	0.5	2.0	L
1499	PI 357714	Yugoslavia	7	8.6	8.0	0.8	1.7	L
1500	PI 175664	Turkey	7	8.6	8.0	0.8	1.7	L
1501	PI 512360	Spain	7	8.6	8.0	0.8	1.7	L
1502	PI 222713	Iran	7	8.6	8.1	0.8	1.5	L
1503	PI 512378	Spain	7	8.6	8.1	0.8	1.6	L
1504	PI 271133	Tunisia	7	8.6	8.3	0.8	1.3	L
1505	PI 171580	Turkey	7	8.6	8.3	0.8	1.3	L
1506	PI 176492	Turkey	7	8.6	8.4	1.1	1.5	L
1507	PI 278003	Turkey	7	8.6	8.4	0.8	1.5	L
1508	PI 278000	Turkey	7	8.6	8.4	0.8	1.5	L
1509	PI 370424	Yugoslavia	7	8.6	8.4	0.8	1.5	L
1510	PI 169297	Turkey	7	8.6	8.6	0.8	1.1	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1511	PI 512361	Spain	7	8.6	8.6	0.5	1.1	L
1512	PI 357748	Yugoslavia	7	8.6	9.0	0.8	0.0	L
1513	PI 175663	Turkey	7	8.6	9.0	0.8	0.0	L
1514	PI 175652	Turkey	7	8.6	9.0	0.8	0.0	L
1515	PI 172795	Turkey	5	8.6	8.2	0.9	1.8	L
1516	PI 229748	Iran	5	8.6	8.2	0.9	1.8	L
1517	PI 368499	Yugoslavia	5	8.6	8.4	0.9	1.3	L
1518	PI 172796	Turkey	5	8.6	8.4	0.9	1.3	L
1519	PI 357692	Yugoslavia	5	8.6	8.6	0.9	0.9	L
1520	PI 169285	Turkey	5	8.6	8.6	0.9	0.9	L
1521	PI 172791	Turkey	5	8.6	8.6	0.9	0.9	L
1522	PI 295845	South Africa	5	8.6	8.8	0.5	0.4	L
1523	PI 240533	Iran	3	8.7	7.7	0.6	2.3	L
1524	PI 175655	Turkey	6	8.7	7.8	0.8	1.8	L
1525	PI 357735	Yugoslavia	6	8.7	7.8	0.8	1.8	L
1526	PI 542123	Botswana	3	8.7	8.0	0.6	1.7	T
1527	PI 278049	Turkey	6	8.7	8.0	0.8	1.7	L
1528	PI 169236	Turkey	6	8.7	8.2	0.8	2.0	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1529	PI 171585	Turkey	6	8.7	8.2	0.5	1.3	L
1530	PI 176907	Turkey	6	8.7	8.3	0.8	1.6	L
1531	PI 270547	Ghana	6	8.7	8.3	0.5	1.6	L
1532	PI 357690	Yugoslavia	6	8.7	8.3	0.8	1.6	L
1533	PI 278023	Turkey	6	8.7	8.3	0.8	1.6	L
1534	PI 379239	Yugoslavia	6	8.7	8.3	0.8	1.6	L
1535	PI 175657	Turkey	6	8.7	8.3	0.8	1.6	L
1536	PI 174105	Turkey	6	8.7	8.5	0.8	1.2	L
1537	PI 278018	Turkey	6	8.7	9.0	0.8	0.0	L
1538	PI 228342	Iran	6	8.7	9.0	0.8	0.0	L
1539	PI 288316	India	3	8.7	9.0	0.6	0.0	T
1540	PI 370425	Yugoslavia	10	8.7	6.8	0.5	1.9	L
1541	PI 512354	Spain	7	8.7	7.3	0.5	1.7	L
1542	PI 379232	Yugoslavia	7	8.7	7.7	0.5	1.9	L
1543	PI 379249	Yugoslavia	7	8.7	7.9	0.5	2.0	L
1544	PI 174109	Turkey	7	8.7	7.9	0.8	2.0	L
1545	PI 169284	Turkey	7	8.7	7.9	0.5	1.7	L
1546	PI 169274	Turkey	7	8.7	8.0	0.8	1.7	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1547	PI 438671	Mexico	7	8.7	8.0	0.8	1.9	L
1548	PI 277980	Turkey	7	8.7	8.1	0.5	1.5	L
1549	PI 278025	Turkey	7	8.7	8.1	0.8	1.5	L
1550	PI 174099	Turkey	7	8.7	8.1	0.8	2.3	L
1551	PI 370433	Yugoslavia	7	8.7	8.4	0.8	1.5	L
1552	PI 593373	P.R. China	7	8.7	8.4	0.8	1.5	L
1553	PI 370430	Yugoslavia	7	8.7	8.4	0.8	1.5	L
1554	PI 385963	Kenya	7	8.7	8.4	0.5	1.5	L
1555	PI 178873	Turkey	7	8.7	8.6	0.5	1.1	L
1556	PI 538888	Russian	7	8.7	8.7	0.5	0.8	L
1557	PI 379234	Yugoslavia	7	8.7	8.7	0.8	0.8	L
1558	PI 370429	Yugoslavia	7	8.7	8.7	0.8	0.8	L
1559	PI 485579	Zimbabwe	4	8.8	6.5	0.5	1.7	T
1560	PI 512402	Spain	8	8.8	7.1	0.5	1.7	L
1561	PI 512368	Spain	9	8.8	7.6	0.7	1.7	L
1562	PI 357717	Yugoslavia	5	8.8	7.4	0.4	2.2	L
1563	PI 271748	Afghanistan	10	8.8	7.7	0.6	1.8	L
1564	PI 278060	Turkey	5	8.8	8.2	0.4	1.8	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1565	PI 368519	Yugoslavia	5	8.8	8.2	0.4	1.3	L
1566	PI 276658	Soviet Union	5	8.8	8.4	0.4	1.3	L
1567	PI 542122	Botswana	5	8.8	8.4	0.4	1.3	L
1568	PI 357665	Yugoslavia	5	8.8	9.0	0.4	0.0	L
1569	PI 176493	Turkey	6	8.8	7.2	0.4	2.0	L
1570	PI 357724	Yugoslavia	6	8.8	7.5	0.4	1.8	L
1571	PI 278045	Turkey	6	8.8	7.7	0.4	2.1	L
1572	PI 276659	Soviet Union	6	8.8	7.7	0.4	2.1	L
1573	PI 278036	Turkey	6	8.8	8.5	0.4	1.2	L
1574	PI 379248	Yugoslavia	6	8.8	9.0	0.4	0.0	L
1575	PI 508442	Korea	7	8.9	8.4	0.4	1.5	L
1576	PI 368496	Yugoslavia	7	8.9	8.4	0.4	1.5	L
1577	PI 368526	Yugoslavia	7	8.9	8.4	0.4	1.5	L
1578	PI 379229	Yugoslavia	7	8.9	9.0	0.4	0.0	L
1579	PI 368521	Yugoslavia	7	8.9	9.0	0.4	0.0	L
1580	PI 490380	Mali	7	8.9	9.0	0.4	0.0	L
1581	PI 357666	Yugoslavia	7	8.9	9.0	0.4	0.0	L
1582	PI 368518	Yugoslavia	8	8.9	8.1	0.4	1.2	L

Appendix Table 1 (continued).

Rank	Cultigen	Seed Source	Mean disease severity on a 0-9 scale[y] No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1583	PI 532670	Zimbabwe	2	9.0	7.5	0.0	2.1	T
1584	PI 177319	Turkey	7	9.0	8.3	0.0	1.3	L
1585	PI 357686	Yugoslavia	6	9.0	8.3	0.0	1.6	L
1586	PI 593378	P.R. China	7	9.0	8.6	0.0	1.1	L
1587	PI 172792	Turkey	7	9.0	8.9	0.0	0.4	L
1588	PI 369220	Soviet Union	5	9.0	9.0	0.0	0.0	L
1589	PI 113326	P.R. China	7	9.0	9.0	0.0	0.0	L
1590	PI 507863	Hungary	7	9.0	9.0	0.0	0.0	L
1591	PI 271132	Tunisia	4	9.0	9.0	0.0	0.0	L
1592	PI 370427	Yugoslavia	6	9.0	9.0	0.0	0.0	L
1593	PI 278038	Turkey	6	9.0	9.0	0.0	0.0	L
1594	PI 368495	Yugoslavia	6	9.0	9.0	0.0	0.0	L
1595	PI 169273	Turkey	7	9.0	9.0	0.0	0.0	L
1596	PI 345547	Ukraine	7	9.0	9.0	0.0	0.0	L
1597	PI 176917	Turkey	6	9.0	9.0	0.0	0.0	L
1598	PI 278058	Turkey	7	9.0	9.0	0.0	0.0	L
1600	PI 357745	Yugoslavia	4	9.0	9.0	0.0	0.0	L
1601	PI 176923	Turkey	7	9.0	9.0	0.0	0.0	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
1602	PI 357751	Yugoslavia	7	9.0	9.0	0.0	0.0	L
1603	PI 512355	Spain	7	9.0	9.0	0.0	0.0	L
1604	PI 229749	Iran	5	9.0	9.0	0.0	0.0	L
1605	PI 269677	Belize	7	9.0	9.0	0.0	0.0	L
1606	PI 222775	Iran	5	9.0	9.0	0.0	0.0	L
1607	PI 357706	Yugoslavia	1	9.0	9.0	-	-	L
Cultivars (Checks)								
1	Tastigold	NA	9	5.2	3.7	1.9	2.8	L
2	Super Sweet	NA	5	6.0	4.8	2.0	1.8	L
3	Black Diamond Yellow Belly	NA	6	6.2	4.7	1.2	1.6	L
4	Chubby Gray	NA	6	6.3	6.0	0.8	2.4	L
5	Carolina Cross #18	NA	7	6.7	6.1	1.8	2.7	L
6	Blacklee	NA	7	6.9	6.7	2.9	3.1	L
7	Graybelle	NA	7	7.0	5.9	1.3	2.3	L
8	Perola	NA	6	7.0	6.0	1.1	1.5	L
9	Desert King	NA	7	7.0	6.0	2.2	3.0	L
10	Quetzali	NA	7	7.0	7.0	1.6	2.0	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
11	EarLy Canada	NA	8	7.1	5.5	1.2L	1.5	L
12	Red & Sweet	NA	6	7.2	6.2	1.0	2.2	L
13	Crimson Sweet	NA	6	7.2	7.0	1.6	2.3	L
14	Black Diamond							
	Yellow Flesh	NA	5	7.2	6.4	0.4	1.7	L
15	Florida Favorite	NA	4	7.3	7.3	0.5	1.7	L
16	Charlee	NA	7	7.3	5.4	1.7	0.5	L
17	Honey Red	NA	7	7.3	6.4	2.2	3.4	L
18	Giza	NA	5	7.4	3.8	0.9	1.8	L
19	Rhode Island Red	NA	5	7.4	6.6	1.1	2.2	L
20	Black Boy	NA	7	7.4	6.3	1.3	1.9	L
21	Golden	NA	7	7.4	6.4	1.0	1.9	L
22	Big Crimson	NA	7	7.4	7.0	1.9	2.8	L
23	Tendergold	NA	6	7.5	7.0	2.0	3.3	L
24	Sugarlee	NA	6	7.5	7.7	1.8	2.1	L
25	Champion #2	NA	7	7.6	7.7	1.5	2.4	L
26	Sweetheart	NA	7	7.6	7.9	1.4	2.0	L
27	Hopi Red Flesh	NA	7	7.7	8.0	2.2	2.6	L

Appendix Table 1 (continued).

			Mean disease severity on a 0-9 scale[y]					
Rank	Cultigen	Seed Source	No. of rep.	Leaf	Stem	SD[x] Leaf	SD Stem	Species
28	Early ArizonaL	NA	7	7.9	7.4	1.6	2.0	L
29	Charleston Gray	NA	7	8.0	6.7	1.3	2.2	L
30	Tenderseewt Orange Flesh	NA	6	8.0	7.2	0.9	2.0	L
31	Princeton	NA	7	8.0	7.4	1.3	2.0	L
32	Moon&Stars	NA	6	8.0	7.7	0.9	1.8	L
33	Peacock Shipper	NA	7	8.1	7.9	1.1	2.0	L
34	Sun Gold	NA	7	8.1	7.9	1.2	2.3	L
35	Mountain Hoosier	NA	7	8.3	7.6	1.0	1.8	L
36	Picnic	NA	6	8.3	7.7	1.0	2.1	L
37	Long Crimson	NA	3	8.3	7.7	1.2	2.3	L
38	Sugarloaf	NA	4	8.5	9.0	1.0	0.0	L
39	Navajo Sweet	NA	7	8.6	8.0	0.8	1.7	L
40	New Winter	NA	1	9.0	9.0	-	-	L
Mean				6.9	6.1			
Range				8.3	9.0			
$LSD_{.05}$				2.0	2.4			

Range/$LSD_{.05}$	4.2	3.8
CV(%)	25.9	37.8

[z] Table represents pooled data from greenhouse screening and missing experiments.
[y]PI accessions were classified into resistant, intermediate, or susceptible classes based on their total plant mean disease severity rating from at least six replicates. Accessions were resistant if their total plant mean disease severity rating was ≤3.0; intermediate if 3.1 to 4; susceptible if ≥4.1.
[x]SD = standard deviation.

Appendix Table 2. Ranking of the final total powdery mildew severity rating for the retested *Citrullus* and *Praecitrullus* PI lines and cultivars for resistance to powdery mildew race 2W.

			Mean disease severity rating (0-9 scale).[z]								
Rank	Cultigen		Total	Greenhouse				Field			
		Rep	plant	Leaf	Stem	SDL[y]	SDS[x]	Leaf	Stem	SDL	SDS
1	PI 632755	5	0.6	1.3	0.6	0.6	2.0	0.3	0.2	1.0	0.0
2	PI 386015	7	1.1	1.0	0.5	0.8	0.8	2.0	0.9	0.8	0.2
3	PI 346082	7	1.5	2.0	1.1	0.6	1.0	2.3	0.6	0.0	0.0
4	PI 525082	7	1.7	2.7	1.5	1.0	1.0	2.3	0.6	0.5	0.6
5	PI 432337	5	1.8	2.5	1.5	1.3	0.8	2.3	1.0	0.6	0.3
6	PI 386024	8	2.1	3.3	2.6	0.8	1.0	2.0	0.6	0.5	0.0
7	PI 269365	8	2.4	3.3	1.7	1.3	1.3	3.3	1.4	1.3	0.5
8	PI 482283	7	3.2	4.0	2.7	0.8	1.0	4.0	2.0	1.0	0.2
9	PI 494532	8	3.4	5.0	2.9	0.8	0.8	4.0	1.6	0.6	0.3
10	PI 482319	7	3.5	4.0	2.1	0.6	0.5	5.5	2.3	0.5	0.2
11	PI 270545	7	3.5	5.3	4.3	0.6	0.0	2.3	1.2	0.6	0.3
12	PI 482246	8	3.6	4.3	2.3	0.6	0.5	5.5	2.3	0.0	0.2
13	PI 500354	7	3.6	4.5	2.7	0.5	0.6	5.3	2.0	0.5	0.5
14	PI 560010	8	3.7	5.8	3.8	1.3	0.5	3.5	1.6	0.6	0.2
15	PI 251244	7	3.7	5.3	3.9	1.4	0.5	4.0	1.9	0.8	0.2
16	PI 186489	8	3.7	5.0	2.7	1.0	1.6	4.5	2.5	0.8	0.8
17	PI 482326	5	3.7	5.0	3.6	1.0	1.0	4.3	2.0	0.5	0.2

Appendix Table 2 (continued).

			Mean disease severity rating (0-9 scale).[z]								
Rank	Cultigen		Total	Greenhouse				Field			
		Rep	plant	Leaf	Stem	SDL[y]	SDS[x]	Leaf	Stem	SDL	SDS
18	PI 560003	8	3.7	5.5	3.8	1.4	0.8	4.0	1.6	0.6	0.2
19	PI 482338	7	3.8	4.5	2.0	0.0	0.0	6.0	3.0	0.0	0.3
20	PI 482259	8	3.8	4.5	2.0	0.6	1.0	5.5	3.2	0.0	0.2
21	PI 307608	5	3.8	6.7	5.1	0.0	0.7	1.0	0.5	0.0	0.3
22	PI 500334	6	3.9	6.0	4.5	0.6	1.0	4.5	1.8	0.5	0.0
23	PI 500329	8	3.9	5.0	3.6	1.0	0.5	5.3	1.6	0.5	0.4
24	PI 500331	6	3.9	5.0	5.0	0.5	0.8	4.3	2.5	0.5	0.3
25	PI 482307	7	3.9	5.3	3.0	0.0	0.5	5.0	2.5	0.0	0.6
26	PI 494531	8	4.0	5.8	3.6	0.8	1.6	4.0	2.7	0.6	0.6
27	PI 560020	8	4.0	5.3	3.6	1.0	1.6	4.8	2.5	0.8	0.3
28	PI 560024	8	4.0	5.3	3.4	1.3	0.6	4.8	2.7	0.8	0.8
29	PI 560006	7	4.0	5.3	3.8	0.0	0.6	4.0	2.7	0.6	0.0
30	PI 482302	5	4.1	7.0	4.5	0.5	0.0	5.3	2.0	0.5	0.2
31	PI 560005	8	4.1	5.3	4.3	1.3	0.5	4.5	2.3	0.8	0.0
32	PI 482311	8	4.1	6.3	3.4	0.5	0.5	4.8	2.0	0.5	0.2
33	PI 482377	6	4.1	6.8	4.7	0.5	0.5	3.8	1.4	0.5	0.3
34	PI 482361	7	4.3	5.8	4.1	0.0	1.0	5.0	2.3	1.0	0.2

Appendix Table 2 (continued).

			Mean disease severity rating (0-9 scale).^{z}								
Rank	Cultigen		Total	Greenhouse				Field			
		Rep	plant	Leaf	Stem	SDL^{y}	SDS^{x}	Leaf	Stem	SDL	SDS
35	PI 560023	3	4.4	6.5	4.5	0.5	0.8	4.8	1.8	0.5	0.2
36	PI 482341	8	4.4	7.0	5.0	0.0	1.0	4.0	1.8	0.5	0.2
37	PI 482318	8	4.6	6.8	5.4	1.0	1.8	4.5	1.6	0.8	0.4
38	PI 482322	6	4.6	6.0	4.1	1.4	1.4	5.0	2.3	0.7	0.0
39	PI 494528	8	4.6	6.5	5.4	1.2	1.2	3.7	2.1	1.2	0.8
40	PI 482298	8	4.7	5.5	4.5	1.0	0.5	5.8	2.9	0.6	1.0
41	PI 381750	8	4.9	6.5	4.7	0.5	0.6	5.3	2.9	0.0	1.6
42	PI 225557	7	4.9	5.8	4.3	0.0	0.6	6.0	3.3	0.6	0.5
43	PI 540911	7	4.9	6.3	5.1	0.6	0.5	5.5	2.9	1.0	1.3
44	PI 482286	5	5.0	6.3	4.5	0.7	0.0	5.5	3.2	0.0	0.3
Cultivars (Checks)											
45	Tastigold	4	5.6	8.0	6.3	0.5	0.6	5.3	2.7	0.5	0.2
46	Charleston Gray	8	5.6	8.3	6.1	0.5	1.0	5.8	2.5	0.5	0.7
47	Peacock Shipper	8	5.7	8.3	5.9	0.6	0.5	5.5	3.4	0.5	0.7

Appendix Table 2 (continued).

			Mean disease severity rating (0-9 scale).[z]								
Rank	Cultigen		Total	Greenhouse				Field			
		Rep	plant	Leaf	Stem	SDL[y]	SDS[x]	Leaf	Stem	SDL	SDS
48	Hopi Red Flesh	6	5.9	8.3	6.3	0.5	0.5	6.3	2.7	0.5	0.9
49	Florida Favorite	8	5.9	8.0	6.0	0.0	0.6	6.0	3.6	0.6	0.7
50	Charlee	6	6.0	8.3	6.8	0.5	0.5	5.8	3.4	0.6	0.7
51	Navajo Sweet	8	6.6	9.0	8.6	0.5	0.6	6.3	2.7	0.0	0.5
52	Chubby Gray	8	6.7	9.0	9.0	0.0	1.0	6.0	2.9	0.5	0.7
53	Moon&Stars	6	6.7	9.0	7.9	0.6	0.6	5.7	3.3	0.6	0.7
Susceptible control											
54	PI 269677	8	7.0	9.0	9.0	0.5	0.6	6.8	3.2	0.0	0.9

[z]PI accessions were classified into resistant, intermediate, or susceptible classes based on their total plant mean disease severity rating from at least six replicates. Accessions were resistant if their total plant disease severity rating was ≤3.0; intermediate if 3.1 to 4; susceptible if ≥4.1. One PI accession and one cultivar was lost due to nonviable seeds.
[y]SDL = standard deviation of leaf rating; [x]SDS = standard deviation of stem rating.