Abstract

CRISWELL, ADAM. Screening Cucumber (*Cucumis sativus* L.) for Resistance to Downy Mildew caused by *Pseudoperonospora cubensis*. (Under the direction of Todd C. Wehner, M.S.)

Downy mildew, a foliar disease caused by the oomycete *Pseudoperonospora cubensis* (Berk. and Curt.) Rostow. is one of the most destructive pathogens of cucurbits. Resistant cultivars are available but nevertheless yield losses are high in North Carolina and Poland if fungicides are not used. The first objective of this experiment was to test all available plant introduction accessions from the U.S. National Plant Germplasm System of cucumber for downy mildew resistance under field conditions. The 1289 cultigens were tested at Clinton NC, USA, and Skierniewice, Poland during 2005-2007 under natural field epidemics of the disease. Averaged over locations, eighty-one cultigens were classified as highly resistant, 130 as moderately resistant, 406 as intermediate, 408 as moderately susceptible, and 271 as highly susceptible. The 40 most resistant and 10 most susceptible cultigens from these field trials, were further evaluated in replicated field and greenhouse experiments in North Carolina, along with 22 check cultivars. Results from the retest study in North Carolina confirmed the results of the initial screening study, although the range of downy mildew ratings in the North Carolina field retest were much narrower compared with the screening results obtained in the larger study. The most resistant and most susceptible lines in the screening study were also the most resistant and most susceptible lines in the field retest. The most resistant 10 cultigens averaged over both locations were Ames 2353, Ames 2354, PI 197085, PI 197088, PI 234517, PI 321008, PI 330628, PI 432878, PI 605996 and PI 618931. These cultigens originated from India, the United States, Pakistan, P.R. China and Taiwan. Despite the identification of resistant plant introduction accessions, they were not significantly better than the most resistant cultivars currently used in either North Carolina or Poland. The most positive aspect of the screening effort was that resistant plant introductions originated from diverse geographic regions.

Because geographic diversity is often associated with genetic diversity in germplasm collections, the newly identified resistant typed may carry unique alleles as compared to commercial material. If so, then the potential exists to develop recombinant types from crosses of commercial by exotic materials which may be more resistant. The second objective of this study was to measure the correlation of four response traits. A low correlation among the four response traits on a diverse array of cucumber cultigens would suggest that the traits are controlled by different genes. Field studies were conducted to measure the response traits of plant stunting, leaf necrosis, chlorosis and sporulation caused by downy mildew infection. Each of the four traits were measured on 67 diverse cucumber cultigens in North Carolina and India. All cucumber cultigens were tested in four replications and two locations under natural field epidemics of the disease. A significant genotype by location interaction was found by analysis of variance and data from the two locations were analyzed separately. In North Carolina, necrosis and chlorosis were highly correlated (r=0.90) while sporulation was moderately correlated with necrosis and chlorosis(r=0.71 and r=0.70, respectively) and not significantly correlated with stunting. Stunting was moderately correlated with necrosis and chlorosis (r=0.43 and r=0.34, respectively). In India, chlorosis and sporulation were highly correlated (r=0.97) while necrosis was moderately correlated with chlorosis, sporulation and stunting (r=0.67 and r=0.0.65 and r=0.76, respectively). Stunting was moderately correlated with chlorosis and sporulation (r=0.55 and r=0.57, respectively). Sporulation or necrosis may be controlled by a different gene(s) but another year of testing is required. Stunting may also be controlled by a different gene(s) but difficulties in differentiating between stunting resulting from genotype and stunting resulting from disease must be resolved. Different degrees of correlation among chlorosis, necrosis and sporulation in North Carolina and India may be due to the presence of different races in the two locations. These differences may also be explained by the variable number and timing of ratings between the two locations. Availability of only one set of data for sporulation in North Carolina may have reduced the correlation between it and necrosis and chlorosis. Sporulation ratings need to be taken on a weekly basis rather than once during the last rating. Therefore, the possibility exists that chlorosis, necrosis and sporulation are response traits controlled by the same genes.

Screening Cucumber (*Cucumis sativus*) for Resistance to Downy Mildew (*Pseudoperonospora cubensis*)

by
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BIOGRAPHY

I was born in North Adams, Massachusetts on August 30th, 1974. I always knew I wanted to pursue a career in science but it took many years for me to make it happen. My interest in horticulture began during a season as a farm hand on an organic farm at the age of 19. From that time forward my focus and interests have evolved around plants and agriculture. I worked for a number of years in the horticulture industry before deciding to go back to school for my bachelor's degree. The desire to continue my experience and education in plant science led me to a master's degree program in the Horticulture Department of North Carolina State University. I am now looking forward to completing my master's degree and finding meaningful employment utilizing my skills and education.

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General Introduction

Species of the Cucurbitaceae are grown widely around the world as crops. The family is comprised of about 118 genera and 825 species that are primarily cold-sensitive, annual vines (Jeffrey, 1990). Liberty Hyde Bailey coined the term 'cucurbit' in reference to cultivated species in the Cucurbitaceae (Robinson and Decker-Walters, 1997). Cucurbit is now commonly used as a general term for all taxa in the family.

The four major food crops of the Cucurbitaceae are watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai), cucumber (*Cucumis sativus* L.), melon (*Cucumis melo* L.) and squash (*Cucurbita* spp.). Other important cucurbit crops include Loofa (*Luffa acutangula* (L.) Roxb.), bottle gourd (*Lagenaria siceraria* (Molina) Stand.), chayote (*Sechium edule* (Jacq.) Swartz), wax gourd (*Benincasa hispida* (Thunb.) Cogn.) and bitter melon (*Momordica charantia* L.) (Robinson and Decker-Walters, 1997). The genus *Cucumis* contains 52 species, of which *C. sativus* and *C. melo* are the two most economically important (Ghebretinsae et al., 2007).

Cucumbers are considered to be of Asiatic origin and are thought to have descended from the closely related, wild *Cucumis sativus* var. *hardwickii* (Royle) Alef., found in the foothills of Nepal and northern India (Whitaker and Davis, 1962; Harlan, 1975). Cucumber has been an important food source for more than 5000 years. Cucumber remains found in Iran have been dated to 3000 b.c.e. and cucumbers have been cultivated in China for at least 2000 years (Robinson and Decker-Walters, 1997). Cucumbers were introduced to ancient Romans and Egyptians approximately 3500 years ago (Leppik, 1966; Sitterly, 1973). In the 14th and 15th centuries, Portuguese sailors carried cucumbers to West Africa while Spanish explorers brought cucumbers to the New World (Robinson and Decker-Walters, 1997). Today, cultivated cucumbers are distributed throughout most temperate and tropical climates and are the fourth most widely grown vegetable crop behind tomato (*Lycopersicon esculentum* Mill.), cabbage (*Brassica oleracea* var. *capitata* L.), and onion (*Allium cepa* L.) (Tatlioglu, 1993).

Cucumbers have both culinary and non food uses. Some cosmetic products, including lotions, perfumes and soaps contain cucumber extracts. Cucumbers are consumed as fresh or processed forms. The fruit are commonly eaten fresh in salads, pickled or cooked. In Asia, cucumber seeds are eaten as well as tender leaves and stems. Cucumber seed oil is sometimes used in French cuisine (Robinson and Decker-Walters, 1997). Cucumber cultivars are classified as slicers, picklers, gherkins, middle-eastern, trellis and European greenhouse types (Shetty and Wehner, 2002). Pickling cucumbers are the most widely grown type in the United States. In 2007, U.S. cucumber growers harvested 56,420 acres of slicing cucumbers and 98,600 acres of pickling cucumbers for a combined market value of $396,123,000 (U.S.D.A.-N.A.S.S., 2007). In 2007, North Carolina growers harvested 7200 acres of slicing cucumbers and 12,100 acres of pickling cucumbers, accounting for 13% of all harvested acreage in the U.S. for a combined market value of $24,652,000$ (USDA, 2007).

Downy mildew, a foliar disease caused by the oomycete *Pseudoperonospora cubensis* (Berk. and Curt.) Rostow. is one of the most destructive pathogens of cucurbits (Palti and Cohen, 1981). The disease was first described in Cuba in 1868 (Berkeley and Curtis, 1868). In 1903, Rostowzew presented observations of infected cucumbers in Russia. Cucurbit downy mildew was reported in Japan in 1927 (Kurosawa, 1927) and has subsequently spread to most countries where cucurbitaceous crops are grown. Berkeley and Curtis (1868) named the pathogen *Peronospora cubensis*. This nomenclature was changed by Rostowzew in 1903 as a result of his study of downy mildew on cucumbers at the Botanical Institute of Moscow. He proposed to rename the pathogen to *Pseudoperonospora cubensis.* The main distinction between the genera *Pseudoperonospora* and *Peronospora* is the mechanism by which sporangia germinate. *Pseudoperonospora* species produce asexual spores called sporangia which germinate and release zoospores. The zoospores are biflagellate and motile in water, once they encyst they will produce a germ tube that enters host stomatal pores. *Peronospora* species produce asexual spores that germinate by means of a germ tube, these spores are commonly called conidia. The germ tube from the conidia directly enters the host through stomatal pores (Palti and Cohen, 1980; Thakur and Mathur, 2001; Agrios, 2005).

Cucurbit downy mildew is distributed widely throughout the world (Palti and Cohen, 1980). The two major factors influencing downy mildew distribution are environment and host range. The disease has been recorded in approximately 70 countries, with the most severe outbreaks occurring in humid regions. Downy mildew on cucurbits can be found in diverse geographic areas ranging from semi-arid to tropical climates. The disease can also be found in northern temperate locations where cucurbits are grown during summer months. Cucumbers are the most susceptible of all the cucurbitaceous crops and downy mildew has been observed on cucumbers in most of Asia, Africa, Europe, Australia and a significant number of countries in the Americas. *C. melo* is considered to be somewhat more resistant but reports of downy mildew infection on melons have been documented in over 50 countries. Other economically important genera susceptible to *P. cubensis* are *Cucurbita* spp., *Citrullus* spp. and *Luffa* spp.

Environmental conditions play a fundamental role in disease intensity (Cohen, 1977). Leaf wetness is critical for the disease to progress and if free moisture is not on the leaf, sporangia will not germinate. Adequate leaf moisture can be supplied by rainfall, dew formation or irrigation (Duvdevani et al., 1946; Thomas, 1977). Ideal temperature for infection is 15° C, but a range between 5° C and 30° C will suffice if sufficient leaf moisture is present.

Cucurbit downy mildew is an obligate parasite and, with the rare exception of oospore production, can only survive and reproduce on living host tissue. There have been some reports of oospores being identified (Hiura and Kawada, 1933; D'Ercole, 1975; Bains et al., 1977) and the possibility exists that these could act as resting structures to help the disease overwinter in cold climates. However, this possibility has never been proven. In cooler cucumber production regions, *P. cubensis* is introduced yearly through the spread of sporangia in wind and storms from warmer regions where the pathogen can overwinter on susceptible hosts (Jenkins, 1942). In the United States, *P. cubensis* overwinters in areas with mild winter temperatures, such as Florida and Texas, on wild and cultivated cucurbits (Bains and Jhooty, 1976a). In 2006 and 2007, *P. cubensis* has also been reported in greenhouse cucumber operations in Ontario, Canada (Hausbeck, 2007).

Studies on the host range of *P. cubensis* indicated that approximately 20 genera, including 50 species in the Cucurbitaceae, were hosts. A total of 19 host species are in the genus *Cucumis* (Palti and Cohen, 1980; Lebeda, 1992a; Lebeda and Widrlechner, 2003). The expression of host resistance or susceptibility to downy mildew is often very obvious. This allows the distinction of pathotypes and races (Lebeda et al., 2006). Pathotypes can be differentiated by observing physiological reaction on a diverse set of cucurbit genera. The most recent studies have indicated the presence of at least six pathotypes (Cohen et al., 2003) and there is some evidence that many more pathotypes exist (Lebeda and Gadasova, 2002; Lebeda and Urban, 2004). For example, Thomas et al. (1987) described pathotype 1 as being virulent on *Cucumis sativus* and *Cucumis melo* var. *cantalupensis* (Syn. *C. melo* var. *reticulatus*) while pathotype 4 was virulent on *C. sativus*, *C. melo* and *Citrullus lanatus*.

Races can be differentiated by observing physiological reaction to downy mildew infection within a species at the variety or cultivar rank. Several races of *P. cubensis* have been reported in differential test studies (Hughes and Van Haltern, 1952; Palti, 1974; Bains and Jhooty, 1976b; Inaba et al., 1986; Angelov et al., 2000; Shetty et al. 2002). Shetty et al. (2002) proposed that at least two races of downy mildew exist, the race in P.R. China and India being distinct from the race present in Poland and the United States. Variability in expression of resistance can make determination of races difficult. This is especially true for cucumbers, Lebeda and Widrlechner (2003) suggested that *C. sativus* germplasm did not possess enough effective sources of resistance to differentiate races. They recommended that cucumbers only be used as susceptible control until further research is published.

Other sources of downy mildew resistance may be found within the genus *Cucumis* (Leppik, 1966). Multiple sources of resistance have been found in *C. melo* (Thomas, 1982; Cohen and Eyal, 1987) and resistance in this species has been fairly well characterized (Bains and Sharma, 1986;

Thomas et al., 1987; Cohen et al., 1989). Studies on wild *Cucumis* accessions have not resulted in new sources of down mildew resistance (Lebeda, 1992b; Lebeda, 1999). Introducing resistance from *C. melo* or other species within *Cucumis* into *C. sativus* has been suggested (Deakin et al., 1971; den Nijs and Custers, 1990; Chen and Adelberg, 2000). However, successful interspecific hybridization has been unsuccessful except for *C. hystrix* Chakr. (Chen et al., 1997).

Although genetic diversity in cucumber is limited for downy mildew resistance, some studies have identified resistant cultigens from different geographic regions. Wehner and Shetty (1997) conducted a screening test of the U.S. germplasm collection of cucumbers. They found that in North Carolina, the most resistant cultigens were all of U.S. origin and were primarily elite cultivars and breeding lines with resistance from an Indian accession (PI 197087). Staub et al. (1989) screened the germplasm collection for six pathogens. They found that 6.2% of the 753 accessions tested were resistant to downy mildew. Most of the resistant cucumbers were from China, Japan and India. Dhillon et al. (1999) tested 217 cultigens in northern India for downy mildew resistance and found nine resistant cultigens of Asian and European origin. Neykov and Dobrev (1987) also found resistant cultivars from Japan and China.

Determining the inheritance of cucumber resistance to downy mildew has been the subject of research for the past 70 years. Early disease screening efforts at the Puerto Rico agriculture experiment station focused on finding resistance from a Chinese cultivar (Roque, 1937). Puerto Rico selections 37 and 40 were found to have good fruiting characteristics as well as showing resistance to downy mildew. Cochran (1937) used the Indian cultivar ‘Bangalore’ as a source of downy mildew resistance for crosses with popular slicing and pickling cultivars of the time. Cochran found some success with crosses to ‘Bangalore’ but did not attempt to determine the precise inheritance of disease resistance.

Jenkins (1946) used P.R. 37 as a resistant parent in downy mildew studies in Minnesota as part of his PhD thesis. He did not attempt to describe the inheritance of downy mildew resistance except to say that it was probably due to a number of factors. Part of his research involved looking at the correlation between physical traits and disease resistance. Of the traits observed (spine color, fruit color, fruit netting, spine texture, and growth habit) only habit of growth appeared to have any relation to resistance. Jenkins suggested that determinate plants seemed to be more susceptible to downy mildew than indeterminate plants. Barnes and Epps (1950) observed that even resistant plants became more susceptible to infection when fruit began to approach maturity. As determinate plants set the majority of their fruit at one time, it seems likely that this is the reason they appeared to be more susceptible.

'Palmetto', a cross between P.R. 40 and 'Cubit', was released in 1948 as a highly resistant slicing cucumber (Barnes, 1948). Resistance was attributed to two primary factors; high resistance to initial infection which was exhibited by very few lesions and limited sporulation, resulting in decreased secondary infection. These resistance mechanisms were thought to be controlled by several genes. The resistance from 'Palmetto' was quickly overcome in the United States a few years after release (Epps and Barnes, 1952). A new type of resistance was described by Barnes and Epps, (1954) which was found in the plant introduction 197087 from India. The reaction of 197087 to downy mildew infection was characterized by small necrotic lesions and sparse sporulation. The main difference between this resistance and previous resistance was the absence of chlorotic tissues. Infected tissue from 197087 quickly turned brown and died, indicating an extreme hypersensitive response.

Shimizu et al. (1963) reported that resistance in 'Aojihai' was controlled by three recessive genes (proposed s_1, s_2 and s_3). Pershin et al. (1988), using cultivar 'Sadao Rischu', determined resistance to be controlled by at least three major genes exhibiting partial dominance and these were linked with at least three powdery mildew (*Podosphaera xanthii* (Castagne) U. Braun & S. Takam.) resistance genes.

Van Vliet and Meysing (1974) concluded that 'Poinsett' downy mildew resistance, probably from 197087, is attributed to a single recessive gene (which they proposed to name p). In addition, they propose that the downy mildew gene is linked or the same as the gene for powdery mildew resistance and is linked with dull green fruit color (D). As a follow up study, Van Vliet and Meysing (1977) confirm that the gene for hypocotyl resistance to powdery mildew is linked or identical to the gene for resistance to downy mildew. They also conclude that the resistance found in 'Poinsett', 'Ashley', 'Taipei', 'Natsufushinari', PI 179676, and PI 234517 all result from the same gene. However, they state that downy mildew resistance in 'Ashley' results from PI 197087 whereas, resistance actually traces back to P.R. 40 (Barnes and Epps, 1956). This would explain why 'Poinsett' was reported as more resistant than 'Ashley' and suggests a different gene. Fanourakis and Simon (1987) reported agreement with Van Vliet and Meysing confirming that downy mildew resistance is controlled by a single recessive gene.

El-Hafaz et al. (1990) report that the cultivars 'Palmetto' and 'Yomaki' are resistant in Egypt. They concluded that resistance was the result of an epistatic interaction between a dominant susceptible gene and a recessive resistance gene. Badr and Mohamed (1998) also determined that resistance is controlled by a pair of dominant and recessive interaction genes. Angelov (1994) report that PI 197088 resistance is due to two recessive genes and that 'Poinsett' resistance is from one recessive gene.

Doruchowski and Lakowska-Ryk (1992) suggested that resistance to downy mildew in Wisconsin 2843 was controlled by three recessive genes (*dm-1*, *dm-2* and *dm-3*), where *dm-3* and either *dm-1* or *dm-2* must be homozygous for resistance. Petrov et al. (2000) reported that the inheritance of resistance in J-13, a derivative of Wisconsin 2843 (resistance from PI 197087 (Peterson et al., 1985)) was unclear. They suggested that it was due to one or two incompletely-dominant genes.

In cucumber, symptoms of downy mildew occur almost entirely on the leaf blades although there is one report of fruit becoming infected (D'Ercole, 1975). Typically, infections first appear as small, water-soaked lesions on the underside of leaves, the lesions will turn chlorotic and dark colored spores form on the leaf bottom. Chlorotic spots may turn necrotic and these lesions are often angular in appearance where they border leaf veins. Eventually the entire leaf will become necrotic and die (Palti and Cohen, 1980). However, symptoms vary depending on relative susceptibility and different symptoms may indicate different mechanisms of resistance.

In previous studies several mechanisms of resistance have been described. Barnes and Epps (1954) described two types of downy mildew resistance, infected chlorotic tissues that eventually turn brown and die and a type of resistance where infected tissues rapidly necrotize and die without going through a chlorotic stage. Sporulation in both types of infection was limited. Lebeda and Prasil (1994), when screening 155 cucumber cultivars for resistance, measured intensity of sporulation for determining resistance or susceptibility. Petrov et al. (2000) describes resistance as being expressed by small, chlorotic, water soaked lesions with little sporulation.

Angelov and Krasteva (2000) describe 2 types of resistance: R1 and R2. R1 is highly resistant and is expressed as small (1 to 2 mm) round chlorotic lesions that necrotize in the center with no visible spore production, R2 is moderately resistant and has larger (3 to 4 mm) lesions that remain chlorotic for longer than 10 days. Neykov and Dobrev (1987) describe resistance as small necrotic lesions on less than 25% of leaves. Ma and Cui (1995) describe resistance as early necrosis with limited haustoria development. Tarakanov, et al. (1988) distinguish between 4 types of disease resistance; complete absence of symptoms, early chlorosis and death of leaves, necrosis of leaves at site of spore penetration and angular chlorotic spots marked with sporulation on the underside of leaves. They suggested that resistance breeding for early chlorosis and death of leaves and necrosis at site of spore penetrations would be most successful. Thomas et al. (1987) measured intensity of sporulation for testing pathotype differences between countries.

There are several proposed inheritance patterns for resistance to downy mildew as follows: three recessive genes (Shimizu et al., 1963; Doruchowski and Lakowska-Ryk, 1992); three partially dominant genes (Pershin et al., 1988); interaction between dominant susceptible and recessive resistance genes (El-Hafaz et al., 1990; Badr and Mohamed, 1998); one or two incompletely dominant genes (Petrov et al., 2000); and finally, a single recessive gene (Van Vliet and Meysing, 1974; 1976; Fanourakis and Simon, 1987; Angelov, 1994). Conflicting results regarding the expression and inheritance of downy mildew resistance in cucumber is likely due to four main factors.

First, the pathogen is highly variable and populations have not been sufficiently studied to have a full understanding of virulence factors (Lebeda and Urban, 2004). Multiple pathotypes and races have been identified (Lebeda and Widrlechner, 2003) and in some cases more than one pathotype in a geographical region has been determined (Lebeda and Urban, 2004). Different races have been reported (Epps and Barnes, 1952; Hughes and Van Haltern, 1952; Angelov et al., 2000; Shetty et al., 2002) and there are likely different genes involved in resistance to different races, if a gene for gene interaction exists.

A second factor is the role environment plays in pathogen virulence. Fluctuating temperature, humidity, rainfall and inoculum concentration all influence the severity of downy mildew infection (Cohen, 1977). Interactions between pathogen, host and environment are complex and not easily elucidated.

A third factor is the differing mechanisms of resistance. Different mechanisms of resistance have been proposed (Barnes and Epps, 1950; 1954; Palti and Cohen, 1980; Tarakanov et al., 1988; Baines, 1991; Angelov and Krasteva, 2000). The previously mentioned inheritance studies examined a number of mechanisms of resistance when evaluating for resistance. Doruchowski and Lakowska-Ryk (1992) used necrotic lesions, Van Vliet and Meysing (1974; 1977) and El Hafaz et al. (1990) used sporulation intensity, Fanourakis and Simon (1987) used incidence of chlorotic and necrotic lesions on cotyledons, and Petrov et al. (2000) used chlorotic lesions for rating resistance. Other studies did not specify how resistance was measured. Different mechanisms of resistance may have independent inheritance patterns and this should be thoroughly tested.

Finally, the source of resistance genes must be considered. Some inheritance studies have investigated resistance which came from India (PI 197087) while other studies examined resistance from China (P.R. 40) and other countries. There are likely at least two gene sources for resistance to downy mildew. One source is from P.R. 40 and the second source is from PI 197087. P.R. 40 is no longer available in the germplasm collection but a cultivar with resistance from P.R. 40 is ‘Ashley’. The combination of the two different sources should provide either, better resistance or more durable resistance. This combination can be found in PI 234517 (SC-50) which does exhibit higher resistance to downy mildew than ‘Ashley’ or PI 197087 but not significantly different resistance from cultivars with resistance from 197087 alone (Wehner and Shetty, 1997).

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Chapter One

Screening cucumber (*Cucumis sativus* L.) for resistance to downy mildew caused by (*Pseudoperonospora cubensis* (Berk. and Curt.) Rostow.)

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Abstract

Downy mildew, a foliar disease caused by the oomycete *Pseudoperonospora cubensis* (Berk. and Curt.) Rostow. is one of the most destructive pathogens of cucurbits. Resistant cultivars are available but yield losses are high in North Carolina and Poland without the use of fungicides. Pesticide resistance has been observed in populations of downy mildew. Higher levels of resistance are needed to reduce the use of pesticides while maintaining adequate yields. The objective of this experiment was to identify new sources of resistance to downy mildew among plant introduction accessions from the U.S. National Plant Germplasm System, elite cultivars, and breeding lines of cucumber. The 1289 cultigens were tested at Clinton NC, USA, and Skierniewice, Poland during 2005-2007 under natural field epidemics of the disease in unreplicated trials. Mean ratings for downy mildew leaf damage in the germplasm screening ranged from 1.0 to 7.3 in North Carolina and from 0.3 to 9.0 in Poland, on a scale of 0 to 9, where 0 indicates no disease symptoms. Eighty-one cultigens were classified as highly resistant (1.0 to 3.0), 130 as moderately resistant (3.1 to 4.0), 406 as intermediate (4.1 to 6.0), 408 as moderately susceptible (6.1 to 7.0), and 271 as highly susceptible (7.1 to 9.0). Genotypic means in the field retest in NC ranged from 0.5 to 7.2 and the means of the greenhouse retest ranged from 0.6 to 6.3. The 40 most resistant and 10 most susceptible cultigens, along with 22 check cultivars were further evaluated in replicated field and greenhouse experiments in North Carolina in 2007. Results from the retest study in NC confirmed the results of the initial screening study, although the range of downy mildew ratings in the NC field retest were much narrower compared with the screening results obtained in the larger study. The most resistant and most susceptible lines in the screening study were also the most resistant and most susceptible lines in the field retest. The most resistant 10 cultigens, averaged over both locations, were Ames 2353, Ames 2354, PI 197085, PI 197088, PI 234517, PI 321008, PI 330628, PI 432878, PI 605996 and PI 618931. These cultigens originated from India, the United States, Pakistan, P.R. China and Taiwan. The most susceptible cultigens over locations were PI 137848, PI 169328, PI 169385 and PI 172846. Despite

the identification of resistant plant introduction accessions, they were not significantly better than the most resistant cultivars currently used in either North Carolina or Poland. The most positive aspect of the screening effort was that resistant plant introductions originated from diverse geographic regions. Because geographical diversity is often associated with genetic diversity in germplasm collections, the newly identified resistant types may carry unique alleles as compared to commercial material. Future breeding efforts should concentrate on combining the resistance from these different sources into breeding lines and cultivars.

Introduction

Cucumber (*Cucumis sativus* L.) is the fourth most widely grown vegetable crop in the world after tomato (*Lycopersicon esculentum* Mill.), cabbage (*Brassica oleracea* var. *capitata* L.), and onion (*Allium cepa* L.) (Tatlioglu, 1993). P.R. China is the world leader in cucumber production, accounting for approximately 62% of the total, followed by Turkey, Iran, the Russian Federation and the United States (USDA, 2007). The oomycete pathogen *Pseudoperonospora cubensis* (Berk. and Curt.) Rostow. causes a major foliar disease in cucumber production (Palti and Cohen, 1980).

Studies on the host range of *P. cubensis* indicated that approximately 20 genera, including 50 species in the Cucurbitaceae, were hosts. A total of 19 host species are in the genus *Cucumis* (Palti and Cohen, 1980; Lebeda, 1992a; Lebeda and Widrlechner, 2003). Epidemics of downy mildew on the genus *Cucumis* have been observed in over 70 countries worldwide (Palti, 1974; Cohen, 1981). In addition to cucumber, other economically important hosts of *P. cubensis* are melon (*Cucumis melo* L.), watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai), and squash (*Cucurbita* spp.) (Whitaker and Davis, 1962).

Between 1982 and 1988 the estimated incidence of downy mildew on cucumbers in North Carolina was 30%. The average dollar loss per year was 2.9% based on yield and quality reduction

(St. Amand and Wehner, 1991). Losses from downy mildew remained minimal compared to other diseases until 2004 when a more virulent form of downy mildew caused a 40% loss for cucumber growers (Colucci et al., 2006). The new form continued to infect cucumber in most production areas in the United States in 2005, 2006 and 2007. These losses make it currently one of the most destructive diseases of cucumber in the United States.

Cucurbit downy mildew is an obligate parasite and, with the rare exception of oospore production, can only survive and reproduce on living host tissue. In cooler cucumber production regions, *P. cubensis* is introduced each summer through the spread of sporangia in wind and storms from warmer regions where the pathogen can overwinter on susceptible hosts. In the United States, *P. cubensis* overwinters in areas with mild winter temperatures, such as southern Florida and southern Texas, on wild and cultivated cucurbits (Bains and Jhooty, 1976a). In 2006 and 2007, *P. cubensis* was reported in greenhouse cucumber operations in Ontario, Canada and there is concern that this could be another source of infection (Hausbeck, 2007). Downy mildew has been a serious problem in Poland since 1985 and was considered to be a major limiting factor for cucumber production in that country (Rondomanski, 1988). In Europe, downy mildew overwinters in areas near the Mediterranean, and is carried north into countries such as Poland in early summer.

In cucumber, symptoms of downy mildew occur on the leaf blades. Infection first appears as small, water-soaked lesions on the underside of leaves, the lesions turn chlorotic, and dark colored spores form on the leaf underside. Chlorotic spots may turn necrotic and these lesions are often angular in appearance where they border leaf veins. Eventually, the entire leaf will become necrotic and die (Palti and Cohen, 1980). Downy mildew symptoms on cucumber will vary depending on its level of resistance. The most resistant cucumbers exhibit a hypersensitive response with small necrotic or chlorotic flecks and limited sporulation. The most susceptible will show many, large chlorotic and necrotic lesions with abundant sporulation, and can be killed by the disease in a few weeks.

Environmental conditions play a fundamental role in disease intensity (Cohen, 1977). Leaf wetness is critical for the disease to progress and if free moisture is not on the leaf, sporangia will not germinate. Sufficient leaf moisture can be supplied by rainfall, dew formation or irrigation. Ideal temperature for sporulation and subsequent infection is 15° C, but a range between 5° C and 30° C will suffice. Another factor influencing cucumber response to downy mildew is the variability of the pathogen population.

Several races of *P. cubensis* have been reported in differential test studies (Palti, 1974; Bains and Jhooty, 1976b; Inaba et al., 1986; Angelov et al., 2000; Shetty et al. 2002). Six pathotypes of *P. cubensis* have been reported based on their compatibility with specific host genera (Thomas et al., 1987; Cohen et al., 2003). Horejsi, Staub and Thomas (2000) stated that no evidence for race differences in the United States and European populations of *P. cubensis* exist. Shetty et al. (2002) also stated that there is no evidence for race differences between the United States and Poland. However, recent studies indicated that European populations of *P. cubensis* are highly variable and may have many pathotypes (Lebeda and Urban, 2004). In the United States, *P. cubensis* does not seem to be as variable. However, historical (Barnes and Epps, 1954) and recent (Holmes et al., 2006) epidemics suggest that the pathogen is subject to change. In the United States, cultivars previously resistant to downy mildew are still resistant to the new strain, but at a lower level. Now, resistant cultivars must be used in combination with fungicides for effective control of the disease. Fungicide-resistant biotypes of downy mildew have been reported (Reuveni et al., 1980), and new sources of genetic host resistance are in high demand.

Wehner and Shetty (1997) examined downy mildew resistance in the United States germplasm collection of cucumbers, including cultivars, breeding lines, land races and plant introduction accessions from around the world, hereafter referred to as cultigens. They reported that in North Carolina, the most resistant cultigens were of U.S. origin and were primarily elite cultivars and breeding lines. All resistance from those lines traced back to PI 197087. Interestingly, PI 197087 was found to be only intermediate in resistance in their screening studies. Staub et al. (1989) screened the germplasm collection for reaction to six pathogens. They found that 6.2% of the 753 accessions tested were resistant to downy mildew and 7.2% were susceptible. Of the resistant accessions, 34% came from China, 28% from Japan and 3% from India. Dhillon et al. (1999) tested 217 cultigens in northern India, using natural infestations in the field, for downy mildew resistance. They reported that five of the nine most resistant cultigens were of Japanese origin, two were Indian landraces and two were European. Neykov and Dobrev (1987) also reported that the most resistant cultivars were of Asian origin, mostly from Japan followed by India and P.R. China. In 1992 (Lebeda, 1992b) and 1994 (Lebeda and Prasil, 1994), 303 and 155 cucumber cultigens respectively, were tested under controlled conditions for downy mildew resistance. Little resistance was reported for these tests. However, they suggested that some cultivars despite doing poorly in the greenhouse tests, have a high degree of field resistance.

Cucumber cultivars resistant to downy mildew have been developed (Sitterly, 1973; Wehner and Shetty, 1997) over the past 50 years. However, the level of resistance in the U.S. has been less useful since 2004. We were interested in identifying higher levels of resistance in the germplasm collection, perhaps from diverse geographic regions, that could be combined to develop cultivars having higher resistance to the new form of the disease. We were also interested in evaluating the 352 accessions added to the germplasm collection since the previous screening studies in 1989. The objective of this study was to evaluate the available United States Department of Agriculture, Agriculture Research Service (U.S.D.A.-A.R.S.) cucumber germplasm collection for field resistance to downy mildew in North Carolina and Poland using commercial cultivars and breeding lines as checks.

Materials and Methods

Controlled experiments were conducted in the North Carolina State University greenhouses in Raleigh, NC. Field studies were conducted at the Horticultural Crops Research Station in Castle Hayne, North Carolina, and at the Research Institute of Vegetable Crops in Skierniewice, Poland. All cucumber PI accessions were obtained from the North Central Regional Plant Introduction Station in Ames, Iowa. The checks were 19 cucumber cultivars used as reference points for downy mildew infection. Countries with the most accessions in the collection of 1,281 were P.R. China (213), India (201), Turkey (171), Spain (70), Yugoslavia (66), Japan (63), Iran (63) and the United States (61) (Table 1.1). Check cultivars were 'Calypso' (North Carolina State Univ.), 'Coolgreen' (Seminis), 'Dasher II' (Seminis), Gy 4 (North Carolina State Univ.), 'Homegreen #2' (USDA-Wisconsin), 'H-19' (Univ. Arkansas), LJ 90430 (USDA-La Jolla), M 21 (NC State Univ.), M 41 (North Carolina State Univ.), 'Marketmore 76' (Cornell Univ.), 'National Pickling' (National Seed Storage Laboratory), 'Poinsett 76' (Cornell Univ.), 'Slice' (Clemson Univ.), 'Straight 8' (National Seed Storage Laboratory), 'Sumter' (Clemson Univ.), 'Tablegreen 72' (Cornell Univ.) 'TMG-1' (P.R. China), WI 2757 (USDA-Wisconsin) and 'Wisconsin SMR 18' (Wisconsin AES).

Inoculum Preparation

For all greenhouse tests, we collected cucumber leaves infected with *P. cubensis* from fields in Clinton, North Carolina that had not been sprayed with fungicides. Leaves were collected in the morning, placed in plastic bags (Ziploc brand) and stored in a cooler with ice. In the laboratory, five heavily-infected leaves were soaked in distilled water and rubbed gently with a glass rod to dislodge sporangia. The spore suspension was filtered through four layers of cheesecloth to remove dirt and debris and the concentration was determined with the use of a hemacytometer (Reichert Scientific Instruments, Bright-Line model). The suspension was adjusted to a final concentration between 8-12000 sporangia/mL. Immediately before inoculation, Tween 20 (0.06 g/L) was added to the inoculum suspension to keep the spores well dispersed in the solution.

In the field, no artificial inoculum was used. Plots were exposed to natural epidemics in the course of the growing season. Epidemics were encouraged using border and spreader rows of susceptible 'Coolgreen' around each field and spaced every sixth plot row to help monitor and spread the inoculum, and by using overhead irrigation. Plots were not planted until border rows showed obvious signs of infection. Plants showed significant symptoms of downy mildew by the vine tip-over stage, approximately three weeks after planting.

In the greenhouse, plants were inoculated at the one- to two-true leaf stage with a hand-pumped spray bottle (1 L size, Delta Industries). Inoculum was applied to upper and lower leaf surfaces of cotyledons and true leaves until run-off. Flats were placed in a dark growth chamber with humidifiers (100% RH, 20 °C) for 48 hours to maximize sporulation. Flats were then moved to a greenhouse (25 to 45°C) and plants were evaluated 8 to 10 days later.

Experimental Design

Germplasm screening

Field tests were performed in 2005, 2006 and 2007 in Poland and North Carolina. Fertilizer was incorporated before planting at a rate of 90-39-74 kg/ha (N-P-K) with an additional 34 kg N/ha applied at the vine-tip-over stage (four to six true leaves). Seeds were planted by hand on raised, shaped beds with centers 1.5 m apart and plots 1.5 m long. Plots were later thinned to six plants at the first true leaf stage. Irrigation was applied when needed to provide a total of 25 to 40 mm per week and a tank mix of 2.2 kg/ha of naptalam and 4.4 kg/ha of bensulide was applied preplant for weed control. Plots were separated at each end by 1.5 m alleys.

Field plots were evaluated three times (on a weekly basis) after symptoms of downy mildew developed. Plots were rated for amount of diseased leaf surface area on a 0 to 9 visual rating scale, where 0 indicates no visual disease symptoms (Jenkins and Wehner, 1983) (Table 1.2).

The experimental design was a randomized complete block design and the experiment was grown at two locations (Poland and North Carolina) and in three years (2005-2007). One replication was each year-location combination. Year was treated as a random effect and all other effects as fixed. Data were analyzed using the General Linear Model, Means and Correlation procedures of the Statistical Analysis System (SAS Institute, Inc., Cary, NC).

Germplasm retest

The 40 most resistant and 10 most susceptible cultigens were tested under field and greenhouse conditions in North Carolina in 2007 based on mean data over locations from 2005 and 2006. Field plots were planted by hand on raised, shaped beds with centers 1.5 m apart and 3.3 m in length. Plots were thinned to six plants at the first true leaf stage. Irrigation and a pre-emergent herbicide were applied as with the screening study. Plots were separated at each end by 1.5 m alleys. Border rows surrounded the entire field and spreader rows were planted after every six plot rows.

In greenhouse tests, seeds were pre-germinated for 36 to 48 hr to ensure maximum plant stand. Seeds were planted in 9x4 flats filled with a mix of peat, vermiculite and perlite (Sun Gro Horticulture, Metromix 200, Bellevue, WA). Greenhouse temperature was 45 / 25°C day / night. Each germplasm retest experiment had four replications with six and four plants per replication for field and greenhouse tests respectively. A randomized complete block design was used for all tests.

Field plots were rated four times (on a weekly basis) after symptoms of downy mildew developed using the same scale as the germplasm screening study. Greenhouse ratings were taken once, 8-10 days after inoculation.

The experiment was a randomized complete block design with four replications in the field and four replications in the greenhouse. Data were analyzed using the General Linear Model, Means and Correlation procedures of the Statistical Analysis System (SAS Institute, Inc., Cary, NC).

Results and Discussion

Germplasm Screening

A significant cultigen effect for North Carolina, Poland and the two locations combined was found by analysis of variance (Table 1.3). There was a significant cultigen by location interaction. However, the interaction effect was detected only because of the large number of degrees of freedom in the F test. In subsets of the data, the interaction was often not significant (data not shown).

The downy mildew rating at five weeks after planting in North Carolina was 4.8, 5.2, and 5.4, for each replication in 2005, 2006 and 2007 respectively. The downy mildew rating at five weeks after planting in Poland was 6.2, 7.7, and 5.3 for each replication in 2005, 2006 and 2007 respectively. The use of multiple years and locations is important for identification of useful levels of resistance, especially for a trait with the variability of downy mildew resistance.

F-Ratio and coefficient of variation indicated that the rating taken five weeks after planting was most useful for distinguishing among cultigens. That rating had a higher F-Ratio and a lower coefficient of variation than the means of ratings at three or four weeks after planting.

Ratings taken at five weeks after planting were the last ratings of the season. This rating was used to rank the cultigens from most resistant to most susceptible since it gave the best indication of resistance or susceptibility. Ratings taken at five weeks after planting are also useful indicators of how well cucumber plants are responding to downy mildew prior to fruit set. Cucumber cultigens, including resistant ones, appear to become more susceptible after fruit set (Barnes and Epps, 1950). In Poland, using the means of all ratings and all years or using the means of all ratings taken at week five after planting were most useful for distinguishing among cultigens. In North Carolina, using the means of all ratings and all years or using the means of all ratings taken at week three or week five after planting were most useful for distinguishing among cultigens (Table 1.4).

Data were summarized as the mean of all ratings taken at week five after planting for each location and combined over locations as well as standard deviations and number of missing observations (Appendix Table 1). Cultigens were ranked from most to least resistant based on ratings taken five weeks after planting.

The LSD (5%) for downy mildew resistance rating was 1.79 in North Carolina, 3.14 in Poland and 1.60 for locations combined. The LSD was higher in Poland than in North Carolina. The extra variation may have been due to Fusarium wilt (caused by *Fusarium oxysporum* f. sp. *cucumerinum*) and angular leafspot (caused by *Pseudomonas syringae* pv. *lachrymans*) present in addition to downy mildew. Differences in disease severity between locations and among replications may have resulted in higher variability.

Cultigens resistant over multiple environments are preferred so all cultigens were ranked using the combined results from Poland and North Carolina (Appendix Table 1). There were 81 highly resistant, 130 moderately resistant, 406 intermediate, 408 moderately susceptible and 271 highly susceptible cultigens. Data from Poland showed a greater range of mean downy mildew ratings compared with data from North Carolina (0.3-9.0 compared with 1.0 to 7.3 respectively). The most resistant PI accessions were not significantly more resistant than the most resistant commercial cultivars used in Poland or North Carolina.

Germplasm Retest

A subset of the U.S.D.A.-A.R.S. cucumber germplasm collection was planted in North Carolina in 2007. These were the 40 most resistant and 10 most susceptible along with 22 check cultivars based on data from North Carolina and Poland for 2005 and 2006. The retest was designed to verify the performance of the most resistant and most susceptible cultigens. Escapes can occur if a cultigen is slow to emerge from the soil or if disease incidence is clustered in the field instead of being evenly distributed. Therefore, we noted germination time for each of the cultigens in the test as well as disease presence in the field.

Analysis of variance indicated a significant cultigen effect (Table 1.6). F-Ratio and coefficient of variation were examined for the mean of all ratings and the means of each weekly rating taken at three, four, five and six weeks after planting (Table 1.7). Results indicated that either the mean of all ratings or the mean of rating taken at five weeks after planting were most useful for determining differences among cultigens for tests conducted in the field. These ratings had a higher F-Ratio and a lower coefficient of variation than the means of ratings taken at three, four, or six weeks after planting. In order to be consistent with the analysis of the germplasm screening the mean of ratings taken at five weeks after planting were used to rank the cultigens from most resistant to most susceptible. Greenhouse results were also analyzed, and the F-Ratio and coefficient of variation for greenhouse tests are presented for all four replications (Table 1.7). The range of ratings in the germplasm retest was narrower than the range in the germplasm screening, perhaps because the retest used a single location and year (Table 1.8).

The greenhouse results were variable and some cultigens did not exhibit typical responses. For example, 'Straight 8', a susceptible check cultivar, was rated highly resistant. Some of the results may be explained by high greenhouse temperature (45°C) during the test. Despite some unusual results in the greenhouse, correlation between the field and greenhouse germplasm retests was moderate ($r=0.67$, $p< .001$). There was variability for disease resistance among tests and replications within tests. Pairs of replications in the field retest were moderately correlated (Table 1.9), and were similar to correlations among locations and among pairs of replications in the field screening tests (data not shown). In the field screening test, the highest mean rating for downy mildew (5.2) was in 2007 and the lowest mean rating for downy mildew (3.9) was in 2005.

Data from the germplasm screening, the field and greenhouse retest were examined for cultigen variability between tests. The inbred check cultivars were no less variable than the plant introduction accessions among replications and between locations (Table 1.10). This suggests that the variability between the tests is not due to genetic factors, but probably results from environmental conditions and sampling error.

Not all cultigens that were resistant in the germplasm screening test were resistant in the germplasm retest. Five cultigens that were highly resistant in the screening test were also ranked highly resistant in the retest (mean rating <3.0). One cultigen, LJ 90420, was rated highly resistant in the germplasm screening test and the germplasm retest. However, the cultigen is *C. sativus* var. *hardwickii* and has seed dormancy and delayed germination. The low ratings for this cultigen were probably the result of late emergence, resulting in escape from much of the downy mildew infection. Therefore, LJ 90430 should not be used as a source of downy mildew resistance.

The remaining cultigens that were highly resistant in the screening test were either moderately resistant or intermediate in the retest. The most susceptible cultigens and check cultivars in the screening test were also the most susceptible in the retest. The cultigens that had the lowest ratings in the screening test also had the lowest ratings in the retest. The cultigens that had the highest ratings in the screening test also had the highest ratings in the retest.

Conclusions

Some cultigens that were resistant in other studies were also resistant in this study. Wehner and Shetty (1997) reported that Gy 4, 'Poinsett 76', M 21 and PI 234517 were the most resistant, we also found those cultigens to be resistant. All of these sources have PI 197087 in their pedigree as the source of downy mildew resistance. PI 234517 also has 'Ashley' as a source of resistance. The resistance from 'Ashley' is from 'P.R. 40' (Puerto Rico 40) and was reported by Barnes (1955). The combination of two resistance sources in PI 234517 did not give a significant increase in resistance compared with the resistance from PI 197087 alone. Additionally, 'Ashley' was as susceptible as the susceptible check 'Straight 8'. This suggests that the resistance from 'P.R. 40' is no longer useful. PI 197087 showed intermediate resistance in our germplasm screening study. This result also reported by Wehner and Shetty (1997). They suggested that the accession may have lost resistance as it went through seed increase and maintenance. This seems to be true since cultivars that owe their resistance to PI 197087 (Gy 4, M 21, 'Poinsett 76') still show a high level of resistance. A second possibility is that downy mildew has evolved to overcome the resistance from PI 197087.

Some of the moderately resistant check cultivars ('Marketmore 76' and 'Dasher II') or intermediate ('Sumter') also have PI 197087 as their resistance source. This leads us to the question, "If the commercial cultivars with downy mildew resistance all have the same genetic source of resistance, then why are some of them resistant and others much less resistant?" When the major resistance conferred by loci from PI 197087 was overcome by downy mildew, which is suspected to have occurred in Poland and North Carolina, other factors may lead to a more quantitative type resistance. These factors could be minor genes for specific resistance or characteristics of plant architecture such as leaf size, density of canopy and size of stomatal opening that collectively inhibit the growth and development of downy mildew with varying effectiveness. Examining these factors more closely may result in a more thorough understanding of downy mildew resistance in cucumber.

Staub et al. (1989) reported 22 PI accessions as having high resistance and Wehner and Shetty (1997) reported that 19 of these were highly resistant in their study. Five of these were highly resistant in our study, PI 197088, PI 234517, PI 267942, PI 321009 and PI 432870. The remaining PI accessions reported to be resistant by Staub et al. (1989) or by Wehner and Shetty (1997) were moderately resistant to intermediate in our study. These were PI 279466, PI 288238, PI 358813, PI 432876, PI 163217, PI 451976, PI 390244, PI 279468, PI 390255, PI 390259, PI 422182, PI 432865, PI 436672, PI 483342 and PI 489754. One cultigen, PI 167223, that was reported as resistant was found to be moderately susceptible in our study.

Resistant cultigens were identified that originated in different geographic regions. The most resistant plant introduction accessions were not significantly more resistant than the most resistant commercial cultivars. Current resistance levels may be improved by combining different alleles or gene loci into a single cultivar. Cultigens from different geographic regions may represent different resistance genes, so that should be researched further. Staub et al. (2002), researching the genetic diversity of cucumber, concluded that four genetically distinct groups exist which are based upon geographic location and date of collection. Testing resistant cultivars from each of these groups for allelism to determine if multiple gene loci are involved in resistance would be the next logical experiment. Resistance may also be influenced by the architectural characteristics of the plant. Research into the effects of leaf size, canopy density and stomatal number and size may provide useful new traits to develop in a breeding program. Finally, no attempt was made to determine the level of heterozygosity for the individual accessions. Heterozygosity can be high and the plant introduction accessions in this study, which are intermediate to susceptible, may still have useful, recessive alleles for resistance. Additionally, cultigens identified as resistant may segregate for higher levels of resistance.

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Table 1.1. Countries of origin and number of PI accessions from the U.S.D.A-A.R.S. cucumber germplasm collection that were evaluated for resistance to downy mildew.[Z]

Seed source	No. of PI accessions
Afghanistan	16
Albania	1
Australia	3
Belgium	1
Bhutan	4
Brazil	2
Bulgaria	1
Canada	7
P.R. China	213
Czech Republic	14
Denmark	3
Egypt	22
Ethiopia	2
France	7
Georgia	3
Germany	5
Greece	1
Hong Kong	4
Hungary	21
India	201
Indonesia	1
Iran	63
Iraq	1
Israel	9
Japan	63
Kazakhstan	2
Kenya	1
Korea, South	16
Lebanon	4
Macedonia	1
Malaysia	2
Mauritius	1
Moldova	2
Myanmar	2
Nepal	6
Netherlands	40
New Zealand	2
Oman	3
Pakistan	14
Philippines	4
Poland	24
Puerto Rico	5
Russian Federation	60
Spain	70
Sri Lanka	1

Table 1.1 Continued

Sweden	4
Syria	14
Taiwan	12
Tajikistan	1
Thailand	2
Turkey	171
Ukraine	7
United States	61
United Kingdom	3
Uzbekistan	6
Yugoslavia	66
Zambia	6
Zimbabwe	2
PI accessions (total)	1281
Check Cultivars	15
Breeding lines	4
Total lines tested	1300

[Z] Some countries listed as the origin of some accessions now no longer exist as political units.

Table 1.2. Disease assessment scale used for testing foliar resistance to downy mildew in cucumber germplasm screening and germplasm retest studies in North Carolina and Poland, 2005-2007.

Rating[z]	Description of symptoms[y]	
0	no symptoms	completely resistant
1	0-3% disease	highly resistant
2	3-6% disease	highly resistant
3	6-12% disease	moderately resistant
4	12-25% disease	intermediate
5	25-50% disease	intermediate
6	50-75% disease	moderately susceptible
7	75-87% disease	highly susceptible
8	87-99% disease	highly susceptible
9	100% disease	plant dead

[z] 0 to 9 visual rating scale (Jenkins and Wehner, 1983).
[y]Symptoms are necrosis and chlorosis of foliage and % is approximately the area of the leaf covered by necrotic or chlorotic lesions.

Table 1.3. Analysis of variance for the foliar downy mildew ratings of the evaluated U.S.D.A.-A.R.S. cucumber germplasm screening.

Source	**DF**	**Mean Sqaure**	**F Value**	**Pr>F**
Dependent Variable: Ratings taken at week five for North Carolina and Poland				
Location	1	4980.85	4.37	0.1047
Year (Location)	4	1138.75	452.38	<.0001
Cultigen	1298	12.62	5.01	<.0001
Cultigen*Location	1286	3.96	1.57	<.0001
Error	4865	2.52		
Dependent Variable: Mean of all ratings taken at week five for Poland				
Cultigen	1298	13.21	3.44	<.0001
Year	2	1836.26	478.12	<.0001
Error	2467	3.84		
Dependent Variable: Mean of all ratings taken at week five for North Carolina				
Cultigen	1286	3.89	3.12	<.0001
Year	2	375.13	300.97	<.0001
Error	3332	1.25		

Table 1.4. F-Ratio and Coefficient of variation for mean of downy mildew ratings taken at 3, 4 and 5 weeks after planting for the germplasm screening in Poland and North Carolina.

Trait	Mean Square	F-Ratio	CV
Mean of all rating and all years for both locations	5.39	4.14	26.12
Mean of all ratings taken at 3 weeks after planting	7.41	5.14	42.05
Mean of all ratings taken at 4 weeks after planting	7.71	3.03	34.56
Mean of all ratings taken at 5 weeks after planting	11.78	4.77	27.69
Mean of all rating and all years for Poland	8.26	4.19	32.74
Mean of all ratings in Poland taken at 3 weeks after planting	4.52	2.60	73.46
Mean of all ratings in Poland taken at 4 weeks after planting	12.53	3.07	43.43
Mean of all ratings in Poland taken at 5 weeks after planting	16.01	4.17	30.52
Mean of all rating and all years for North Carolina	2.90	4.07	19.15
Mean of all ratings in NC taken at 3 weeks after planting	4.20	3.60	27.62
Mean of all ratings in NC taken at 4 weeks after planting	3.31	2.84	23.73
Mean of all ratings in NC taken at 5 weeks after planting	4.47	3.59	23.44

Table 1.5. Most resistant and least resistant cucumber accessions with check cultivars for the germplasm screening of downy mildew foliar resistance in North Carolina and Poland.

		Poland-NC 2005-2007						
Cultigen	**Seed Source**	**Rating 3 Total[z]**	**SD**	**Rating 3 NC[y]**	**SD**	**Rating 3 Poland[x]**	**SD**	**Missing Replications[w]**
Ames 2353	United States	1.0	0.9	1.7	0.6	0.3	0.6	0
Ames 2354	United States	1.0	0.9	1.7	0.6	0.3	0.6	0
PI 197088	India	1.0	1.1	1.7	1.2	0.3	0.6	0
PI 197085	India	1.2	1.2	1.3	0.6	1.0	1.7	0
PI 330628	Pakistan	1.2	1.2	2.0	1.0	0.3	0.6	0
PI 234517	United States	1.3	1.2	2.3	0.6	0.3	0.6	0
PI 432878	P.R. China	1.3	1.2	1.7	0.6	1.0	1.7	0
PI 605996	India	1.3	1.0	1.0	1.0	1.7	1.2	0
PI 618931	P.R. China	1.3	1.2	2.0	0.0	0.0	-	3
PI 321008	Taiwan	1.5	1.4	2.7	0.6	0.3	0.6	0
PI 432875	P.R. China	1.5	1.2	2.0	0.0	1.0	1.7	0
Poinsett 76	Cornell Univ.	1.6	1.3	3.0	0.0	0.7	0.6	1
Ames 7752	United States	1.7	1.5	2.5	0.7	0.0	-	3
PI 605924	India	1.7	1.5	2.7	1.5	0.7	0.6	0
PI 618937	P.R. China	1.7	1.4	2.3	0.6	1.0	1.7	0
PI 197086	India	1.8	1.3	1.7	1.2	2.0	1.7	0
PI 321009	Taiwan	1.8	2.6	3.3	3.2	0.3	0.6	0
PI 432886	P.R. China	1.8	1.7	2.7	1.5	1.0	1.7	0
PI 390267	Japan	2.0	1.7	3.0	1.0	1.0	1.7	0
PI 432874	P.R. China	2.0	2.3	3.7	2.1	0.3	0.6	0
PI 605932	India	2.0	0.9	2.3	0.6	1.7	1.2	0
PI 606015	India	2.0	1.6	3.0	1.0	0.5	0.7	1
Homegreen #2	USDA-Wis	2.2	1.7	3.3	0.6	1.0	1.7	0
PI 518849	P.R. China	2.2	1.9	3.3	1.5	1.0	1.7	0
PI 605929	India	2.2	1.5	3.0	1.0	1.3	1.5	0
PI 618893	P.R. China	2.2	1.5	3.0	1.0	1.3	1.5	0
Gy 4	NC State Univ.	2.3	0.8	2.3	0.6	2.3	1.2	0
PI 426170	Philippines	2.3	1.2	2.7	0.6	2.0	1.7	0
PI 508455	South Korea	2.3	1.8	3.3	1.5	1.3	1.5	0
WI 2757	USDA-Wis	2.5	1.7	3.5	0.7	1.5	2.1	2
PI 418963	P.R. China	2.6	2.3	4.5	2.1	1.3	1.5	1
PI 606017	India	2.6	2.7	4.0	2.6	0.5	0.7	1
PI 606019	India	2.6	1.1	3.0	1.0	2.0	1.4	1
PI 267741	Japan	2.7	2.4	4.0	2.6	1.3	1.5	0
PI 432859	P.R. China	2.7	1.5	3.3	1.2	2.0	1.7	0
PI 605995	India	2.8	1.5	3.3	1.5	2.0	1.4	1
PI 606051	India	2.8	1.2	3.3	1.2	2.3	1.2	0
Ames 26084	United States	3.0	2.3	2.7	0.6	3.3	3.5	0
Calypso	NC State Univ.	3.0	2.5	2.5	0.7	3.3	3.5	1
LJ 90430	USDA, La Jolla	3.0	4.1	2.0	-	3.3	4.9	3
M 21	NC State Univ.	3.0	2.1	1.7	0.6	4.3	2.3	0
Slice	Clemson Univ.	3.0	1.1	3.7	0.6	2.3	1.2	0

Table 1.5 Continued

Marketmore 76	Cornell Univ.	3.5	2.5	7.0	-	2.3	1.2	2
PI 432884	P.R. China	3.7	2.8	4.0	2.6	3.3	3.5	0
Dasher II	Seminis	4.0	4.6	3.0	-	4.5	6.4	3
H-19	Univ. Arkansas	4.5	3.1	3.3	1.5	5.7	4.2	0
Sumter	Clemson Univ.	5.3	2.5	3.8	1.5	7.0	2.4	0
Straight 8	United States	5.7	2.3	3.7	0.6	7.7	1.2	0
Wis.SMR 18	Univ. Wisconsin	6.3	1.8	5.0	1.0	7.7	1.2	0
Ames 25699	Syria	7.3	1.4	6.3	0.6	8.3	1.2	0
PI 211983	Iran	7.3	1.4	6.3	0.6	8.3	1.2	0
PI 525151	Egypt	7.3	1.4	6.3	0.6	8.3	1.2	0
PI 218199	Lebanon	7.4	1.7	6.0	1.4	8.3	1.2	1
PI 171601	Turkey	7.5	1.8	6.0	1.0	9.0	0.0	0
PI 176523	Turkey	7.5	1.2	6.7	0.6	8.3	1.2	0
Ames 23009	Czech Republic	7.7	1.6	6.3	1.2	9.0	0.0	0
PI 458851	USSR	7.7	1.0	7.0	0.0	8.3	1.2	0
Ames 19225	Russian Federation	7.8	1.0	7.3	0.6	8.3	1.2	0
PI 344350	Turkey	7.8	1.3	6.7	0.6	9.0	0.0	0
Ashley	Clemson Univ.	-	-	-	-	-	-	6
Chinese Long Green	Oris	-	-	-	-	-	-	6
Heidan #1	P.R. China	-	-	-	-	-	-	6
National Pickling	NSSL	-	-	-	-	-	-	6
Nong Chen #4	P.R. China	-	-	-	-	-	-	6
TMG-1	P.R. China	-	-	-	-	-	-	6
LSD (5%)		1.60		1.79		3.14		

[Z] Mean of all ratings taken at week 5 after planting for North Carolina and Poland during 2005, 2006 and 2007.
[Y] Mean of ratings taken at week 5 after planting for North Carolina during 2005, 2006 and 2007.
[X] Mean of ratings taken at week 5 after planting for Poland during 2005, 2006 and 2007.
[W] Each year and each location is considered a replication for a total of six replications.

Table 1.6. Analysis of variance for the downy mildew foliar ratings of the cucumber germplasm retest in 2007.

Dependent Variable: Field ratings taken at week five after planting

Source	DF	Sum of Squares	Mean Sqaure	F Value	Pr>F
Cultigen	64	496.17	7.75	8.66	<.0001
Replication	3	58.24	19.41	21.68	<.0001
Error	184		0.90		

Dependent Variable: Greenhouse ratings taken 8-10 days after inoculation

Source	DF	Sum of Squares	Mean Sqaure	F Value	Pr>F
Cultigen	58	419.05	7.23	4.92	<.0001
Replication	3	3.70	1.23	0.84	0.47
Error	171		1.47		

Table 1.7. F-Ratio and coefficient of variation (CV) for germplasm retest in field and greenhouse.

Trait	Mean Square	F-Ratio	CV
Field			
Mean of all rating and all replications	4.09	10.16	28.92
Mean of all ratings taken at 3 weeks after planting	3.53	5.35	35.57
Mean of all ratings taken at 4 weeks after planting	2.79	3.56	25.85
Mean of all ratings taken at 5 weeks after planting	8.27	9.05	36.33
Mean of all ratings taken at 6 weeks after planting	5.73	4.87	40.63
Greenhouse			
Mean of all replications for greenhouse	6.93	4.70	62.86

Table 1.8. Mean ratings for downy mildew foliar resistance of cucumber accessions in the germplasm retest studies, North Carolina, 2007.

Cultigen name	Seed source	Field rating[z]	SD	Missing Replications	Greenhouse rating[y]	SD	Missing Replications
LJ 90430	USDA, La Jolla	0.5	0.4	0	-	-	4
PI 197085	India	1.9	0.9	0	0.8	0.3	0
PI 197086	India	1.9	0.5	0	2.5	0.4	0
M 21	NC State Univ.	2.0	0.7	0	1.6	0.6	0
PI 330628	Pakistan	2.3	0.6	0	0.7	0.5	0
Ames 2353	United States	3.0	0.4	0	2.8	2.2	0
Ames 7752	United States	3.0	1.1	0	1.2	0.8	0
PI 605996	India	3.0	0.7	0	2.6	1.1	0
PI 197088	India	3.1	1.4	0	1.1	0.6	0
Ames 2354	United States	3.4	1.4	0	2.4	1.3	0
PI 605932	India	3.5	0.4	0	2.0	1.6	0
Gy 4	NC State Univ.	3.6	0.8	0	1.1	1.7	0
PI 605924	India	3.8	1.2	0	1.0	1.2	0
Poinsett 76	Cornell Univ.	3.8	1.0	0	3.3	1.7	0
Ames 26084	United States	3.9	0.8	0	1.6	1.3	0
Nong Chen #4	P.R. China	3.9	0.6	0	2.3	0.7	0
PI 390267	Japan	3.9	0.3	0	3.4	1.0	0
PI 321008	Taiwan	4.1	1.4	0	2.6	1.0	0
Sumter	Clemson Univ.	4.1	1.3	0	2.1	1.9	0
PI 432878	P.R. China	4.2	2.1	0	-	-	4
Calypso	NC State Univ.	4.3	0.5	0	1.8	1.1	0
PI 234517	United	4.3	2.2	0	3.1	1.1	0
PI 321009	Taiwan	4.3	1.5	0	2.1	0.7	0
PI 432886	P.R. China	4.3	1.4	0	1.0	0.7	0
Heidan #1	P.R. China	4.5	0.7	0	3.3	0.5	0
PI 426170	Philipp	4.5	0.7	0	1.7	2.4	0
PI 418963	P.R. China	4.6	0.6	0	3.1	0.5	0
PI 432884	P.R. China	4.6	1.7	0	2.1	0.7	0
PI 605929	India	4.6	1.4	0	0.6	0.6	0
PI 618893	P.R. China	4.6	1.3	0	2.1	0.8	1
PI 618937	P.R. China	4.8	1.0	0	3.1	0.6	0
PI 432875	P.R. China	4.9	1.5	0	1.9	1.1	0
PI 606017	India	4.9	1.3	0	3.2	0.8	0
Slice	Clemson Univ.	4.9	0.5	0	1.2	0.7	0
PI 518849	P.R. China	5.0	1.2	0	-	-	4
PI 606015	India	5.0	0.7	0	3.0	0.5	0
PI 432859	P.R. China	5.1	1.3	0	1.7	0.7	0
PI 605995	India	5.1	1.0	0	1.3	1.2	0
PI 606051	India	5.1	0.9	0	3.3	0.8	0
Homegreen #2	USDA-Wis.	5.2	1.0	1	1.7	0.7	0
Ashley	Clemson Univ.	5.3	1.0	0	2.9	1.0	0
Dasher II	Seminis	5.3	0.9	0	2.6	1.1	0
TMG-1	P.R. China	5.5	-	3	-	-	0

Table 1.8 Continued

Marketmore 76	Cornell Univ.	5.6	1.0	0	3.0	2.1	0
PI 606019	India	5.8	1.7	0	2.8	0.4	0
PI 508455	South	5.9	1.2	0	0.7	0.6	0
PI 171601	Turkey	6.0	0.8	0	4.5	2.4	0
PI 176523	Turkey	6.0	0.7	0	4.7	0.9	0
PI 211983	Iran	6.1	0.5	0	5.2	1.1	0
National Pickling	NSSL	6.2	1.3	1	4.0	1.3	0
PI 218199	Lebanon	6.4	0.5	0	5.0	2.6	0
PI 525151	Egypt	6.4	0.8	0	6.3	0.3	0
Ames 19225	Russian Federation	6.5	0.9	0	4.0	0.9	0
Ames 25699	Syria	6.5	0.7	0	5.4	0.6	0
PI 458851	USSR	6.6	0.9	0	4.2	1.5	0
Straight 8	United States	6.6	1.1	0	1.9	1.9	0
Ames 23009	Czech Republic	6.8	0.3	0	4.2	0.8	0
PI 344350	Turkey	6.9	0.9	0	4.4	1.3	0
Wis.SMR 18	Univ. Wisconsin	6.9	0.3	0	4.2	1.5	0
PI 432874	PR Chi	7.0	3.5	1	5.0	1.1	1
PI 267741	Japan	7.2	1.6	1	1.9	0.3	1
Chinese Long Green	Oris	-	-	4	-	-	4
H-19	Univ. Arkansas	-	-	4	4.0	1.1	0
PI 618931	P.R. China	-	-	4	-	-	4
WI 2757	USDA-Wis	-	-	4	3.1	1.9	0
LSD (5%)		1.31			1.70		

[z] Mean of field disease ratings taken at five weeks after planting for all replications.
[y] Mean of greenhouse disease ratings for four replications.

Table 1.9. Correlation among replications for downy mildew ratings for the germplasm retest field study, North Carolina, 2007.

Trait	Replication 1[z]	Replication 2[y]	Replication 3[x]	Replication 4[w]
Replication 1	1.00	0.78**	0.60**	0.67**
Replication 2		1.00	0.71**	0.61**
Replication 3			1.00	0.71**
Replication 4				1.00

[z] Mean of all ratings over weeks for replication one.
[y] Mean of all ratings over weeks for replication two.
[x] Mean of all ratings over weeks for replication three.
[w] Mean of all ratings over weeks for replication four.
** = significant at 0.01 level.

Table 1.10. Mean downy mildew disease foliar ratings over replications for the germplasm screening study in North Carolina and Poland in 2005-2007, and for the germplasm retest study in the field and greenhouse in 2007.[Z]

	Cultigens					
	Resistant			**Susceptible**		
	Poinsett 76	**PI 197085**	**PI 330628**	**Wis. SMR 18**	**PI 344350**	**Ames 19225**
Seed Source	Cornell	India	Pakistan	Univ. Wis.	Turkey	Russian Federation
North Carolina						
Year 1	-	2.0	3.0	4.0	7.0	7.0
Year 2	3.0	1.0	1.0	5.0	6.0	7.0
Year 3	3.0	1.0	2.0	6.0	7.0	8.0
Poland						
Year 1	0.0	0.0	0.0	7.0	9.0	9.0
Year 2	1.0	3.0	1.0	9.0	9.0	9.0
Year 3	1.0	0.0	0.0	7.0	9.0	7.0
Retest - Field						
Replication 1	3.0	1.0	1.5	6.5	6.0	5.5
Replication 2	3.0	1.5	2.0	7.0	6.5	6.0
Replication 3	4.0	2.0	2.5	7.0	7.0	7.0
Replication 4	5.0	3.0	3.0	7.0	8.0	7.5
Retest - Greenhouse						
Replication 1	1.4	1.1	1.3	3.0	6.0	3.1
Replication 2	4.8	0.5	0.1	2.9	2.8	3.8
Replication 3	2.4	0.9	0.5	5.5	4.8	3.8
Replication 4	4.5	0.6	0.8	5.5	4.3	5.3

[Z] All ratings are taken at 5 weeks after planting except greenhouse which only had 1 rating. Values for all ratings were based on a single plot in the field, but were means over 4 single-plant ratings per plot in the greenhouse. The initial screening experiment was unreplicated within site-year combinations.

Chapter Two

Evaluating Cucumber Mechanisms of Resistance to Downy Mildew

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Abstract

Downy mildew, a foliar disease caused by *Pseudoperonospora cubensis* (Berk. and Curt.) Rostow. is a devastating disease of cucumbers. Environmental variability, pathogen variability and a narrow genetic base in cucumber contribute to difficulties in identifying higher sources of resistance. However, different resistance traits have been evaluated that may help plant breeders identify new sources of resistance. The objective of this study was to measure the correlation of different traits. A low correlation among the four commonly measured traits on a diverse array of cucumber cultigens would suggest that the traits were controlled by different genes. Field studies were conducted to measure the response traits of plant stunting, leaf necrosis, chlorosis and sporulation caused by downy mildew. Each of the four traits were measured on 67 diverse cucumber cultigens in North Carolina and India. In 2007, All cucumber cultigens were tested in four replications and two locations under natural field epidemics of the disease. A significant genotype by location interaction was found by analysis of variance and data from the two locations were analyzed separately. In North Carolina, necrosis and chlorosis were highly correlated ($r=0.90$, $p<0.001$) while sporulation was moderately correlated with necrosis ($r=0.71$, $p<0.001$), chlorosis ($r=0.70$, $p<0.001$) and not significantly correlated with stunting. Stunting was least well correlated with necrosis($r=0.43$, $p<0.001$) and chlorosis ($r=0.34$, $p<0.001$). In India, chlorosis and sporulation were highly correlated ($r=0.97$, $p<0.001$) while necrosis was moderately correlated with chlorosis ($r=0.67$, $p<0.001$), sporulation ($r=0.65$, $p<0.001$) and stunting ($r=0.76$, $p<0.001$). Stunting was moderately correlated with chlorosis ($r=0.55$, $p<0.001$) and sporulation ($r=0.57$, $p<0.001$). Sporulation or necrosis may be controlled by a different gene(s) but further research is necessary. Stunting may also be controlled by a different gene(s) but difficulties in differentiating between stunting resulting from genotype and stunting resulting from disease must be resolved. Different degrees of correlations among chlorosis, necrosis and sporulation in North Carolina and India may be due to the presence of different races in the two locations. These differences may also be explained by the variable number and timing of ratings

between the two locations. The lack of more than one observation per replication for sporulation in North Carolina may have contributed to the reduced correlation between it and necrosis and chlorosis. Sporulation ratings need to be taken on a weekly basis rather than once during the last rating. Therefore, the possibility exists that chlorosis, necrosis and sporulation are response traits controlled by the same genes.

Introduction

The oomycete pathogen *Pseudoperonospora cubensis* (Berk. and Curt.) Rostow. causes a major foliar disease that causes problems in the production of cucumber (*Cucumis sativus* L.) (Palti and Cohen, 1980). Research on disease resistance is being conducted around the world with a major objective to increase the level of resistance to downy mildew in cucumber. Environmental variability (Cohen, 1977; Palti and Cohen, 1980), pathogen variability (Thomas et al., 1987; Cohen et al., 2003) and a narrow genetic base in cucumber (Lebeda, 1992; Lebeda and Prasil, 1994) contribute to difficulties in identifying higher sources of resistance. However, different resistance traits have been evaluated that may help plant breeders identify new sources of resistance.

Barnes and Epps (1954) described two types of downy mildew resistance: 1) infected chlorotic tissue that eventually turned necrotic and 2) infected tissues that necrotize rapidly without going through a chlorotic stage, the classic hypersensitive response that limits disease spread. With both types of infection, sporulation was limited. Lebeda and Prasil (1994) screened 155 cucumber cultivars for downy mildew resistance using intensity of sporulation as the criterion for determining resistance. Van Vliet and Meysing (1974) and Thomas et al. (1987) also used intensity of sporulation as the criterion for testing differences in resistance levels. Petrov et al. (2000) defined resistant plants as having only small, chlorotic, water-soaked lesions with little sporulation. Angelov and Krasteva (2000) described two types of resistance, R1 and R2. R1 plants were highly resistant and had small (1 to 2 mm diameter), round, chlorotic lesions that necrotize in the center with no visible spore production. R2 plants were moderately resistant and had larger (3 to 4 mm diameter) lesions that remain chlorotic for longer than 10 days. Neykov and Dobrev (1987) described the resistant reaction as small, necrotic lesions on less than 25% of leaves. Ma and Cui (1995) described resistance as early necrosis with limited haustoria development. Tarakanov et al. (1988) distinguished among 4 types of disease resistance: 1) complete absence of symptoms, 2) early chlorosis and death of leaves, 3) necrosis of leaves at the site of spore penetration, and 4) angular spots marked with sporulation on the underside of leaves.

Bains (1990) organized the reaction of cucurbits to downy mildew into four categories of lesions. Plants in category 1 had small, chlorotic lesions with little or no sporulation. Plants in category 2 had small, chlorotic lesions with the centers collapsing. Plants in category 3 had chlorotic lesions that developed rapidly, covering large areas of the leaf, and had abundant sporulation. Plants in category 4 had lesions that were small, necrotic spots with no chlorotic phase.

Different researchers have defined downy mildew resistance using measures such as plant stunting, leaf necrosis, leaf chlorosis, or sporulation on the leaf underside (Criswell and Wehner, in press). These traits may be independently controlled. If there are different mechanisms contributing to downy mildew resistance, then one method of improving resistance would be to combine genes for contrasting mechanisms into a single cultivar. The purpose of this study was to determine the relation of contrasting resistance measures for downy mildew reaction in cucumber. A low correlation among the four measures on a diverse array of cultivars, breeding lines, land races and plant introduction accessions from around the world (hereafter collectively referred to as cultigens) would suggest that traits were controlled by different genes. In that case, it may be possible to combine the different traits for resistance into a single cultivar. We selected a set of 67 cucumber cultigens for study that differed in downy mildew resistance, because they provide a genotypic range in the four contrasting measures of downy mildew reaction: necrosis, chlorosis, sporulation, and stunting.

Materials and Methods

Location and Seed Sources

All experiments were conducted at the Horticultural Crops Research Station in Castle Hayne, North Carolina (U.S.) and in Bangalore, Karnataka (India). All *Cucumis* plant introduction accessions were obtained from the North Central Regional Plant Introduction Station in Ames, Iowa. The checks were 21 cucumber cultivars differing for downy mildew resistance used to evaluate severity of disease. Check cultivars were 'Ashley' (Clemson Univ.) 'Calypso' (North Carolina State Univ.), 'Chinese Long Green' (Oris), 'Dasher II' (Seminis), Gy 4 (North Carolina State Univ.), 'Homegreen #2' (USDA-Wisconsin), H-19 (Univ. Arkansas), LJ 90430 (USDA, La Jolla), M 21 (North Carolina State Univ.), M 41 (North Carolina State Univ.), 'Marketmore 76' (Cornell Univ.), 'National Pickling' (National Seed Storage Laboratory), 'NongChen #4' (PR China), 'Poinsett 76' (Cornell Univ.), 'Slice' (Clemson Univ.), 'Straight 8' (National Seed Storage Laboratory), 'Sumter' (Clemson Univ.), 'Tablegreen 72' (Cornell Univ.) 'TMG-1' (PR China), WI 2757 (USDA-Wisconsin) and 'Wisconsin SMR 18' (Wisconsin AES).

Inoculation Procedure

In the field, no artificial inoculum was used. Plots were exposed to natural epidemics in the course of the growing season. Epidemics were encouraged using overhead irrigation, and border and spreader rows of susceptible 'Coolgreen' around each field and spaced every fifth row to help monitor and spread the inoculum. Plots were not planted until border rows showed obvious signs of infection. Plants showed significant symptoms of downy mildew by the vine tip-over stage, approximately three weeks after planting.

Disease Assessment Scale

Field plots were rated four times (on a weekly basis) in North Carolina and three times (on a bi-weekly basis) in India, after symptoms of downy mildew developed. Cucumber reaction to downy mildew was evaluated as necrotic lesions, chlorotic lesions, degree of stunting and intensity of sporulation. Ratings were done on a 0 to 9 scale based on percent of symptomatic leaf area; a method developed by Jenkins and Wehner (1983) (Table 2.1).

For necrosis, we rated plants for the percentage of all leaves that had at least some necrotic tissue. Leaves were examined from each of the plants in the plot and a subjective average value from 0-9 was given during each rating session for each plot, where 0 indicated no visible symptoms. Chlorosis was evaluated in a similar manner, where necrosis and chlorosis were present on the same leaf, chlorosis was measured as the percentage of non-necrotic tissue with chlorotic lesions. Stunting was measured as reduction in plant size relative to the larger cultivars used as checks in the field study. Finally, sporulation on the underside of leaves was evaluated based on a percentage of leaf underside covered in spores.

In North Carolina, sporulation ratings were taken once at the last rating date from leaves towards the base of the vine. In India, sporulation data was taken three times from leaves towards the base of the vine. Leaves from the tip of the vine often do not show significant sporulation even on susceptible cultivars (Palti and Cohen, 1981; Criswell et al., in press). Visible signs of sporulation take between three and twelve days to appear (Cohen, 1977; Zitter et al. 1996). Therefore, new growth has either not had enough time to show symptoms or is more resistant.

Experiment Design

Field tests were planted on 18 July 2007 in North Carolina and on 5 November 2007 in Karnataka. All cucumbers were grown using recommended horticultural practices as summarized by Schultheis (1990). Fertilizer was incorporated before planting at a rate of 90-39-74 kg/ha (N-P-K) with an additional 34 kg N/ha applied at the vine-tip-over stage (four to six true leaves). Seeds were planted by hand in plots 3.3 m long that were on raised, shaped beds with centers 1.5 m apart. Plots were later thinned to six plants at the first true leaf stage. Irrigation was applied when needed to provide a total of 25 to 40 mm per week, and a tank mix of 2.2 kg/ha of naptalam and 4.4 kg/ha of bensulide was applied preplant for weed control. Plots were separated at each end by 1.5 m alleys.

Spreader rows surrounded the entire field and were spaced every five rows. Spreader and border rows were planted on 10 June 2007 for North Carolina and 2 October 2007 for Karnataka.

Sixty-seven cultivars that differed for downy mildew resistance were grown under heavy downy mildew incidence in the field. The experiment was a randomized complete block design with two locations (India and North Carolina) and four replications, with four rating dates in North Carolina and three rating dates in India. Data were analyzed using the General Linear Model, Means and Correlation procedures of SAS (SAS Institute, Inc., Cary, NC).

Results and Discussion

North Carolina and India

A significant genotype by location interaction was found by analysis of variance for each of the traits measured (Table 2.2). The significant interaction is likely due to the presence of a different race of downy mildew in the two locations (Shetty et al., 2002). Different rating times may also account for some of the interaction. Ratings were taken weekly in North Carolina and bi-weekly in India. There can be significant differences in ratings between weeks especially if environmental conditions are favorable for disease development. Therefore, the data was analyzed and presented for each location separately.

North Carolina

A significant cultigen effect was found by analysis of variance for each of the traits measured (Table 2.3). A significant replication effect indicated variability in the field. In order to determine how cultigens were to be ranked from most resistant to most susceptible, F-Ratio and coefficient of variation were examined for each of the resistance traits being measured.

The mean overall ratings for chlorosis or the mean overall ratings for necrosis were most useful for determining differences among cultigens (Table 2.4). These ratings had higher F-Ratios and a lower coefficient of variation than stunting or sporulation or individual weekly ratings.

It may be useful to take data on sporulation as frequently as for other methods of evaluation. Additionally, determining stunting for the cultigens in this study was difficult due to the diverse genotypes present. In some cases, plants were not stunted, but were genetically dwarf. However, stunting is a useful trait, since plants that grow well under high disease incidence may have an advantage in setting fruit and supporting it while it develops.

In the test of a diverse set of cultigens, necrosis and chlorosis were highly correlated (Table 2.5). This suggested that the two traits might be controlled by the same genes or by two sets of genes that are linked. A suspected new race of downy mildew has been affecting cucumber crops in North Carolina since 2004 (Colucci et al., 2006). The hypersensitive reaction described by Barnes and Epps (1954) appears to have lost effectiveness in controlling downy mildew.

The type line for the hypersensitive response is PI 197087. We did not use that cultigen because it was reported to have lost resistance by Wehner and Shetty (1997). They suggested that PI 197087 may have lost resistance during seed increase and maintenance. For this experiment, we chose cultivars that had resistance derived from PI 197087 ('Dasher II', Gy 4, 'Homegreen #2', M 21, 'Poinsett 76', and 'Slice') and that were stable for resistance. Although these cultivars were resistant, they did not express the typical hypersensitive response.

Sporulation was moderately correlated with necrosis and chlorosis (Table 2.5). One cultigen, PI 432874, had low sporulation and high necrosis and chlorosis. Two cultigens, Gy 4 and 'Calypso', had high sporulation and intermediate necrosis and chlorosis (Table 2.6). PI 432874 had a low rate of germination, therefore data from only one replication was available and the traits measured on this cultigen need to be confirmed. There were no cultigens that had high sporulation and low necrosis or chlorosis. The mechanism of sporulation may be controlled by a separate gene from necrosis or chlorosis but this needs further research. Cultigens with low sporulation ratings were PI 197088 and PI 605996. Cultigens with high sporulation ratings were Wisconsin SMR 18 and PI 525151.

Stunting was the least well correlated with necrosis or chlorosis and was not significantly correlated with sporulation. The plant stunting trait could possibly provide a method for selecting higher resistance to downy mildew. However, accurate rating of stunting can be difficult, because some cultivars are genetically dwarf or may emerge late from the soil. Thus, cultivars that receive a high rating for stunting should be checked in the absence of disease to determine if they are susceptible, or have inherently dwarf. Plants that were large under heavy disease pressure may be useful sources of additional resistance genes. Cultigens with low stunting ratings were PI 197086 and PI 197085. Cultigens with high stunting ratings were PI 267741 and Ames 19225.

The most resistant cultigens often had the lowest ratings for all traits measured in this study (Table 2.6). With the exception of the stunting trait, the most susceptible cultigens had high ratings for all traits measured in this study. These results suggested that high resistance is due to a combination of resistance traits, some of which may be independent of each other.

India

A significant cultigen effect was found by analysis of variance for each of the traits measured (Table 2.7). A significant replication effect was also found indicating variability in the field. When determining how cultigens were to be ranked from most resistant to most susceptible, F-Ratio and coefficient of variation were examined for the means of each of the resistance traits being measured.

Weekly ratings, mean overall ratings, and all replications were studied for all traits (Table 2.8). Results indicated that mean overall ratings for chlorosis was most useful for determining differences among cultigens. This rating had a higher F-Ratio and lower coefficient of variation than for necrosis, stunting or sporulation.

Correlation between chlorosis and sporulation was high indicating that these two resistance traits may have genes in common (Table 2.9). There were 21 cultigens that had low ratings for both chlorosis and sporulation and 16 cultigens that had high ratings for both chlorosis and sporulation (Table 2.10). Necrosis was moderately correlated with chlorosis and with sporulation and may be controlled by a different set of genes. Cultigens with low necrosis and high chlorosis and sporulation ratings were 'Marketmore 76', PI 606051 and LJ 90430. There were no cultigens with high necrosis ratings and low chlorosis or sporulation ratings.

Stunting was moderately correlated with necrosis, chlorosis and sporulation. Cultigens with low stunting ratings were PI 197085 and PI 605996. Cultigens with high stunting ratings were PI 525151 and Ames 25699.

No resistant cultigens had high ratings for any of the traits measured except M 21. This is a breeding line from NC State University had low ratings for all traits except stunting which was high. That is explained by the fact that M 21 is a dwarf, determinate inbred.

The most susceptible cultigens all had high chlorosis and sporulation ratings, and most had high necrosis and stunting ratings as well. LJ 90430, which is *Cucumis sativus* var. *hardwickii*, had low ratings for necrosis and stunting. This cultigen has delayed germination and is a small plant for the first few weeks until it begins to branch. After months of growth, plant size is large.

The most resistant cultigens tended to have the lowest ratings for all traits, and the most susceptible cultigens tended to have highest ratings for all traits (Table 2.10). High resistance is due to a combination of traits, possibly controlled by different sets of genes.

Conclusions

Data for both locations were analyzed separately due to the possibility of two different races of downy mildew. Resistance may be differentially expressed depending on the race of downy mildew and the genotype of the cucumber. In North Carolina, chlorosis was effective for distinguishing downy mildew resistance among cultigens. Necrosis was highly correlated with chlorosis, indicating that the two traits may be different physiological responses of the same genetic mechanism. Sporulation was moderately correlated with necrosis and chlorosis, and may represent a second defense response controlled by separate genes. However, more research is needed to determine this. Sporulation ratings should be taken weekly as with the other traits. Stunting was the least well correlated with any of the other traits and may also represent a physiological response to downy mildew infection controlled by separate genes. Stunting ratings should be checked in a separate planting where downy mildew is controlled so that plant size without disease can be used for comparison.

In India, chlorosis was also the best trait to use for detecting differences in resistance to downy mildew among diverse cucumber cultigens. Chlorosis was highly correlated with sporulation which suggested that the two traits are controlled by the same genetic mechanism. Necrosis was moderately correlated with chlorosis, sporulation and stunting and may represent a physiological response controlled by a separate gene or gene loci. Stunting was least well correlated with the other traits and this physiological response to downy mildew may also be controlled by a separate gene or gene loci. Difficulties in measuring stunting need to be addressed, one method for doing this would be to include plots sprayed with an effective fungicide to compare plant stunting between sprayed and unsprayed plots.

Different degrees of correlations among chlorosis, necrosis and sporulation in North Carolina and India may be due to the presence of different races in the two locations. These differences may also be explained by the variable number and timing of ratings between the two locations. The lack of more than one observation per replication for sporulation in North Carolina may have reduced the correlation between it and necrosis and chlorosis. Therefore, the possibility exists that chlorosis, necrosis and sporulation are response traits controlled by the same genes. If this were true, then ratings based on chlorotic lesions would be most useful and efficient when rating for downy mildew resistance. If the traits are controlled by different genes, then combining the genes into a single inbred may produce resistance higher than is currently available. Finally, resistance to stunting may prove useful for enhancing cucumber performance when infected by *P. cubensis*.

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Table 2.1. Subjective rating scale for field assessment of foliar resistance to downy mildew in cucumber using sporulation, necrosis, chlorosis, and stunting.

Subjective rating scale	Percent of leaf area affected by chlorosis, necrosis or sporulation[z]	Description of symptoms for plant stunting[y]
0	No symptoms	No symptoms
1	1-3	Trace
2	3-6	Trace
3	6-12	Slight
4	12-25	Slight
5	25-50	Moderate
6	50-75	Moderate
7	75-87	Severe
8	87-99	Severe
9	100	Plant dead

[z] Sporulation was rated on underside of foliage and was approximate area of leaf covered, leaf necrosis and chlorosis was rated as approximate leaf area covered with lesions.
[y] Stunting was measured as reduction in plant size relative to the resistant cultivars used as checks.

Table 2.2. Analysis of variance for downy mildew ratings taken on each of four traits for resistance in North Carolina and India.

		Dependent Variable			
		Chlorosis[z]	Necrosis[y]	Stunting[x]	Sporulation[w]
Source	**DF**	**Mean Square**	**Mean Square**	**Mean Square**	**Mean Square**
Location	1	7.26[ns]	183.19[*]	42.18[*]	0.63[ns]
Replication(Loc)	6	7.12[**]	6.90[**]	6.30[**]	7.10[ns]
Cultigen	65	21.02[**]	14.23[**]	9.77[**]	37.00[**]
Cultigen*Location	64	10.51[**]	6.80[**]	8.00[**]	11.77[**]
Error	363	0.90	1.11	1.24	1.42

[z] Mean of all chlorosis ratings
[y] Mean of all necrosis ratings
[x] Mean of all stunting ratings
[w] Mean of last sporulation rating
[ns] Not significant
[*,**] Significant at 0.01 and 0.001 respectively

Table 2.3. Analysis of variance for downy mildew ratings taken on each of four traits for resistance in North Carolina.

		Dependent Variable			
Source	DF	Chlorosis[z] Mean Square	Necrosis[y] Mean Square	Stunting[x] Mean Square	Sporulation[w] Mean Square
Cultigen	65	4.34**	4.15**	6.72**	13.82**
Replication	3	4.84**	3.84**	10.11**	1.88*
Error	187	0.47	0.49	1.64	1.85

[z] Mean of all chlorosis ratings over weeks
[y] Mean of all necrosis ratings over weeks
[x] Mean of all stunting ratings over weeks
[w] Mean of all sporulation ratings over weeks
*,** Significant at 0.01 and 0.001 respectively

Table 2.4. F-Ratios and Coefficient of variation for means of downy mildew ratings taken on each of four traits for resistance in North Carolina.

Trait	Mean Square	F-Ratio	CV
Mean of all ratings and all replications for necrosis	4.13	8.45	16.53
Mean of all ratings and all replications for chlorosis	4.37	9.27	17.56
Mean of all ratings and all replications for stunting	6.87	4.20	35.21
Mean of all ratings taken at 6 weeks after planting sporulation	13.28	7.20	27.12
Mean of all ratings taken at 3 weeks after planting for necrosis	5.64	4.97	32.56
Mean of all ratings taken at 4 weeks after planting for necrosis	3.10	2.63	21.65
Mean of all ratings taken at 5 weeks after planting for necrosis	8.40	7.46	22.10
Mean of all ratings taken at 6 weeks after planting for necrosis	5.07	3.83	29.99
Mean of all ratings taken at 3 weeks after planting for chlorosis	3.50	2.74	32.00
Mean of all ratings taken at 4 weeks after planting for chlorosis	3.82	3.36	27.74
Mean of all ratings taken at 5 weeks after planting for chlorosis	8.81	7.34	24.26
Mean of all ratings taken at 6 weeks after planting for chlorosis	6.82	4.78	31.85
Mean of all ratings taken at 4 weeks after planting stunting	5.67	3.92	28.41
Mean of all ratings taken at 5 weeks after planting stunting	8.81	3.55	52.87
Mean of all ratings taken at 6 weeks after planting sporulation	13.28	7.20	27.12

Table 2.5. Correlations of genotypic means for downy mildew resistance traits for North Carolina.

Trait	Chlorosis [y]	Stunting [x]	Sporulation [w]
Necrosis[z]	0.90**	0.43**	0.71**
Chlorosis	1.00	0.34**	0.70**
Stunting	0.34**	1.00	0.05ns

[z] Mean of all ratings and all replications for necrosis
[y] Mean of all ratings and all replications for chlorosis
[x] Mean of all ratings and all replications for stunting
[w] Mean of all ratings taken at 6 weeks after planting sporulation
** Indicates significant at p-value ≤ 0.01
ns Not significant

Table 2.6. Means and standard deviation of resistance traits for all ratings and replications in North Carolina, ranked from most resistant to most susceptible by chlorosis.

Cultigen	Seed source	Chlorosis Mean[z]	SD	Necrosis Mean[y]	SD	Stunting Mean[x]	SD	Sporulation Mean[w]	SD
LJ 90430	USDA, La Jolla	1.6	1.0	2.1	1.6	6.4	0.8	2.3	1.0
PI 618931	PR China	2.0	-	1.0	-	-	-	-	-
PI 330628	Pakistan	2.1	0.8	2.1	0.7	2.8	1.3	2.3	2.5
PI 197085	India	2.1	0.9	2.2	0.6	0.9	0.8	2.8	2.4
M 21	NC State Univ.	2.1	0.3	2.7	0.6	3.1	0.5	2.3	1.3
Ames 2353	United States	2.1	0.3	2.9	0.6	2.8	0.3	3.5	2.1
PI 197086	India	2.2	0.4	1.9	0.4	0.8	0.5	2.3	1.5
PI 197088	India	2.4	0.9	2.8	0.6	2.3	1.6	1.3	0.5
Ames 7752	United States	2.5	0.8	3.3	0.5	3.3	1.4	3.0	0.8
Ames 2354	United States	2.6	0.9	3.8	0.9	2.9	1.1	4.3	1.5
PI 605996	India	2.9	0.4	2.9	0.5	2.3	0.9	1.3	0.6
PI 605932	India	2.9	0.4	3.5	0.5	2.5	0.4	4.5	1.7
PI 605924	India	3.1	0.7	2.8	1.0	2.0	1.4	3.5	2.4
Gy 4	NC State Univ.	3.1	0.6	3.9	0.8	2.6	0.8	6.5	1.3
Calypso	NC State Univ.	3.1	0.3	4.1	0.1	3.8	0.9	6.5	1.0
Poinsett 76	Cornell Univ.	3.1	0.9	3.7	0.7	5.0	2.0	4.3	2.1
PI 234517	United States	3.3	1.5	4.0	1.7	3.6	1.7	3.3	0.6
PI 605929	India	3.3	0.7	4.1	1.0	4.5	1.9	3.8	0.5
TMG-1	PR China	3.3	-	5.3	-	6.0	-	4.0	-
PI 390267	Japan	3.4	0.1	3.6	0.1	2.4	1.3	4.5	1.7
PI 426170	Philippines	3.4	0.5	4.3	0.5	3.0	1.2	5.3	1.5
PI 321009	Taiwan	3.6	0.7	3.8	0.9	3.6	0.8	4.3	2.3
PI 432886	PR China	3.6	0.7	4.1	0.8	4.9	1.1	3.0	2.0
PI 618893	PR China	3.7	0.2	3.9	0.4	2.6	0.9	3.0	0.8
PI 432884	PR China	3.7	1.0	4.2	1.0	3.4	1.7	5.5	0.6
Ames 26084	United States	3.8	0.4	4.1	0.6	2.0	0.4	5.0	1.4
NongChen #4	PR China	3.8	0.0	4.1	0.3	4.4	2.1	5.3	1.2
Slice	Clemson Univ.	3.8	0.3	4.4	0.8	3.1	1.3	5.8	1.3
Heidan #1	PR China	3.8	0.1	3.6	0.7	4.0	0.9	5.3	1.0
PI 321008	Taiwan	3.9	1.2	3.6	0.7	4.6	2.3	3.7	0.6
PI 618937	PR China	3.9	0.8	3.9	0.6	2.8	1.0	5.8	0.5
Sumter	Clemson Univ.	3.9	0.9	4.6	0.3	5.5	1.1	3.0	1.4
Homegreen #2	USDA-Wis	4.1	0.5	4.2	0.6	5.0	2.3	7.3	0.6
Dasher II	Seminis	4.1	0.7	4.8	0.5	3.0	1.2	6.3	1.0
PI 418963	PR China	4.1	0.4	3.8	0.1	2.8	1.0	3.5	2.1
PI 432878	PR China	4.1	1.4	3.9	0.8	5.6	1.4	7.0	2.8
PI 432875	PR China	4.2	0.9	4.4	0.4	4.3	2.0	2.5	1.3
PI 605995	India	4.2	0.6	4.7	0.6	4.9	1.1	2.8	1.5
PI 606017	India	4.3	0.7	4.3	0.5	4.0	1.2	6.3	1.3
PI 606051	India	4.3	0.5	4.6	0.7	3.8	1.2	4.5	1.0
PI 518849	PR China	4.3	0.2	4.3	0.6	5.5	1.1	3.5	1.3
PI 432859	PR China	4.3	0.5	5.3	0.7	4.3	2.5	6.0	0.8
PI 606015	India	4.4	0.1	4.8	0.5	4.4	1.5	4.8	1.5

Table 2.6 Continued

National Pickling	NSSL	4.4	0.7	4.5	0.7	5.2	1.5	5.3	1.5
PI 508455	South Korea	4.4	1.0	4.6	0.9	4.5	1.4	4.8	1.0
Marketmore 76	Cornell Univ.	4.6	0.6	4.6	0.6	3.8	1.2	6.3	1.0
Straight 8	United States	4.6	0.5	5.4	0.6	5.0	0.9	6.5	1.3
PI 211983	Iran	4.6	0.3	5.7	0.3	2.6	0.3	8.5	0.6
Ashley	Clemson Univ.	4.8	1.1	5.2	1.2	4.9	1.0	7.0	1.7
PI 171601	Turkey	4.9	0.9	5.3	0.9	2.5	0.7	7.8	0.5
PI 176523	Turkey	5.0	0.4	5.1	0.6	2.0	1.0	8.0	0.8
PI 267741	Japan	5.1	1.0	5.9	1.1	6.7	1.4	6.3	3.1
PI 458851	Russian Federation	5.3	0.6	5.5	0.5	4.6	1.3	7.3	1.7
Ames 23009	Czech Republic	5.3	0.2	5.8	0.5	3.3	0.6	8.0	0.0
PI 606019	India	5.3	1.3	4.7	0.9	4.3	1.7	6.0	1.0
PI 525151	Egypt	5.4	0.4	5.3	0.4	2.9	0.9	8.3	1.0
Ames 19225	Soviet Union	5.5	0.4	5.9	0.5	5.4	1.1	6.5	1.3
Wis.SMR 18	Univ. Wis.	5.6	0.5	5.6	0.2	3.0	0.7	9.0	0.0
PI 218199	Lebanon	5.6	0.6	5.8	0.6	4.8	1.9	7.7	1.2
PI 344350	Turkey	5.8	0.7	5.8	0.2	4.1	2.1	7.3	0.6
Ames 25699	Syria	5.8	0.4	5.6	0.6	2.5	0.9	8.0	0.8
PI 432874	PR China	5.9	2.0	6.0	2.0	6.3	2.6	3.0	-
Chinese Long Green	Oris	-	-	-	-	-	-	-	-
H-19	Univ.Arkansas	-	-	-	-	-	-	-	-
WI 2757	USDA-Wis	-	-	-	-	-	-	-	-
LSD (5%)		0.95		0.97		1.77		1.88	

[z] Mean of all ratings and all replications for chlorosis
[y] Mean of all ratings and all replications for necrosis
[x] Mean of all ratings and all replications for stunting
[w] Mean of all ratings taken at 6 weeks after planting sporulation

Table 2.7. Analysis of variance for downy mildew ratings taken on each of four traits for resistance in India.

		Dependent Variable			
		Chlorosis[z]	Necrosis[y]	Stunting[x]	Sporulation[w]
Source	**DF**	**Mean Square**	**Mean Square**	**Mean Square**	**Mean Square**
Cultigen	66	34.68**	20.31**	14.41**	37.44**
Replication	3	11.74**	6.27*	3.49*	9.99**
Error	182	1.53	1.70	0.92	2.50

[z] Mean of all chlorosis ratings
[y] Mean of all necrosis ratings
[x] Mean of all stunting ratings
[w] Mean of all sporulation ratings
*,** Significant at 0.01 and 0.001 respectively

Table 2.8. F-Ratios and Coefficient of variation for means of downy mildew ratings taken on each of four traits for resistance in India.

Trait	Mean Square	F-Ratio	CV
Field			
Mean of all ratings and all replications for necrosis	19.70	11.62	43.22
Mean of all ratings and all replications for chlorosis	33.68	22.01	34.79
Mean of all ratings and all replications for stunting	13.94	15.19	25.81
Mean of all ratings and all replications for sporulation	36.24	14.53	39.01
Mean of all ratings taken at 5 weeks after planting for necrosis	18.49	9.08	53.09
Mean of all ratings taken at 7 weeks after planting for necrosis	22.99	9.54	46.25
Mean of all ratings taken at 3 weeks after planting for chlorosis	29.11	16.22	54.90
Mean of all ratings taken at 5 weeks after planting for chlorosis	44.70	12.76	47.20
Mean of all ratings taken at 7 weeks after planting for chlorosis	41.65	11.03	47.00
Mean of all ratings taken at 5 weeks after planting stunting	11.85	10.19	33.37
Mean of all ratings taken at 7 weeks after planting stunting	17.16	10.99	29.93
Mean of all ratings taken at 3 weeks after planting sporulation	42.42	8.59	67.41
Mean of all ratings taken at 5 weeks after planting sporulation	46.28	8.24	56.77
Mean of all ratings taken at 7 weeks after planting sporulation	41.78	6.98	53.81

Table 2.9. Correlation of genotypic means for downy mildew resistance traits for India.

Trait	Chlorosis [y]	Stunting [x]	Sporulation [w]
Necrosis[z]	0.67**	0.76**	0.65**
Chlorosis	1.00	0.55**	0.97**
Stunting	0.55**	1.00	0.57**

[z] Mean of all ratings and all replications for necrosis.
[y] Mean of all ratings and all replications for chlorosis.
[x] Mean of all ratings and all replications for stunting.
[w] Mean of all ratings taken at 6 weeks after planting sporulation.
** Indicates significant at p-value ≤ 0.01

Table 2.10. Means and standard deviation of resistance traits for all ratings and replications in India, ranked from most resistant to most susceptible by chlorosis.

Cultigen	Seed Source	Chlorosis Mean[z]	SD	Necrosis Mean[y]	SD	Stunting Mean[x]	SD	Sporulation Mean[w]	SD
PI 432886	PR China	0.0	0.0	0.1	0.3	2.5	0.6	0.0	0.0
PI 518849	PR China	0.0	-	0.0	-	1.7	-	0.0	-
PI 432878	PR China	0.0	0.0	2.2	-	2.8	-	0.0	0.0
PI 432884	PR China	0.0	0.0	1.0	0.9	2.4	0.9	0.0	0.0
Ames 2354	United States	0.0	0.0	5.1	1.1	4.9	0.8	2.2	2.8
Ames 2353	United States	0.0	0.0	3.6	1.0	4.3	0.7	0.0	0.0
PI 618893	PR China	0.0	0.0	1.4	1.1	1.7	0.5	0.0	0.0
PI 618931	PR China	0.0	-	2.2	-	3.3	-	0.0	-
PI 432875	PR China	0.2	0.4	0.8	0.3	2.5	1.0	0.0	0.0
PI 605996	India	0.2	0.4	0.7	0.5	0.8	0.7	0.2	0.4
PI 432874	PR China	0.4	0.5	1.7	0.8	3.3	1.6	2.6	3.7
PI 432859	PR China	0.4	0.7	2.4	0.3	2.8	0.5	0.0	0.0
NongChen #4	PR China	0.4	0.4	1.1	1.0	2.4	0.7	0.2	0.4
PI 618937	PR China	0.7	1.0	0.8	0.7	1.8	0.8	1.5	1.7
PI 197085	India	0.7	0.9	1.5	0.5	0.4	0.5	1.5	1.7
PI 605924	India	1.1	0.4	1.1	1.3	0.4	0.3	0.7	0.6
M21	NC State Univ.	1.1	2.2	2.2	1.8	8.6	0.6	1.9	3.9
PI 197086	India	1.3	0.9	1.0	1.1	0.7	0.5	0.9	1.1
Heidan #1	PR China	1.3	1.1	1.4	1.1	2.5	0.3	1.5	1.6
PI 418963	PR China	1.3	1.3	0.7	1.1	2.8	0.8	1.5	1.0
PI 390267	Japan	1.5	1.2	0.6	1.1	1.0	0.5	2.2	2.3
PI 197088	India	1.5	1.4	0.1	0.3	0.8	0.3	1.5	1.6
PI 508455	South Korea	1.5	1.4	1.8	0.8	2.2	0.8	1.7	1.5
PI 234517	United States	1.5	0.6	2.6	0.5	5.6	0.5	2.8	1.5
PI 330628	Pakistan	1.6	1.8	0.7	0.8	1.4	0.7	2.3	1.9
PI 605932	India	1.9	1.0	2.8	1.4	3.2	0.5	1.5	0.6
Poinsett 76	Cornell Univ.	1.9	2.0	1.4	1.0	3.1	0.3	3.0	2.6
PI 605929	India	2.2	1.9	2.0	2.0	3.3	1.0	2.8	2.6
PI 321008	Taiwan	2.4	1.3	0.7	1.1	1.4	1.7	2.0	1.6
PI 321009	Taiwan	2.5	2.3	1.1	1.5	2.1	1.1	2.9	1.7
Ames 26084	United States	2.6	2.5	5.3	1.7	5.8	1.7	3.3	2.7
Slice	Clemson Univ.	2.8	0.4	3.1	2.8	3.3	0.6	3.9	1.9
TMG-1	PR China	3.3	-	0.0	-	2.2	-	4.4	-
PI 426170	Philippines	3.3	1.3	2.6	2.1	3.8	1.1	3.9	2.8
Gy 4	NC State Univ.	3.3	1.4	5.3	2.1	5.1	1.5	3.9	1.4
Ames 7752	United States	3.5	0.7	3.2	1.1	4.6	0.9	4.6	0.9
PI 606019	India	3.9	2.0	1.7	1.1	3.3	0.8	4.5	1.8
PI 606017	India	4.6	2.9	1.7	0.6	2.5	1.0	5.4	1.8
Sumter	Clemson Univ.	4.7	2.9	0.3	0.6	5.6	1.2	7.2	2.1
PI 605995	India	4.8	1.3	1.4	1.7	3.1	0.7	6.7	1.6
PI 267741	Japan	4.9	1.6	1.8	1.2	2.8	1.0	5.6	1.4
Calypso	NC State Univ.	5.2	0.9	5.6	2.3	6.1	0.8	5.9	0.6
Ashley	Clemson Univ.	5.4	1.1	0.8	1.0	3.2	0.8	6.5	1.6

Table 2.10 Continued

Homegreen #2	USDA-Wis	5.7	1.9	4.6	1.7	2.4	0.9	8.0	1.9
PI 606015	India	5.7	2.9	0.8	0.7	2.6	0.5	4.3	3.0
Marketmore 76	Cornell Univ.	6.1	0.9	2.4	1.7	3.3	0.8	6.7	1.5
PI 606051	India	6.5	1.5	2.4	2.1	3.3	0.0	6.1	1.9
Ames 19225	Russian Federation	6.9	1.9	4.3	2.7	7.1	1.2	7.0	1.5
Dasher II	Seminis	6.9	0.7	5.8	1.5	4.4	0.9	7.6	1.3
National Pickling	NSSL	7.2	0.4	3.9	2.3	6.3	1.1	8.7	0.4
LJ 90430	USDA, La Jolla	7.4	1.9	1.0	0.8	2.1	1.1	8.1	1.7
PI 218199	Lebanon	7.6	0.9	4.6	1.3	5.1	0.8	8.0	1.4
Straight 8	United States	8.0	1.1	6.5	1.1	4.0	0.9	8.0	1.4
PI 176523	Turkey	8.0	0.4	5.4	2.3	4.3	0.9	8.9	0.0
PI 525151	Egypt	8.1	0.6	7.6	0.3	8.2	0.8	8.9	0.0
PI 211983	Iran	8.3	0.7	6.9	1.0	4.7	1.0	8.7	0.4
Wis. SMR 18	Univ. Wis.	8.3	0.7	7.2	0.8	5.3	2.0	8.7	0.4
Ames 23009	Czech Republic	8.5	0.7	6.9	1.1	5.7	2.4	8.9	0.0
PI 344350	Turkey	8.5	0.7	7.1	1.4	6.4	1.6	8.5	0.7
PI 171601	Turkey	8.5	0.7	7.0	0.6	6.5	1.4	8.7	0.4
Ames 25699	Syria	8.7	0.4	8.3	0.5	7.8	0.9	8.3	1.1
PI 458851	Russian Federation	8.9	0.0	8.3	0.5	6.9	0.7	8.9	0.0
LSD (5%)		1.71		1.80		1.33		2.19	

[z] Mean of all ratings and all replications for necrosis.
[y] Mean of all ratings and all replications for chlorosis.
[x] Mean of all ratings and all replications for stunting.
[w] Mean of all ratings and all replications for sporulation.

APPENDIX

Appendix Table 1. Cucumber germplasm screening ranked from most to least downy mildew resistant by rating three (taken five weeks after planting) with standard deviation, means of rating three in North Carolina and Poland and number of missing replications.

Cultigen	Seed Source	Rating 3 Total[z]	SD	Rating 3 NC[y]	Rating 3 Poland[x]	Missing replications[w]
PI 197088	India	1.0	1.1	1.7	0.3	0
Ames 2354	United States	1.0	0.9	1.7	0.3	0
PI 267942	Japan	1.0	-	-	1.0	5
Ames 2353	United States	1.0	0.9	1.7	0.3	0
PI 197085	India	1.2	1.2	1.3	1.0	0
PI 330628	Pakistan	1.2	1.2	2.0	0.3	0
PI 432878	P.R. China	1.3	1.2	1.7	1.0	0
PI 618931	P.R. China	1.3	1.2	2.0	0.0	3
PI 234517	United States	1.3	1.2	2.3	0.3	0
PI 605996	India	1.3	1.0	1.0	1.7	0
PI 321008	Taiwan	1.5	1.4	2.7	0.3	0
PI 432875	P.R. China	1.5	1.2	2.0	1.0	0
Poinsett 76	Cornell Univ.	1.6	1.3	3.0	0.7	1
PI 432882	P.R. China	1.7	1.4	2.3	1.0	0
PI 618937	P.R. China	1.7	1.4	2.3	1.0	0
PI 605924	India	1.7	1.5	2.7	0.7	0
Ames 7752	United States	1.7	1.5	2.5	0.0	3
PI 197086	India	1.8	1.3	1.7	2.0	0
PI 321009	Taiwan	1.8	2.6	3.3	0.3	0
PI 432886	P.R. China	1.8	1.7	2.7	1.0	0
PI 532162	Oman	2.0	1.4	-	2.0	4
PI 605932	India	2.0	0.9	2.3	1.7	0
PI 432874	P.R. China	2.0	2.3	3.7	0.3	0
PI 390267	Japan	2.0	1.7	3.0	1.0	0
PI 432885	P.R. China	2.0	2.0	3.7	0.3	0
PI 606015	India	2.0	1.6	3.0	0.5	1
PI 605929	India	2.2	1.5	3.0	1.3	0
Homegreen #2	USDA-Wis	2.2	1.7	3.3	1.0	0
PI 432877	P.R. China	2.2	2.4	4.0	0.3	0
PI 518849	P.R. China	2.2	1.9	3.3	1.0	0
PI 618893	P.R. China	2.2	1.5	3.0	1.3	0
PI 618869	P.R. China	2.2	2.4	1.3	3.0	0
PI 511820	Taiwan	2.2	1.1	3.0	1.7	1
PI 618948	P.R. China	2.2	1.6	3.3	0.5	1
PI 390251	Japan	2.2	1.1	3.0	1.7	1
Gy 4	NC State Univ.	2.3	0.8	2.3	2.3	0
PI 426170	Philippines	2.3	1.2	2.7	2.0	0
PI 390246	Japan	2.3	2.2	4.0	0.7	0
PI 508455	South Korea	2.3	1.8	3.3	1.3	0
PI 385967	Kenya	2.3	1.4	2.7	2.0	0
PI 200815	Myanmar	2.4	1.3	3.5	1.7	1
PI 605928	India	2.5	2.4	2.3	2.7	0

Appendix Table 1. Continued

PI 418962	P.R. China	2.5	1.2	3.0	2.0	0
WI 2757	USDA-Wis	2.5	1.7	3.5	1.5	2
PI 618892	P.R. China	2.5	0.8	2.7	2.3	0
PI 432854	P.R. China	2.5	1.6	3.7	1.3	0
PI 391570	P.R. China	2.5	1.2	3.3	1.7	0
Ames 26049	Sri Lanka	2.6	2.6	1.7	4.0	1
PI 418963	P.R. China	2.6	2.3	4.5	1.3	1
PI 606017	India	2.6	2.7	4.0	0.5	1
PI 432881	P.R. China	2.6	1.8	3.7	1.0	1
PI 500366	Zambia	2.6	1.5	3.5	2.0	1
PI 430585	P.R. China	2.6	1.5	3.5	2.0	1
PI 606019	India	2.6	1.1	3.0	2.0	1
PI 618933	P.R. China	2.7	2.5	2.7	2.7	0
PI 432873	P.R. China	2.7	2.9	3.0	2.3	0
PI 432859	P.R. China	2.7	1.5	3.3	2.0	0
Ames 20089	Egypt	2.7	2.3	1.7	3.7	0
PI 267741	Japan	2.7	2.4	4.0	1.3	0
PI 618924	P.R. China	2.7	1.4	3.7	1.7	0
PI 212233	Japan	2.8	3.1	3.0	2.7	2
PI 432897	P.R. China	2.8	2.8	3.0	2.7	1
PI 478365	P.R. China	2.8	1.8	4.0	2.0	1
PI 432870	P.R. China	2.8	2.5	1.3	5.0	1
PI 605995	India	2.8	1.5	3.3	2.0	1
PI 618911	P.R. China	2.8	2.2	4.3	0.5	1
PI 606035	India	2.8	1.1	3.3	2.0	1
PI 606060	India	2.8	2.4	3.0	2.7	0
PI 618894	P.R. China	2.8	2.4	2.3	3.3	0
PI 618912	P.R. China	2.8	2.5	3.0	2.7	0
PI 606051	India	2.8	1.2	3.3	2.3	0
PI 432883	P.R. China	2.8	2.8	3.3	2.3	0
PI 605930	India	2.8	2.4	2.3	3.3	0
PI 618861	P.R. China	2.8	2.8	3.3	2.3	0
PI 618922	P.R. China	2.8	2.5	4.7	1.0	0
PI 418964	P.R. China	2.8	1.5	3.7	2.0	0
PI 432879	P.R. China	2.8	3.3	2.7	3.0	0
PI 561145	United States	2.8	3.2	2.3	3.3	0
PI 432862	P.R. China	2.8	2.0	4.3	1.3	0
PI 419214	Hong Kong	2.8	1.0	3.3	2.3	0
PI 227208	Japan	2.8	3.4	2.7	3.0	0
M 21	NC State Univ.	3.0	2.1	1.7	4.3	0
Calypso	NC State Univ.	3.0	2.5	2.5	3.3	1
Ames 26084	United States	3.0	2.3	2.7	3.3	0
PI 606048	India	3.0	2.3	2.7	3.3	0
PI 374694	Japan	3.0	2.4	3.3	2.7	0
Slice	Clemson Univ.	3.0	1.1	3.7	2.3	0
Ames 4759	United States	3.0	2.4	3.3	2.7	0
PI 618899	P.R. China	3.0	2.4	3.3	2.7	0
PI 451975	Canada	3.0	2.4	3.3	2.7	0

Appendix Table 1. Continued

PI 390268	Japan	3.0	3.3	3.0	3.0	0
PI 618863	P.R. China	3.0	2.4	3.3	2.7	0
PI 618906	P.R. China	3.0	2.4	3.3	2.7	0
LJ 90430	USDA,La Jolla	3.0	4.1	2.0	3.3	3
PI 618918	P.R. China	3.0	2.5	4.7	0.5	1
PI 618896	P.R. China	3.0	3.2	2.7	3.3	0
PI 518851	P.R. China	3.2	2.5	3.7	2.7	0
PI 618955	P.R. China	3.2	2.5	3.7	2.7	0
PI 390255	Japan	3.2	2.9	4.0	2.3	0
PI 511819	Taiwan	3.2	2.6	3.7	2.7	0
PI 390258	Japan	3.2	2.2	3.0	3.3	0
PI 508460	South Korea	3.2	2.5	3.7	2.7	0
PI 618905	P.R. China	3.2	2.2	2.7	3.7	0
PI 518850	P.R. China	3.2	2.5	3.7	2.7	0
PI 618923	P.R. China	3.2	3.1	3.0	3.3	0
PI 618934	P.R. China	3.2	2.6	4.7	1.7	0
PI 618907	P.R. China	3.2	2.2	3.0	3.3	0
PI 508453	South Korea	3.2	2.2	3.3	3.0	0
PI 618919	P.R. China	3.2	2.2	3.3	3.0	0
PI 487424	P.R. China	3.2	2.5	3.7	2.7	0
PI 504573	India	3.2	1.9	4.3	2.0	0
PI 618958	P.R. China	3.2	2.6	3.7	2.7	0
PI 227210	Japan	3.2	1.7	4.3	2.0	0
PI 432856	P.R. China	3.2	1.2	4.0	2.3	0
PI 432891	P.R. China	3.2	3.1	2.3	4.0	0
PI 432853	P.R. China	3.2	1.5	4.0	2.0	1
PI 321006	Taiwan	3.2	1.9	4.3	1.5	1
Ames 25154	Russian Federation	3.3	2.6	4.0	2.7	0
PI 481614	Bhutan	3.3	2.0	3.0	3.7	0
PI 618944	P.R. China	3.3	2.6	4.0	2.7	0
PI 432876	P.R. China	3.3	2.9	4.3	2.3	0
PI 432858	P.R. China	3.3	2.1	3.0	3.7	0
Ames 26085	United States	3.3	2.7	4.0	2.7	0
PI 606018	India	3.3	2.6	4.0	2.7	0
PI 618874	P.R. China	3.3	2.6	4.0	2.7	0
PI 618909	P.R. China	3.3	2.7	4.0	2.7	0
PI 432887	P.R. China	3.3	3.1	3.3	3.3	0
PI 418989	P.R. China	3.3	1.6	4.3	2.3	0
PI 618908	P.R. China	3.3	3.1	3.3	3.3	0
PI 436608	P.R. China	3.3	3.0	2.7	4.0	0
PI 481616	Bhutan	3.4	2.5	6.0	1.7	1
PI 390261	Japan	3.4	1.8	5.0	2.3	1
PI 419183	P.R. China	3.4	3.5	3.5	3.3	1
PI 504568	India	3.4	2.3	3.0	4.0	1
PI 606539	India	3.5	1.8	2.7	4.3	0
PI 532523	Japan	3.5	2.7	4.3	2.7	0
PI 618867	P.R. China	3.5	2.8	2.0	5.0	0
PI 618938	P.R. China	3.5	1.8	2.7	4.3	0

Appendix Table 1. Continued

Marketmore 76	Cornell Univ.	3.5	2.5	7.0	2.3	2
PI 464873	P.R. China	3.5	2.6	4.0	3.0	0
PI 606007	India	3.5	2.0	3.3	3.7	0
PI 279466	Japan	3.5	2.5	3.0	3.7	2
PI 390262	Japan	3.5	2.8	4.0	3.0	0
PI 489752	P.R. China	3.5	2.1	3.3	3.7	0
PI 390263	Japan	3.5	1.8	2.7	4.3	0
Ames 20206	India	3.5	2.0	3.3	3.7	0
PI 483339	South Korea	3.5	3.1	3.7	3.3	0
PI 321011	Taiwan	3.5	3.2	3.7	3.3	0
Ames 7730	United States	3.5	2.3	3.7	3.3	0
PI 618872	P.R. China	3.5	3.0	3.0	4.0	0
Ames 7753	United States	3.5	2.6	3.0	4.0	2
PI 432860	P.R. China	3.5	2.2	5.3	1.7	0
PI 279463	Japan	3.5	0.7	4.0	3.0	4
PI 618913	P.R. China	3.5	2.6	4.3	2.7	0
PI 279467	Japan	3.6	2.6	4.5	3.0	1
PI 163216	Pakistan	3.6	1.7	4.7	2.0	1
PI 606020	India	3.6	2.2	4.7	2.0	1
PI 605990	India	3.6	2.6	4.5	3.0	1
PI 605968	India	3.6	0.9	4.0	3.0	1
PI 511818	Taiwan	3.7	1.8	4.3	3.0	0
PI 427230	Nepal	3.7	3.5	4.3	3.0	0
PI 432884	P.R. China	3.7	2.8	4.0	3.3	0
PI 511817	Taiwan	3.7	2.7	4.3	3.0	0
PI 432895	P.R. China	3.7	2.7	2.3	5.0	0
PI 432894	P.R. China	3.7	2.3	4.0	3.3	0
PI 618940	P.R. China	3.7	1.6	3.0	4.3	0
PI 419009	P.R. China	3.7	2.7	4.7	2.7	0
PI 192940	P.R. China	3.7	2.0	3.7	3.7	0
PI 390241	Japan	3.7	2.2	3.7	3.7	0
PI 618875	P.R. China	3.7	2.7	4.7	2.7	0
PI 302443	Taiwan	3.7	2.1	3.7	3.7	0
PI 436672	P.R. China	3.7	2.3	4.0	3.3	0
PI 618886	P.R. China	3.7	2.2	5.3	2.0	0
Ames 7735	United States	3.7	3.0	3.7	3.7	0
PI 482463	Zimbabwe	3.7	2.3	4.3	3.0	0
PI 390238	Japan	3.7	2.7	3.0	4.3	0
PI 390952	Russian Federation	3.7	0.8	4.3	3.0	0
PI 606044	India	3.7	1.6	3.0	4.3	0
PI 618876	P.R. China	3.7	2.0	3.7	3.7	0
PI 483340	South Korea	3.7	2.8	3.0	4.3	0
PI 390264	Japan	3.7	3.4	4.0	3.3	0
PI 432864	Japan	3.7	2.9	3.3	4.0	0
PI 618921	P.R. China	3.7	2.3	3.7	3.7	0
PI 432871	P.R. China	3.7	2.3	4.0	3.3	0
PI 618860	P.R. China	3.7	2.8	3.0	4.3	0
PI 432865	Japan	3.7	2.8	3.0	4.3	0

Appendix Table 1. Continued

PI 183056	India	3.7	2.3	4.3	3.0	0
Tablegreen 72	Cornell Univ.	3.7	2.0	3.7	3.7	0
PI 605939	India	3.7	2.3	5.0	1.0	3
PI 390260	Japan	3.8	2.5	4.0	3.7	2
PI 419078	P.R. China	3.8	2.5	3.5	4.0	2
PI 214049	India	3.8	3.0	3.0	4.3	1
PI 432851	P.R. China	3.8	2.2	4.0	3.7	1
PI 605993	India	3.8	2.5	4.0	3.5	1
PI 390259	Japan	3.8	3.1	3.0	5.0	1
PI 605992	India	3.8	0.8	4.3	3.0	1
PI 114339	Japan	3.8	2.3	4.0	3.7	1
PI 605965	India	3.8	2.4	3.7	4.0	1
PI 618947	P.R. China	3.8	3.3	3.5	4.0	1
PI 390245	Japan	3.8	3.1	3.0	4.3	1
PI 606000	India	3.8	2.6	4.5	3.3	1
PI 390243	Japan	3.8	2.6	4.0	3.7	0
PI 390266	Japan	3.8	2.9	3.0	4.7	0
PI 390256	Japan	3.8	3.2	4.3	3.3	0
PI 618902	P.R. China	3.8	3.2	4.3	3.3	0
PI 618942	P.R. China	3.8	2.3	4.3	3.3	0
PI 419017	P.R. China	3.8	1.9	4.0	3.7	0
PI 267743	Hong Kong	3.8	2.2	4.0	3.7	0
PI 478366	P.R. China	3.8	3.0	5.0	2.7	0
Ames 19223	Russian Federation	3.8	3.0	4.0	3.7	0
PI 606041	India	3.8	2.3	4.3	3.3	0
PI 432892	P.R. China	4.0	2.8	3.3	4.7	0
PI 481617	Bhutan	4.0	1.5	3.7	4.3	0
PI 605933	India	4.0	2.5	3.0	5.0	0
PI 504564	India	4.0	1.5	3.7	4.3	0
PI 482464	Zimbabwe	4.0	2.2	4.0	4.0	1
PI 605920	India	4.0	2.8	3.3	4.7	0
Dasher II	Seminis	4.0	4.6	3.0	4.5	3
PI 105340	P.R. China	4.0	3.7	4.7	3.3	0
PI 267935	Japan	4.0	2.0	4.3	3.7	0
PI 179676	India	4.0	1.5	3.7	4.3	0
PI 605973	India	4.0	2.5	3.0	5.0	0
PI 618946	P.R. China	4.0	2.1	4.3	3.7	0
PI 605994	India	4.0	2.4	4.7	3.3	0
PI 419010	P.R. China	4.0	3.0	4.0	4.0	0
PI 606055	India	4.0	1.5	3.7	4.3	0
PI 606058	India	4.0	2.4	4.5	3.7	1
PI 432868	P.R. China	4.0	2.9	4.0	4.0	0
PI 427089	P.R. China	4.0	3.5	4.7	3.3	0
PI 179678	India	4.0	1.0	4.7	3.0	1
PI 500365	Zambia	4.0	1.5	3.7	4.3	0
PI 390269	Japan	4.0	2.4	5.0	3.0	0
PI 164173	India	4.0	2.6	4.0	4.0	2
Ames 22385	Nepal	4.0	2.5	2.3	5.7	0

Appendix Table 1. Continued

PI 606006	India	4.0	1.7	3.3	5.0	1
PI 378066	Japan	4.2	2.3	2.7	5.7	0
PI 483344	South Korea	4.2	1.5	4.0	4.3	0
PI 618943	P.R. China	4.2	2.1	4.7	3.7	0
PI 483343	South Korea	4.2	2.4	3.3	5.0	0
PI 618953	P.R. China	4.2	2.4	3.3	5.0	0
PI 419079	P.R. China	4.2	2.7	4.0	4.3	0
PI 489753	P.R. China	4.2	2.6	5.0	3.3	0
PI 606028	India	4.2	2.1	4.7	3.7	0
PI 255935	Netherlands	4.2	2.1	4.7	3.7	0
PI 508454	South Korea	4.2	2.4	4.7	3.7	0
PI 618903	P.R. China	4.2	3.3	4.7	3.7	0
Ames 19226	Russian Federation	4.2	2.4	3.3	5.0	0
PI 618870	P.R. China	4.2	2.6	4.0	4.3	0
PI 605954	India	4.2	2.1	4.7	3.7	0
PI 606047	India	4.2	1.5	4.0	4.3	0
PI 605919	India	4.2	2.4	3.3	5.0	0
PI 358814	Malaysia	4.2	3.1	2.0	6.3	0
PI 419041	P.R. China	4.2	2.7	4.0	4.3	0
PI 422182	Netherlands	4.2	1.6	3.7	5.0	1
PI 279468	Japan	4.2	2.9	3.5	4.7	1
PI 606016	India	4.2	1.6	3.7	5.0	1
PI 500359	Zambia	4.3	3.0	3.0	5.7	0
PI 525075	Mauritius	4.3	2.3	3.7	5.0	0
PI 426169	Philippines	4.3	3.3	3.0	5.7	0
PI 267745	Brazil	4.3	2.3	5.0	3.7	0
Ames 4833	United States	4.3	2.7	3.7	5.0	0
PI 419077	P.R. China	4.3	2.7	4.0	4.7	0
PI 518852	P.R. China	4.3	1.8	4.3	4.3	0
PI 606052	India	4.3	2.2	3.0	5.7	0
PI 483342	P.R. China	4.3	2.3	3.7	5.0	0
Ames 12781	Nepal	4.3	2.8	4.0	4.7	0
PI 605975	India	4.3	1.6	4.3	4.3	0
PI 618873	P.R. China	4.3	2.2	5.0	3.7	0
PI 462369	India	4.3	2.1	3.0	5.7	0
PI 618929	P.R. China	4.3	2.7	3.7	5.0	0
PI 435947	Russian Federation	4.3	2.3	3.7	5.0	0
Ames 26918	P.R. China	4.3	2.2	5.0	3.7	0
PI 606014	India	4.3	2.7	4.0	4.7	0
PI 163222	Pakistan	4.3	2.2	3.0	5.7	0
PI 435946	Russian Federation	4.3	2.2	5.0	3.7	0
PI 606010	India	4.3	2.3	3.7	5.0	0
PI 532521	Japan	4.3	2.8	4.3	4.3	0
PI 618928	P.R. China	4.3	3.1	3.0	5.7	0
PI 432893	P.R. China	4.3	2.9	4.7	4.0	0
PI 432855	P.R. China	4.3	2.8	4.3	4.3	0
PI 605917	India	4.3	3.2	3.3	5.3	0
PI 197087	India	4.3	2.1	5.0	3.7	0

Appendix Table 1. Continued

PI 164465	India	4.3	1.6	4.3	4.3	0
PI 618889	P.R. China	4.3	2.7	4.3	4.3	0
PI 606049	India	4.4	2.9	4.0	4.7	1
PI 605931	India	4.4	2.6	5.5	3.7	1
PI 606005	India	4.4	2.2	4.7	4.0	1
PI 618862	P.R. China	4.4	1.7	5.3	3.0	1
PI 618936	P.R. China	4.4	2.2	4.7	4.0	1
PI 432880	P.R. China	4.5	2.6	4.3	4.7	0
PI 532522	Japan	4.5	3.1	3.3	5.7	0
PI 531313	Hungary	4.5	2.0	3.3	5.7	0
PI 227207	Japan	4.5	2.7	4.3	4.7	0
PI 481612	Bhutan	4.5	2.8	4.7	4.3	0
PI 263080	Moldova	4.5	2.3	4.0	5.0	0
PI 605916	India	4.5	2.0	3.3	5.7	0
H-19	Univ. Arkansas	4.5	3.1	3.3	5.7	0
PI 390247	Japan	4.5	2.8	2.0	7.0	0
PI 432863	Japan	4.5	3.6	2.7	6.3	0
PI 390257	Japan	4.5	1.5	4.7	4.3	0
PI 605921	India	4.5	2.9	5.0	4.0	0
PI 500360	Zambia	4.5	2.0	3.3	5.7	0
PI 618957	P.R. China	4.5	2.6	4.3	4.7	0
PI 561148	United States	4.5	2.3	4.0	5.0	0
PI 508456	South Korea	4.5	2.0	3.3	5.7	0
PI 432867	P.R. China	4.5	2.3	4.0	5.0	0
PI 605941	India	4.5	3.1	5.3	3.7	0
Ames 19224	Russian Federation	4.5	2.3	4.0	5.0	0
PI 224668	South Korea	4.5	3.1	5.0	4.0	0
PI 263046	Russian Federation	4.5	2.3	4.0	5.0	0
PI 401732	Puerto Rico	4.5	2.3	4.0	5.0	0
PI 436648	P.R. China	4.5	2.2	3.3	5.7	0
PI 400270	Japan	4.5	2.9	3.3	5.7	0
PI 618954	P.R. China	4.5	2.7	4.7	4.3	0
PI 606024	India	4.5	3.1	3.7	5.3	0
PI 605912	India	4.5	2.0	3.3	5.7	0
PI 618932	P.R. China	4.5	1.8	4.7	4.3	0
PI 164679	India	4.6	2.2	3.0	5.7	1
PI 605946	India	4.6	1.5	4.3	5.0	1
PI 606057	India	4.6	2.2	3.0	5.7	1
Ames 26086	United States	4.7	2.7	3.0	6.3	0
PI 432896	P.R. China	4.7	2.7	4.7	4.7	0
PI 179921	India	4.7	1.9	3.7	5.7	0
PI 206043	Puerto Rico	4.7	2.4	4.3	5.0	0
PI 606054	India	4.7	1.9	3.7	5.7	0
PI 288238	Japan	4.7	3.4	2.3	7.0	0
PI 532161	Oman	4.7	1.6	5.0	4.3	0
PI 267197	P.R. China	4.7	2.3	3.7	5.7	0
PI 188807	Philippines	4.7	2.7	3.0	6.3	0
PI 618939	P.R. China	4.7	2.3	4.3	5.0	0

Appendix Table 1. Continued

PI 618927	P.R. China	4.7	2.3	4.3	5.0	0
PI 432869	P.R. China	4.7	3.1	4.0	5.3	0
PI 508459	South Korea	4.7	2.9	3.7	5.7	0
PI 390240	Japan	4.7	2.0	5.0	4.3	0
PI 606053	India	4.7	1.9	3.7	5.7	0
Ames 19222	Russian Federation	4.7	2.3	4.3	5.0	0
PI 390239	Japan	4.7	1.6	5.0	4.3	0
PI 618920	P.R. China	4.7	3.4	5.3	4.0	0
Ames 7736	United States	4.7	3.4	3.0	6.3	0
PI 508457	South Korea	4.7	2.9	3.7	5.7	0
PI 605918	India	4.7	2.7	3.0	6.3	0
Ames 21761	Bulgaria	4.7	3.7	3.3	6.0	0
PI 281448	South Korea	4.7	2.7	5.0	4.3	0
PI 605927	India	4.7	2.4	4.3	5.0	0
PI 618961	P.R. China	4.7	2.9	3.7	5.7	0
PI 466923	Russian Federation	4.7	2.0	5.0	4.3	0
PI 618959	P.R. China	4.7	2.9	3.7	5.7	0
PI 504563	Japan	4.7	2.3	4.3	5.0	0
PI 606003	India	4.7	1.9	5.0	4.3	0
PI 605922	India	4.7	2.7	3.0	6.3	0
PI 391571	P.R. China	4.7	2.3	4.3	5.0	0
PI 512618	Spain	4.7	2.3	5.7	3.7	0
PI 263081	P.R. China	4.7	2.4	5.7	3.7	0
PI 500370	Zambia	4.8	2.9	4.0	5.0	2
PI 92806	P.R. China	4.8	1.7	4.5	5.0	2
PI 606045	India	4.8	1.5	4.0	7.0	2
PI 358813	Malaysia	4.8	3.0	2.7	8.0	1
PI 372900	Netherlands	4.8	2.0	3.3	7.0	1
PI 436649	P.R. China	4.8	2.8	4.0	6.0	1
PI 606066	India	4.8	1.5	4.7	5.0	1
PI 261645	India	4.8	3.4	4.0	5.3	1
PI 175121	India	4.8	2.4	4.0	6.0	1
PI 217644	India	4.8	1.8	4.7	5.0	1
PI 279465	Japan	4.8	3.1	4.3	5.3	0
PI 518853	P.R. China	4.8	2.4	4.7	5.0	0
Ames 12782	Nepal	4.8	2.7	3.3	6.3	0
PI 164734	India	4.8	1.8	4.0	5.7	0
PI 249562	Thailand	4.8	2.4	2.7	7.0	0
PI 606036	India	4.8	1.8	4.0	5.7	0
PI 451976	Japan	4.8	2.2	4.7	5.0	0
PI 506461	Ukraine	4.8	1.8	4.0	5.7	0
PI 606030	India	4.8	2.3	4.7	5.0	0
PI 532524	Japan	4.8	3.0	4.0	5.7	0
PI 264229	France	4.8	2.6	3.3	6.3	0
PI 432890	P.R. China	4.8	3.2	4.3	5.3	0
PI 605911	India	4.8	2.6	3.3	6.3	0
PI 250147	Pakistan	4.8	2.9	4.0	5.7	0
PI 321007	Taiwan	4.8	2.0	4.0	5.7	0

Appendix Table 1. Continued

PI 618897	P.R. China	4.8	2.2	4.7	5.0	0
PI 263084	P.R. China	4.8	2.4	6.0	3.7	0
PI 605925	India	4.8	2.0	4.0	5.7	0
PI 618901	P.R. China	4.8	2.2	4.7	5.0	0
PI 605972	India	4.8	2.6	5.0	4.7	0
PI 605983	India	4.8	2.3	4.7	5.0	0
Ames 1763	United States	4.8	1.8	4.0	5.7	0
PI 164816	India	4.8	2.9	4.0	5.7	0
PI 508458	South Korea	4.8	2.4	4.7	5.0	0
PI 419135	P.R. China	4.8	1.8	4.0	5.7	0
PI 432852	Japan	4.8	3.1	4.0	5.7	0
PI 164670	India	4.8	1.8	4.0	5.7	0
PI 175120	India	4.8	1.8	4.0	5.7	0
PI 606034	India	4.8	2.6	3.3	6.3	0
PI 357854	Yugoslavia	5.0	2.8	-	5.0	4
PI 470254	Indonesia	5.0	2.2	3.0	7.0	0
Ames 3951	Australia	5.0	2.4	5.0	5.0	0
Ames 7749	United States	5.0	3.5	-	5.0	3
PI 163213	Pakistan	5.0	2.3	3.0	5.7	2
Ames 19039	Kazakhstan	5.0	2.3	5.0	5.0	0
PI 606009	India	5.0	1.7	4.3	5.7	0
PI 432889	P.R. China	5.0	3.8	4.0	6.0	0
PI 512617	Spain	5.0	2.2	5.7	4.3	0
Ames 3941	United States	5.0	2.4	5.0	5.0	0
PI 289698	Australia	5.0	1.9	4.3	5.7	0
PI 390242	Japan	5.0	2.4	3.7	6.3	0
PI 227209	Japan	5.0	2.0	4.0	5.7	1
PI 618952	P.R. China	5.0	2.3	5.0	5.0	0
M 41	NC State Univ.	5.0	5.7	-	5.0	4
PI 605997	India	5.0	2.5	3.7	6.3	0
PI 605923	India	5.0	2.2	3.0	7.0	0
PI 618914	P.R. China	5.0	3.3	3.7	6.3	0
PI 605953	India	5.0	2.2	5.0	5.0	0
PI 540414	Uzbekistan	5.0	2.8	5.3	4.7	0
PI 414159	United States	5.0	1.7	4.3	5.7	0
PI 618941	P.R. China	5.0	1.7	4.3	5.7	0
PI 267742	Hong Kong	5.0	2.4	5.0	5.0	0
PI 175111	India	5.0	1.7	4.3	5.7	0
PI 618888	P.R. China	5.0	2.4	5.0	5.0	0
PI 618930	P.R. China	5.0	1.7	4.3	5.7	0
PI 618885	P.R. China	5.0	2.3	5.0	5.0	0
PI 605961	India	5.0	1.6	4.3	7.0	2
PI 414158	United States	5.0	2.5	5.7	4.0	1
Ames 26916	P.R. China	5.0	2.3	5.7	4.0	1
PI 391572	P.R. China	5.0	2.8	4.3	5.7	0
PI 432888	P.R. China	5.0	2.8	4.3	5.7	0
PI 618891	P.R. China	5.0	2.4	3.7	6.3	0
PI 504816	P.R. China	5.0	2.9	5.7	4.3	0

Appendix Table 1. Continued

PI 344441	Iran	5.0	1.7	4.3	5.7	0
PI 263049	Russian Federation	5.0	1.8	4.3	5.7	0
PI 504569	India	5.2	2.1	3.3	7.0	0
PI 504562	Russian Federation	5.2	1.8	6.0	4.3	0
PI 263085	P.R. China	5.2	2.3	5.3	5.0	0
PI 606022	India	5.2	2.0	3.3	7.0	0
PI 605998	India	5.2	2.0	3.3	7.0	0
PI 171608	Turkey	5.2	1.6	4.7	5.7	0
PI 606001	India	5.2	1.7	4.7	5.7	0
Ames 4421	United States	5.2	2.4	5.3	5.0	0
PI 306180	Russian Federation	5.2	3.1	5.0	5.3	0
PI 390265	Japan	5.2	2.8	4.7	5.7	0
PI 605964	India	5.2	1.7	4.7	5.7	0
PI 512623	Spain	5.2	1.6	4.7	5.7	0
PI 436609	P.R. China	5.2	2.7	4.7	5.7	0
PI 605977	India	5.2	1.6	4.7	5.7	0
PI 606064	India	5.2	2.9	2.7	7.7	0
PI 504813	Japan	5.2	2.7	4.7	5.7	0
PI 606043	India	5.2	1.7	4.7	5.7	0
PI 163218	Pakistan	5.2	1.6	4.7	5.7	0
PI 618956	P.R. China	5.2	2.3	5.3	5.0	0
PI 606046	India	5.2	2.4	4.0	6.3	0
PI 605915	India	5.2	2.0	3.3	7.0	0
PI 605949	India	5.2	2.4	5.3	5.0	0
PI 606056	India	5.2	2.3	4.0	6.3	0
PI 249561	Thailand	5.2	2.4	4.0	6.3	0
PI 618951	P.R. China	5.2	3.0	4.7	5.7	0
Ames 23007	Czech Republic	5.2	1.7	4.7	5.7	0
Ames 3944	United States	5.2	2.3	4.0	6.3	0
PI 605976	India	5.2	2.7	4.7	5.7	0
PI 163223	Pakistan	5.2	2.0	4.0	7.0	1
PI 308915	Russian Federation	5.2	3.2	4.5	5.7	1
PI 288332	India	5.2	2.3	5.3	5.0	1
PI 257487	P.R. China	5.2	2.9	5.3	5.0	1
PI 222782	Iran	5.2	1.8	5.3	5.0	1
PI 511821	Taiwan	5.3	2.6	4.5	6.0	2
Ames 7755	United States	5.3	2.1	3.5	7.0	2
PI 390244	Japan	5.3	2.1	5.5	5.0	2
Ames 7750	United States	5.3	3.3	2.0	6.3	2
Sumter	Clemson Univ.	5.3	2.5	3.8	7.0	0
PI 483341	South Korea	5.3	1.9	5.0	5.7	0
PI 618877	P.R. China	5.3	2.3	4.3	6.3	0
PI 173893	India	5.3	1.9	3.7	7.0	0
PI 512594	Spain	5.3	1.5	5.0	5.7	0
PI 512628	Spain	5.3	1.9	3.7	7.0	0
Ames 22384	Nepal	5.3	1.6	5.0	5.7	0
PI 390252	Japan	5.3	3.1	4.3	6.3	0
PI 618926	P.R. China	5.3	2.3	4.3	6.3	0

Appendix Table 1. Continued

PI 618879	P.R. China	5.3	2.9	5.0	5.7	0
PI 304803	Japan	5.3	2.3	4.3	6.3	0
PI 618904	P.R. China	5.3	2.3	4.3	6.3	0
PI 279464	Japan	5.3	2.3	4.3	6.3	0
PI 606013	India	5.3	2.3	4.3	6.3	0
PI 211984	Iran	5.3	2.9	5.0	5.7	0
PI 401733	Puerto Rico	5.3	2.0	3.7	7.0	0
PI 618868	P.R. China	5.3	1.6	5.0	5.7	0
PI 606011	India	5.3	2.3	4.3	6.3	0
Ames 3942	United States	5.3	2.7	5.0	5.7	0
PI 605938	India	5.3	2.9	3.7	7.0	0
PI 306179	Russian Federation	5.3	2.7	5.0	5.7	0
PI 504571	United States	5.3	2.7	5.0	5.7	0
PI 512632	Spain	5.3	1.9	5.0	5.7	0
PI 422179	Netherlands	5.3	3.3	4.3	6.3	0
PI 422173	Netherlands	5.3	3.2	4.3	6.3	0
PI 390249	Japan	5.3	2.3	4.3	6.3	0
PI 436673	P.R. China	5.3	2.3	5.7	5.0	0
PI 618895	P.R. China	5.3	1.9	5.0	5.7	0
PI 489754	P.R. China	5.3	2.7	5.0	5.7	0
PI 512598	Spain	5.3	2.4	4.3	6.3	0
PI 173892	India	5.4	1.5	4.3	7.0	1
PI 618864	P.R. China	5.4	2.5	4.0	6.3	1
PI 504572	P.R. China	5.4	2.6	4.0	6.3	1
PI 432850	P.R. China	5.4	2.3	5.0	6.0	1
PI 605974	India	5.4	1.7	5.7	5.0	1
PI 605945	India	5.4	2.5	3.7	8.0	1
PI 271328	India	5.5	1.8	4.0	7.0	0
PI 271327	India	5.5	2.5	3.3	7.7	0
PI 215589	India	5.5	2.5	3.3	7.7	0
PI 618900	P.R. China	5.5	2.5	4.7	6.3	0
PI 390250	Japan	5.5	2.5	3.3	7.7	0
PI 422199	Netherlands	5.5	3.1	4.7	6.3	0
PI 606068	India	5.5	1.8	4.0	7.0	0
PI 618915	P.R. China	5.5	2.2	4.7	6.3	0
PI 200818	Myanmar	5.5	2.0	4.0	7.0	0
PI 419136	P.R. China	5.5	3.0	5.3	5.7	0
PI 618871	P.R. China	5.5	1.5	5.3	5.7	0
PI 606008	India	5.5	2.3	4.7	6.3	0
PI 422177	Netherlands	5.5	2.7	3.3	7.7	0
PI 271334	India	5.5	2.3	4.7	6.3	0
PI 419182	P.R. China	5.5	2.3	4.7	6.3	0
PI 618883	P.R. China	5.5	1.5	5.3	5.7	0
PI 173889	India	5.5	1.8	4.0	7.0	0
PI 478364	P.R. China	5.5	1.8	5.3	5.7	0
PI 605979	India	5.5	1.6	5.3	5.7	0
PI 561147	United States	5.5	1.8	4.0	7.0	0
PI 308916	Russian Federation	5.5	2.3	4.7	6.3	0

Appendix Table 1. Continued

PI 422186	Netherlands	5.5	2.3	4.7	6.3	0
PI 606033	India	5.5	2.2	4.7	6.3	0
PI 257486	P.R. China	5.5	2.3	4.7	6.3	0
PI 512641	Spain	5.5	2.3	4.7	6.3	0
PI 175679	Turkey	5.5	2.5	4.7	6.3	0
PI 326596	Hungary	5.5	2.8	4.0	7.0	0
Ames 19220	Russian Federation	5.5	2.3	4.7	6.3	0
PI 606065	India	5.5	2.8	5.3	5.7	0
PI 338235	Turkey	5.5	2.7	5.3	5.7	0
PI 321010	Taiwan	5.5	2.0	5.3	5.7	0
PI 532519	Russian Federation	5.5	3.1	3.0	8.0	2
PI 422169	Czech Republic	5.6	2.6	5.0	6.0	0
PI 512615	Spain	5.6	1.9	3.5	7.0	1
PI 606050	India	5.6	1.7	4.7	7.0	1
PI 605966	India	5.6	2.2	5.3	6.0	1
PI 605942	India	5.6	2.4	4.0	8.0	1
PI 504814	P.R. China	5.7	2.7	5.7	5.7	0
Straight 8	NSSL	5.7	2.3	3.7	7.7	0
PI 500361	Zambia	5.7	1.5	4.3	7.0	0
PI 401734	Puerto Rico	5.7	2.3	3.7	7.7	0
PI 163217	Pakistan	5.7	1.8	4.3	7.0	0
PI 269481	Pakistan	5.7	2.4	3.7	7.7	0
PI 422167	Netherlands	5.7	2.4	5.0	6.3	0
PI 606023	India	5.7	2.3	3.7	7.7	0
Ames 4832	United States	5.7	1.8	5.7	5.7	0
PI 368556	Yugoslavia	5.7	1.5	4.3	7.0	0
PI 344440	Iran	5.7	2.3	5.0	6.3	0
PI 209069	United States	5.7	2.2	5.0	6.3	0
PI 370447	Yugoslavia	5.7	1.5	4.3	7.0	0
PI 422172	Netherlands	5.7	2.3	3.7	7.7	0
PI 183127	India	5.7	1.6	4.3	7.0	0
PI 370022	India	5.7	2.2	4.3	7.0	0
PI 422200	Czech Republic	5.7	2.4	3.7	7.7	0
PI 606032	India	5.7	3.0	5.0	6.3	0
PI 606040	India	5.7	1.5	4.3	7.0	0
PI 618917	P.R. China	5.7	2.2	5.0	6.3	0
PI 605988	India	5.7	2.3	3.7	7.7	0
PI 109483	Turkey	5.7	1.5	4.3	7.0	0
PI 618881	P.R. China	5.7	2.2	5.0	6.3	0
Ames 26917	P.R. China	5.7	2.7	4.3	7.0	0
Ames 19219	Tajikistan	5.7	2.1	5.0	6.3	0
Ames 13338	Spain	5.7	2.2	5.0	6.3	0
PI 605971	India	5.7	2.2	5.0	6.3	0
PI 605936	India	5.7	1.5	4.3	7.0	0
PI 344445	Iran	5.7	2.3	5.0	6.3	0
PI 618945	P.R. China	5.7	1.8	5.7	5.7	0
PI 269480	Pakistan	5.7	3.0	3.0	8.3	0
PI 422185	Netherlands	5.7	2.3	3.7	7.7	0

Appendix Table 1. Continued

PI 220171	Afghanistan	5.7	1.5	5.0	7.0	3
PI 605984	India	5.8	2.4	4.7	9.0	2
PI 379279	Yugoslavia	5.8	1.9	6.0	5.7	2
PI 390248	Japan	5.8	2.7	3.0	7.7	1
PI 169401	Turkey	5.8	2.6	5.7	6.0	1
PI 605960	India	5.8	1.6	5.0	7.0	1
PI 211589	Afghanistan	5.8	1.3	5.0	7.0	1
PI 605914	India	5.8	1.6	5.0	7.0	1
PI 605967	India	5.8	2.4	4.0	7.7	0
Ames 7731	United States	5.8	1.8	6.0	5.7	0
PI 605982	India	5.8	2.1	4.0	7.7	0
PI 512624	Spain	5.8	1.3	4.7	7.0	0
PI 419040	P.R. China	5.8	2.1	5.3	6.3	0
PI 605937	India	5.8	2.1	4.0	7.7	0
PI 432872	P.R. China	5.8	2.2	5.3	6.3	0
Ames 22386	Nepal	5.8	2.2	4.0	7.7	0
PI 432857	P.R. China	5.8	2.2	5.3	6.3	0
PI 171609	Turkey	5.8	1.3	4.7	7.0	0
PI 606012	India	5.8	2.2	4.0	7.7	0
PI 368557	Yugoslavia	5.8	1.6	4.7	7.0	0
PI 212985	India	5.8	1.3	4.7	7.0	0
PI 391568	P.R. China	5.8	1.3	4.7	7.0	0
Ames 13247	Spain	5.8	2.4	4.0	7.7	0
PI 605991	India	5.8	1.3	4.7	7.0	0
PI 326597	Hungary	5.8	2.2	4.0	7.7	0
PI 422218	Israel	5.8	2.9	3.3	8.3	0
PI 368555	Yugoslavia	5.8	1.6	4.7	7.0	0
Ames 21695	United States	5.8	2.2	4.0	7.7	0
PI 376064	Israel	5.8	2.2	4.0	7.7	0
PI 605969	India	5.8	2.1	4.0	7.7	0
PI 618880	P.R. China	5.8	2.9	6.0	5.7	0
PI 478367	P.R. China	5.8	3.0	5.3	6.3	0
PI 605951	India	5.8	1.3	4.7	7.0	0
Ames 13341	Spain	5.8	2.2	4.0	7.7	0
PI 351139	Russian Federation	5.8	3.4	5.7	6.0	0
PI 379284	Yugoslavia	5.8	1.5	4.7	7.0	0
PI 605958	India	5.8	2.0	5.3	6.3	0
PI 165509	India	5.8	1.3	4.7	7.0	0
PI 618949	P.R. China	5.8	2.2	5.3	6.3	0
PI 175691	Turkey	5.8	2.2	5.3	6.3	0
PI 390253	Japan	5.8	2.4	5.3	6.3	0
PI 512644	Spain	5.8	2.4	5.3	6.3	0
PI 531310	Hungary	5.8	2.5	4.0	7.7	0
PI 504570	India	5.8	2.7	4.0	7.7	0
Ames 13336	Spain	5.8	1.5	4.7	7.0	0
PI 512607	Spain	5.8	2.1	4.0	7.7	0
PI 379280	Yugoslavia	5.8	1.5	4.7	7.0	0
PI 618866	P.R. China	6.0	3.3	3.0	9.0	0

Appendix Table 1. Continued

PI 169384	Turkey	6.0	2.4	3.5	7.7	1
PI 605959	India	6.0	2.0	4.7	8.0	1
Ames 13356	Spain	6.0	1.5	5.0	7.0	0
PI 606004	India	6.0	1.0	5.3	7.0	1
PI 512336	Hong Kong	6.0	2.0	5.0	7.0	2
Ames 13351	Spain	6.0	1.3	5.0	7.0	0
PI 264227	France	6.0	2.0	4.3	7.7	0
PI 531308	Hungary	6.0	3.0	5.7	6.3	0
Ames 13357	Spain	6.0	1.4	4.5	7.0	1
PI 165499	India	6.0	1.4	4.5	7.0	1
PI 606067	India	6.0	1.1	5.0	7.0	0
PI 271754	Netherlands	6.0	2.2	4.3	7.7	0
PI 422180	Netherlands	6.0	2.0	4.7	8.0	1
PI 512640	Spain	6.0	1.3	5.0	7.0	0
PI 422192	Czech Republic	6.0	1.7	5.0	7.0	0
PI 326598	Hungary	6.0	1.3	5.0	7.0	0
PI 606002	India	6.0	1.2	5.7	7.0	2
PI 164950	Turkey	6.0	2.0	4.3	7.7	0
PI 370019	India	6.0	2.0	4.3	7.7	0
Ames 13355	Spain	6.0	2.1	4.3	7.7	0
PI 518854	P.R. China	6.0	2.2	5.5	6.3	1
PI 263082	P.R. China	6.0	1.5	5.0	7.0	0
PI 504815	P.R. China	6.0	2.5	5.0	7.0	0
PI 427090	P.R. China	6.0	2.2	4.3	7.7	0
PI 432849	P.R. China	6.0	1.7	6.5	5.7	1
PI 512601	Spain	6.0	1.3	5.0	7.0	0
PI 164284	India	6.0	1.2	5.3	7.0	1
PI 512620	Spain	6.0	1.5	5.0	7.0	0
PI 532160	Oman	6.0	1.2	5.0	7.0	2
PI 605999	India	6.0	2.7	3.7	8.3	0
PI 264231	France	6.0	1.7	5.0	7.0	0
PI 605913	India	6.0	1.3	5.0	7.0	0
PI 605935	India	6.0	2.0	4.3	7.7	0
PI 206425	Turkey	6.0	1.3	5.0	7.0	0
PI 618878	P.R. China	6.0	2.2	5.5	6.3	1
PI 217946	Pakistan	6.0	2.1	4.3	7.7	0
PI 391573	P.R. China	6.0	2.4	5.7	6.3	0
PI 436610	P.R. China	6.0	2.4	5.7	6.3	0
PI 169402	Turkey	6.0	2.7	3.7	8.3	0
PI 357834	Yugoslavia	6.0	2.1	5.7	6.3	0
PI 267086	Russian Federation	6.0	2.2	4.3	7.7	0
PI 357836	Yugoslavia	6.0	2.0	5.7	6.3	0
PI 137844	Iran	6.0	3.0	6.5	5.7	1
PI 605955	India	6.0	2.2	4.7	8.0	1
PI 176516	Turkey	6.0	2.6	5.0	6.3	2
PI 531314	Hungary	6.0	2.6	4.0	8.0	2
PI 357857	Yugoslavia	6.0	2.6	5.0	6.3	2
PI 355053	Iran	6.0	2.5	5.0	7.0	0

Appendix Table 1. Continued

PI 379282	Yugoslavia	6.0	2.2	5.7	6.3	0
PI 222987	Iran	6.0	2.0	4.7	8.0	1
PI 504559	Russian Federation	6.0	1.4	5.3	7.0	1
PI 176924	Turkey	6.0	1.0	5.3	7.0	1
PI 344347	Turkey	6.0	1.3	5.0	7.0	0
PI 391569	P.R. China	6.0	2.1	4.7	8.0	1
PI 357862	Yugoslavia	6.0	2.1	4.7	8.0	1
Ames 3943	United States	6.0	2.0	5.7	6.3	0
PI 368553	Yugoslavia	6.0	1.3	5.0	7.0	0
PI 169390	Turkey	6.0	3.0	4.5	7.0	1
PI 222986	Iran	6.0	1.7	4.5	7.0	1
PI 379283	Yugoslavia	6.0	1.3	5.0	7.0	0
PI 605944	India	6.2	1.8	4.7	7.7	0
PI 512633	Spain	6.2	2.2	4.7	7.7	0
PI 512634	Spain	6.2	1.7	5.3	7.0	0
PI 255936	Netherlands	6.2	1.8	4.7	7.7	0
PI 605986	India	6.2	2.0	6.0	6.3	0
PI 606031	India	6.2	1.8	4.7	7.7	0
Ames 3947	Canada	6.2	2.2	4.7	7.7	0
PI 262990	Netherlands	6.2	1.9	4.7	7.7	0
PI 605950	India	6.2	2.6	4.0	8.3	0
PI 618884	P.R. China	6.2	1.3	5.3	7.0	0
PI 605956	India	6.2	1.8	4.7	7.7	0
Ames 13339	Spain	6.2	2.0	4.7	7.7	0
PI 422191	Netherlands	6.2	1.9	4.7	7.7	0
PI 169391	Turkey	6.2	1.8	4.7	7.7	0
PI 422181	Czech Republiclic	6.2	1.6	5.3	7.0	0
Ames 13358	Spain	6.2	1.0	5.3	7.0	0
PI 466921	Russian Federation	6.2	2.7	5.3	7.0	0
PI 264667	Germany	6.2	2.0	4.7	7.7	0
PI 163221	Pakistan	6.2	2.0	4.7	7.7	0
PI 174160	Turkey	6.2	2.6	6.0	6.3	0
PI 512609	Spain	6.2	2.0	4.7	7.7	0
PI 271326	India	6.2	1.9	4.7	7.7	0
Ames 7741	United States	6.2	1.8	4.7	7.7	0
PI 512638	Spain	6.2	2.2	4.7	7.7	0
PI 422176	Netherlands	6.2	1.8	4.7	7.7	0
PI 606026	India	6.2	1.9	4.7	7.7	0
PI 288990	Hungary	6.2	1.8	4.7	7.7	0
PI 220860	South Korea	6.2	1.9	4.7	7.7	0
PI 379281	Yugoslavia	6.2	1.2	5.3	7.0	0
PI 206952	Turkey	6.2	2.7	4.0	8.3	0
PI 379287	Yugoslavia	6.2	1.9	4.7	7.7	0
PI 432866	P.R. China	6.2	1.9	4.7	7.7	0
Ames 21698	Puerto Rico	6.2	2.0	4.7	7.7	0
Ames 13257	Spain	6.2	2.3	6.0	6.3	0
PI 283901	Czech Republic	6.2	2.5	4.0	8.3	0
PI 512613	Spain	6.2	1.6	5.3	7.0	0

Appendix Table 1. Continued

Ames 13354	Spain	6.2	2.0	6.0	6.3	0
PI 618898	P.R. China	6.2	2.3	6.0	6.3	0
PI 369717	Poland	6.2	2.0	6.0	6.3	0
PI 172844	Turkey	6.2	1.3	5.3	7.0	0
PI 512604	Spain	6.2	1.8	4.7	7.7	0
Ames 7742	United States	6.2	2.5	5.3	7.0	0
PI 344348	Turkey	6.2	2.6	4.0	8.3	0
PI 227013	Iran	6.2	1.9	4.7	7.7	0
PI 512608	Spain	6.2	1.9	4.7	7.7	0
Ames 23612	France	6.2	1.8	4.7	7.7	0
Ames 25929	Poland	6.2	1.9	4.7	7.7	0
PI 202801	Syria	6.2	1.8	4.7	7.7	0
PI 605952	India	6.2	2.2	6.0	6.3	1
PI 605926	India	6.2	1.3	5.0	7.0	1
PI 267746	India	6.2	2.7	4.3	9.0	1
PI 606042	India	6.2	2.3	6.0	6.3	1
PI 422190	Netherlands	6.2	2.2	6.0	6.3	1
PI 512637	Spain	6.2	2.3	4.0	7.7	1
PI 606038	India	6.2	2.3	4.0	7.7	1
PI 368558	Yugoslavia	6.2	2.8	5.0	7.0	1
PI 605989	India	6.2	2.2	4.0	7.7	1
Ames 13347	Spain	6.2	2.8	4.3	9.0	1
PI 255938	Netherlands	6.2	1.3	5.7	7.0	1
PI 605943	India	6.2	1.9	5.0	8.0	1
PI 174164	Turkey	6.2	2.3	4.0	7.7	1
PI 283900	Czech Republic	6.2	1.1	5.0	7.0	1
PI 512642	Spain	6.3	1.5	6.0	7.0	2
PI 175688	Turkey	6.3	1.5	4.0	7.0	2
PI 422184	Czech Republic	6.3	1.5	5.7	7.0	0
Ames 25933	Poland	6.3	2.0	5.0	7.7	0
PI 164819	India	6.3	1.6	5.0	7.7	0
PI 512619	Spain	6.3	0.8	5.7	7.0	0
PI 275410	Netherlands	6.3	2.1	5.0	7.7	0
Ames 13345	Spain	6.3	1.2	5.7	7.0	0
PI 618925	P.R. China	6.3	1.8	5.0	7.7	0
PI 171604	Turkey	6.3	1.2	5.7	7.0	0
PI 222243	Iran	6.3	2.9	6.3	6.3	0
PI 422196	Netherlands	6.3	0.8	5.7	7.0	0
PI 137836	Iran	6.3	2.0	5.0	7.7	0
Ames 3946	United States	6.3	1.2	5.7	7.0	0
PI 314426	Georgia	6.3	1.2	5.7	7.0	0
Ames 19228	Moldova	6.3	2.4	4.3	8.3	0
PI 368552	Yugoslavia	6.3	1.8	5.0	7.7	0
PI 261609	Spain	6.3	1.8	5.0	7.7	0
PI 605957	India	6.3	2.3	5.7	7.0	0
PI 512635	Spain	6.3	1.8	5.0	7.7	0
PI 618916	P.R. China	6.3	2.7	5.7	7.0	0
PI 176957	Turkey	6.3	1.8	5.0	7.7	0

Appendix Table 1. Continued

PI 183445	India	6.3	2.0	5.0	7.7	0
PI 344353	Turkey	6.3	2.3	4.3	8.3	0
PI 406473	Netherlands	6.3	1.8	5.0	7.7	0
PI 264666	Germany	6.3	1.8	5.0	7.7	0
Ames 13349	Spain	6.3	1.2	5.7	7.0	0
PI 466922	Russian Federation	6.3	2.5	4.3	8.3	0
PI 532520	Russian Federation	6.3	1.8	5.0	7.7	0
PI 226510	Iran	6.3	1.8	5.0	7.7	0
PI 206954	Turkey	6.3	1.8	5.0	7.7	0
PI 179259	Turkey	6.3	1.6	5.7	7.0	0
Wis. SMR 18	Wisconsin AES	6.3	1.8	5.0	7.7	0
PI 357849	Yugoslavia	6.3	1.6	5.7	7.0	0
PI 605981	India	6.3	2.0	5.0	7.7	0
PI 229808	Canada	6.3	1.8	5.0	7.7	0
PI 357853	Yugoslavia	6.3	1.6	5.0	7.7	0
Ames 3948	Canada	6.3	2.0	5.0	7.7	0
PI 285610	Poland	6.3	2.0	5.0	7.7	0
Ames 7745	United States	6.3	2.0	5.0	7.7	0
PI 135123	New Zealand	6.3	1.8	5.0	7.7	0
PI 206955	Turkey	6.3	2.1	5.0	7.7	0
PI 512616	Spain	6.3	1.8	5.0	7.7	0
PI 165506	India	6.3	1.8	5.0	7.7	0
PI 264664	Germany	6.3	2.1	5.0	7.7	0
PI 507875	Hungary	6.3	2.1	6.3	6.3	0
PI 372905	Netherlands	6.3	1.8	5.0	7.7	0
PI 351140	Russian Federation	6.3	1.8	5.0	7.7	0
PI 357837	Yugoslavia	6.3	1.8	5.0	7.7	0
PI 167223	Turkey	6.3	2.4	4.3	8.3	0
PI 222720	Iran	6.3	1.8	5.0	7.7	0
PI 264228	France	6.3	1.8	5.0	7.7	0
PI 167198	Turkey	6.3	1.8	5.0	7.7	0
PI 205996	Sweden	6.3	1.0	5.7	7.0	0
PI 357859	Yugoslavia	6.3	1.8	5.0	7.7	0
PI 357852	Yugoslavia	6.3	2.0	5.0	7.7	0
PI 368560	Yugoslavia	6.3	1.2	5.7	7.0	0
PI 606039	India	6.4	2.8	3.5	8.3	1
PI 209065	United States	6.4	2.2	4.5	7.7	1
PI 606027	India	6.4	2.2	4.5	7.7	1
PI 512631	Spain	6.4	1.9	4.5	7.7	1
PI 171611	Turkey	6.4	1.8	5.3	8.0	1
PI 344438	Iran	6.4	0.9	5.5	7.0	1
PI 223841	Philippines	6.4	1.9	4.5	7.7	1
PI 357841	Yugoslavia	6.4	2.2	4.5	7.7	1
PI 432848	P.R. China	6.5	2.0	5.3	7.7	0
PI 163214	Pakistan	6.5	2.2	4.7	8.3	0
Ames 13334	Spain	6.5	1.2	6.0	7.0	0
PI 518848	P.R. China	6.5	1.8	5.3	7.7	0
PI 178888	Turkey	6.5	1.2	6.0	7.0	0

Appendix Table 1. Continued

PI 419108	P.R. China	6.5	2.3	4.7	8.3	0
PI 531309	Hungary	6.5	2.5	4.7	8.3	0
PI 373918	United Kingdom	6.5	0.8	6.0	7.0	0
PI 605947	India	6.5	1.4	6.0	7.0	0
PI 531312	Hungary	6.5	2.2	4.7	8.3	0
PI 103049	P.R. China	6.5	0.8	6.0	7.0	0
PI 261608	Spain	6.5	0.8	6.0	7.0	0
PI 171603	Turkey	6.5	2.2	4.7	8.3	0
Ames 25932	Poland	6.5	1.8	5.3	7.7	0
PI 171610	Turkey	6.5	1.0	5.0	7.0	2
PI 165046	Turkey	6.5	1.2	6.0	7.0	0
PI 169315	Turkey	6.5	2.3	4.7	8.3	0
Ames 7740	United States	6.5	1.8	5.3	7.7	0
Ames 25938	Poland	6.5	1.6	5.3	7.7	0
PI 172843	Turkey	6.5	1.5	5.3	7.7	0
Ames 3945	United States	6.5	1.8	5.3	7.7	0
PI 422188	Netherlands	6.5	1.5	5.3	7.7	0
PI 339241	Turkey	6.5	1.5	5.3	7.7	0
PI 512605	Spain	6.5	2.3	4.7	8.3	0
Ames 25156	Russian Federation	6.5	2.3	6.0	7.0	0
PI 296120	Egypt	6.5	1.6	5.3	7.7	0
PI 605978	India	6.5	1.5	5.3	7.7	0
PI 368548	Yugoslavia	6.5	1.6	5.3	7.7	0
PI 502331	Uzbekistan	6.5	1.8	5.3	7.7	0
PI 118279	Brazil	6.5	1.6	5.3	7.7	0
PI 422197	Czech Republic	6.5	2.7	4.0	9.0	0
PI 211985	Iran	6.5	1.6	5.3	7.7	0
PI 561146	United States	6.5	1.8	5.3	7.7	0
PI 357844	Yugoslavia	6.5	2.3	4.7	8.3	0
PI 605963	India	6.5	1.6	5.3	7.7	0
PI 175681	Turkey	6.5	1.8	5.3	7.7	0
PI 211980	Iran	6.5	2.2	4.7	8.3	0
PI 271337	India	6.5	1.5	5.3	7.7	0
PI 357851	Yugoslavia	6.5	1.8	5.3	7.7	0
PI 339244	Turkey	6.5	2.2	4.7	8.3	0
PI 285606	Poland	6.5	0.8	6.0	7.0	0
PI 326595	Hungary	6.5	1.2	6.0	7.0	0
PI 339245	Turkey	6.5	1.5	5.3	7.7	0
PI 422174	Netherlands	6.5	2.8	4.0	9.0	0
Ames 13348	Spain	6.5	2.2	4.7	8.3	0
PI 342951	Denmark	6.5	2.3	4.7	8.3	0
PI 370450	Yugoslavia	6.5	2.3	4.7	8.3	0
Ames 25155	Russian Federation	6.5	1.8	5.3	7.7	0
PI 178884	Turkey	6.5	2.2	4.7	8.3	0
PI 344437	Iran	6.5	2.2	4.7	8.3	0
PI 357850	Yugoslavia	6.5	2.2	4.7	8.3	0
Ames 13346	Spain	6.5	1.5	5.3	7.7	0
PI 385968	United Kingdom	6.5	2.2	4.7	8.3	0

Appendix Table 1. Continued

Ames 7785	United States	6.5	1.8	5.3	7.7	0
PI 277741	Netherlands	6.5	1.6	5.3	7.7	0
PI 264665	Germany	6.5	2.2	4.7	8.3	0
PI 357832	Yugoslavia	6.5	1.5	5.3	7.7	0
PI 249550	Iran	6.5	2.0	5.3	7.7	0
PI 506462	Ukraine	6.5	1.5	5.3	7.7	0
PI 251519	Iran	6.5	2.3	4.7	8.3	0
Ames 19230	Russian Federation	6.5	1.6	5.3	7.7	0
Ames 25934	Poland	6.5	2.0	6.7	6.3	0
PI 512639	Spain	6.5	1.8	5.3	7.7	0
PI 167050	Turkey	6.5	2.0	5.3	7.7	0
PI 283902	Czech Republic	6.5	2.1	5.0	8.0	2
Ames 13342	Spain	6.5	2.0	5.3	7.7	0
PI 280096	Ukraine	6.5	1.8	5.3	7.7	0
PI 220791	Afghanistan	6.5	1.5	5.3	7.7	0
PI 267088	Russian Federation	6.5	1.6	5.3	7.7	0
PI 504565	Russian Federation	6.5	0.8	6.0	7.0	0
PI 357863	Yugoslavia	6.5	1.5	5.3	7.7	0
PI 135122	New Zealand	6.5	1.5	5.3	7.7	0
PI 169388	Turkey	6.5	1.6	5.3	7.7	0
PI 218036	Iran	6.5	1.5	5.3	7.7	0
PI 357830	Yugoslavia	6.5	0.8	6.0	7.0	0
PI 271331	India	6.5	0.8	6.0	7.0	0
PI 561144	United States	6.6	2.2	5.0	7.7	1
PI 221440	Afghanistan	6.6	1.8	5.0	7.7	1
PI 176952	Turkey	6.6	1.7	5.0	7.7	1
PI 263083	P.R. China	6.6	1.8	5.0	7.7	1
PI 206953	Turkey	6.6	1.8	5.0	7.7	1
PI 177363	Syria	6.6	1.5	5.7	8.0	1
Ames 1760	United States	6.6	1.8	5.0	7.7	1
PI 226461	Iran	6.6	2.5	4.0	8.3	1
PI 339246	Turkey	6.6	1.5	5.7	8.0	1
PI 368559	Yugoslavia	6.6	1.7	5.0	7.7	1
PI 288996	Hungary	6.6	1.8	5.0	7.7	1
PI 422198	Netherlands	6.6	1.7	5.0	7.7	1
PI 379286	Yugoslavia	6.6	1.8	5.0	7.7	1
Ames 25930	Poland	6.7	2.1	5.0	8.3	0
PI 172849	Turkey	6.7	2.1	5.7	7.7	0
Ames 13350	Spain	6.7	1.4	5.7	7.7	0
PI 618865	P.R. China	6.7	1.4	5.7	7.7	0
PI 372898	Netherlands	6.7	1.4	5.7	7.7	0
PI 606021	India	6.7	2.1	5.0	8.3	0
PI 540415	Uzbekistan	6.7	2.3	5.7	7.7	0
PI 292011	Israel	6.7	1.6	5.7	7.7	0
PI 169392	Turkey	6.7	1.9	5.7	7.7	0
PI 292012	Israel	6.7	2.1	5.0	8.3	0
PI 504567	Russian Federation	6.7	2.0	5.7	7.7	0
PI 275411	Netherlands	6.7	1.6	5.7	7.7	0

Appendix Table 1. Continued

PI 618910	P.R. China	6.7	1.6	5.7	7.7	0
PI 458855	Russian Federation	6.7	1.5	5.7	7.7	0
PI 285604	Poland	6.7	1.6	5.7	7.7	0
PI 181942	Syria	6.7	2.3	5.0	8.3	0
PI 176950	Turkey	6.7	1.4	5.7	7.7	0
PI 357865	Yugoslavia	6.7	1.6	5.7	7.7	0
PI 109063	Turkey	6.7	2.1	5.0	8.3	0
PI 229309	Iran	6.7	2.1	5.0	8.3	0
PI 175686	Turkey	6.7	2.0	5.0	8.3	0
PI 265887	Netherlands	6.7	1.4	5.7	7.7	0
PI 169353	Turkey	6.7	2.1	5.0	8.3	0
PI 255934	Netherlands	6.7	1.4	5.7	7.7	0
PI 372893	Netherlands	6.7	2.3	5.0	8.3	0
PI 109482	Turkey	6.7	2.0	5.0	8.3	0
PI 357831	Yugoslavia	6.7	1.4	5.7	7.7	0
PI 285605	Poland	6.7	1.6	5.7	7.7	0
PI 506465	Ukraine	6.7	2.1	5.0	8.3	0
PI 525156	Egypt	6.7	2.1	7.0	6.3	0
PI 171612	Turkey	6.7	1.6	5.7	7.7	0
PI 512636	Spain	6.7	2.1	5.0	8.3	0
PI 188749	Egypt	6.7	2.1	5.0	8.3	0
PI 169352	Turkey	6.7	1.6	5.7	7.7	0
PI 175692	Turkey	6.7	1.4	5.7	7.7	0
PI 314425	Georgia	6.7	1.6	5.7	7.7	0
PI 357860	Yugoslavia	6.7	1.6	5.7	7.7	0
PI 204569	Turkey	6.7	2.1	5.0	8.3	0
PI 605962	India	6.7	1.5	5.7	7.7	0
PI 376063	Israel	6.7	2.1	5.0	8.3	0
PI 169400	Turkey	6.7	1.5	5.7	7.7	0
PI 344443	Iran	6.7	2.3	7.0	6.3	0
PI 212059	Greece	6.7	1.6	5.7	7.7	0
PI 368549	Yugoslavia	6.7	2.1	5.0	8.3	0
PI 357856	Yugoslavia	6.7	1.6	5.7	7.7	0
PI 169389	Turkey	6.7	1.4	5.7	7.7	0
PI 507876	Hungary	6.7	1.6	5.7	7.7	0
PI 228344	Iran	6.7	1.4	5.7	7.7	0
PI 339248	Turkey	6.7	1.5	5.7	7.7	0
PI 164743	India	6.7	2.3	5.0	8.3	0
PI 618950	P.R. China	6.7	2.1	5.0	8.3	0
PI 251028	Afghanistan	6.7	1.6	5.7	7.7	0
PI 293432	Lebanon	6.7	1.6	5.7	7.7	0
PI 227235	Iran	6.7	1.4	5.7	7.7	0
PI 175680	Turkey	6.8	2.1	5.5	8.0	2
Ames 7739	United States	6.8	2.1	4.0	7.7	2
PI 512606	Spain	6.8	2.1	4.0	7.7	2
PI 357848	Yugoslavia	6.8	1.8	5.5	7.7	1
Ames 7737	United States	6.8	1.5	5.5	7.7	1
PI 171600	Turkey	6.8	1.5	6.0	8.0	1

Appendix Table 1. Continued

PI 211986	Iran	6.8	1.5	6.0	8.0	1
PI 205181	Turkey	6.8	2.3	4.5	8.3	1
PI 178885	Turkey	6.8	1.3	6.0	7.7	0
NSL 209654	United States	6.8	1.3	6.0	7.7	0
PI 209066	United States	6.8	2.0	5.3	8.3	0
PI 606037	India	6.8	2.0	5.3	8.3	0
PI 169319	Turkey	6.8	1.7	6.0	7.7	0
PI 504566	Russian Federation	6.8	1.3	6.0	7.7	0
PI 356832	Netherlands	6.8	2.4	5.3	8.3	0
PI 357838	Yugoslavia	6.8	1.2	6.0	7.7	0
PI 257286	Spain	6.8	1.9	5.3	8.3	0
PI 605934	India	6.8	1.9	5.3	8.3	0
PI 304805	United States	6.8	1.7	6.0	7.7	0
Ames 19221	Ukraine	6.8	2.0	5.3	8.3	0
PI 357869	Yugoslavia	6.8	1.9	5.3	8.3	0
PI 512599	Spain	6.8	1.9	5.3	8.3	0
PI 211728	Afghanistan	6.8	1.8	5.3	8.3	0
Ames 19229	Russian Federation	6.8	1.9	5.3	8.3	0
Ames 21694	United States	6.8	1.7	6.0	7.7	0
PI 357864	Yugoslavia	6.8	1.6	6.0	7.7	0
PI 255937	Netherlands	6.8	2.0	5.3	8.3	0
PI 355055	Iran	6.8	1.8	5.3	8.3	0
PI 169387	Turkey	6.8	1.2	6.0	7.7	0
PI 222244	Iran	6.8	1.6	6.0	7.7	0
PI 357861	Yugoslavia	6.8	1.8	5.3	8.3	0
PI 193496	Ethiopia	6.8	2.0	5.3	8.3	0
PI 326594	Hungary	6.8	1.9	5.3	8.3	0
Ames 22250	Albania	6.8	1.7	6.0	7.7	0
PI 165029	Turkey	6.8	1.3	6.0	7.7	0
PI 344349	Turkey	6.8	1.2	6.0	7.7	0
PI 512602	Spain	6.8	1.3	6.0	7.7	0
PI 176521	Turkey	6.8	1.2	6.0	7.7	0
PI 211982	Iran	6.8	1.9	5.3	8.3	0
PI 176956	Turkey	6.8	2.5	4.7	9.0	0
PI 357835	Yugoslavia	6.8	1.0	6.7	7.0	0
PI 422183	Netherlands	6.8	1.9	5.3	8.3	0
PI 182190	Turkey	6.8	1.6	6.0	7.7	0
PI 222783	Iran	6.8	2.3	5.3	8.3	0
PI 169380	Turkey	6.8	2.0	5.3	8.3	0
PI 357840	Yugoslavia	6.8	1.3	6.0	7.7	0
PI 183231	Egypt	6.8	1.9	5.3	8.3	0
Ames 25937	Poland	6.8	1.3	6.0	7.7	0
PI 227664	Iran	6.8	1.3	6.0	7.7	0
PI 525163	Egypt	6.8	1.8	5.3	8.3	0
PI 288995	Hungary	6.8	2.6	4.7	9.0	0
PI 458846	Russian Federation	6.8	2.3	5.3	8.3	0
PI 458853	Russian Federation	6.8	1.3	6.0	7.7	0
PI 274902	United Kingdom	6.8	2.0	5.3	8.3	0

Appendix Table 1. Continued

PI 293923	Israel	6.8	1.9	5.3	8.3	0
PI 357846	Yugoslavia	6.8	2.0	5.3	8.3	0
PI 512627	Spain	6.8	1.9	5.3	8.3	0
PI 490996	Turkey	6.8	1.9	5.3	8.3	0
PI 512610	Spain	6.8	1.3	6.0	7.7	0
PI 222985	Iran	6.8	2.0	5.3	8.3	0
PI 179260	Turkey	6.8	2.5	4.7	9.0	0
PI 211943	Iran	6.8	1.3	6.0	7.7	0
Ames 25935	Poland	6.8	2.0	5.3	8.3	0
PI 137845	Iran	6.8	1.3	6.0	7.7	0
PI 357845	Yugoslavia	6.8	1.6	6.0	7.7	0
PI 211978	Iran	6.8	1.9	5.3	8.3	0
PI 525153	Egypt	6.8	1.3	6.0	7.7	0
PI 263078	Ukraine	6.8	2.0	5.3	8.3	0
PI 422189	Netherlands	6.8	1.6	6.0	7.7	0
PI 458848	Russian Federation	6.8	1.3	6.0	7.7	0
PI 182192	Turkey	6.8	1.6	6.0	7.7	0
PI 177360	Turkey	6.8	1.3	6.0	7.7	0
PI 357847	Yugoslavia	6.8	1.2	6.0	7.7	0
PI 525154	Egypt	6.8	1.3	6.0	7.7	0
PI 169377	Turkey	6.8	1.9	5.3	8.3	0
PI 370448	Yugoslavia	6.8	1.3	6.0	7.7	0
PI 169399	Turkey	6.8	1.2	6.0	7.7	0
Ames 7758	United States	7.0	-	-	7.0	5
PI 279469	Japan	7.0	0.0	-	7.0	4
PI 338234	Turkey	7.0	0.0	-	7.0	4
PI 306785	Canada	7.0	0.0	7.0	7.0	2
PI 512614	Spain	7.0	1.2	6.0	7.7	1
PI 422168	Czech Republiclic	7.0	1.9	5.7	8.3	0
PI 288991	Hungary	7.0	1.9	5.7	8.3	0
PI 458852	Russian Federation	7.0	1.3	6.3	7.7	0
PI 506464	Russian Federation	7.0	1.1	6.3	7.7	0
PI 512603	Spain	7.0	1.7	5.7	8.3	0
Ames 19231	Russian Federation	7.0	1.9	5.7	8.3	0
PI 422171	Netherlands	7.0	1.9	5.7	8.3	0
PI 211988	Iran	7.0	1.8	6.3	7.7	0
PI 512626	Spain	7.0	1.9	5.7	8.3	0
Ames 7744	United States	7.0	1.9	5.7	8.3	0
Ames 7738	United States	7.0	1.9	5.7	8.3	0
PI 390951	Georgia	7.0	1.7	5.7	8.3	0
Ames 19038	Kazakhstan	7.0	1.7	5.7	8.3	0
PI 343452	Russian Federation	7.0	1.9	5.7	8.3	0
PI 344442	Iran	7.0	1.9	5.7	8.3	0
Ames 21696	United States	7.0	1.9	5.7	8.3	0
PI 169395	Turkey	7.0	1.7	5.7	8.3	0
PI 137839	Iran	7.0	1.9	5.7	8.3	0
PI 534541	Syria	7.0	1.9	5.7	8.3	0
PI 169381	Turkey	7.0	1.2	6.0	7.7	1

Appendix Table 1. Continued

PI 512600	Spain	7.0	1.7	5.7	8.3	0
PI 209068	United States	7.0	1.9	5.7	8.3	0
PI 174166	Turkey	7.0	2.3	5.0	9.0	0
PI 172851	Turkey	7.0	1.8	5.7	8.3	0
PI 606029	India	7.0	1.4	6.3	7.7	0
Ames 13352	Spain	7.0	1.3	6.3	7.7	0
PI 275412	Netherlands	7.0	1.1	6.3	7.7	0
PI 175693	Turkey	7.0	2.3	5.0	9.0	0
PI 525161	Egypt	7.0	1.9	5.7	8.3	0
Ames 23008	Czech Republic	7.0	1.9	5.7	8.3	0
PI 512625	Spain	7.0	1.1	6.3	7.7	0
PI 605940	India	7.0	2.3	5.0	9.0	0
PI 169393	Turkey	7.0	2.3	5.7	8.3	0
PI 137853	Iran	7.0	2.3	5.0	9.0	0
PI 220790	Afghanistan	7.0	1.8	5.7	8.3	0
PI 178887	Turkey	7.0	1.3	6.3	7.7	0
PI 176525	Turkey	7.0	2.3	5.0	9.0	0
PI 167079	Turkey	7.0	2.3	5.0	9.0	0
PI 263048	Uzbekistan	7.0	2.0	5.0	8.3	1
PI 512597	Spain	7.0	1.9	5.7	8.3	0
PI 169403	Turkey	7.0	1.8	5.7	8.3	0
PI 176524	Turkey	7.0	1.9	5.7	8.3	0
PI 379278	Yugoslavia	7.0	1.9	5.7	8.3	0
PI 458850	Russian Federation	7.0	1.9	5.7	8.3	0
PI 344444	Iran	7.0	1.8	5.7	8.3	0
PI 512595	Spain	7.0	1.9	5.7	8.3	0
PI 271753	Belgium	7.0	2.3	5.0	9.0	0
PI 164951	Turkey	7.0	1.9	5.7	8.3	0
PI 344439	Iran	7.0	1.9	5.7	8.3	0
PI 540416	Uzbekistan	7.0	2.1	5.7	9.0	1
PI 344432	Iran	7.0	1.9	5.7	8.3	0
PI 174174	Turkey	7.0	1.9	5.7	8.3	0
PI 357866	Yugoslavia	7.0	1.8	5.7	8.3	0
PI 207476	Afghanistan	7.0	1.7	5.7	8.3	0
PI 370449	Yugoslavia	7.0	1.7	5.7	8.3	0
PI 458854	Russian Federation	7.0	1.7	5.7	8.3	0
PI 283899	Czech Republiclic	7.0	1.9	5.7	8.3	0
PI 339247	Turkey	7.0	1.9	5.7	8.3	0
Ames 19218	Russian Federation	7.0	1.7	5.7	8.3	0
PI 390953	Uzbekistan	7.0	1.9	5.7	8.3	0
PI 176519	Turkey	7.0	2.0	5.0	8.3	1
PI 172839	Turkey	7.0	2.0	5.0	8.3	1
PI 357843	Yugoslavia	7.0	2.0	5.0	8.0	3
Coolgreen	Seminis	7.0	1.7	5.7	8.3	0
PI 209067	United States	7.0	1.7	5.7	8.3	0
PI 171607	Turkey	7.0	1.7	5.7	8.3	0
PI 535880	Poland	7.0	1.4	6.3	7.7	0
PI 169351	Turkey	7.0	1.3	6.3	7.7	0

Appendix Table 1. Continued

PI 525159	Egypt	7.0	1.1	6.3	7.7	0
PI 181755	Lebanon	7.0	1.7	5.7	8.3	0
PI 233932	Canada	7.0	1.9	5.7	8.3	0
PI 344352	Turkey	7.0	2.3	5.0	9.0	0
PI 171602	Turkey	7.0	1.9	6.0	7.7	1
PI 354952	Denmark	7.0	1.3	6.3	7.7	0
PI 169350	Turkey	7.0	1.1	6.3	7.7	0
PI 285609	Poland	7.0	1.1	6.3	7.7	0
PI 269482	Pakistan	7.0	1.3	6.3	7.7	0
PI 211979	Iran	7.0	1.1	6.3	7.7	0
PI 137835	Iran	7.0	1.1	6.3	7.7	0
PI 618882	P.R. China	7.2	1.6	6.0	8.3	0
PI 182189	Turkey	7.2	1.6	6.0	8.3	0
PI 175697	Turkey	7.2	1.5	6.0	8.3	0
PI 357868	Yugoslavia	7.2	1.6	6.0	8.3	0
PI 171605	Turkey	7.2	1.8	6.7	7.7	0
PI 605970	India	7.2	1.6	6.0	8.3	0
PI 135345	Afghanistan	7.2	1.5	6.0	8.3	0
PI 355052	Israel	7.2	1.6	6.0	8.3	0
PI 204692	Turkey	7.2	1.8	6.0	8.3	0
PI 181753	Syria	7.2	1.9	6.0	8.3	0
PI 267747	United States	7.2	1.6	6.0	8.3	0
PI 525165	Egypt	7.2	1.6	6.0	8.3	0
PI 172841	Turkey	7.2	1.6	6.0	8.3	0
PI 251520	Iran	7.2	1.6	6.0	8.3	0
PI 137857	Iran	7.2	1.8	6.0	8.3	0
PI 172845	Turkey	7.2	1.8	6.0	8.3	0
PI 344067	Turkey	7.2	1.5	6.0	8.3	0
PI 432861	P.R. China	7.2	1.6	6.0	8.3	0
PI 211962	Iran	7.2	2.5	5.3	9.0	0
Ames 13353	Spain	7.2	1.8	6.7	7.7	0
PI 211967	Iran	7.2	1.6	6.0	8.3	0
PI 506463	Russian Federation	7.2	1.6	6.0	8.3	0
PI 211117	Israel	7.2	1.6	6.0	8.3	0
PI 264668	Germany	7.2	2.1	5.3	9.0	0
PI 264226	France	7.2	2.4	5.3	9.0	0
PI 422170	Netherlands	7.2	1.8	6.0	8.3	0
PI 458847	Russian Federation	7.2	1.9	6.0	8.3	0
PI 171606	Turkey	7.2	2.2	5.3	9.0	0
PI 167134	Turkey	7.2	2.2	5.3	9.0	0
PI 525152	Egypt	7.2	2.2	5.3	9.0	0
PI 324239	Sweden	7.2	2.4	5.3	9.0	0
PI 220338	Afghanistan	7.2	2.0	5.3	9.0	0
PI 525155	Egypt	7.2	1.8	6.0	8.3	0
PI 248778	Iran	7.2	2.4	5.3	9.0	0
PI 288993	Hungary	7.2	2.1	5.3	9.0	0
PI 319216	Egypt	7.2	1.6	6.0	8.3	0
PI 368554	Yugoslavia	7.2	1.6	6.0	8.3	0

Appendix Table 1. Continued

PI 175696	Turkey	7.2	2.2	5.3	9.0	0
PI 181910	Syria	7.2	1.6	6.0	8.3	0
PI 357833	Yugoslavia	7.2	1.6	6.0	8.3	0
PI 137847	Iran	7.2	1.8	6.0	8.3	0
PI 357858	Yugoslavia	7.2	1.8	6.0	8.3	0
PI 174177	Turkey	7.2	1.8	6.0	8.3	0
PI 357867	Yugoslavia	7.2	1.8	6.0	8.3	0
PI 178886	Turkey	7.2	1.6	6.0	8.3	0
PI 535881	Poland	7.2	1.5	6.0	8.3	0
PI 169397	Turkey	7.2	2.4	5.3	9.0	0
PI 174170	Turkey	7.2	1.6	6.0	8.3	0
PI 360939	Netherlands	7.2	1.8	6.0	8.3	0
PI 183677	Turkey	7.2	2.2	5.3	9.0	0
PI 220169	Afghanistan	7.2	1.6	6.0	8.3	0
PI 193497	Ethiopia	7.2	1.8	6.0	8.3	0
PI 169386	Turkey	7.2	1.6	6.0	8.3	0
PI 169334	Turkey	7.2	1.6	6.0	8.3	0
PI 209064	United States	7.2	1.5	6.0	8.3	0
PI 172847	Turkey	7.2	1.5	6.0	8.3	0
PI 173674	Turkey	7.2	1.6	6.0	8.3	0
PI 292010	Israel	7.2	1.6	6.0	8.3	0
PI 176517	Turkey	7.2	1.6	6.0	8.3	0
Ames 19227	Russian Federation	7.2	1.8	5.5	8.3	1
PI 137856	Iran	7.2	1.8	5.5	8.3	1
PI 296121	Egypt	7.2	2.5	4.5	9.0	1
PI 458849	Russian Federation	7.2	2.0	6.0	9.0	1
PI 296387	Iran	7.2	1.8	5.5	8.3	1
PI 211977	Iran	7.2	2.0	5.5	8.3	1
PI 223437	Afghanistan	7.2	2.0	5.5	8.3	1
PI 357842	Yugoslavia	7.2	2.0	5.5	8.3	1
PI 507874	Hungary	7.2	1.8	5.5	8.3	1
PI 344433	Iran	7.2	2.0	5.5	8.3	1
PI 534539	Syria	7.2	1.8	5.5	8.3	1
PI 339250	Turkey	7.2	2.0	5.5	8.3	1
PI 181756	Lebanon	7.3	2.1	5.7	9.0	0
Ames 7751	United States	7.3	1.5	6.0	8.0	3
PI 344351	Turkey	7.3	1.5	6.3	8.3	0
Ames 25931	Poland	7.3	1.4	6.3	8.3	0
Ames 13335	Spain	7.3	2.1	6.3	8.3	0
PI 414157	United States	7.3	1.5	6.3	8.3	0
PI 379285	Macedonia	7.3	1.5	6.3	8.3	0
PI 176953	Turkey	7.3	2.1	6.3	8.3	0
PI 525150	Egypt	7.3	1.4	6.3	8.3	0
PI 167197	Turkey	7.3	1.4	6.3	8.3	0
PI 175689	Turkey	7.3	1.5	6.3	8.3	0
PI 205995	Sweden	7.3	1.5	6.3	8.3	0
PI 174167	Turkey	7.3	2.1	5.7	9.0	0
PI 176520	Turkey	7.3	1.5	6.3	8.3	0

Appendix Table 1. Continued

PI 344435	Iran	7.3	2.1	5.7	9.0	0
PI 175690	Turkey	7.3	1.9	5.7	9.0	0
Ames 25936	Poland	7.3	2.1	5.7	9.0	0
PI 172838	Turkey	7.3	2.1	5.7	9.0	0
PI 175683	Turkey	7.3	2.0	6.3	8.3	0
PI 176518	Turkey	7.3	2.0	5.7	9.0	0
PI 344434	Iran	7.3	2.1	5.7	9.0	0
PI 392292	Russian Federation	7.3	1.5	6.3	8.3	0
PI 525157	Egypt	7.3	2.1	5.7	9.0	0
PI 169394	Turkey	7.3	1.9	5.7	9.0	0
PI 370643	Russian Federation	7.3	1.5	6.3	8.3	0
PI 177364	Iraq	7.3	2.0	5.7	9.0	0
PI 357839	Yugoslavia	7.3	1.5	6.3	8.3	0
PI 339243	Turkey	7.3	1.9	5.7	9.0	0
PI 169398	Turkey	7.3	2.1	5.7	9.0	0
PI 512596	Spain	7.3	1.0	7.0	7.7	0
PI 534545	Syria	7.3	1.5	6.3	8.3	0
PI 390954	Russian Federation	7.3	1.5	6.3	8.3	0
PI 288994	Hungary	7.3	1.4	6.3	8.3	0
PI 534543	Syria	7.3	1.5	6.3	8.3	0
PI 183224	Egypt	7.3	1.4	6.3	8.3	0
PI 211983	Iran	7.3	1.4	6.3	8.3	0
PI 176951	Turkey	7.3	2.0	5.7	9.0	0
PI 368550	Yugoslavia	7.3	1.9	5.7	9.0	0
PI 182188	Turkey	7.3	1.4	6.3	8.3	0
PI 525151	Egypt	7.3	1.4	6.3	8.3	0
Ames 25699	Syria	7.3	1.4	6.3	8.3	0
PI 525162	Egypt	7.3	1.4	6.3	8.3	0
PI 368551	Yugoslavia	7.3	0.8	7.0	7.7	0
PI 458856	Ukraine	7.3	0.8	7.0	7.7	0
Ames 3950	Australia	7.4	1.5	6.0	8.3	1
PI 605980	India	7.4	2.3	6.3	9.0	1
PI 264230	France	7.4	2.6	5.0	9.0	1
PI 172848	Turkey	7.4	1.5	6.0	8.3	1
PI 263047	Russian Federation	7.4	2.3	5.0	9.0	1
PI 285607	Poland	7.4	1.7	6.0	8.3	1
PI 179263	Turkey	7.4	2.3	5.0	9.0	1
PI 164952	Turkey	7.4	1.7	6.3	9.0	1
PI 218199	Lebanon	7.4	1.7	6.0	8.3	1
PI 263079	Russian Federation	7.4	1.7	6.0	8.3	1
PI 175695	Turkey	7.4	1.7	6.3	9.0	1
PI 167358	Turkey	7.5	1.9	5.0	8.3	2
PI 257494	Iran	7.5	2.0	6.0	9.0	0
PI 504561	Russian Federation	7.5	1.5	6.7	8.3	0
PI 204690	Turkey	7.5	1.8	6.0	9.0	0
PI 458845	Russian Federation	7.5	1.5	6.7	8.3	0
PI 211975	Iran	7.5	1.8	6.0	9.0	0
PI 169383	Turkey	7.5	1.5	6.7	8.3	0

Appendix Table 1. Continued

PI 105263	Turkey	7.5	2.0	6.0	9.0	0
PI 176954	Turkey	7.5	1.8	6.0	9.0	0
PI 174173	Turkey	7.5	1.8	6.0	9.0	0
PI 177359	Turkey	7.5	2.0	6.0	9.0	0
PI 109484	Turkey	7.5	1.8	6.0	9.0	0
PI 204567	Turkey	7.5	1.8	6.0	9.0	0
PI 288992	Hungary	7.5	2.0	6.0	9.0	0
PI 181940	Syria	7.5	1.8	6.0	9.0	0
PI 285603	Poland	7.5	2.0	6.0	9.0	0
PI 356809	Russian Federation	7.5	2.0	6.0	9.0	0
PI 357855	Yugoslavia	7.5	1.8	6.0	9.0	0
PI 220789	Afghanistan	7.5	2.0	6.0	9.0	0
PI 171601	Turkey	7.5	1.8	6.0	9.0	0
PI 167043	Turkey	7.5	2.1	6.0	9.0	0
PI 343451	Russian Federation	7.5	1.8	6.0	9.0	0
PI 172840	Turkey	7.5	1.8	6.0	9.0	0
PI 246930	Afghanistan	7.5	1.2	6.7	8.3	0
PI 176523	Turkey	7.5	1.2	6.7	8.3	0
PI 175694	Turkey	7.6	2.2	5.5	9.0	1
PI 176522	Turkey	7.6	2.2	5.5	9.0	1
PI 288237	Egypt	7.6	2.2	5.5	9.0	1
PI 167389	Turkey	7.6	2.2	5.5	9.0	1
PI 137851	Iran	7.6	1.3	6.5	8.3	1
Ames 3949	Canada	7.7	1.0	7.0	8.3	0
PI 169378	Turkey	7.7	1.6	6.3	9.0	0
Ames 23009	Czech Republic	7.7	1.6	6.3	9.0	0
PI 167052	Turkey	7.7	1.6	6.3	9.0	0
PI 222099	Afghanistan	7.7	2.0	6.3	9.0	0
PI 169304	Turkey	7.7	1.5	6.3	9.0	0
PI 534540	Syria	7.7	1.5	6.3	9.0	0
PI 177361	Turkey	7.7	1.6	6.3	9.0	0
PI 458851	Russian Federation	7.7	1.0	7.0	8.3	0
PI 169382	Turkey	7.7	1.5	6.3	9.0	0
PI 171613	Turkey	7.7	1.6	6.3	9.0	0
PI 204568	Turkey	7.7	1.5	6.3	9.0	0
PI 342950	Denmark	7.7	1.6	6.3	9.0	0
PI 267087	Russian Federation	7.8	1.5	6.0	8.3	2
PI 285608	Poland	7.8	1.1	7.0	8.3	1
PI 525158	Egypt	7.8	1.6	6.0	9.0	1
Ames 21224	United States	7.8	1.6	6.0	9.0	1
PI 172842	Turkey	7.8	1.8	6.7	9.0	0
PI 338236	Turkey	7.8	1.6	6.7	9.0	0
PI 181752	Syria	7.8	1.3	6.7	9.0	0
PI 181874	Syria	7.8	1.3	6.7	9.0	0
PI 344350	Turkey	7.8	1.3	6.7	9.0	0
Ames 19225	Russian Federation	7.8	1.0	7.3	8.3	0
PI 226509	Iran	8.0	1.4	6.5	9.0	1
PI 169385	Turkey	8.0	2.0	5.0	9.0	2

Appendix Table 1. Continued

PI 212599	Afghanistan	8.0	1.3	7.0	9.0	0
PI 169328	Turkey	8.0	1.7	6.0	9.0	3
PI 172846	Turkey	8.0	1.1	7.0	9.0	0
PI 137848	Iran	8.2	1.1	7.0	9.0	1
PI 172852	Turkey	8.3	1.2	-	8.3	3
PI 284699	Sweden	9.0	-	-	9.0	5
Ames 7760	United States	-	-	-	-	6
NationlPcklng	NSSL	-	-	-	-	6
TMG-1	P.R. China	-	-	-	-	6
LSD (5%)		1.60		1.79	3.14	

[Z] Mean of all ratings taken at week 5 after planting for North Carolina and Poland during 2005, 2006 and 2007.

[Y] Mean of ratings taken at week 5 after planting for North Carolina during 2005, 2006 and 2007.

[X] Mean of ratings taken at week 5 after planting for Poland during 2005, 2006 and 2007.

[W] Each year and each location is considered a replication for a total of six replications.