SCREENING OF GERMPLASM ACCESSIONS FROM THE BRASSICA SPECIES FOR RESISTANCE AGAINST PG3 AND PG4 ISOLATES OF BLACKLEG

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

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ABSTRACT

Marino, Dante; M.S.; Department of Plant Pathology; College of Agriculture, Food Systems, and Natural Resources; North Dakota State University; May 2011. Screening of Germplasm Accessions From the *Brassica species* for Resistance Against PG3 and PG4 Isolates of Blackleg. Major Professor: Dr. Luis del Rio.

Blackleg is a disease of canola and rapeseed cultivars that is caused by the fungus *Leptosphaeria maculans* (Desm.) Ces. & de Not., and it is by far the most destructive pathogen of canola in North America. In recent years, blackleg strains belonging to pathogenicity groups (PG) 3 and 4 have been discovered in North Dakota. Recent outbreaks of the disease have added a sense of urgency to characterize the risk these new strains represent for the canola industry and to identify sources of resistance against them. Thus, the objectives of this study were to screen germplasm collections of *Brassica rapa, B. napus,* and *B. juncea* for their reaction to PG3 and PG4 and to evaluate the reaction of a sample of currently used canola commercial cultivars grown in North Dakota to PG3 and PG4 as means to estimate the risk these new strains represent. All canola germplasm and commercial cultivars were evaluated in replicated trials in greenhouse conditions using cotyledon bioassays. In 2009 and 2010, the effect of these strains, using five inoculation sequences, on the reaction of canola seedlings was also evaluated. Field trials were not conducted because of the limited geographical distribution of the new strains. No adequate sources of resistance were identified among the 277 *B. rapa* and 130 *B. napus* accessions evaluated; however, 22 of the 406 accessions of *Brassica juncea* evaluated were considered to have moderate levels of resistance. *B. juncea* seedlings that survived these inoculations were self-pollinated and their progeny (F_1) were also screened. As before, surviving seedlings were self-pollinated. These F_2 seeds are the elite materials that could be used in

future breeding programs. The complementary study evaluating the role of sequence inoculations in reaction of canola seedlings to blackleg indicated that an increased susceptibility to PG3 occurred when seedlings were first inoculated with PG4; however, reaction to PG4 was not enhanced by a prior inoculation with PG3. All 75 commercial cultivars evaluated were susceptible to PG3 and PG4, indicating that the risk these new strains represent to the canola industry of the region is serious. Further, when a subsample of 16 cultivars were challenged with PG2, they were either resistant or moderately resistant, suggesting the ratings the industry are using relate to reaction of those cultivars to PG2 but not to the new strains; thus, growers should use caution when using these ratings while deciding on which cultivars to plant.

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TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

Figure | Page

LIST OF APPENDIX TABLES

Table Page

CHAPTER 1. INTRODUCTION

Blackleg, caused by the fungus *Leptosphaeria maculans* (Desm.) Ces. & de Not. *Phoma lingam* (Tode ex. Schw.) is its anamorph. Blackleg is the most destructive pathogen of canola in North America (Fitt *et al.*, 2006) and has an economic impact on canola production worldwide. According to the Northern Canola Growers Association, North Dakota leads the production of canola in the United States. The total amount of canola production in North Dakota was recorded at 1 million metric tons in 2010. The total value of canola production in North Dakota has also reached a record of $437 million (NCGA, 2010).

As canola is an important crop to North Dakota, blackleg disease is becoming main concern that needs to be investigated. There is a lack of knowledge about the impact of new strains of *L. maculans* on commercially available canola cultivars. Also, there is limited knowledge on what sources of resistance can be used to combat the disease. This study provides to contribute to the research of blackleg disease by identifying sources of resistance against the new strains and by characterizing the reaction of commercial cultivars to these strains.

One of the traits that make this pathogen difficult to control is its ability to change virulence profile. A set of three differential cultivars, Westar, Glacier, and Quinta has been used in North America to characterize pathogenicity groups (PG) (Mengistu *et al.*, 1991). A larger set has been developed to identify strains to race level (Balesdent *et al.*, 2005), but the set is not available to the scientific community at large.

Isolates that show virulence profiles typical of PG 2 have been the most prevalent in the upper Northern Plains since the discovery of blackleg in North Dakota canola fields in

1991 (Lamey and Hershman, 1993). Since then, resistance to PG2 isolates has been incorporated into most commercial cultivars. The recent discovery of isolates belonging to PG3, PGT, and PG4 in western Canada and North Dakota (Bradley *et al.*, 2005; Chen and Fernando, 2006); however, is an indication that the blackleg population may be shifting. And while the prevalence of PGs 3 and 4 in North Dakota at the time of discovery was limited to a few counties, it is just a matter of time for the new strains to spread to all canola growing regions of North Dakota. Further, a potential shift in virulence of blackleg is cause for alarm since their impact on commercial canola genotypes is largely unknown.

Germplasm collections are very useful genetic resources for all kinds of traits including disease resistance. Recently Zabala (2008) reported *Brassica rapa* plant introductions with acceptable levels of resistance against *Sclerotinia sclerotiorum*. Khot (2006) identified sources of resistance to the same pathogen in a *Brassica napus* collection.

Resistance to blackleg can be expressed at the seedling stage and in adult plants (Delourme *et al.,* 2006). The former is considered vertical or monogenic resistance and can be easily detected in greenhouse inoculations; expression of horizontal resistance in adult plants is more easily detected under field conditions. Thus, all screenings and evaluations need to be conducted in controlled environments like greenhouse rooms. This research was motivated by the need for information on sources of resistance to PG3 and PG4 strains of blackleg and the lack of information on the reaction of commercial cultivars to them. The main objectives of this study were to identify sources of resistance within the collections of *Brassica rapa, B. napus* and B. *juncea* accessions maintained by the USDA- National Genetics Resources Program (NGRP) and to characterize the reaction of commercially available canola genotypes to PG3 and PG4 strains of blackleg. The secondary objective is to develop pre-breeding materials by self-pollinating the accessions selected through different rounds of inoculations.

CHAPTER 2.

LITERATURE REVIEW

2.1. Economic Importance of Crop and Pathogen

2.1.1. Economic Importance of the Crop

Major canola producing countries in Europe are Germany, France, Poland, Sweden, The United Kingdom, and Ukraine. In Asia, China and India are the main canola producers. In Oceania, Australia is the major producer while on the American continent the USA and Canada are the top producers. Spring varieties are commonly grown in Australia, India, China, the Northern Plains and Pacific Northwest of the USA, Northern Europe and most of Canada. Winter types are commonly grown in southwest Europe, China, Eastern Canada, the Pacific Northwest, and southeastern parts of the United States (Berry and Spink, 2006; Kimber and McGregor, 1995).

In 2009, North Dakota accounted for approximately 90% of the canola area harvested in the United States (Kandel, 2009). An estimated 305,000 ha were planted in that year, down from a high of 535,000 ha in 2001. In the last ten years, the average yield in North Dakota has ranged from 1.23 to 1.84 tons per hectare; the 2009 harvest was valued at approximately $213 million. In 2009, production of winter canola expanded in Oklahoma and for the first time into western states such as Oregon and Idaho. In that year, those three states produced 38,500 metric tons, a sizable increase from the 10,500 metric tons harvested in 2008 (USDA, 2010).

The main force driving the increase of canola production in these states is related to the mandate for biodiesel use in Washington and Oregon, which started in 2006 and encourages local biodiesel production (Painter and Roe, 2007). In North Dakota, farmers were encouraged to increase canola production because of the establishment of new crushing facilities in the region and more competitive market prices of the commodity. In Canada, the crop is grown in 8.76 million ha, and its contribution to the economy is estimated at approximately $13.8 billion in Canadian currency (CCC, 2010).

2.1.2. Economic Importance of Blackleg Disease

Blackleg epidemics caused significant economic damages in different regions and years and remains a major concern in most canola producing areas in the world (Gladders *et al.*, 2006).

In the United Kingdom, blackleg epidemics in 2002 and 2003, caused yield losses estimated at €56 million each season (Fitt *et al.*, 2006). In Australia, the disease was responsible for losses of €11.3 million in 1998 and 1999 (Khangura and Barbetti, 2001). In France, blackleg accounts for 5 to 20% yield reductions with an estimated value ranging between €36.8 and €147 million (Allard *et al.*, 2002). In Poland, the effects of blackleg have not been quantified, and the disease is caused by *L. biglobosa*, a closely related species. *L. biglobosa* can cause severe cankers on the mid and upper part of the stem under the stress of hot summer temperatures, which are normally observed before harvest (Huang *et al.*, 2005; Jedryczka *et al.*, 1999; West *et al.*, 2001; Karolewski *et al.*, 2002).

While there is no official quantification of the yield losses caused by blackleg in canola in North Dakota, anecdotal information by growers estimate its impact at up to 45% of obtainable yield in some fields in recent years (L. del Rio, personal communication). Field surveys conducted between 1991 and 2002 indicated the statewide incidence of blackleg in North Dakota fields at 6.7%, with a peak of 27.7% in 1992 and 5.9% of the fields with more than 45% incidence in 2002 (Lamey *et al.*, 2003).

2.2. Canola/Rapeseed

2.2.1. Taxonomic Classification

The Brassicaceae family consists of 375 genera and 3,200 species of plants. The *Brassica* genus consists of approximately 100 species. Among them, *Brasica napus* L., spp. *oleifera*, is known as oilseed rape or rapeseed, which is thought to have originated from a cross that had a maternal donor derived from two diploids and related species such as *Brassica oleracea* and *B. rapa.*

2.2.2. Development of Canola as a Commercial Crop

Canola is a genetic variation of rapeseed developed in the early 1970s by Canadian plant breeders who used traditional plant breeding methods to produce rapeseed plants with low eicosenoic and erucic acid contents. In 1973, the oil and food processing industry, advised by the Canadian Health and Welfare Department, converted varieties of rapeseed with higher erucic acid content (more than 40%) into cultivars with ≤5% erucic acid and low glucosinate content (3% mg per gram or less in food products). In 1974, Dr. Baldur Stefansson, a plant breeder from the University of Manitoba, developed the first *Brassica napus* variety, named "Tower," which was identified as canola and had less than 2% of erucic acid and a total of 30 μmoles/g of glucosinalate levels (Codex, 2001).

2.2.3. Uses of Canola/Rapeseed

The manipulations of genes that control oil quality make the attainment of different products possible. As an example, commodity canola oil contains traces of erucic acid, 5% to 8% saturated fats, 60% to 65% monounsaturated fats, and 30% to 35% polyunsaturated fats. In addition, cultivars that yield oils with 45% or more erucic acid have seed meals high or low in glucosinolates are classified as industrial rapeseed. Their end use is as lubricants and hydraulic fluids. Also, the term "specialty canola" refers to cultivars with oils that contain less than 4% linolenic acid (18:3) and/ or greater than 70% oleic acid (18:1) for use in high temperatures or continuous frying. These characteristics confer greater temperature stability and improved shelf life to the specialty oil (Potts *et al.*, 1999; McVetty and Scarth, 2002).

2.2.4. Types of Canola Cultivars

Winter varieties of canola are those that require a vernalization period, while spring varieties do not. In Australia, most of the canola crops are spring varieties and are grown between latitudes 30° S and 38° S. The normal planting time is April or May, and the growing season is 5-7 months with crops ripening in late spring or early summer. The normal yield is 1 to 2 metric tons per ha. Under an excellent production environment, a yield of 5 t/ha can be reached. Early frosts after flowering are responsible for important yield losses due to the abortion of seeds.

Spring type cultivars *B. napus* are produced in Canada, northern Europe, and China. Also, in the Northern Plains and in the southeastern United States, where the winters are mild, spring type *B. napus* can be grown as a fall-planted crop. In Canada, the growing season lasts for less than 4 months, and spring varieties are the most predominantly planted.

Spring type *B. rapa* cultivars are planted in fertile areas in Canada and in northern Europe, China and India. In India, *B. juncea* is dominant, whereas in Europe and Canada, *B. juncea* is planted in minor areas just for condiment use (Sovero, 1993). In the USA, spring cultivars of *Brassica napus* dominate the markets, and major production areas are the Northern Plains and the Pacific Northwest (Raymer *et al.*, 1990).

2.2.5. Agronomic Requirements

For both the spring and winter varieties, the average sowing rate varies between 4 and 6 kg ha^{-1} when using varieties and 4 kg ha^{-1} when using hybrid seeds. The goal is to achieve a population of 50-70 plants m^{-2} with both varieties. Under normal soil conditions, for both winter and spring varieties, the canola seed is located no deeper than 2 cm. The crop is swathed 10 to 20 days before harvest to hasten the drying rate and avoid any shattering due to wind or hail. The crop exhibits its natural tolerance to grass selective herbicides such as trifluralin and clopyralid. Over a hundred herbicide tolerant hybrids have been released during the last decade, accounting for 95% of the total canola acreage (CCC, 2011).

Among the different traits introgressed, the most importants are related to the tolerance to triazine, imidazolinone, and glyphosate herbicides. These varieties have been widely adopted by farmers and have allowed the canola industry to grow steadily. The use of this technology makes it possible to reduce costs, to simplify the management of the crop, and to control broad leaves and grass weeds with a single pass of an herbicide in post-emergency. Glyphosate- and glufosinate-resistant varieties are predominant, accounting for 55% and 28% of the seed market, respectively. Clearfield or Imidazolinone-tolerant varieties account for 12% of canola production (Harker *et al.*, 2000). Imidozolinone herbicides contain acetolactate synthase inhibitors (ALS) that control broadleaf and grass weeds. Liberty Link canola (LL), also called glufosinate-tolerant canola, can be offered over glyphosate or imidazolinone, therefore lessening the risk of resistance development.

2.2.6. Pest Problems

Canola plants, like most cultivated crops, are attacked by a number of insect pests. Some of the most important insect pests in North Dakota are the redlegged earth mite (*Halotydeus destructor* Tucker), blue oat mite (*Penthaleus major* Dugès), cutworms (*Agrotis infusa* Boisduval), cabbage aphids (*Brevicoryne brassicae* L.) and mustard aphid (*Lipaphis erysimi* Kaltenbach), Diamond back moths (*Plutella xylostella* L.), Heliothis caterpillars (*Helicoverpa punctigera* Wallengren), known as Native budworm and *H. armigera* (Hübner) and Rutherglen bug (*Nysius vinitor* Bergroth). The most susceptible stages of the crop are from planting to seedling and from flowering to seed set (Knodel, 2010).

The most difficult weeds to control are broad leaf weeds, especially those belonging to the Brassicaceae family; because there are no other herbicide options that control these weeds by using conventional varieties in post-emergency applications. For that reason, the use of herbicide-tolerant cultivars is increasing every season.

Among the most important diseases that limit the development of canola are Sclerotinia stem rot (*Sclerotinia* spp.) and Blackleg (*Leptosphaeria maculans).* Other diseases include phytophthora root rot, caused by the fungus *Phytophthora megasperma* var. *megasperma,* downy mildew, caused by *Peronospora parasitica*, and alternaria leaf spot, caused by the fungus *Alternaria brassicae,* which can cause serious yield loss in wet seasons (Howlett *et al*., 1999). Blackleg is one of the most destructive diseases affecting canola. The fungus can be carried on infected seeds, survive on canola stubble, kill seedlings, or reduce seed yield in older plants. To avoid these diseases, rotation is one of the best management practices, and forecast models play a key role in improving the efficiency of fungicide applications (Salam *et al.,* 2003).

2.3. Blackleg Disease

2.3.1. Causal Organisms

Blackleg (Phoma stem canker), caused by *Leptosphaeria maculans* (Desm.) Ces. et de Not. anamorph *Phoma lingam* (Tode: Fr.), is the disease that causes the most serious economic impact on canola production worldwide. *L. maculans* can survive on canola residues. Under undesirable crop rotation conditions, there is an increase in the inoculum pressure for subsequent canola crops. The seedling stage is the most vulnerable, but symptoms can also appear during the entire growing season. In Europe and the USA, *L. maculans* co-exists with *L. biglobosa.* (West *et al.*, 2002), which is associated with damage in upper stem lesions.

2.3.2. Symptoms

When ascospores or pycnidiospores of *L. maculans* infect cotyledons or rosette leaves, the pathogen spreads from leaf lesions down through the petiole to the stem (Figure 1). The fungus enters through stomata or wounds (Huang *et al.*, 2003). Circular pale grey lesions with numerous pycnidia in the center of cotyledons and dead leaf tissue indicate the first symptoms of seed-borne infections (Gugel and Petrie, 1992). On dead leaves, stem and roots, *L. maculans* produces globose and ostiolate black pseudothecia (300-500 um diameter). Asci contain 8 asco, are clavate and bitunicate and measure 80-125 x 15-22 μm (Punithalingam and Holliday, 1972).

Ascospores have 5 septae, are cylindrical and yellow to brown; ascospores measure 35-70 x 5-8 μm. Pycnidia are globose and have 200-400 μm diameter of. Pycnidiospores are shortly cylindrical and hyaline and measure 3-5 x 1.5-2 μm.

The fungus moves biotrophically in the lamella and petiole of the leaf, without manifestation of symptoms, from cotyledons and leaf lesions to infect the stem and hypocotyls (Hammond and Lewis, 1987). As a consequence, severe seedling blight can be provoked. This type of infection causes the stem to constrict above the ground and below the first leaves (Barbetti and Khangura, 1999).

Phoma stem cankers are developed when the pathogen colonizes and kills the stem cortex, wood and xylem cells of the host (West *et al.*, 2001). Compared with leaf lesions, stem cankers have a purple or black border and are similar in shape. Those lesions, which encircle the basal stem, result in lodging and death of the plant.

The lesions originate on the leaves and are associated with leaf scars, which transfer to the stem base where they are usually a dark brown or purple color and produce a crown or root collar. Dry rots, or cankers, are formed during the pod development and seed ripening stage. Terms such as canker, blackleg, crown, collar rot and basal canker are used to describe symptoms of a stem base disease (Hammond and Lewis, 1987).

Stem cankers (upper or phoma stem lesions) originate from phoma leaf spot lesions that move to the upper parts of the stem and occur at flowering stages (Hammond, 1985). Crown cankers and phoma stem lesions encircle the stem, which causes the pods to ripen prematurely causing the plant to lodge (Davies, 1986).

In roots, the symptoms of the fungus are caused by the growth of the pathogen within the xylem tissues during the flowering stage. Subsequently, cankers appear on the stem base and completely girdle the stem during pod filling. These cankers destroy vascular tissues and limit plant growth, which results in yield reduction. The incidence and severity of epidemics depend on several factors, which include the rate of inoculum survival, maturation of fruiting bodies, timing of ascospore release, infection conditions, host growth stage at time of infection, and host resistance (Fit *et al.*, 2003).

Figure 1: A and B – Early development of blackleg symptoms on seedlings, C and D – Blackleg stem symptoms on adult plant.

2.3.3. Disease Epidemiology

2.3.3.1. Disease Cycle

L. maculans is a monocyclic pathogen. Epidemics of this disease are initiated by airborne ascospores (sexual spores), which are the primary inoculum and can originate from infected stubble for at least three years after the harvest of an infected crop (Guo and

Fernando, 2005). Pycnidiospores asexual spores were important during the epidemic that occurred during the 1970s in Australia (Barbetti, 1976; Hua *et al.,* 2004). In Canada, pycnidiospores are also crucial in the development of the disease (Guo and Fernando, 2005).

Pycnidiospores inoculum is needed in large doses to develop disease symptoms, and they are not important as ascospores in the development of widespread epidemics (Wood and Barbetti, 1977; Salam *et al.*, 2003). Seedling emergence often coincides with early ascospore showers (Salam *et al.*, 2003) and are highly susceptible to infection up to the six-leaf stage (Khangura and Barbetti, 2001). After infection, pycnidiospores (asexual spores) act as secondary inoculum and are spread by rain to adjacent plants (Fernando *et al.*, 2003). Canker development is still possible after the six-leaf stage, but the yield losses are of minor importance (Hammond, 1985). The link between cotyledon leaf lesions and the severity of crown cankers is related to temperatures in the range of 11/18°C for growth stages up the 5^{th} leaf, whereas infections occur at nearly all growth stages at the temperature range of 18/24°C (Hua *et al.*, 2005).

2.3.3.2. Survival and Pathogenic Activity

The fungus survives as a saprophyte on infected stubble and its pathogenic activity has two periods of symptomless growth. The first occurs in leaves after the penetration of stomata by the hyphae produced from airborne ascospores before the appearance of leaf lesions (Toscano-Underwood *et al.*, 2003). During this period of intercellular growth, the fungus is biotrophic. The second symptomless period occurs between the appearance of leaf lesions and the appearance of cankers on the stems (Huang *et al.*, 2006). Once strains of compatible mating types meet, pseudothecia are formed and mature on the woody remains of infected plants. After this necrotrophic phase, the pathogen produces pycnidia in the dead tissues (Hammond, 1985). Rain splash is involved in the dispersal of pycnidiospores to other plants. Temperature and humidity (rainfall and dew) mainly influence the process of pseudothecial maturation, which ranges from 51 days after harvest in France to 9 months after harvest in Saskatchewan, Canada (Khangura *et al.*, 2007). The optimal environmental conditions for the formation of pseudothecia and the release of spores are 14°C and 100% RH (West *et al.*, 2001).

Researchers can predict the pseudothecia maturity and release of ascospores by tracking the weather conditions 16 to 19 rain days after harvest, when average temperatures are 14°C. Other factors such as rainfall, heavy dew, and high humidity affect the release of ascospores (Salam *et al.*, 2003).

2.3.3.3. Disease Dispersal

Driven by wind, ascospores can be dispersed up to 5 km from the infested stubble (Guo and Fernando, 2005; West and Fitt, 2005). From 9 pm to 4 am, when temperatures are 13 to 18°C and RH is higher than 80%, dispersal of ascospores and pycnidiospores occurs. After rainfall $\geq$2mm, peak ascospores dispersal occur for numerous hours and continues for the next 3 days, while the peak pycnidiospores dispersal occur during rainfall (Guo and Fernando, 2005). The periods of ascospores and pycnidiospores dispersal coincide with susceptible growth stages of canola. The process of ascospores' release can last three to four months or even longer, with a production peak one or two months after its onset (Khangura *et al.*, 2001). Ascospore dispersal in Saskatchewan starts on canola stubble in June while some ascospores remain until late July. Variations between locations and seasons influence the temporal pattern of ascospore discharge and make it difficult to manage blackleg at regional and individual farms (Khangura *et al.*, 2002).

2.3.3.4. Inoculation Period

The time from inoculation to penetration decreases with increasing temperature. Observed 24 hours after inoculation at temperatures of 5°C, the penetration process through stomata occurs and decreases to 16 hours, when the temperature increases to 10°C. The time needed for penetration decreases to 12 h after inoculation at temperatures of 15 and 20°C (Huang *et al.*, 2003).

The optimum temperature for infection is about 18°C; at this temperature the shortest wetness period is needed for infection to occur (Biddulph *et al.*, 1999). The efficiency of infection is greatest at 18-20°C, with most lesions produced when the wetness duration is at least 48 hours. This happens as a result of a temperature increase from 5 to 20°C, decreasing the time for germination and penetration (Toscano-Underwood *et al.*, 2001).

Also, the incubation period, time from inoculation to the appearance of the first lesions, decreases from 15 to 5 days when temperatures increase from 8 to 20°C (Toscano-Underwood *et al.*, 2001). But, leaf wetness duration influences the length of the incubation period only at sub-optimal temperatures.

The process of canker development occurs at optimal temperatures of 20 to 24°C and the development of the disease decreases when the temperature ranges from 4 to 8°C. Also, temperatures of 28 to 30°C stop the development of the disease (Li *et al.*, 2006). At 18 and 24°C (which represent temperatures of night and day), the severity of crown cankers increase, compared with temperatures of 11 and 18°C.

Phoma leaf spots occur under leaf wetness duration ranging from 8 to 72 hours, when temperatures range from 8 to 24°C (Biddulph *et al.*, 1999). Leaf wetness duration of 48 h at 20°C generated the higher number of leaf spot lesions; as leaf wetness duration decreases with increasing or decreasing temperatures, the amount of lesions decrease.

2.3.4. Leptosphaeria maculans as Blackleg Causal Agent

2.3.4.1. Taxonomy

According to its taxonomical classification, *Leptosphaeria maculans* (Desm.) Ces. & de Not. (anamorph *Phoma lingam* Tode ex Fr.) belongs to the Kingdom: Fungi; Phylum: Ascomycota; Class: Dothideomycetes (Loculoascomycetes); and order: Pleosporales.

2.3.4.2. Morphological, Physiological and Genetic of L. maculans

The taxonomic group of *L. maculans* comprises several closely related species that are morphologically similar (Cozinjnsen *et al.*, 2001). Two pathotypes of *L. maculans* are differentiated among various isolates according to the production of the phytotoxin sirodesmin PL, and their ability to cause stem cankers on canola. The 'A' group, also termed Tox+, produces sirodesmin PL, which acts as a virulence factor in the late stages of canola infection and causes stem cankers. The 'B' group, which is genetically similar to 'A' group, also termed Tox0, comprises several species, is weakly virulent, and does not produce sirodesmin PL or cause stem cankers (Rouxel *et al.*, 2004).

Many isolates of *Leptosphaeria maculans* grow as saprophytes or as pathogens on crucifers. Based on the morphological characteristics of pseudothecia, two related species, *L. maculans* and *L. biglobosa*, can be isolated as saprophytes or as pathogens (Shoemaker and Brun, 2001). The existence of up to seven subspecies within these two species was revealed using biochemical criteria (Mendès-Pereira *et al.*, 2003). Brassica crops with stem canker lesions are related to the existence of *L. maculans*. On the other hand, phoma stem lesions are caused by *L. biglobosa*. Existing in Europe, Canada and the USA, the two species are dispersed worldwide and show few differences (Mendès-Pereira *et al.*, 2003). Located in most of the productive regions around the world *L. maculans* is a new and expanding species which threatens to overcome the less harmful *L. biglobosa* (West and Fitt, 2005).

This species complex provides different methods for researching speciation issues because of the existence of "the close taxonomic, biological and geographical relationships between *L. maculans* and *L. biglobosa"* (Rouxel and Balesdent, 2005)

2.3.4.2.1. Mating Types

The importance of sexual reproduction of *L. maculans* is related to the production of ascospores as a source of genetic variation. Mating type (MAT) genes are helpful in determining the relationship of closely related species (Pöggeler, 1999). *L. maculans* has a single mating type (MAT) locus with two alternate forms, also called idiomorphs (Venn, 1979). For two isolates to mate, idiomorphs must be different. According to Cozijnsen and Howlett (2003), "idiomorphs in *L. maculans* encode single proteins with DNA-binding domains, such as an alpha box for MAT 1-2 strains". Sexual reproduction is the source of ascospores production and enables genetic recombination. More population genetic studies are needed that characterize genetic diversity and epidemiology (Cozijnsen and Howlett, 2003).

2.3.4.2.2. Toxin Production

Toxins are implicated as virulence factors in numerous fungal diseases and can be host-specific or non-host specific (Markham and Hille, 2001; Howelett, 2006). Among the nonspecific phytotoxins isolated, epopythiodiosoperazines (EPTs) are the most important, while specific toxins have not been isolated (Gugel and Petrie, 1992). Host-selective toxins are secondary metabolites implicated in cell death in plant-fungus interactions and can be used for rapid screening and the selection of blackleg resistance plants (De March *et al.*, 1986). Four different phytotoxins of blackleg were isolated from different isolates of *L. maculans*: sirodesmins H, J 2, K 3 and phomalirazine 6 (Pedras *et al.*, 1990). Two host-selective toxins, phomalide 4 and phomalairdenone A 55, were isolated from *L. maculans.*

Phomalide 4 appears to be essential for host-selectivity and virulence of *L. maculans* when the pathogen causes damage on leaves of *Brassica napus*, *B. rapa* and other susceptible species. Phomalairdenone A 550, produced by Polish isolates of *L. maculans*, causes chlorotic, necrotic, and reddish lesions on susceptible cultivars of *B. juncea*, but not on *B. napus* or *B. rapa* (Pedras, 2001).

2.3.4.2.3. Genetics

L. maculans can be grown on a specific media. It is haploid, transformable and outcross is also possible. Field gel electrophoresis techniques indicate *L. maculans* has 15 chromosomes ranging in size from 0.6 and 3.5 Mb. (Morales *et al.*, 1993) The interactions between Westar, Quinta and Glacier cultivars and *L. maculans* at the seedling stage is due to the existence of three sets of corresponding avirulence and resistance genes (Ansan-Melayah *et al.*, 1998).

Ascospores, the source of primary inoculum, have genetic variability, which is generated as a result of sexual reproduction. A single mating type locus and two different varying forms are present in the Ascomycetes, which make reproduction possible (Cozijnsen *et al.*, 2001).

2.3.4.2.4. Pathogenicity Groups and Races

There are currently two classification systems in use. North America (US and Canada) uses the PG system, but Europe and Australia have moved into race classification. Classification into pathogenicity groups has been made possible through the evaluation of the interactions between isolates and three differential cultivars, two of which share a common resistance gene (*Rml3*) but carry an extra resistance gene. The other differential, Westar, does not carry any resistance gene. Table 1 shows the reaction in differential cultivars when they are inoculated with different PGs.

Classification into races rather than pathogenicity groups has resulted in a more accurate assessment of the virulence structure of *L. maculans* populations and facilitated the use and transfer of R genes among cultivars from different regions (Rouxel *et al.*, 2003). To date, nine avirulence genes (*AvrLm1–AvrLm9*) have been identified in *Leptosphaeria maculans*, combinations which could theoretically generate up to 512 different races of the fungus. However, in Europe, only eight races have been identified (Balesdent, 2006). From the number of PGs and races identified, it is clear that the North American system is no longer adequate to describe the blackleg populations from the region; a single PG probably has multiple races.

Currently, only a few countries lead the research on race structures, which include Germany, France, Canada, and Australia. Nevertheless, this research is limited in terms of comparison between race structures in various countries because an international set of differentials is still not available for researchers as countries lack a common race terminology and a shared plant and isolate differential (Balesdent, 2005).

Table 1. Pathogenicity group system used to classify *Leptosphaeria maculans* strains into pathogenicity groups.

Pathogenicity groups[1]	Differentials		
	Westar(none)[2]	Glacier (*Rlm2,3*)	Quinta (*Rlm1,3*)
PG1	0 (R)[3]	0 (R)	0 (R)
PG2	7-9 (S)	0-2 (R)	3-6 (I)
PG3	7-9 (S)	7-9 (S)	3-6 (I)
PG4	7-9 (S)	7-9 (S)	7-9 (S)
PGT	7-9 (S)	3-6 (I)	7-9 (S)

[1] Classification according to Mengistu *et al.*
[2] Resistance genes in parentheses
[3] According to the Delwiche rating scale (1980), R = Resistant reaction (0-3); I = Intermediate reaction (3-6), and S = Susceptible reaction (6-9). Mengistu *et al.*, 1991

2.3.5. Disease Management

2.3.5.1. Cultural Practices

Infected seed is the major cause of the introduction of blackleg into previously uninfected regions (Hall *et al.*, 1996). Adjusting the time of seeding to avoid coincidence with conditions that favor high levels of inoculums is not always effective, especially in areas where ascospores are released throughout the entire growing season (Gugel and Petrie, 1992). Crop rotation of at least 3 years between canola crops reduces the severity of blackleg because it lowers the vitality of the fungus on the stubble of previous canola crops. But the effectiveness of crop rotation may be diminished if there are adjacent fields with infected stubble because ascospores can be dispersed up to 2 km (Petrie, 1986). Cultivation and burial of crop residues promotes its fast decomposition and shortens the survivability of the pathogens on infested materials (Abawi and Grogan, 1979).

2.3.5.2. Fungicides

Different factors such as the epidemiology of the disease and economic return of the crop influence the chemical management decisions in different regions (West *et al.*, 2001). In order to protect the seedling for a long period of time, flutriafol, combined with other management practices, is used to coat fertilizer granules. This option offers good protection when there is low cultivar resistance, when the crop has high yield potential, and when the level of inoculum is moderate to severe (Barbetti and Khangura, 1999).

In Canada and Europe, iprodione, thiram and carbathin are used as seed treatments (West *et al.*, 2001). The use of foliar fungicide is recommended with cultivars with low to moderate level of resistance (Brown *et al.*, 1976). According to the 2011 Field Crop Fungicide Guide, in North Dakota, the options suggested for seed treatment include the following active ingredients: azoxystrobin, fludioxonil, and metalaxyl. Also, the following combinations are recommended: difenoconazole + metalaxyl M + fludioxonil + thiamethoxam; thiram + carboxin + metalaxyl + clothianidin; as well trifloxistrobin+ carboxin + metalaxyl + clothianidin (McMullen and Markell, 2010).

Foliar fungicide applications, especially with triazoles have produced inconsistent degrees of control (Gugel and Petrie, 1992). Furthermore, application of fungicides is generally inefficient because targeting the disease accurately is complicated due to the asymptomatic phase of the disease, which makes identification difficult. This also adds to an increased risk of environmental pollution because fungicides may be applied when they are not necessary. The application of prothioconazole as a foliar fungicide does not control phoma stem cankers in the average environmental conditions of Canada where the primary inoculum comes from stubble infested fields that release conidia and ascospores throughout the entire growing season (Kharbanda, 1992). In order to control crown canker in western Europe, the application of difenconazole as a foliar fungicide or in mixture with carbendazim and/or flusilazole normally offers good quality control (Gladders *et al.*,1998).

In western Europe, autumn, which coincides with the seedling stage, is the best time to apply foliar fungicide in order to manage crown canker epidemics (Gladders *et al.*, 1998). It is important to use accurate forecast models to predict the severity of epidemics because the fungicides have low eradicant activity and limited protectant activity as a result of "chemical decomposition, leaf expansion and the production of new untreated leaves" (West *et al.*, 2001). According to the 2011 Field Crop Fungicide Guide, in North Dakota, the options for foliar sprays include the following active ingredients: azoxystrobin, applied at 2 to 4 leaf stage, or pyraclostrobin, also applied at 2 to 4 leaf stage (McMullen and Markell, 2010).

Researchers in the UK are trying to develop more accurate forecast models because the ones based on weather patterns and ascospore development that predict the incidence of phoma leaf spotting on crops in the autumn often do not allow growers sufficient time to control the disease before the fungus reaches the stem. As a consequence of the inaccuracy of the current model, farmers in the UK have often applied fungicides unnecessarily (Fitt *et al.*, 1997). The new models under development are based on the link among weather factors, ascospore maturation, release and infection. Also, they use immunological techniques to detect airborne ascospores and symptomless leaf infection. In France, a model has been developed that uses weather factors such as 7 rain-days after sowing, maturation of pseudothecia or first detection of >20 ascospores per day and other biological parameters to predict the risk of infection (Penaud *et al.*, 1999).

2.3.5.3. Resistant Cultivars

Resistant cultivars have been used to manage the disease in Australia, Canada and Europe (Bansal *et al.*, 1994), but the change of the pathogen and the apparition of new races make relying only on this practice unsustainable. For this reason, breeding for disease resistance is a continuous effort (Delourme *et al.*, 2006).

In the past, the use of resistant varieties and four-year crop rotations has effectively controlled the disease, but such a long rotation program has become unpopular among growers. Chemical control of the disease is not economically viable in most conditions (West *et al.*, 2001). For these reasons, it is crucial to breed for resistance (Fernando *et al.*, 2007).

2.3.5.4. Genetic Resistance

Host resistance has been the most economical and effective method to control blackleg (Delourme *et al.*, 2006). There are 14 major genes conferring resistance against *L. maculans* (Balesdent *et al.*, 2002). The introgression of few of these genes in adapted cultivars prevents the spread of the pathogen to the stem and the development of cankers.

Resistance in *Brassica napus* is controlled monogenically by specific resistance genes that interact in gene-for-gene mode or by genes inherited poligenically and expressed quantitatively. Nevertheless, the development of new pathotypes as a consequence of the pathogen's ability to change is making the management of the disease unsustainable through the use of cultivars with race-specific resistance (Delourme *et al.*, 2006).

Qualitative resistance, also known as vertical or complete resistance, is considered single-gene-race specific and protects the plant when the corresponding avirulent allele is predominant in the local *L. maculans* population (Rouxel *et al.*, 2003). This kind of resistance operates in cotyledons and leaves during the first symptomless phase, immediately after the penetration of leaves by hyphae from the ascospores (Balesdent *et al.*, 2001). Although vertical resistance is expressed as a hypersensitive reaction, it has been considered non-durable (Lindhout, 2002; Parlevliet, 2002). Environmental factors such as temperature have influenced the expression of the resistance (Huang *et al.*, 2006).

The use of vertical resistance puts pressure on the pathogen to shift their populations and as a consequence, resistance could breakdown. This situation has been already observed with blackleg in France and Australia (Brun *et al.*, 2000; Sprague *et al.*, 2006).

Quantitative resistance controls the spread of the pathogen down the leaf petiole or into the stem tissues during the long period of symptomless growth between the appearance of leaf lesions and the appearance of cankers on stems (Pilet *et al.*, 1998; Delourme *et al.*, 2006). It acts by impeding the growth of the pathogen within the stem tissues, and has been associated with more rapid lignifications of resistant cultivars (Hammond & Lewis, 1987). This kind of resistance is mediated by many genes and is more durable (Boyd, 2006).

As a result, selecting cultivars for quantitative resistance currently relies on field experiments that assess stem cankers before harvest (Fitt *et al.*, 2006). Although quantitative resistance is more stable or durable than vertical resistance, the level of protection may not be as effective (Pilet *et al.*, 2001). In Australia, *L. maculans* can overcome this kind of resistance under glasshouse conditions (Li *et al.*, 2005).

Conventional methods for blackleg resistance breeding have the constraints of dealing with polygenic pools of genes, the important variability of pathogens (Williams, 1992), and the complexity of field testing designs (Pilet *et al.*, 1998). While progress has been made to understand resistance at a molecular level, studying genetics is increasingly important because it gives plant breeders methods to develop long lasting resistant cultivars.

Knowing the genetic background of a cultivar is necessary to predict how it will perform when exposed to new pathotypes. Unfortunately, genetic background information is usually not revealed by the seed industry, and often cultivars are rated as resistant, but there is no information about which pathotypes they are resistant to.

The most important factors to consider when breeding for durable resistance are the types of resistance present in the host and the genetic background of the host and pathogens, although the area and climate where the crop is grown should also be considered. Durable resistance is difficult to breed for a pathogen like *L. maculans*, in which air-borne ascospore dispersal and sexual recombination of the pathogen occurs frequently (McDonald and Linde, 2002). Taking this into account, modeling the effects of different deployment strategies in space (pattern of areas sown with cultivars with different genes) and time (seasonal pattern of deployment), in relation to different measures of resistance durability (van den Bosch and Gilligan, 2003), can be used to guide different proposed deployment strategies (Pietravalle *et al.*, 2006).

The breakdown of resistance, caused by major genes, occurred recently in Australia (Li *et al.*, 2003). The durability of major gene resistance may be increased by diversification schemes, which classify the current commercial cultivars by the resistance genes they carry in order to guide strategies for deployment of these genes (Gladders *et al.*, 2006). Modeling the effects of different deployment strategies in space (pattern of areas sown to cultivars with different genes) and time (seasonal pattern of deployment), in relation to different measures of durability of resistance (van den Bosch and Gilligan, 2003), can be used to guide different proposed deployment strategies (Pietravalle *et al.*, 2006).

The symptomless phase of blackleg disease makes identifying a correct time to apply fungicides difficult (Rouxel and Balesdent, 2005). For the above reasons, it is a priority to breed cultivars with durable resistance, which is referred to as quantitative resistance. In the meantime, the possibility of developing cultivars with vertical resistance makes it possible to find accessions with resistance that could be used in subsequent breeding programs to breed for more durable resistance. The possibility of developing cultivars with qualitative resistance makes the management of the disease feasible until cultivars with quantitative resistance are available. The value of vertical resistance in an accession is to find resistance genes that can be introgressed into commercial cultivars. Plants that have acceptable levels of vertical resistance should also be tested to determine how they will perform. And those will be source o resistance in accessions that could be used in subsequent breeding programs. In this study, different collections of accessions were screened in order to find sources of vertical resistance.

2.3.5.4.1. <u>Factors Implicated in Field Resistance</u>

In order to sustainably manage Phoma stem canker, it is important to breed cultivars that are resistant at both stages. Seedling and adult plant resistance have different genetic backgrounds, and in the adult, the resistance slows down and obstructs the spread of the disease in the leaf and seedlings. The process obstructs the spread of the disease down the petiole to the hypocotyls or stem (Rimmer and van den Berg, 1992).

Field resistance to phoma stem canker is the product of numerous factors: one of them is genetic resistance to penetration of cotyledons by conidia (Badawy *et al.*, 1991). Another component is disease escape, which happens when plants drops infected leaves before the pathogen has the chance to enter the stem. Additionally, the disease tolerance component lessens the manifestation of symptoms in the plants by working with the genetic resistance component. Furthermore, tolerance characteristics could be provided by inhibitory chemicals, the toughness and thickness of the stem. Finally, cultural practices such as good crop rotation and environmental factors such as temperature decrease the risk of infection and do not contribute to disease development (West *et al*., 2001).

Different sources of resistance are expressed at various stages of development of plants (Rimmer and van Der Berg, 1992). Total resistance at seedling and adult stages of *B. nigra* and *B. juncea* L. has been introgressed into *B. napus* (Roy, 1984; Struss *et al*., 1991). The majority of the introgressed seedling resistance were found to be monogenic or oligogenic at the intraspecific level (Stringam *et al*., 1992).

It has been reported that gene linkage controls resistance at both developmental stages in *B. napus* (Zhu and Rimmer, 2003). While other studies suggest a consistent correlation between plant resistance stages, the existence of allelic loci was not proved. Other research has concluded that separate genetic control governs resistance at both stages (Ballinger and Salisbury, 1996).

2.3.5.4.2. Screening for Resistance

When screening for resistance, factors such as spore concentration, temperature, and photoperiod influence the manifestation of the symptoms. However, Bansal et al., 2002 reported that increase of inoculum concentration over the range of 5 x 10^5 to 4 x 10^6 pycnidiospores per ml, respectively, did not affect levels of cotyledon infection. When pycnidiospore-inoculum was used, incubation time period did not have a marked effect on the number infected plants. Wood and Barbetti's study (1977) reported that under a natural light photoperiod of 8 h at 10, 15, or 20°C, a temperature of 20°C caused more rapid symptom development than lower temperatures. As a result, it can be concluded that low temperatures slow down disease incidence, but do not decrease it (Wood and Barbetti, 1977).

Seedlings can be screened for qualitative resistance in cotyledon tests (Balesdent *et al.*, 2001), which was the practice used to screen the different collections of *Brassicas*. Cotyledon biossays are among the most effective methods for screening resistant materials against blackleg in greenhouse conditions (Rimmer and van den Berg, 1992).Temperature during the incubation period is one of the critical factors that influences disease severity. The expression of symptoms is delayed as temperatures decrease after being inoculated with ascospores of *L. maculans*. Other factors that influence the duration of the incubation period are inoculum concentration, relative humidity, photoperiod duration, and the degree of plant tissue injury (Bansal *et al.*, 2002).

2.4. Nonparametric Data Analysis

The Delwiche scale (1980) that measures severity of infection is an example of an ordinal scale. The differences between the measured values and means cannot be interpreted in the same sense as the means observed in a continuous scale. Parametric statistics were used in previous studies until to analyze non-parametric information using simple experimental design such as one-way layout (Munzel and Bandelow, 1998). With the latest development of software, plant pathologists can analyze ordinal data using nonparametric methods generated from more complex designs. The statistical approach to manage ordinal data should keep the initial order of the ordinal scale values. The use of rank transformations methods is adequate for this task. Differences in ranks are the parameter that allows easy identification of the differences between ordinal values.

The Kruskal-Wallis and Friedman tests are two nonparametric methods based on rank transformation. The first test gives the same kind of information as the one-way analysis of variance (ANOVA) and the second test is adequate to analyze randomized complete block design (RCBD).

The Brunner nonparametric method allows the analysis of any experimental design using normalized distributions instead of the sampler distribution. The normalized distribution represents random variables such as continuous and ordinal categories. The relative treatment effects can be assessed by the midrank values. There is a connection between the mean ranks and the relative effects of the Brunner method used in many nonparametric analyses. The ranks are used as a natural and convenient tool for estimating the relative treatment effects. The use of estimated relative effects and confidence intervals in this kind of analysis can be used to detect differences between treatments (accessions). The lower the relative effect of a particular accession the higher will be its resistance value. Relative effects are analogous to means used in parametric statistical analysis.

The median disease ratings per isolate provide one convenient and traditional summary of the central value for each treatment. The estimated relative effects will be values linked to the median rating where the largest values will correspond with the largest median ratings.

Shah and Madden (2004) also developed a method which used normalized distribution to test the null hypothesis. This method was used to analyze data obtained from the cotyledon inoculation test, which was used to evaluate the collections of *Brassica* germplasms when challenged with isolates of PG3 and PG4 of blackleg. Median disease severity ratings "provide one convenient summary of the central value of each treatment"

(Shah and Madden, 2004). Using Brunner's method, the confidence interval parameter was deducted based on the standard error *(se).* The parameters estimated relative effects (RE) and confidence intervals were used to detect differences between treatments. A lower value of RE indicated a higher degree of resistance in the material evaluated. Differences in relative effects measure treatment differences.

CHAPTER 3.

MATERIALS AND METHODS

This research was divided into 6 sections, all of which were conducted in greenhouse conditions. The first three experiments were designed to evaluate and identify resistance to pathogenicity groups 3 and 4 of *L. maculans* in plant introductions from *Brassica rapa*, *Brassica napus*, and *Brassica juncea* collections. The following three experiments were designed to evaluate the reaction of 75 commercial canola cultivars to PG2, PG3 and PG4 and also to compare the effect of different sequences of inoculation on the reaction of ten commercial cultivars.

The activities conducted in preparation for the actual screening, such as planting methods, inoculum preparations, growth conditions and the evaluation of disease reaction were common for all sections. The experiments were laid out using randomized complete block design (RCBD) with two replications and the experiments were conducted in 2009 and 2010. The accessions were evaluated in trials, each of them containing 9 accessions and the commercial cultivar DK 3042 as a susceptible control. Finally, the 277 accessions of the *B. rapa* collection were evaluated in 31 trials, the 130 *B. napus* accessions in 15 trials, and the 406 *B. juncea* in 45 trials. For each accession a minimum of six plants were evaluated using a 0-9 scale developed by Delwiche (1980) where 0 to 3 correspond to the resistant category, 4 to 6 to the moderately resistant category and 7 to 9 to the susceptible category. According to their scores, individual plant materials showing a moderately resistant (MR) or resistant (R) were identified and transplanted into larger pots. They were then taken to flowering in order to evaluate disease reactions in the next generation after being self-pollinated.

3.1. Preparation of Plant Materials for Inoculation

During the identification of sources of resistance it is recommended that greenhouse evaluations be accompanied by corresponding field trials. In this case, however, the limited geographic distribution and the low frequency of PGs 3 and 4 strains, in the most important canola production area in North Dakota, which include the north central counties Bottineau, Rollete, Towner, Cavalier, and neighboring areas, prevent us from conducting field trials. According to Pongam et al., 1999 isolates that belong to PG3 and PG4 in North Dakota were similar to those that exist in United Kingdom. PG4 strains were first detected in 2003 in a commercial field in Cavalier, ND (Chen and Fernando, 2006).

Seeds of each accession were planted in one insert containing 6 cells. Ten inserts corresponding to 9 accessions plus the control constitute a trial (E.C.Geiger, Inc., Harleysville PA). Greenhouse artificial soilless mix (Professional Growing Mix 1 SunGro Horticulture Canada Seba Beach, AB, Canada) was used as subtract to grow the plants. The trials were watered daily, and the greenhouse room was illuminated with high pressure sodium lamps (1,000 $\mu mol/m^2s$). The natural light, combined with artificial illumination, lasted for about 16 hours per day. The temperature inside the greenhouse room ranged between 20 and 25°C. At planting time, 3 seeds were sown in each cell and fertilized with 3.3 g of 12-24-12 and 1 g/pot of insecticide imidacloprid was applied (Marathon, OHP Inc.). After germination, seedling populations were thinned down after 9 days in order to leave six plants per insert (one per cell). A total of 21,336 plants that belong to the different Brassica collections and the commercial cultivars were screened in this study. The experiments were conducted as a RCBD, except the experiment that compared the effect of different sequences of inoculation where a CRD was used. All accessions and commercial cultivars were inoculated using the cotyledon inoculation technique approximately 10 to 12 days after planting.

The plant materials used in this study were obtained from the National Plant Germplasm System USDA-ARS. The different *Brassica spp* collections are maintained at the North Central Regional Plant Introduction station in Ames, IA (http://www.ars-grin.gov/ars/MidWest/Ames/). In this study, 277 accessions of *Brassica rapa*, 130 *B. napus* and 407 *B. juncea* accessions, were evaluated for their reaction to PG3 and PG4 of *L. maculans*. Additionally, 75 of the most commonly grown canola cultivars that were part of the NDSU field trials during 2008 were evaluated for their reaction to strains of the same *L. maculans* PGs. Arbitrarily, in order to have cultivars that represent the seed companies that are in the field trial evaluation of NDSU, a sample of 16 commercial cultivars were selected from the 75 cultivars, and also evaluated for their reaction to PG2 of *L. maculans*. For the same reason mentioned above, a sample of ten commercial cultivars (Table 2) selected from the 75 cultivars was also evaluated for their reaction to five different inoculation sequences during 2009 and 2010 with two replications. The disease reaction was evaluated after 12 days of inoculation, and the inoculation process was similar to the previous experiments described.

3.2. Inoculum Production and Storage

Four *L. maculans* isolates belonging to PG3, identified as BL729, BL730, BL731, and BL732, and isolate BL736, belonging to PG4 were used in all studies reported in this thesis. All isolates were collected from plant residues from canola grown in North Dakota.

Single spore cultures of *L. maculans* isolates belonging to PG3 and PG4 were grown in potato dextrose agar (Difco; Becton, Dickinson and Company, Sparks, MD

USA). For PG3, a mixture of spores of four isolates was used. For PG4, only one isolate was used (the only one available). These cultures were transferred to V8 juice agar medium and supplemented with rose Bengal (0.05g/l) and $CaCO_3$ (3g/l) for spore production.

Table 2. Characteristics of 10 commercial cultivars evaluated for their reaction to PG3 and PG4 strains of blackleg inoculated alone or in different sequences.

Company	Cultivar	Type[1]	Blackleg Rating[2]
Cargill	V2018	H,HO	MR
Canterra	30507-B6	H,TR	MR
Integra Seed	IX08-7323R	H,TR	R
Brett Young	6235RR	H,TR	MR
Monsanto	G67012	H,TR	R
Mycogen Seeds	G2X0043	OP, HO	R
Agriprogress	30412-B6	H,TR	MR
Croplan Hyclass	924	H,TR	R
Bayer Invigor	5440	H,LL,TR	R
DKL	30-42	H, TR	R

Adapted from Kandel, 2008.

[1]OP-Open Pollinated, H-Hybrid, Syn-Synthetic. TR-Traditional Oil Type, HO-High Oleic Oil Type

[2]Blackleg Rating: S = Susceptible, MS = Moderately Susceptible, MR = Moderately Resistant, R = Resistant, ratings are provided by the companies.

Isolates were incubated for two weeks at 21°C under 24 hours of light conditions. After incubation, the cultures were flooded with 5 ml of sterile distilled water, and their surface was gently rubbed with a bent glass rod to suspend the spores in the water. The spore concentrations were adjusted to 10^7 spores $ml^{-1}$and stored for future use in 1.5 ml polyethylene microcentrifuge capsules (VWR International, LLC, PA) at -20°C. To reduce variation among batches and to eliminate the repeated sub-culturing, all batches were inoculated using spores from the frozen stock. Viability of inocula was periodically checked by incubating spores in water and estimating spore germination after 24 h of incubation at 21°C.

3.3. Inoculation and Incubation Procedures

Cotyledon bioassay was used to select resistant plant materials (Rimmer and van den Berg, 1992). The methodology and reaction assessment were similar for all the experiments carried out for this study (Figure 2).

Each seedling, simultaneously received inoculum from both PGs, but in separate cotyledon leaves approximately 10 days after planting. A tiny spot of red color was used to identify the cotyledon inoculated with PG4, whereas any mark was used to identify the cotyledon inoculated with PG3. Inoculum from each group was applied at a concentration of 10^7 spores per ml. Each cotyledon leaf was previously wounded lightly by gently pricking the center of each lobule with a needle. A 10μl aliquot of the stock suspension was placed on top of each wound using a micropipette. A cool-mist machine was used to increase relative humidity in the greenhouse room for the 24 h after inoculation. The plants were incubated at 20°C in a greenhouse room.

3.4. Disease Evaluation

Ten to twelve days after inoculation, disease reaction was evaluated using a 0-9 scale developed by Delwiche (1980) (Table 3 and Figure 3).

Materials showing a resistant or moderately resistant reaction to both groups were transplanted into larger pots, taken to flowering, and self-pollinated to increase seed production. The seed obtained from those plants were planted and inoculated in a new round in order to prove the existence of resistance.

Seedlings were considered resistant if their reaction scores were below 3 on the scale, partially resistant if their score ranged between 3 and 6, and susceptible when their scores were in the range of 6 to 9 (Delwiche, 1980).

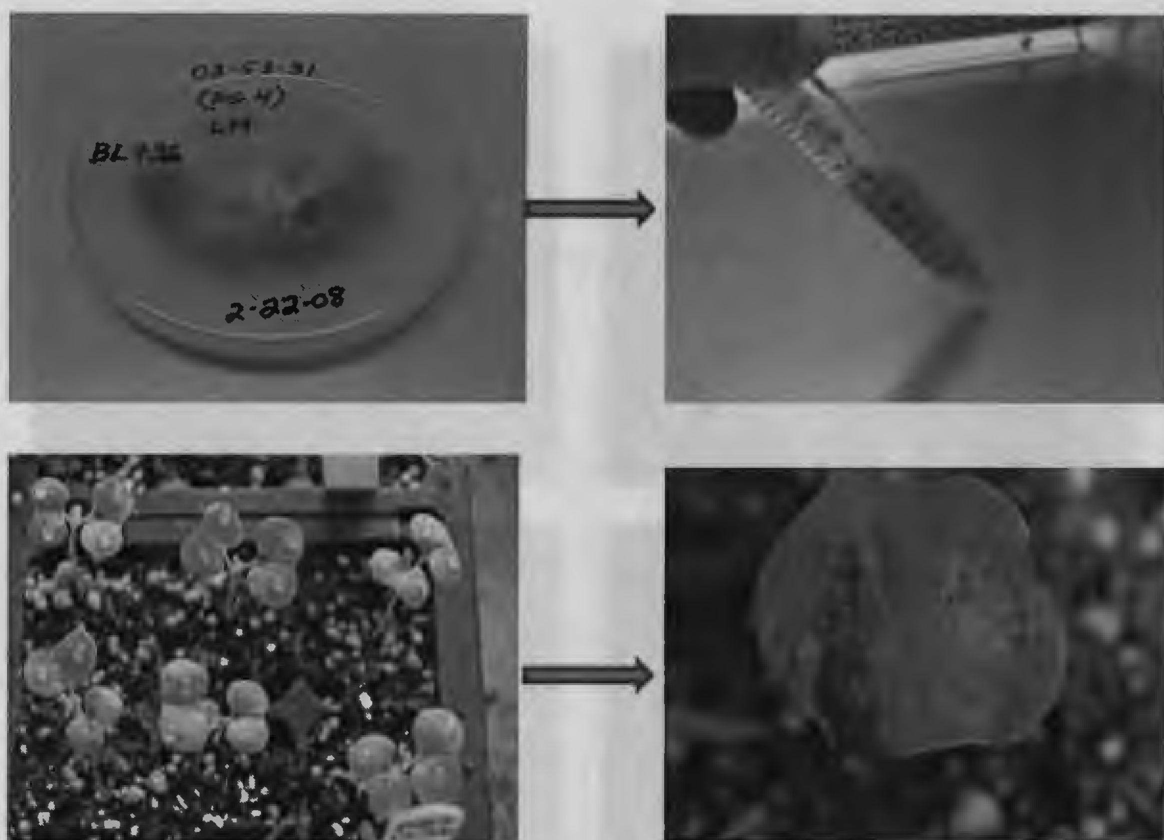

Figure 2: Process of inoculum preparation and disease evaluation on seedling of *Brassica spp* using three *Leptosphaeria maculans* isolates of pathogenicity group 3 and one isolate of pathogenicity group 4 in greenhouse conditions.

Table 3. Descriptions of symptoms and signs according to the Delwiche scale (1980).

Categories	Symptoms and signs description
0	No darkening around wound, as in controls.
1	Limited blackening around wound, lesion diameter: 0.5-1.5mm, faint chlorotic halo may be present, sporulation absent
3	Dark necrotic lesions, 1.5-3.0mm, chlorotic halo may be present, sporulation absent.
5	Non sporulating 3-6 mm lesions, sharply delimited by dark necrotic margin, may show grey-green tissue collapse as in IP 7 and 9 or dark necrosis throughout.
7	Grey-green tissue collapse 3-5 mm diameter, sharply delimited, non darkened margin.
9	Rapid tissue collapse at about 10 days, accompanied by profuse sporulation in large, more than 5 mm, lesions with diffuse margins.

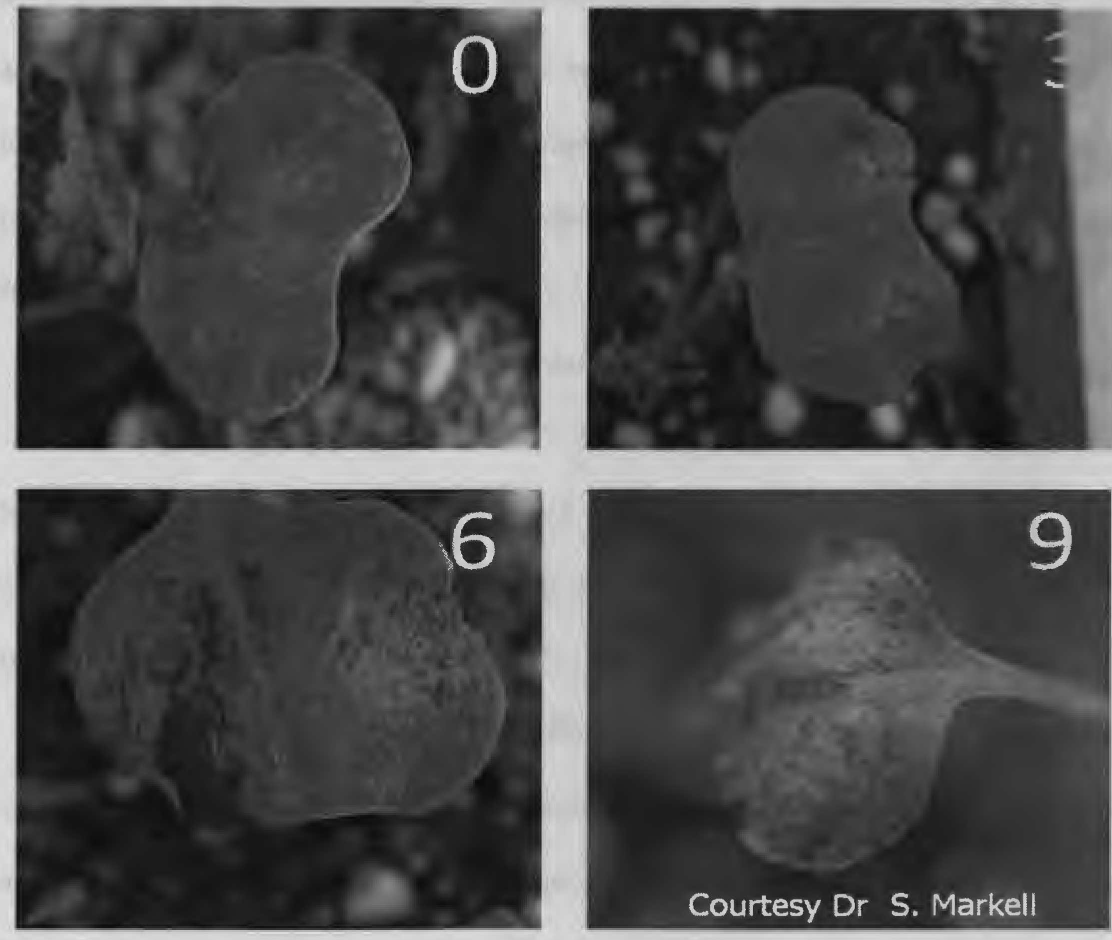

Figure 3: Blackleg severity scale: No presence of lesions =0: Presence of dark necrotic lesions= 3: Collapse of grey-green tissue=6: Collapse of rapid tissue and lesions with diffuse margins=9.

Individual plants that belonged to accessions with acceptable levels of resistance (<5 in the Delwiche scale) were selected, transplanted and taken to flowering and seed production. The next generations were evaluated in subsequent rounds of inoculations.

3.5. Experiments Conducted

The screening process was similar for all plant introduction materials evaluated. As outlined above, seedlings were inoculated simultaneously but in different cotyledons, with spore suspensions of isolates that belonged to both PGs. Reactions to inoculation were evaluated separately, and those accessions showing resistant reactions to both PGs were advanced for evaluation in advanced generations. Resistant materials were self-pollinated and their S_1 seeds were advanced to the second phase of the study, where they were inoculated again with both PGs. Plants showing a resistant reaction were taken to seed production. Resistant materials were self-pollinated and their progeny screened again to achieve S_2 generation.

3.5.1. Screening of Brassica rapa Plant Introduction Materials

In this study the reaction of 277 *B. rapa* accessions to *L. maculans* isolates belonging to pathogenicity groups 3 and 4 were evaluated. Also, 33 plant introduction materials previously identified as having adequate levels of resistance to *Sclerotinia sclerotiorum* (Zabala, 2008) were evaluated.

3.5.2. Screening of Brassica napus Plant Introduction Materials

In this study, 130 *B. napus* accessions were evaluated for their reaction to *L. maculans* isolates belonging to pathogenicity groups 3 and 4. In addition, 21 plant introduction materials previously identified by Khot (2006) as having adequate levels of resistance to *Sclerotinia sclerotiorum* were also evaluated.

3.5.3. Screening of Brassica juncea Plant Introduction Materials

A group of 406 *B. juncea* accessions were screened for their reaction to *L. maculans* isolates belonging to pathogenicity groups 3 and 4.

3.5.4. Evaluation of Reaction of Commercial Cultivars to PG2

In this study 16 commercial canola cultivars from ten seed companies were evaluated for their reaction to PG2 strains of *L. maculans*. This set of cultivars was a subset of the 75 commercial cultivars evaluated later for their reaction to PG3 and PG4. These cultivars had been part of the NDSU 2008 variety trials (Kandel, 2008). PG2 is considered the most prevalent pathogenicity group in North Dakota.

3.5.5. Evaluation of Reaction of Commercial Cultivars to PG3 and PG4

In this study, the reactions of 75 commercial canola cultivars commonly grown in North Dakota to PG3 and PG4 strains of blackleg were assessed. These cultivars were produced by 12 seed companies and were chosen from the 2008 canola field trial evaluations (Kandel, 2008). These cultivars were considered either resistant (R) or moderately resistant (MR) to blackleg by the companies that produced them, although it is not clear whether the rating refers to a particular PG or is a blanket statement.

3.5.6. Effect of Timing and Sequence of Inoculation on Reaction to Disease

In this study, 10 commercial cultivars were evaluated for their reaction to different inoculation sequences during 2009 and 2010 with two replications. The objective of this study was to determine if there was synergism in the simultaneous inoculation of PG3 and PG4 and to detect other possible interactions between the cultivars and the inoculation methods. In all cases when seedlings were inoculated with spores of a second PG, either separately or simultaneously, the inoculum of the second PG was deposited in the cotyledon not inoculated with the first PG. In cases when a single PG was used, seedlings were inoculated in both cotyledons.

In the first treatment, the cultivars were inoculated with a blend of four PG3 isolates, and 24 h later with a PG4 isolate. In the second treatment, the cultivars were first inoculated with the PG4 isolate, and 24 h later with the blend of PG3 isolates. In the third treatment, cultivars were inoculated only with PG4. In the fourth treatment, cultivars were inoculated only with the blend of PG3 isolates. In the fifth treatment, cultivars were inoculated with the blend of PG3 isolates and PG4 simultaneously. The process of inoculum preparation and disease evaluations were similar to those described for the other experiments. All treatments were incubated 24 h in the mist chamber.

3.6. Statistical Analyses

3.6.1. Analyses of Reaction of Plant Introduction Materials and Commercial Cultivars

Since disease data was collected using a categorical scale, median values rather than arithmetic means were calculated for each treatment and replication. The median values of the control materials used in each batch for each PG throughout the experiments were used to determine whether the batches were significantly different from each other, at a probability level of 5%, within a year and then between years. This was conducted running analyses of variances for each level. Upon confirmation that there were no statistical differences among batches, using a Bartlett chi-square test within a year and between years, the data from both years in each study were combined. Years were considered as random effects whereas accessions were considered as fixed effects. Treatment medians for each replication were ranked using PROC RANK from SAS v. 9.2 (SAS Institute, Cary, NC) and the ranks analyzed using the ANOVA F-TEST option of PROC MIXED from SAS. PROC MIXED was used in order to deal with the random and the fixed effects and to have a better estimate of the standard error. The ANOVA F-TEST option runs an ANOVA-type analysis and calculates treatment relative effects (Shah and Madden, 2004). This test is equivalent to Friedman's non-parametric test and was used to determine whether the treatments were different or not. To discriminate among treatments, the estimated treatment relative effect and its 95% confidence interval were calculated using the ld_ci.sas macro developed by Dr. E. Brunner (University of Gottingen, Germany). According to Shah and Madden, 2004 "one can think of the relative treatment effects as a generalized expectation or mean".

3.6.2. Analyses of Reaction of Commercial Cultivars to Blackleg Sequence Inoculations

Data from the ten commercial canola cultivars was processed in similar manner, although there were no batches in this study. Median treatments values were ranked and analyzed as described using the ANOVA F-TEST option of PROC MIXED from SAS and single-degree-of-freedom ANOVA analysis was used to compare treatments.

CHAPTER 4.

RESULTS

4.1. Evaluation of *Brassica rapa* Accessions for their Reaction to PG3 Isolates of *L. maculans*

Out of the 277 accessions evaluated for their reaction to PG3, none were selected based on the high values of median disease ratings according to the Delwiche scale.

The median disease rating for PG3 varied between 5 and 9 (Figure 4) and the relative effect varied between 0.10 and 0.95. Most of the *Brassica rapa* accessions (160) representing 58% showed a median disease rating of 6. Nevertheless, 7 accessions, representing 2%, of the total evaluated had a median disease rating between 5 and 6. The remaining 110 accessions (40%) showed a median disease rating over 7. Treatment relative effects of the best 10% accessions are presented in Table 4. Data for the remaining accessions were placed in Appendix 1.

Just 10 accessions representing 3.6% of the total evaluated had a relative effect below 0.2. Six of these accessions, Ames 9244, 340179, 169064, 370733, 173846, and 171521 had an overall median disease rating of 5 in the 0-9 Delwiche scale (Table 4). The remaining accessions in this group had median of 6. Additionally, 20 accessions, representing 7.2 % of the total evaluated showed a relative effect between 0.2 and 0.3. The remaining 246 accessions (89%) had a relative effect higher than 0.3.

Based on the range of confidence intervals for each relative treatment effect, there is no overlap for estimated relative effects between accessions that scored 5 and those that scored 9. This means that those accessions are statistically different. There was no significant difference between accessions that scored 5, 6, 7 and 8 (Table 4 and Appendix

1), a confirmation that most accessions in the *B. rapa* collection are susceptible to PG3 and PG4 strains of blackleg.

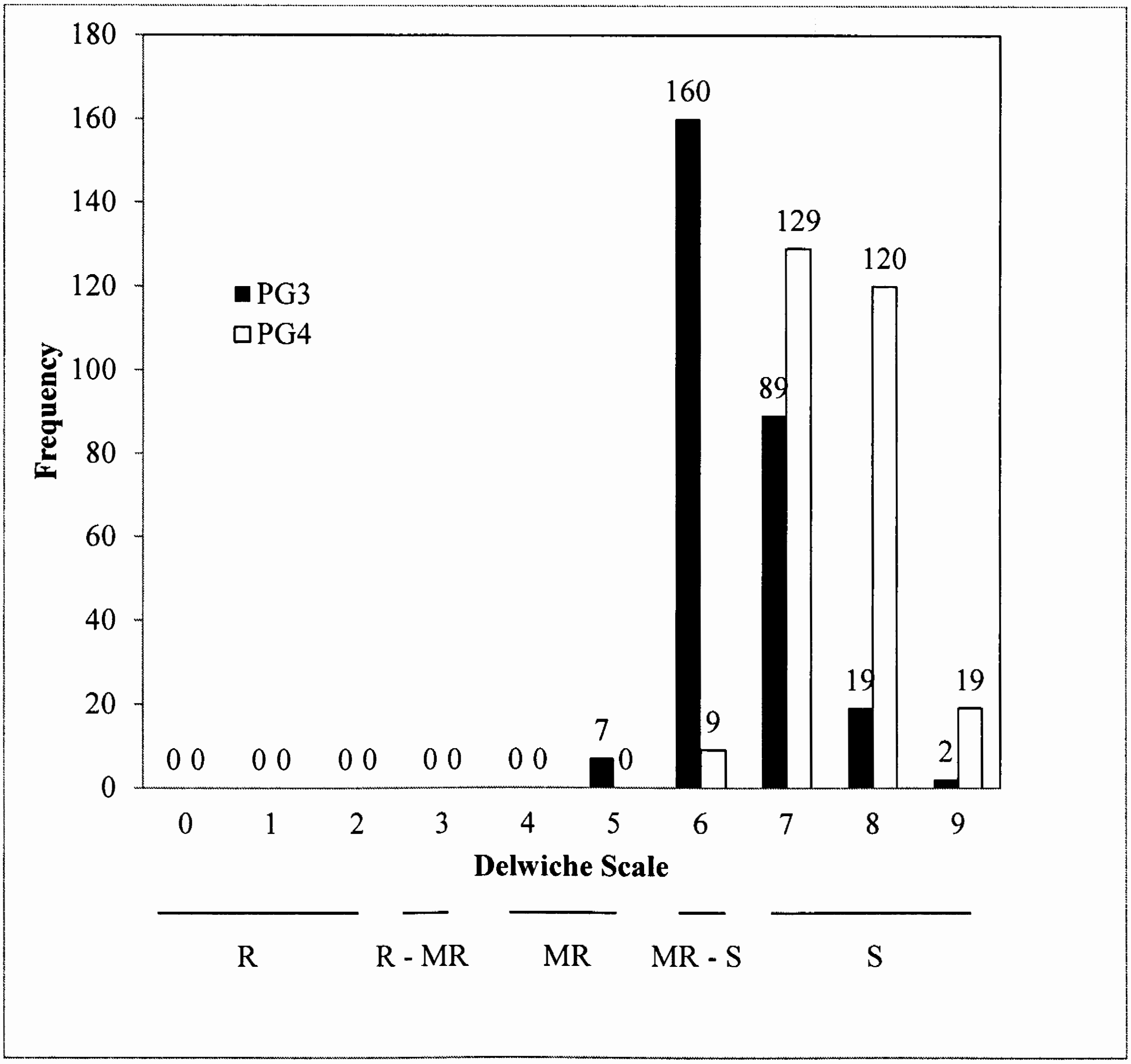

Figure 4. Frequency distribution of the reaction of *Brassica rapa* accessions to inoculation with *L. maculans* isolates of the pathogenicity groups 3 and 4 (R=Resistant, R-MR=Resistant to moderately resistant, MR=Moderately resistant, S=Susceptible).

4.2. Evaluation of *Brassica rapa* Accessions for their Reaction to PG4 Isolate of *L. maculans*

As a population, the 277 *B. rapa* accessions were more susceptible to PG4 than to PG3 (Figure 5). Of all materials evaluated only nine (3.2% of the population) were classified in the lower part of moderately resistant; the rest were considered susceptible.

Table 4. Median disease ratings, mean ranks, and estimated relative treatment effects for the severity of symptoms on 29 *Brassica rapa* plant introduction materials inoculated on seedling cotyledons with three *Leptosphaeria maculans* isolates of pathogenicity group 3 in greenhouse conditions.

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
3	Ames 9244	5	97.88	0.10	(0.020)	0.03	0.34
32	PI 340179	5	69.75	0.11	(0.020)	0.03	0.33
74	PI 347596	6	149.50	0.11	(0.020)	0.03	0.33
67	Ames 9741	6	137.38	0.17	(0.023)	0.06	0.39
209	PI 169064	5	117.75	0.17	(0.023)	0.06	0.39
217	PI 370733	5	208.00	0.17	(0.023)	0.06	0.39
248	PI 173846	5	191.00	0.17	(0.023)	0.06	0.39
258	PI 173871	6	120.75	0.17	(0.023)	0.06	0.39
247	PI 171521	5	86.63	0.18	(0.022)	0.07	0.38
51	PI 163947	6	150.38	0.19	(0.039)	0.04	0.57
2	PI 179863	7	145.25	0.21	(0.054)	0.03	0.71
13	Ames 9263	6	113.88	0.24	(0.039)	0.07	0.57
27	PI 319413	5	117.50	0.24	(0.020)	0.13	0.40
35	PI 340181	6	91.38	0.24	(0.039)	0.07	0.57
43	Ames 9474	6	205.88	0.24	(0.039)	0.07	0.57
84	PI 347605	6	158.38	0.24	(0.020)	0.13	0.40
95	PI 633173	6	120.75	0.24	(0.020)	0.13	0.40
141	PI 426177	6	163.25	0.24	(0.020)	0.13	0.40
249	PI 173848	6	138.50	0.24	(0.020)	0.13	0.40
6	PI 314137	6	86.25	0.25	(0.018)	0.15	0.39
31	PI 175085	6	150.50	0.25	(0.037)	0.08	0.56
33	PI 426281	6	153.25	0.25	(0.018)	0.15	0.39
36	Ames 9396	6	68.63	0.25	(0.018)	0.15	0.39
41	PI 340184	6	134.00	0.25	(0.018)	0.15	0.39
46	PI 340188	6	121.75	0.25	(0.018)	0.15	0.39
50	PI 340189	6	99.88	0.25	(0.018)	0.15	0.39
55	Ames 9668	6	96.63	0.25	(0.018)	0.15	0.39
56	PI 340195	6	158.38	0.25	(0.018)	0.15	0.39
207	PI 169061	6	83.13	0.25	(0.018)	0.15	0.39

Standard errors (*se*) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, *se* can be roughly approximated by *se* / N, in which *se* is the standard error of the mean rank for the i^{th}accession (treatment) as determined in the MIXED procedure of SAS v.9.2 with the LSMEANS option (SAS Institute, Cary, NC).

Nine accessions, representing 3% of the population, had a median disease rating of 6; whereas 129 accessions (47%) had a median of 7. Almost one half of the population, 139 accessions had a median disease rating of 8 or 9 (Figure 4).

Treatment relative effect of the top 10% accessions is presented in Table 5; data for the remaining 244 accessions are in Appendix 2. The median disease rating for PG4 among the top 10% accessions ranged between 6 and 9, although only three accessions had ratings $\geq$8 and their relative effect between 0.05 and 0.23 (Table 5). When the entire population was considered, however, the treatment relative effect ranged between 0.5 and 0.91 (Appendix 2).

Just 3 accessions, representing 1% of the accessions evaluated, had a relative effect below 0.1. Additionally, 14 accessions representing 5% of the total evaluated showed a relative effect between 0.1 and 0.2. There were 37 accessions, representing 13%, that showed relative effect between 0.2 and 0.3 The remaining 223 accessions, representing 80% of the accessions evaluated, had a relative effect higher than 0.3 (Table 5 and Appendix 2).

Contrary to what was observed with the PG3 inoculations, significant differences in reaction were observed among the top 10% accessions with PI347596 being statistically less susceptible than the rest of top 10% materials (Table 5). Besides this, however, and based on the range of confidence intervals for each relative treatment effect, there was overlap for estimated relative effects between most accessions, which means there was no significant difference between the median disease rating of 6 , 7 , 8 or 9 (Table 5 and Appendix 2).

4.3. Evaluation of *Brassica napus* Accessions for their Reaction to PG3 Isolates of *L.maculans*

Response of the 130 accessions evaluated for their reaction to PG3 resembled that of the *B. rapa* collection. Most materials were considered susceptible with the highest proportion (63%) having a median disease rating ranging between 7 and 8 and the remaining accessions (37%) having a rating of 6 in the 0-9 scale of Delwiche (Figure 5).

The best 29 accessions according had a treatment relative effect that ranged between 0.14 and 0.37 (Table 6). However, when the entire population was considered, the treatment relative effect extended up to 0.98 (Appendix 3). Forty nine accessions, representing 37% of the population evaluated had a median disease rating of 6 for disease reaction; these accessions had a treatment relative effect ranging between 0.18 and 0.7 (Table 6).

Just three accessions, 432392, Ames 25110, and 537010 had a relative effect value >0.20. Ten other accessions, representing 7.6% of the population, showed relative effect values between 0.25 and 0.30. The remaining 118 (90.1%) accessions showed a relative effect higher than 0.32 (Table 6).

There is no significant difference between estimated relative effects (pi) between the accessions that scored 6, 7 and those that scored 8, which was evaluated based on the range of confidence intervals for each relative treatment effect.

4.4. Evaluation of *Brassica napus* Accessions for their Reaction to PG4 Isolate of *L. maculans*

Just as in the case of PG3, none of the 130 *B. napus* accessions evaluated for their reaction to PG4 were considered resistant. The median disease rating for PG4 ranged between 6 and 9 (Figure 5). Only two accessions, representing 1% of the accessions eva-

Table 5. Median disease ratings, mean ranks, and estimated relative treatment effects for the severity of symptoms on 33 *Brassica rapa* plant introduction materials inoculated on seedling cotyledons with *Leptosphaeria maculans* isolates of pathogenicity group 4 in greenhouse conditions.

				Treatment effect					Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect		Standard error			Lower Limit	Upper Limit
74	PI 347596	6	40.00	0.05	(	0.004	)		0.02	0.08
3	Ames 9244	6	3.00	0.09	(	0.019	)		0.02	0.32
12	PI 263054	6	16.00	0.09	(	0.018	)		0.02	0.30
13	Ames 9263	6	3.00	0.10	(	0.018	)		0.03	0.30
109	PI 633178	7	89.50	0.10	(	0.018	)		0.03	0.30
46	PI 340188	6	89.50	0.12	(	0.016	)		0.05	0.27
73	Ames 9888	6	16.00	0.15	(	0.022	)		0.05	0.36
32	PI 340179	7	89.50	0.16	(	0.021	)		0.06	0.35
58	Ames 9677	7	149.00	0.16	(	0.021	)		0.06	0.35
99	PI 347612	6	89.50	0.16	(	0.021	)		0.06	0.35
116	PI 426284	7	149.00	0.16	(	0.021	)		0.06	0.35
119	PI 352793	7	208.50	0.16	(	0.021	)		0.06	0.35
75	PI 347610	7	149.00	0.17	(	0.019	)		0.08	0.34
62	PI 347596	7	40.00	0.18	(	0.016	)		0.10	0.32
67	Ames 9741	7	16.00	0.18	(	0.016	)		0.10	0.32
71	PI 347595	7	89.50	0.18	(	0.016	)		0.10	0.32
217	PI 370733	8	208.50	0.18	(	0.034	)		0.05	0.51
100	PI 370731	7	208.50	0.22	(	0.018	)		0.12	0.36
222	PI 370735	9	208.50	0.22	(	0.018	)		0.12	0.36
225	PI 370736	8	89.50	0.22	(	0.018	)		0.12	0.36
248	PI 173846	7	89.50	0.22	(	0.018	)		0.12	0.36
33	PI 426281	7	208.50	0.23	(	0.014	)		0.15	0.34
38	Ames 9411	7	89.50	0.23	(	0.014	)		0.15	0.34
48	PI 340187	7	89.50	0.23	(	0.033	)		0.08	0.51
49	Ames 9495	7	40.00	0.23	(	0.014	)		0.15	0.34
68	PI 340196	7	16.00	0.23	(	0.033	)		0.08	0.51
81	PI 347599	7	40.00	0.23	(	0.014	)		0.15	0.34
82	PI 426290	7	40.00	0.23	(	0.014	)		0.15	0.34
85	PI 426261	7	208.50	0.23	(	0.014	)		0.15	0.34
111	PI 352790	7	208.50	0.23	(	0.014	)		0.15	0.34
115	PI 633181	7	16.00	0.23	(	0.014	)		0.15	0.34
184	PI 352818	7	16.00	0.23	(	0.014	)		0.15	0.34
276	PI 426263	7	89.50	0.23	(	0.014	)		0.15	0.34

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

luated had a value for median disease reaction of 6. The remaining 99% of the accessions evaluated had a rating score that ranged between 7 and 9, and were considered susceptible to PG4.The top 15 accessions, representing roughly 11% of the population evaluated had estimated treatment relative effects ranging from 0.15 and 0.28 (Table 7). However, when the entire population was considered, that value extended to 0.99 (Appendix 4).

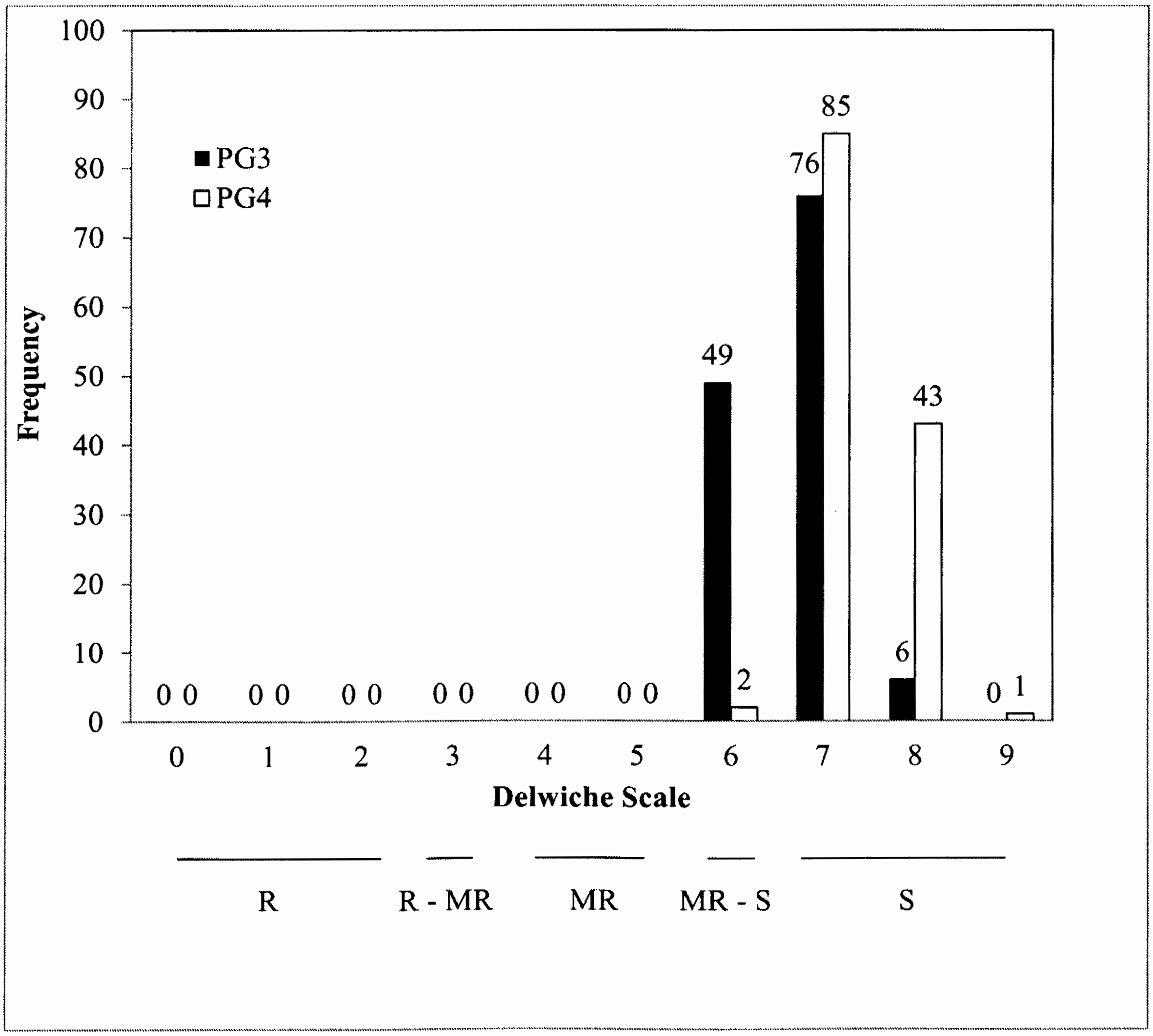

Figure 5. Frequency distribution of the reaction of *Brassica napus* accessions to inoculation with *L. maculans* isolates of the pathogenicity group 3 and group 4 (R=Resistant, R-MR=Resistant to moderately resistant, MR=Moderately resistant, S=Susceptible).

Table 6. Median disease ratings, mean ranks, and estimated relative treatment effects for the severity of symptoms on 29 *Brassica napus* plant introduction materials inoculated on seedling cotyledons with *Leptosphaeria maculans* isolates of pathogenicity group 3 in greenhouse conditions.

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
105	PI 537010	7	66.75	0.18	(0.020)	0.09	0.36
82	PI 458945	7	55.25	0.25	(0.040)	0.08	0.58
12	Ames 21490	6	41.25	0.29	(0.034)	0.12	0.55
56	PI 311730	7	72.00	0.29	(0.034)	0.12	0.55
73	PI 436554	7	87.88	0.29	(0.034)	0.12	0.55
81	PI 469882	7	38.13	0.29	(0.034)	0.12	0.55
92	PI 469729	7	72.88	0.29	(0.034)	0.12	0.55
95	PI 469758	6	44.38	0.29	(0.034)	0.12	0.55
114	PI 597828	7	87.88	0.29	(0.034)	0.12	0.55
17	Ames 25113	6	35.75	0.30	(0.039)	0.11	0.60
70	PI 432393	8	103.00	0.30	(0.039)	0.11	0.60
77	PI 26637	7	72.88	0.32	(0.054)	0.09	0.71
64	PI 431571	7	95.75	0.33	(0.053)	0.09	0.71
8	Ames 19202	6	44.38	0.34	(0.032)	0.16	0.57
29	Ames 26169	6	45.63	0.34	(0.032)	0.16	0.57
33	Ames 26653	6	46.50	0.34	(0.032)	0.16	0.57
36	PI 458941	6	46.50	0.34	(0.032)	0.16	0.57
76	PI 443015	7	55.25	0.34	(0.032)	0.16	0.57
87	PI 458940	7	72.00	0.34	(0.032)	0.16	0.57
91	PI 458954	6	46.50	0.34	(0.032)	0.16	0.57
94	PI 469756	7	56.00	0.34	(0.032)	0.16	0.57
112	PI 537019	7	74.63	0.34	(0.032)	0.16	0.57
117	PI 603024	7	52.63	0.34	(0.032)	0.16	0.57
59	PI 311733	7	72.00	0.37	(0.047)	0.14	0.69
93	PI 469730	7	63.25	0.37	(0.058)	0.10	0.76
96	PI 469761	6	39.25	0.37	(0.024)	0.23	0.54
99	PI 469814	6	39.25	0.37	(0.048)	0.13	0.69

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

From the top 11% accessions, seven, showed a value for relative effect of >0.22, with the most resistant accessions, Ames 21490, having a disease rating of 6 and a treatment relative effect of 0.15 (Table 7). Eight other accessions had relative treatment effects that ranged between 0.22 and 0.28. The remaining 88.5% of accessions had relative treatment effects higher than 0.30 (Appendix 4), with the most susceptible accession being Ames 211489.

The confidence interval for the accessions that scored 6 varied between 0.06 and 0.7. For the accessions that scored 7, the confidence interval was between 0.08 and 0.93, whereas the only accession that scored 9 had a confidence interval between 0.97 and 0.99. There was no significant difference between the accessions that scored 6, 7 and 8 (Table 7).

Table 7. Median disease ratings, mean ranks, and estimated relative treatment effects for the severity of symptoms on 15 *Brassica napus* plant introduction materials inoculated on seedling cotyledons with *Leptosphaeria maculans* isolates of pathogenicity group 4 in greenhouse conditions.

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
12	Ames 21490	6	17.63	0.15	(0.020)	0.06	0.34
105	PI 537010	8	93.25	0.18	(0.018)	0.09	0.33
14	Ames 25110	7	25.50	0.21	(0.025)	0.09	0.42
29	Ames 26169	7	26.00	0.21	(0.025)	0.09	0.42
57	PI 311731	8	94.75	0.21	(0.025)	0.09	0.42
82	PI 458945	7	64.00	0.21	(0.025)	0.09	0.42
95	PI 469758	7	46.63	0.21	(0.025)	0.09	0.42
34	PI 391553	7	31.38	0.23	(0.022)	0.11	0.40
46	PI 282571	7	58.50	0.23	(0.022)	0.11	0.40
114	PI 597828	7	78.75	0.23	(0.022)	0.11	0.40
73	PI 436554	7	70.63	0.25	(0.038)	0.08	0.56
85	PI 535865	7	74.13	0.25	(0.018)	0.15	0.38
27	Ames 26167	7	35.13	0.28	(0.022)	0.16	0.44
92	PI 469729	7	58.88	0.28	(0.040)	0.09	0.59
94	PI 469756	8	83.75	0.28	(0.022)	0.16	0.44

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

4.5. Evaluation of *Brassica juncea* Accessions for their Reaction to PG3 Isolates of *L. maculans*

The median disease rating for the 407 accessions (one control included) evaluated for their reaction to PG3 isolates of *L. maculans* varied between 4 and 8 (Figure 6). The general median disease rating of 44 accessions (11%) showed values between 4 and 5, and were classified as moderately resistant; 277 accessions, representing 68% of all accessions, had a general median disease rating of 6. The remaining 86 accessions (21%) showed a median disease rating higher than 6 and were classified as susceptible according to the Delwiche scale.

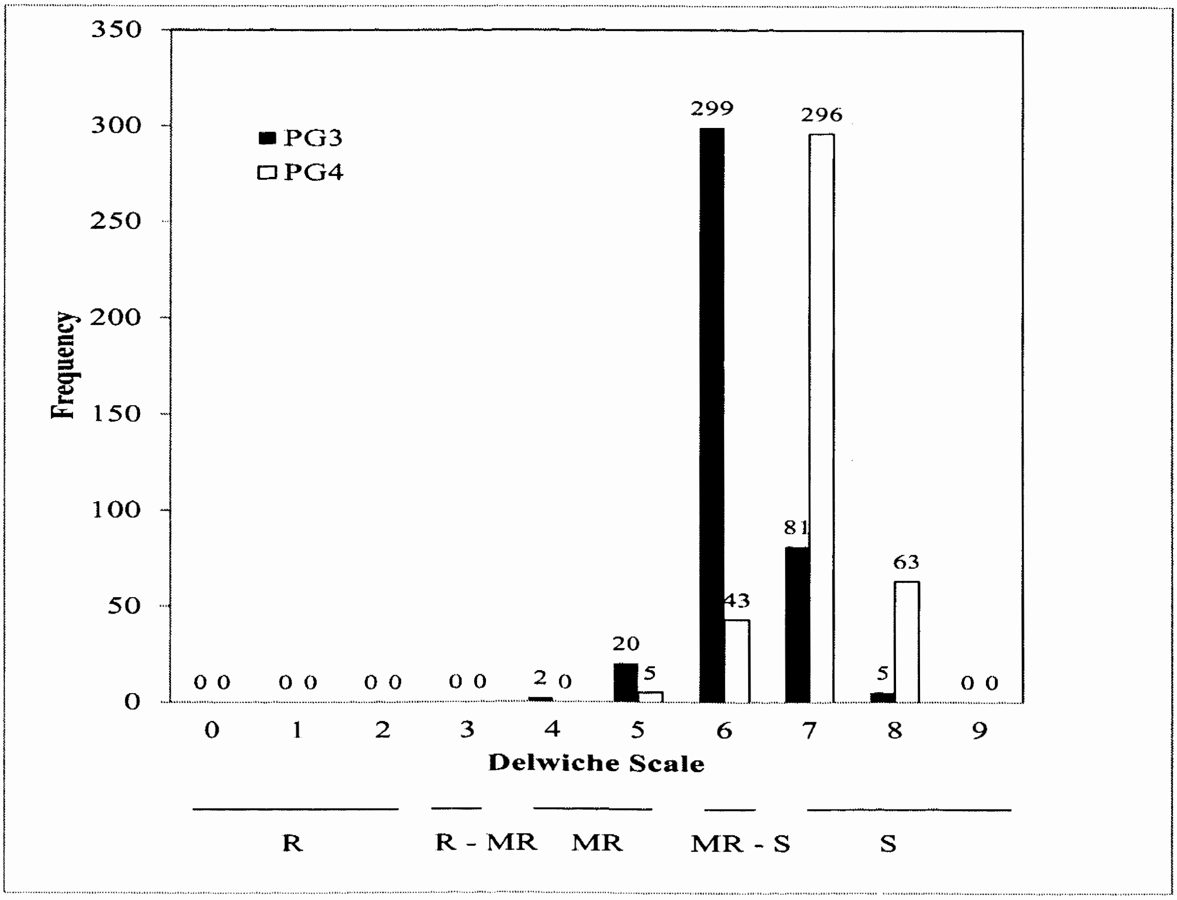

Figure 6. Frequency distribution of the reaction of *Brassica juncea* accessions to inoculation with L. maculans isolates of the pathogenicity group 3 and group 4 (R=Resistant, R-MR=Resistant to moderately resistant, MR=Moderately resistant, S=Susceptible).

The top 28 accessions according to the relative effect are reported in Table 8. These accessions, representing 7 % of the population, had a relative effect <0.2. The best material was PI426295. Of the remaining accessions 36 showed a relative effect between 0.2 and 0.3 and 343 accessions, representing 84 % of the population, had a treatment relative effect >0.3 (Appendix 5).

4.6. Evaluation of *Brassica juncea* Accessions for their Reaction to PG4 Isolate of *L. maculans*

The *B. juncea* population evaluated was considered as more sensitive to PG4 than to PG3 with roughly 12% of the materials being considered as moderately resistant (Figure 6). The median disease rating for the 407 accessions evaluated varied between 5 and 8. Of these, 6 accessions (2%) showed a general median disease rating of 5 and were considered as moderately resistant. Of all accessions evaluated, 42 (10 %) showed a general median disease rating of 6, and the remaining 359 accessions (88 %) showed a median disease rating of 7 and 8 (Appendix 6).

The 37 best accessions according to treatment relative effects are reported in Table 9. The top accessions were PI 426295, which was also considered the best material for its reaction to PG3, PI 426253, PI 390136, and PI 426343 (Table 9).

4.6.1. Development and Screening of F_2 Plants

Throughout this study, the reaction of individual plants was recorded allowing the selection of individual plants even if the reaction of the plant introduction as a group was not too promising. Of all *Brassica juncea* accessions evaluated in 2009 (406 accessions with 4,884 individual plants), 34 of them were identified as potential sources of resistance based on the low score that they had. These accessions had disease rating scores ≤ 5 to the reaction of both PG3 and PG4. In 2009, these accessions had in some instances more than

Table 8. Median disease ratings, mean ranks, and estimated relative treatment effects for the severity of symptoms on 28 *Brassica juncea* plant introduction materials inoculated on seedling cotyledons with *L. maculans* isolates of pathogenicity group 3 in greenhouse conditions.

				Treatment effect		Confidence Interval (95%)	
Accession number	**Name**	**Median Disease Rating**	**Mean Rank**	**Treatment relative effect**	**Standard error**	**Lower Limit**	**Upper Limit**
147	PI 426295	4	2.75	0.01	(0.002)	0.00	0.05
155	PI 426303	4	35.25	0.01	(0.001)	0.00	0.02
189	PI 426338	5	274.00	0.01	(0.001)	0.01	0.03
103	PI 340204	6	45.50	0.04	(0.010)	0.01	0.19
126	PI 347619	5	45.50	0.04	(0.010)	0.01	0.19
142	PI 426253	6	6.75	0.04	(0.006)	0.02	0.11
281	PI 458934	5	113.00	0.04	(0.010)	0.01	0.19
194	PI 426343	5	11.00	0.05	(0.009)	0.01	0.16
118	PI 340220	6	45.50	0.08	(0.001)	0.07	0.09
125	PI 347618	7	45.50	0.08	(0.001)	0.07	0.09
134	PI 390136	6	11.00	0.08	(0.001)	0.07	0.09
212	PI 426361	6	37.75	0.08	(0.001)	0.07	0.09
390	PI 649115	6	45.50	0.08	(0.001)	0.07	0.09
401	PI 531272	6	45.88	0.10	(0.011)	0.05	0.20
399	PI 649124	6	113.00	0.12	(0.012)	0.06	0.23
139	PI 390141	5	80.88	0.15	(0.028)	0.04	0.45
335	PI 603012	6	136.63	0.15	(0.026)	0.04	0.43
367	PI 633108	6	187.88	0.15	(0.027)	0.04	0.43
374	PI 633115	6	127.00	0.15	(0.027)	0.04	0.43
255	PI 426406	6	274.00	0.16	(0.002)	0.15	0.18
197	PI 426346	6	242.25	0.17	(0.025)	0.06	0.41
366	PI 633107	6	82.63	0.17	(0.025)	0.06	0.41
380	PI 649105	6	240.13	0.17	(0.026)	0.05	0.43
21	PI 175100	7	52.63	0.19	(0.023)	0.07	0.40
78	PI 249555	7	141.25	0.19	(0.024)	0.08	0.41
336	PI 603013	6	113.13	0.19	(0.023)	0.07	0.40
338	PI 603015	6	108.25	0.19	(0.023)	0.07	0.40
392	PI 649117	6	106.50	0.19	(0.023)	0.07	0.40

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

Table 9. Median disease ratings, mean ranks, and estimated relative treatment effects for the severity of symptoms on 38 *Brassica juncea* plant introduction materials inoculated on seedling cotyledons with *Leptosphaeria maculans* isolates of pathogenicity group 4 in greenhouse conditions.

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
147	PI 426295	5	2.75	0.00	(0.001)	0.00	0.02
134	PI 390136	6	11.00	0.02	(0.002)	0.01	0.04
142	PI 426253	7	6.75	0.02	(0.001)	0.01	0.03
194	PI 426343	5	11.00	0.02	(0.002)	0.01	0.04
155	PI 426303	5	35.25	0.06	(0.016)	0.01	0.32
212	PI 426361	6	37.75	0.06	(0.015)	0.01	0.29
252	PI 426403	6	25.38	0.06	(0.009)	0.02	0.16
103	PI 340204	7	45.50	0.07	(0.013)	0.02	0.23
118	PI 340220	7	45.50	0.07	(0.013)	0.02	0.23
125	PI 347618	8	45.50	0.07	(0.013)	0.02	0.23
126	PI 347619	6	45.50	0.07	(0.013)	0.02	0.23
187	PI 426336	6	43.00	0.07	(0.013)	0.02	0.23
390	PI 649115	7	45.50	0.07	(0.013)	0.02	0.23
130	PI 370746	7	72.25	0.12	(0.002)	0.11	0.13
132	PI 387819	7	72.25	0.12	(0.002)	0.11	0.13
133	PI 390135	6	72.25	0.12	(0.002)	0.11	0.13
144	PI 426292	6	72.25	0.12	(0.002)	0.11	0.13
177	PI 426326	6	72.25	0.12	(0.002)	0.11	0.13
188	PI 426337	6	72.25	0.12	(0.002)	0.11	0.13
256	PI 426407	6	45.88	0.12	(0.002)	0.11	0.13
257	PI 426408	7	45.88	0.12	(0.002)	0.11	0.13
301	PI 459008	6	45.88	0.12	(0.002)	0.11	0.13
359	PI 633100	7	61.63	0.12	(0.014)	0.05	0.26
401	PI 531272	7	45.88	0.12	(0.002)	0.11	0.13
21	PI 175100	7	52.63	0.15	(0.010)	0.10	0.23
337	PI 603014	7	50.88	0.15	(0.010)	0.10	0.23
79	PI 250130	7	41.63	0.16	(0.017)	0.07	0.31
162	PI 426311	6	43.00	0.16	(0.016)	0.08	0.30
154	PI 426302	6	59.75	0.18	(0.031)	0.05	0.48
214	PI 426363	6	112.75	0.18	(0.019)	0.09	0.35
281	PI 458934	6	113.00	0.18	(0.019)	0.09	0.35
352	PI 633093	8	113.00	0.18	(0.019)	0.09	0.35
399	PI 649124	7	113.00	0.18	(0.019)	0.09	0.35
366	PI 633107	7	82.63	0.20	(0.032)	0.06	0.50
139	PI 390141	7	80.88	0.21	(0.027)	0.08	0.45

Table 9. Continued

				Treatment effect				Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect		Standard error		Lower Limit	Upper Limit
283	PI 458943	6	80.88	0.21	(	0.027	)	0.08	0.45
333	PI 549282	7	76.63	0.21	(	0.027	)	0.08	0.45

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

one plant that showed disease reaction scores ≤ 5. These plants were selected. As an example of this selection procedure, one plant from PI 426295, scored 3 for both PG groups in 2009. That plant, which is considered a parental line was identified as 147-6-2, where 147 stands for the entry number used to denominate PI 426295 in the study, 6 stands for the entry number used to denominate PI 426295 in the study, (6^{th} in a group of six plant) and 2 stands for the replication in which that plant was grown. Plant 147-6-2 had a disease reaction of 3 for both PGs in the first round of selections. This plant was transplanted and allowed to produce seed by self-pollination. Twelve F_1 seeds from this plant were inoculated and scored. A median disease score rating was calculated for all the F_1 plants. F_1 plants had a score of 4 and 6 for the entire group and plant number 3 from the first replication had low disease score reaction of the group to both PG3 and PG4 and thus it was selected for seed production. The selected plant was identified as 147-6-2/3-1. The identity of this plant is a combination of the parental line (147-6-2) and the plant identification in the second screening: plant #3 of replication #1. Plant 147-6-2/3-1 was taken to seed production by self-pollination. Seeds by 147-6-2/3-1 constitute the F_2 generation. F_2 seeds from 22 different accessions were produced and saved (Table 10). In most cases, the scores of the F_1 generation were similar to those produced by the parental plant; however, in a few instances the F_1 generation tended to be slightly more sensitive than its parent as was the case of some plants from PI.

Table 10. Elite *Brassica juncea* F_2 lines derived through self-pollination of seedlings that survived cotyledon inoculations with strains of pathogenicity groups 3 and 4 of *Leptosphaeria maculans* in greenhouse conditions.

	Disease reaction F_0			Disease reaction F_1		
Parental Line	PG 3	PG 4	ID	PG 3	PG 4	ID
PI 340205	4	6		4	6	
104-5-1	3	3	104-5-1/5-1	3	4	104-5-1/5-1/2-2*
PI 340211	6	7		4	6	
109-4-1	4	4	109-7-1/4-1	-	-	-
PI340221	5	6		4	5	
119-2-1	3	4	119-2-1/2-1	3	4	119-2-1/2-1/5-1* 119-2-1/2-1/6-2*
PI 347619	5	6		3	5	
126-4-1	4	4	126-4-1/2-2	3	4	126-4-1/2-2/5-1*
PI 358591	5	6		4	5	
127-2-1	4	4	127-2-1/1-2	3	4	127-2-1/1-2/1-1*
127-3-1	3	3	127-3-1/1-1	3	3	127-3-1/1-1/1-1*
PI379103	6	6		5	6	
131-4-2	4	5	131-4-2/2-2	3	3	131-4-2/2-2/2-2*
131-5-2	3	3	131-5-2/1-2	4	5	131-5-2/1-2/6-2*
PI 390135	6	6		5	7	
133-2-2	4	5	133-2-2/3-2	3	5	133-2-2/3-2/2-1*
PI 390636	6	6		5	7	
134-4-1	3	3	134-4-1/6-1	-	-	-
PI 390137	5	5		5	6	
135-3-1	4	4	135-3-1/5-1	-[1]	-	-
135-2-2	4	4	135-2-2/5-1	3	4	135-2-2/5-1/5-2*
PI 390140	6	6		4	5	
138-6-2	3	3	138-6-2/1-2	3	3	138-6-2/1-2/3-1*
PI 426292	6	6		5	6	
144-3-2	4	4	144-3-2/2-1	2	4	144-3-2/2-1/3-1*
144-5-2	4	4	144-5-2/6-2	4	4	144-5-2/6-2/1-2*
PI 426295	4	4		5	6	
147-3-2	3	3	147-3-2/6-1	-	-	-
147-4-1	3	4	147-4-1/6-2	-	-	-
147-5-1	4	4	147-5-1/3-2	-	-	-
147-5-2	3	4	147-5-2/1-1	4	4	147-5-2/1-1/1-1*

Table 10. Continued

Parental Line	Disease reaction F_0 PG 3	PG 4	ID	Disease reaction F_1 PG 3	PG 4	ID
147-6-2	3	3	147-6-2/3-1	3	4	147-6-2/3-1/2-1*
PI 426300	6	7		5	7	
152-3-2	3	4	152-3-2/6-2	3	5	152-3-2/6-2/1-2*
PI 426303	4	5				
155-1-2	4	4	155-1-2/1-2	4	5	155-1-2/1-2/4-2*
155-4-2	3	3	155-4-2/6-1	4	4	155-4-2/6-1/6-1*
155-5-2	3	3	155-5-2/6-2	3	3	155-5-2/6-2/2-1*
PI 426326	6	6		4	5	
177-1-1	4	5	177-1-1/2-1	-	-	-
177-3-2	4	5	177-3-2/5-1	-	-	-
PI 426336	5	6		4	5	
187-2-2	4	4	187-2-2/3-2	4	4	187-2-2/3-2/4-2*
187-3-3	4	5	187-3-3/2-1	4	4	187-3-3/2-1/3-1*
PI 426337	6	6		5	5	
188-5-2	3	4	188-5-2/6-2	4	4	
PI 426338	4	7		6	6	
189-5-2	3	3	189-5-2/3-1	3	4	189-5-2/3-1/3-2*
PI 426341	8	8		6	6	
192-1-2	3	3	192-1-2/1-1	4	4	192-1-2/1-1/5-2*
PI 426343	5	5		5	6	
194-6-1	4	5	194-6-1/2-1	4	4	194-6-1/2-1/6-2*
194-5-2	4	4	194-5-2/1-1	4	4	194-5-2/1-1/5-2*
PI 426352	6	7		6	7	
203-3-1	3	3	203-3-1/1-1	4	4	203-3-1/1-1/4-1*
PI 426361	5	5		6	7	
212-2-1	3	4	212-2-1/1-2			
PI 426363	6	6		5	6	
214-5-1	3	3	214-5-1/3-1	3	4	214-5-1/3-1/1-2*
PI 426367	6	6		4	5	
218-6-2	4	4	218-6-2/1-2	3	4	218-6-2/1-2/2-1*
PI 426384	6	7				
234-4-2	2	4	234-4-2/1-2	-	-	-
PI 426406	5	7		6	6	
255-6-2	4	5	255-6-2/1-2	4	3	255-6-2/1-2/1-2*
PI 458934	4	6				
281-2-1	4	4	281-2-1/5-2	-	-	-
PI 458996	7	8				

Table 10. Continued

Parental Line	Disease reaction F_0 PG 3	PG 4	ID	Disease reaction F_1 PG 3	PG 4	ID
289-4-2	3	3	289-4-2/2-2	-	-	-
PI 478332	5	7				
313-2-2	3	3	313-2-2/1-2	-	-	-
PI 633092	5	6		4	5	
351-2-1	4	4	351-2-1/4-1	3	4	351-2-1/4-1/3-1*
PI 633098	4	5				
357-2-1	4	4	357-2-1/3-2	-	-	-
PI 649113	7	7		4	5	
388-2-1	2	3	388-2-1/3-1	4	4	388-2-1/3-1/3-2*
PI 649114	5	6				
389-3-1	3	4	389-3-1/6-2	-	-	-
PI 649123	5	6				
398-4-1	4	5	398-4-1/1-1	-	-	-

[1]Those plants were not advanced to the next generation
*Elite materials selected that showed resistance to PG3 and PG4

4.7. Evaluation of 16 Commercial Cultivars for their Reaction to 3 PG2 Isolates *L. maculans*

The median disease ratings for the 16 commercials cultivars evaluated for their reaction to PG2 varied between 1 and 4 (Table 11), with treatment relative effect values that varied between 0.09 and 0.85. These results are, for the most part, consistent with the blackleg disease rating advertised by the seed companies that produced the cultivars. Those cultivars were classified in the lower part of the Delwiche scale as resistant and moderately resistant (Table 11).

4.8. Evaluation of 75 Commercial Cultivars for their Reaction to PG3 Isolates of *L. maculans*

The 75 commercial canola cultivars evaluated in this study, were representative of the genotypes currently in use by growers in North Dakota. The reaction of these genotypes to inoculation with PG3 and PG4 was one of almost complete susceptibility with 84% and

97% of genotypes scoring between 7 and 9 in the Delwiche scale (Figure 7). Only 12 genotypes were considered moderately resistant to PG3, but none to PG4.

Table 11. Median disease ratings, mean ranks, and estimated relative treatment effects for the severity of symptoms on 16 commercial canola cultivars inoculated with *Leptosphaeria maculans* isolates of pathogenicity group2 in greenhouse conditions.

					Treatment effect		Confidence Interval (95%)	
Cultivars	**Blackleg rating provided by company[1]**	**Median Disease Rating**	**Proposed reaction[1]**	**Mean Rank**	**Treatment relative Effect**	**Standard error**	**Lower Limit**	**Upper Limit**
Dekalb IS3057	R	1	R	2.00	0.09	(0.004)	0.06	0.14
Mycogen Seeds DN0 51505	R	1	R	2.00	0.09	(0.004)	0.06	0.14
Canterra SWK5352RR	MR	1	R	3.75	0.22	(0.025)	0.08	0.54
Croplan Hyclass 712	R	2	R	6.00	0.34	(0.050)	0.08	0.80
Agriprogress 30214-C7	R	2	R	6.50	0.35	(0.008)	0.28	0.43
Croplan Hyclass 906P	R	2	R	6.50	0.35	(0.008)	0.28	0.43
Monsanto G72021	R	2	R	6.50	0.35	(0.008)	0.28	0.43
Mycogen Seeds Nexera 830CL	R	2	R	6.50	0.35	(0.008)	0.28	0.43
Bayer Invigor 5630	R	2	R	8.75	0.47	(0.022)	0.28	0.67
Bayer Invigor 8440	R	2	R	8.75	0.47	(0.012)	0.36	0.58
Cargill V2018	MR	3	R	12.00	0.68	(0.002)	0.66	0.70
Agriprogress 30509-C7	MR	4	R-MR	13.75	0.78	(0.013)	0.64	0.87
Brett Young 6235RR	MR	4	R-MR	15.00	0.85	(0.004)	0.81	0.89
Integra Seed IX087121R	R	4	R-MR	15.00	0.85	(0.004)	0.81	0.89
Pioneer 45 H26	R	4	R-MR	15.00	0.85	(0.004)	0.81	0.89
Dekalb 3042	R	4	R-MR	16.25	0.92	(0.011)	0.67	0.96

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

[1]R=Resistant MR=Moderately Resistant R-MR= Resistant to moderately resistant

When inoculated with PG 3, commercial cultivars had a median disease rating that varied between 5 and 8. Data from the best 21 materials are presented in table 12. Among them, the best cultivar was Brett Young's 6051 RR with a median disease rating of 5 that placed it in the moderately resistant part of the scale. However, when one considers the confidence intervals for the treatment relative effect. It is clear that there are not significant differences among cultivars. Data from the remaining 56 materials is presented in appendix 7.

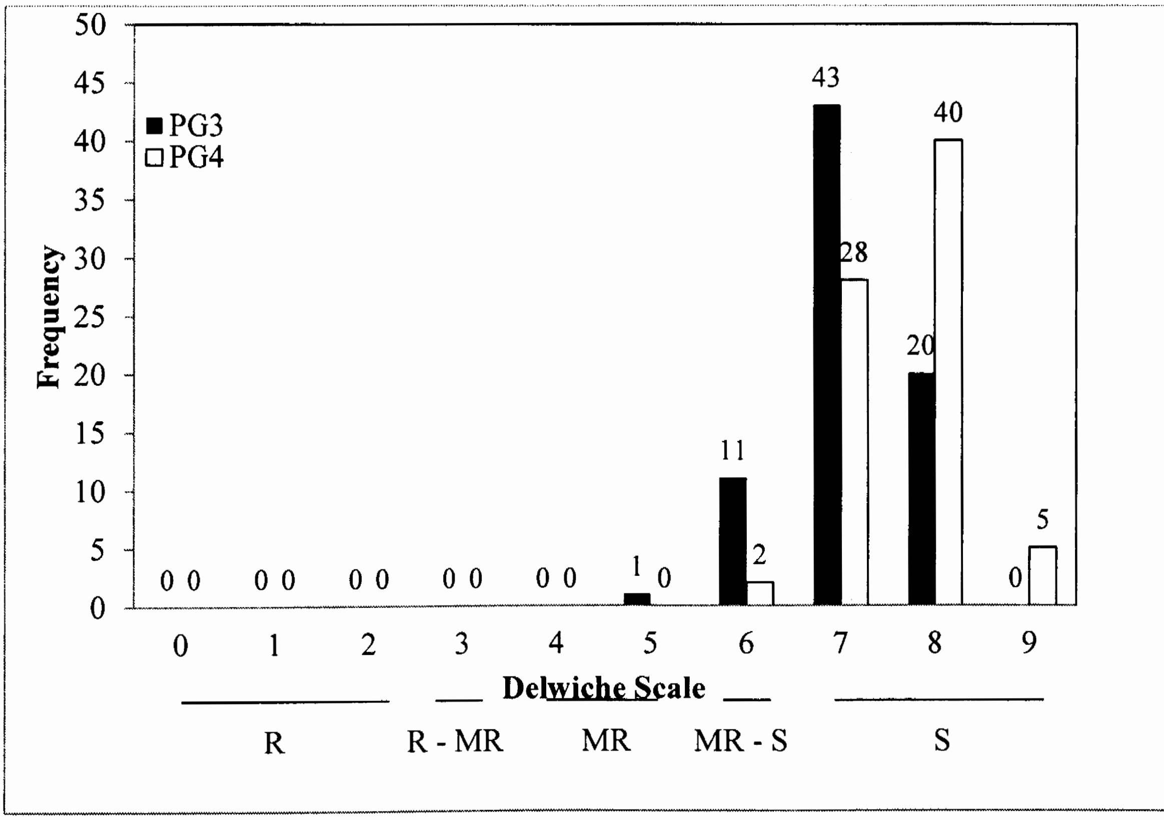

Figure 7. Frequency distribution of the reaction of 75 commercials cultivars to inoculation with *L. maculans* isolates of the pathogenicity group 3 and group 4 (R=Resistant, R-MR=Resistant to moderately resistant, MR=Moderately resistant, S=Susceptible).

4.9. Evaluation of 75 Commercial Cultivars for their Reaction to PG4 Isolates of *L. maculans*

For PG4 the median disease rating varied between 6 and 9 (Figure 7). Of the 75 materials evaluated in this study, 28 had a median disease rating of 7; 40 had a median disease rating of 8, and 5 had a median disease rating of 9.

The 27 accessions with the lowest estimated treatment relative treatment effect are reported in Table 13 whereas the remaining 48 accessions are in Appendix 8. According to the confidence interval values there was no overlapping between the median disease rating values for the cultivars rate 6, 7, 8, and the median disease rating for the cultivars rate 9. That means there was significant difference between those groups (Table 13). There was no significant difference between the median disease rating 8 and 9.

Table 12. Median disease ratings, mean ranks and estimated relative treatment effects for the severity of symptoms on 21 commercial canola cultivars inoculated with *Leptosphaeria maculans* isolates of pathogenicity group 3 in greenhouse conditions.

				Treatment effect		Confidence Interval (95%)	
Name	Median Disease Rating	Proposed reaction[1]	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
Agriprogress H7385	7	S	7.38	0.09	(0.0167)	0.03	0.29
Brett Young 6051 RR	5	MR	7.88	0.10	(0.0163)	0.03	0.29
Agriprogress 30216-C7	6	MR-S	11.50	0.14	(0.0116)	0.08	0.24
Agriprogress 30509-C7	6	MR-S	11.50	0.14	(0.0116)	0.08	0.24
Mycogen Seeds G2X0054	7	S	10.88	0.14	(0.0116)	0.08	0.24
Brett Young 6235RR	7	S	12.50	0.16	(0.0170)	0.08	0.32
Cargill 04H272	6	MR-S	14.50	0.18	(0.0134)	0.11	0.29
Proseed 2030	7	S	14.50	0.18	(0.0134)	0.11	0.29
Bayer Invigor 5550	6	MR-S	17.25	0.23	(0.0323)	0.08	0.51
Pioneer 45 H26	7	S	18.13	0.23	(0.0328)	0.08	0.52
Agriprogress 30522-C7	7	S	19.88	0.25	(0.0293)	0.10	0.50
Agriprogress H6195	6	MR-S	18.00	0.25	(0.0293)	0.10	0.50
Canterra 30507	6	MR-S	18.00	0.25	(0.0293)	0.10	0.50
Interstate 1005	6	MR-S	18.50	0.25	(0.0293)	0.10	0.50
Integra Seed IX08-7323R	7	S	19.25	0.25	(0.0293)	0.10	0.50
Proseed 50 Caliber	6	MR-S	18.63	0.25	(0.0293)	0.10	0.50
Agriprogress 30422-C7	7	S	19.88	0.25	(0.0293)	0.10	0.50
Bayer Invigor 5630	7	S	20.13	0.26	(0.0045)	0.23	0.29
Croplan Hyclass 940	6	MR-S	19.25	0.27	(0.0490)	0.07	0.67
Bayer Invigor 5440	6	MR-S	22.13	0.29	(0.0258)	0.15	0.49
Mycogen Seeds G2X0039	7	S	22.50	0.29	(0.0258)	0.15	0.49

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

[1]MR=Moderately Resistant MR-S=moderately resistant to susceptible S=susceptible

A summary of all the Brassica collection and commercial cultivars screened and evaluated in this experiment for their reaction to *L. maculans* pathogenicity group 3 and group 4 are presented in Table 13.

Table 13. Summary table for all the Brassica collections and commercial cultivars evaluated for their reaction to *Leptosphaeria maculans* isolates of pathogenicity group 3 and group 4 in greenhouse conditions.

		B. rapa		*B. napus*		*B. juncea*		Commercials cultivars	
Scale	Proposed Reaction[1]	PG3	PG4	PG3	PG4	PG3	PG4	PG3	PG4
0	R	0	0	0	0	0	0	0	0
1	R	0	0	0	0	0	0	0	0
2	R	0	0	0	0	0	0	0	0
3	R-MR	0	0	0	0	0	0	0	0
4	MR	0	0	0	0	2	0	0	0
5	MR	7	0	0	0	20	5	1	0
6	MR-S	160	9	49	2	299	43	11	2
7	S	89	129	76	85	81	296	43	28
8	S	19	120	6	43	5	63	20	40
9	S	2	19	0	1	0	0	0	5

[1]R=Resistant R-MR=Resistant to moderately resistant MR=Moderately resistant MR-S=Moderately resistant to susceptible S=Susceptible

4.10. Evaluation of the Effect of Inoculation Sequence on Plant Reaction

According to the analysis of variance, there are significant differences only for the inoculation factor ($p=0.01$) and the cultivar factor ($p=0.04$). There was no interaction between inoculation sequences and cultivars ($p=0.8$).

There were significant differences between the median disease ratings of the 10 cultivars evaluated, although all ratings ranked in the susceptible range of the Delwiche scale (1980) (Table 14). Cultivars Cargill V2018 and Mycogen Seeds G2X0043 with medians of 7 and 7.3 showed less susceptibility than Croplan Hyclass 924, and Canterra 30507-B6.

The effect of sequence of inoculations on the reaction of plants was studied using single-degree ANOVA analysis (Table 15).

Results indicate that plants inoculated with PG3 alone were less susceptible than those challenged with PG3 after the plants had been inoculated with PG4 or those that were inoculated simultaneously with PG3 and PG4 (Table 16). The difference between inoculation with PG3 only and inoculation of PG3 after PG4 was significant ($p=0.007$) whereas the difference between inoculation with PG3 only and inoculation with PG3 and PG4 simultaneously was not significant ($p=0.09$). The same result was observed for PG4 only. Plants inoculated with PG4 alone were less susceptible than those challenged with PG4 after the plants had been inoculated with PG3 ($p=0.004$) or those that were inoculated simultaneously with PG3 and PG4 ($p=0.04$) (Table 16). This increased sensitivity, however, was not observed with the simultaneous inoculation. Plants inoculated with PG3 and PG4 simultaneously were equally susceptible than those challenged with PG4 after plants had been inoculated with PG3 ($p=0.07$) or those that were inoculated with PG3 after plant had been inoculated with PG4 ($p=0.38$). The industry denomination of resistant or moderately resistant to blackleg did not apply for the reaction of the commercial cultivars to inoculations with PG3 ($p=0.26$) and/or PG4 ($p=0.6$). All cultivars were equally susceptible to both and the sequence in which these plants were inoculated did not significantly affect their reaction to blackleg (Table 16).

Table 14. Median disease ratings, mean ranks, and estimated relative treatment effects for the severity of foliar symptoms on 27 commercials canola cultivars inoculated on seedling cotyledons with *Leptosphaeria maculans* isolates of pathogenicity group 4 in greenhouse conditions.

					Treatment effect		Confidence Interval (95%)	
Accession number	**Name**	**Median Disease Rating**	**Proposed reaction[1]**	**Mean Rank**	**Treatment relative effect**	**Standard error**	**Lower Limit**	**Upper Limit**
16	Bayer Invigor 5630	6	MR-S	3.13	0.04	(0.002)	0.02	0.05
77	Proseed 2030	7	S	7.00	0.09	(0.006)	0.06	0.14
1	Agriprogress H7385	7	S	8.50	0.10	(0.017)	0.04	0.29
23	Brett Young 6235RR	7	S	8.25	0.11	(0.016)	0.04	0.28
9	Agriprogress 30216-C7	7	S	9.88	0.13	(0.014)	0.06	0.26
24	Cargill 04H272	7	S	10.50	0.13	(0.014)	0.06	0.26
65	Mycogen Seeds G2X0054	7	S	11.00	0.15	(0.012)	0.09	0.25
82	Pioneer 45 H26	7	S	13.00	0.15	(0.019)	0.06	0.34
14	Agriprogress 30509-C7	7	S	13.50	0.17	(0.017)	0.09	0.32
49	Integra Seed IX08-7323R	7	S	13.25	0.17	(0.017)	0.09	0.32
6	Agriprogress 30522-C7	7	S	15.88	0.19	(0.013)	0.12	0.30
22	Brett Young 6051 RR	7	S	14.88	0.20	(0.032)	0.06	0.50
80	Agriprogress 30422-C7	8	S	15.00	0.20	(0.032)	0.06	0.50
61	Mycogen Seeds G2X0039	7	S	17.00	0.21	(0.017)	0.12	0.35
21	Brett Young 4414RR	8	S	17.75	0.24	(0.031)	0.09	0.50
35	Croplan Hyclass 940	7	S	19.00	0.26	(0.028)	0.11	0.49
29	Canterra SWK5352RR	7	S	21.00	0.27	(0.004)	0.25	0.30
75	Monsanto DKL52-41Plus	7	S	21.00	0.27	(0.004)	0.25	0.30
8	Agriprogress H6195	7	S	25.25	0.34	(0.018)	0.23	0.47
13	Agriprogress 30611-C7	7	S	26.13	0.34	(0.018)	0.23	0.47
19	Bayer Invigor 5550	6	MR-S	26.13	0.34	(0.034)	0.16	0.59
25	Cargill V2018	7	S	26.13	0.34	(0.018)	0.23	0.47
34	Canterra 30507	8	S	25.50	0.34	(0.018)	0.23	0.47
41	Croplan Hyclass 410	7	S	26.13	0.34	(0.018)	0.23	0.47
71	Monsanto G72003	7	S	26.13	0.34	(0.018)	0.23	0.47
31	Canterra 1818	8	S	26.88	0.36	(0.029)	0.19	0.57
37	Croplan Hyclass 906P	7	S	26.63	0.36	(0.029)	0.19	0.57

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC). [1]MR-S=moderately resistant to susceptible S=susceptible

Table 15. Median disease rating of the 10 cultivars evaluated.

Brand cultivar	Median disease rating		
	PG3 only	PG4 only	PG3 and PG4
Croplan Hyclass 924	8.3	8.6	9.0
Canterra 30507-B6	8.0	8.0	8.0
DKL 30-42	7.5	8.6	8.5
Agriprogress 30412-B6	7.0	8.5	7.8
Brett Young 6235RR	7.4	7.6	7.9
Monsanto G67012	7.8	7.5	7.5
Bayer Invigor 5440	8.1	6.6	7.8
Integra Seed IX08-7323R	5.8	7.5	8.0
Cargill V2018	5.6	7.9	7.3
Mycogen Seeds G2X0043	5.6	8.9	7.4
Least significant difference (LSD)	ns	Ns	ns

Table 16. ANOVA of median of different inoculation sequences with isolates from blackleg pathogenicity groups 3 and 4 on cotyledon leaves.

Contrast		Median 1[1]	Median 2	Pr > F
PG3 vs.:				
PG3 after PG4		7.1	7.7	0.007
PG3 simultaneous with PG4		7.1	7.9	0.093
PG4 vs.:				
PG4 after PG3		8.0	8.4	0.004
PG4 simultaneous with PG3		8.0	8.5	0.043
PG4 and PG3 simultaneous vs.:				
PG3 after PG4		7.9	7.7	0.073
PG4 after PG3		8.5	8.4	0.378
Resistant vs. moderately resistant				
	PG3	7.8		0.258
	PG4		7.9	0.596

[1] Median 1 represents median value of term to the left of the vs. term; median 2 represents the median value of the term to the right of the vs. term

CHAPTER 5.

DISCUSSION

This study was conducted to identify potential sources of resistance against, and to characterize the reaction of commonly planted canola cultivars to, *Leptosphaeria maculans* pathogenicity groups 3 and 4. The second objective was intended to be a means to estimate the potential risk the discovery of new pathogenicity groups represent to the canola industry of the region. To fulfill the first objective, seedlings from three different plant introduction collections, *Brassica rapa, B. napus,* and *B. juncea* were screened at the cotyledon stage using pycnidiospores suspension of strains from both PGs. For the second objective 75 commercial canola cultivars were screened using similar inoculation protocol. All screening procedures were conducted in greenhouse conditions. While field trials to validate the reaction of germplasm at any and all stages of the screening process are highly desirable (Khot et al., 2011), in this case it was impractical. The geographic distribution of pathogenicity groups 3 and 4 in North Dakota is still limited and would be almost impossible to identify fields that only have one PG and not the other (Chen and Fernando, 2006). Further, to raise seedlings from all accessions to get to the flowering stage would have required far more greenhouse space than what is available to the canola pathology program at this time. Nevertheless we had the opportunity to observe some of the selected materials get to produce seeds. During the growth of these materials, which come from 38 accessions, plants from only 22 accessions (representing 40% of the selections) survived long enough to produce seed, this is an indication that resistance against one of the races (PG3 or PG4) at the seedling stage does not translate directly into adult plant resistance.

The cotyledon inoculation technique used allowed us to characterize the reaction of genotypes at the seedling stage (Zhu and Rimmer, 2003). Wounding seedlings before inoculation allows to evaluate disease reaction faster and increases disease development. Also, testing disease reaction at the cotyledon stage, when the seedlings exhibit less differentiated tissue and highest degree of sensitivity is advantageous because the morphological differences between accessions are smaller than at the adult stage (Sjodin and Glimelius, 1988). Further, cotyledon inoculations have been used successfully by other researchers who proved its effectiveness to screen for resistance to *L. maculans* in large number of plants (McNabb et al., 1993).

After screening the accessions from the three collections, just 22 *B. juncea* accessions were deemed as moderately resistant to PG3 and PG4 according to the Delwiche scale (Delwiche, 1980). *B. juncea* has been known to be a source of resistance against blackleg (Mengistu et al., 1991).

None of the *B. rapa* accessions was considered to have useful levels of resistance, especially to PG4, since the most resistant materials were grouped bordering susceptibility in the Delwiche scale; this finding is in agreement with findings of other researchers (Delourme et al., 2006). No resistant materials were found among the *B. napus* accessions evaluated either. However, the number of accessions tested from this species was relatively small and was the result of our desire to verify whether some of the accessions deemed to be resistant to *Sclerotinia sclerotiorum* (Khot et al., 2011) also were resistant to blackleg. The lack of correspondence in the reaction of these accessions to both pathogens is not surprising since both organisms interact with plants in different manners; *S. sclerotiorum* is a known necrotroph (Bolton et al., 2006) whereas *L. maculans* acts as a biotroph at least in the initial stages of infection (Howlett et al., 2001). No attempts were made to evaluate these *B. napus* accessions for their reaction to PG2 strains since resistance to this group is no longer needed.

All commercial cultivars evaluated for their reaction to pathogenicity group 2 proved to be resistant or moderately resistant to it. PG2 has been the most prevalent blackleg strain in North Dakota until recently (Chen and Fernando, 2006). The reaction recorded was consistent with the information provided by the seed companies that produced these materials. However, when these cultivars were tested for their reaction to PG3 and PG4, they all proved to be very susceptible. This suggests that blackleg company ratings are related to reaction to PG2 *L. maculans* only. While it is very likely that seed companies are already actively testing for resistance against these new strains in confined environments; it is less likely they are doing field verification since distribution of these PGs is still limited and because characterization of these PGs requires the use of a differential set (Mengistu et al., 1991).

All commercials cultivars evaluated under greenhouse conditions for their reaction to PG3 and PG4 were highly susceptible. This is a clear indication of the magnitude of the threat these new strains represent to the canola industry of the state and country since more than 90% of the canola produced in the US is planted in North Dakota (USDA, 2010). Until the time resistance is incorporated in commercial cultivars growers will need to go back to classic disease management practices such as longer crop rotations, crop residue management, and fungicide use (West et al., 2001). Development of strains with new pathogenicity profiles, races, or pathogenicity groups, is not foreign to *L. maculans* (Balesdent et al., 2005; Chen and Fernando, 2006; Mengistu et al, 1991). In the past, rape/canola producing areas have been troubled by these shifts in population (Bokor et al., 1975; Rouxel et al., 2003), This ability has reduced the time a vertical gene could be used from several years to a few growing seasons (Sprague et al., 2006) and is the best example of why horizontal resistance is needed. Incorporation of horizontal resistance into commercial cultivars is more difficult and advances at a much slower rate than incorporation of vertical genes, however, it is also longer lasting (Oliver and Solomon, 2010)

While the levels of resistance found in the materials evaluated are not very high, they represent an opportunity that should be explored in mode depth; an example of this would be the development and evaluation of lines produced by crosses made between the best materials identified in this study (good by good cross). The process of moving genes from lines at pre-breeding status into advanced breeding lines will take some time, that could be shorten if tissue culture techniques are used because homozygosity can be achieved more quickly than traditional breeding techniques (Roy, 1984; Su, 2009) and if a more intensive collaboration between the university and the seed industry is established.

LITERATURE CITED

Abawi, G.S. and Grogan, R.G. 1979. Epidemiology of diseases caused by *Sclerotinia* species. Phytopathology 69:896-899.

Allard L.M., Brun, H., Jouffret, P., Lagarde, F., Penaud, A., Pinochet, X, Simonin P. and Taverne, M. 2002. Les maladies du colza. Points Techniques du CETIOM, 80.

Ansan-Melayah, D., Balesdent, M. H., Delourme, R., Pilet, M. L., Tanguy, X., Renard, M., and Rouxel, T. 1998. Genes for race-specific resistance against blackleg disease in *Brassica napus* L.. Plant Breed. 117:373-378.

Badawy, H.M.A., Hoppe, H.H., and Koch, E. 1991. Differential reactions between the genus *Brassica* and aggressive single spore isolates of *Leptosphaeria maculans*. J. Phytopath. 13:109-119.

Balesdent, M. H., Attard, A., Ansan-Melayah, D., Delourme, R., Renard, M., and Rouxel, T. 2001. Genetic control and host range of avirulence toward *Brassica napus* cultivars Quinta and Jet Neuf in *Leptosphaeria maculans*. Phytopathology 91:70-76.

Balesdent, M. H., Louvard, K., Pinochet, X., and Rouxel, T. 2006. A large-scale survey of races of *Leptosphaeria maculans* occurring on oilseed rape in France. Eur. J. Plant Path. 114: 53–65.

Balesdent, M.H., Attard, A., Kuhn, M.L., and Rouxel, T. 2002. New avirulence genes in the phytopathogenic fungus *Leptosphaeria maculans*. Phytopathology 92: 1122-1133.

Balesdent, M. H., Barbetti, M. J., Li, H., Sivasithamparam, K., Gout, L., and Rouxel, T. 2005. Analysis of *Leptosphaeria maculans* race structure in a worldwide collection of isolates. Pop. Biol. 95:1061-1071.

Ballinger, D.J., and Salisbury, P.A. 1996. Seedling and adult plant evaluation of race variability in *Leptosphaeria maculans* on *Brassica* species in Australia. Aust. J. Exp. Agric. 36:485–488.

Bansal, V.K., Blenis, P., Stringam, G.R., Tewari, J.P., and Thiagarajah, M.R. 2002. Screening of *Brassica napus* against blackleg caused by *Leptosphaeria maculans*: effects of inoculums concentration, subculturing of the pathogen, and time of disease screening. Can. J. Plant Pathol. 24:323–326.

Bansal, V.K., Kharbanda, P.D., Stringam G.R., Thiagarajah, M.R., and Tewari, J.P. 1994. A comparison of greenhouse and field screening methods for blackleg resistance in doubled haploid lines of *Brassica napus*. Plant Dis. 78:276-281.

Barbetti, M. J. 1976. The role of pycnidiospores of *Leptosphaeria maculans* in the spread of blackleg disease in rape. Aust. J. Exp. Anim. Husb. 16:911-914.

Barbetti, M.J. and Khangura, R.K. 1999. Managing blackleg in the disease-prone environment of Western Australia. Proceeding of the 10th international rapeseed Congress. Canberra, Australia. Available from http://www.Regional.org.au/papers/index.htm. Accessed January 12, 2011.

Berry, P. M. and Spink, J. H. 2006. A physiological analysis of oilseed rape yields: Past and future. J. Agric. Sci. 144:381-392.

Biddulph, H.E., Fitt, B.D.L., Leech, P.K., Welham, S.J., and Gladders, P. 1999. Effects of temperature and wetness duration on infection of oilseed rape leaves by ascospores of *Leptosphaeria maculans* (stem canker). Eur. J. Plant Pathol. 105:769-781.

Bokor, A., Barbetti, M.J., Brown, A.G.P., MacNish, G.C., and Wood, P. McR. 1975. Blackleg of rapeseed. J. Ag. West. Aust. 16:7-10.

Bolton, M.D., Thomma, B.P.H.J., and Nelson, B.D. 2006. *Sclerotinia sclerotiorum* (Lib.) de Bary: biology and molecular traits of a cosmopolitan pathogen. Mol. Plant Pathol. 7:1-16

Boyd, L.A. 2006. Can the durability of resistance be predicted? J. Sci. Food and Ag. 86: 2523–2526.

Bradley, C.A., Chen, Y., and Fernando, W.G.D. 2005. First report of pathogenicity groups 3 and 4 of *Leptosphaeria maculans* on canola in North Dakota. Plant Dis. 89:776.

Brown, A.G.P., Barbetti M.J., and Wood, P.McR. 1976. Effect of benomyl on`blackleg' disease of rape in Western Australia. Aust. J. Exp. Ag. Anim. Husb. 16: 276-279.

Brun, H., Levivier, S., Ruer, D., Somda, I., Chevre, A.M, and Renard, M. 2000. A field method for evaluating the potential durability of new resistance sources: application to the *Leptosphaeria maculans/Brassica napus* pathosystem. Phytopathology 90:961-966.

Canola Council of Canada. 2010. Provincial acreages and yields. Available from http://www.canolacouncil.org/acreageyields.aspx: Accessed October 13, 2010.

Canola Council of Canada (CCC). 2011. Socio-economic Value Report. Available from http://www.canolacouncil.org/canadian_canola_industry.aspx: Accessed February 9, 2011.

Chen, Y. and Fernando, W.G. 2006. Prevalence of pathogenicity groups of *Leptosphaeria maculans* in western Canada and North Dakota. Can. J. Plant Pathol. 28:533-539.

Chen, Y. and Ghanbarnia, K. 2007. Breeding for blackleg resistance: biology and epidemiology. Adv. Bot. Res. 45:271-311.

Codex Alimentarius. 2001. Codex standard for named vegetable oils CX-STAN 210-1999. Codex Alimentarius 8:11-25.

Cozijnsen, A.J. and Howlett, B.J. 2003. Characterisation of the mating-type locus of the plant pathogenic ascomycete *Leptosphaeria maculans*. Curr. Genet. 43:351-7.

Cozinjnsen, A.J., Popa, K. M., Purwantara, A., Rolls, B.D., and Howlett, B. 2001. Genome analysis of the plant pathogenic ascomycete *Leptosphaeria maculans*; mapping mating type and host specificity loci. Mol. Plant Pathol. 1:293–302.

Davies, J.L.M.1986. Diseases of oilseed rape. In: Oilseed rape. D.H. Scarisbrick and R.W. Daniels (eds.) London: Collins, 195-236.

De March, G., Seguin-Swartz, G., and Petrie, G.A. 1986. Virulence and culture filtrate toxicity in *Leptosphaeria maculans*: perspectives for in vitro selection. Can. J. Plant Pathol. 8: 422-428.

Delourme, R., Chèvre, A. M., Brun, H., Rouxel, T., Balesdent, M. H., Dias J. S., Salisbury, P., Renard, M., and Rimmer, S. R. 2006. Major gene and polygenic resistance to *Leptosphaeria maculans* in oilseed rape (*Brassica napus*) Eur. J. Plant Pathol. 114.2: 41-52.

Delwiche, P.A. 1980. Genetic aspects of blackleg (*Leptosphaeria maculans*) resistance in rapeseed (*Brassica napus*). Ph.D. Dissertation University of Wisconsin, Madison, WI, 144.

Fernando,W.G.http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B7CT0-4P0VFXPB&_user=513528&_coverDate=12%2F31%2F2007&_rdoc=1&_fmt=high&_orig=gateway&_origin=gateway&_sort=d&_docanchor=&view=c&_searchStrId=1659227987&_rerunOrigin=scholar.google&_acct=C000025359&_version=1&_urlVersion=0&_userid=513528&md5=7667d2d439ca5ae95818bf4c04e6e078&searchtype=a - implicit0

Fernando, W.G.D., Parks, P.S., Tomm, G., Viau, L.V., and Jurke, C. 2003. First report of blackleg disease caused by *Leptosphaeria maculans* on canola in Brazil. Plant Dis. 87:314.

Fitt, B.D.L., Brun, H., Barbetti, M.J., and Rimmer, S.R. 2006. World-wide importance of phoma stem canker (*Leptosphaeria maculans* and *L. biglobosa*) on oilseed rape (*Brassica napus*). Eur. J. Plant Pathol. 114: 3-15.

Fitt, B.D.L., Gladders, P., Turner, J.A., Sutherland, K.G., Welham, S.J., and Davies, J.M.L. 1997. Prospects for developing a forecasting scheme to optimize use of fungicides for disease control on winter oilseed rape in the UK. Aspects Appl. Biol. 48:135-142.

Fitt, B.D.L., Hall, A. M., Hu, X.J., Huang,Y.J., and Toscano-Underwood, C. 2003. Effects of temperature on ascospore germination and penetration of oilseed rape (*Brassica napus*) leaves by A- or B-group *Leptosphaeria maculans* (Phoma stem canker). Plant Pathol. 52:245-255.

Gladders, P., Evans, N., Marcroft, S., and Pinochet, X. 2006. Dissemination of information about management strategies and changes in farming practices for the exploitation of resistance to *Leptosphaeria maculans* (Phoma Stem Canker) in Oilseed Rape cultivars. Eur. J. Plant Pathol. 114:117-126.

Gladders, P., Symonds, B.V., Hardwick, N.V., and Sansford, C.E. 1998. Opportunities to control canker (*Leptosphaeria maculans*) in winter oilseed rape by improved spray timing. International Organization for Biological Control Bulletin 21:111-120.

Guo, X.W. and Fernando, W.G.D. 2005. Seasonal and diurnal patterns of spore dispersal by *Leptosphaeria maculans* from canola stubble in relation to environmental conditions. Plant Dis. 89:99-104.

Gugel, R.K. and Petrie, G.A. 1992. History, occurrence, impact and control of blackleg of rapeseed. Can. J. Plant Pathol. 14:36-45.

Hall, R., Chigogora, J.L., and Phillips, L.G. 1996. Role of seedborne inoculum of *Leptosphaeria maculans* in development of blackleg on oilseed rape. Can. J. Plant Pathol. 18:35-42.

Hammond, K.E. 1985. Systemic infection of *Brassica napus spp. oleifera* (Metzger) Sinsk, by *Leptosphaeria maculans*. Ph.D. Dissertation, University of East Anglia, Norwich, UK.

Hammond, K.E. and Lewis, B.G. 1987. The establishment of systemic infection in leaves of oilseed rape by *Leptosphaeria maculans.* Plant Pathol. 36:135-147.

Harker, K. N., Blackshaw, R. E., Kirkland, K. J., Derksen, D.A. and Wall, D. 2000. Herbicide-tolerant canola: weed control and yield comparisons in western Canada. Can. J. Plant Sci. 80: 647–654.

Howlett, B.J. 2006. Secondary metabolite toxins and nutrition of plant pathogenic fungi. Curr. Opin. Plant Biol. 9:371-375.

Howlett, B.J., Ballinger, D.J., and Barbetti, M.J. 1999. Diseases of canola in Australia. p. 47-52. In: P.A. Salisbury, R. Potter, G. McDonald, and A.G. Green (eds.), Canola in Australia: the first thirty years. Proceedings of the 10th international rapeseed congress. ACT, Canberra. Available at

http://www.regional.org.au/au/gcirc/index.htm.
Accessed February 12, 2011.

Howlett, B.J., Idnurm, A., and Pedras, M.S.C. 2001. *Leptosphaeria maculans*, the causal agent of blackleg disease of Brassicas. Fung. Gen. Biol. 33:1-14.

Hua, L., Sivasithamparam, K., Barbetti, M.J., and Kuo, J. 2004. Germination and invasion by ascospores and pycnidiospores of *Leptosphaeria maculans* on spring-type *Brassica napus* canola varieties with varying susceptibility to blackleg. J.Gen. Plant Pathol. 70: 261–269.

Hua, L., Smyth, F., Barbetti, M.J., and Sivasithamparam, K. 2005. Relationship between *Brassica napus* seedling and adult plant responses to *Leptosphaeria maculans* is determined by plant growth stage at inoculation and temperature regime. Field Crops Res. 96:428-427.

Huang, Y.J., Evans, N., Li, Z.Q., Eckert, M., Chevre, A.M., Renard, M., and Fitt, B.D. 2006. Temperature and leaf wetness duration affect phenotypic expression of Rlm6-mediated resistance to *Leptosphaeria maculans* in *Brassica napus*. New Phytol. 170:129-41.

Huang, Y.J., Fitt, B.D.L., Jedryczka, M., Dakowska, S., West, J.S., Gladders, P., Steed, J.M., and Li, Z.Q. 2005. Patterns of ascospore release in relation to phoma stem canker epidemiology in England (*Leptosphaeria maculans*) and Poland (*Leptosphaeria biglobosa*). Eur. J. Plant Pathol. 111: 263-277.

Huang, Y.J., Toscano-Underwood, C., Fit, B.D.L., Hu, X.J. and Hall, A.M. 2003. Effects of temperature on ascospore germination and penetration of oilseed rape (*Brassica napus*) leaves by A- or B group *Leptosphaeria maculans* (phoma stem canker). Plant Pathol. 52: 245-255.

Jedryczka, M., Fitt, B.D.L., Kachlicki, P., Lewartowska, E., Balesdent, M.H., and Rouxel, T. 1999. Comparison between Polish and United Kingdom populations of *Leptosphaeria maculans*, cause of stem canker of winter oilseed rape. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz 106: 608-617.

Kandel, H. 2009. 2009 canola variety trials. N.D. State Univ. Ext. Serv. Rep. No. A-1124.

Kandel, H. 2008. 2008 canola variety trials. N.D. State Univ. Ext. Serv. Rep. No. A-1124.

Karolewski, Z., Kosiada, T., Hylak-Nowosad, B., and Nowacka, K. 2002. Changes in population structure of *Leptosphaeria maculans* in Poland. Phytopath. Poland 25: 27-34.

Khangura, R.K. and Barbetti, M. 2001. Prevalence of blackleg (*Leptosphaeria maculans*) on canola (*Brassica napus*) in Western Australia. Aust. J. Exp. Ag. 41:1-9.

Khangura, R., Speijers, J., Barbetti, M.J., Salam, M.U., and Diggle, A.J. 2007. Epidemiology of blackleg (*Leptosphaeria maculans*) of canola (*Brassica napus*) in relation to maturation of pseudothecia and discharge of ascospores in Western Australia. Phytopathol. 97:1011-21.

Khangura, R.K., Barbetti, M.J., Salam, M.U., and Diggle, A.J. 2001. Maturation of pseudothecia and ascospore discharge by blackleg fungus on canola residues in Western Australia: Preliminary results from field observations. p. 87-91. In: Proc. 12th Australian research Assembly on Brassicas. Geelong, Victoria.

Khangura, R.K., Barbetti, M.J., Salam, M.U., and Diggle, A.J. 2002. Environmental influences on production and release of ascospores of blackleg and their implications in blackleg management in canola. p. 50-54. In: Department of Agriculture, Oilseed Updates 2002: Agribusiness Crop Updates 2002. WesternAustralia, South Perth.

Kharbanda, P.D. 1992. Performance of fungicides to control blackleg of canola. Can. J. Plant Pathol. 14:169-176.

Khot, S.D. 2006. Evaluation of *Brassica napus* Accessions for Resistance to *Sclerotinia sclerotiorum*. MS Thesis. North Dakota State University, Fargo, ND.

Kimber, D. S. and McGregor, D. I. 1995. The species and their origin, cultivation and world production. pp. 1-7. In: Brassica Oilseeds. D.S. Kimber and D.I. McGregor (eds). CAB International, Wallington, U.K.

Knodel, J. 2010. North Dakota field crop insects management guide. N.D. State Univ. Ext. Serv. No. E-1143.

Lamey, H. A. and Hershman, D.E. 1993. Black Leg of Canola (*Brassica napus*) caused by *Leptosphaeria maculans* in North Dakota. Plant Dis. 77:1263.

Lamey, A., Knodel, J., Endres, G., Andol, K., Ashley, R., Beneda, R., Bradley, C., Johnson, N., Knoke, S., Liane, M., Miller, M., Nyegaard, C., Peterson, N., and Lykken, T. 2003. 2002 Canola Disease Survey in North Dakota and Minnesota. Northern Canola News 9.1:4-5.

Li, H., Barbetti, M.J., and Sivasithamparam, K. 2005. Hazard from reliance on cruciferous hosts as sources of major gene-based resistance for managing blackleg (*Leptosphaeria maculans*) disease. Field Crops Res. 91:185-198.

Li, H., Sivasithamparam, K., and Barbetti, M.J. 2003. Breakdown of a *Brassica rapa* subsp. *sylvestris* single dominant blackleg resistance gene in *Brassica napus* rapeseed by *Leptosphaeria maculans* field isolates in Australia. Plant Dis. 87:752–752.

Li, H., Smyth, F., Barbetti, M.J., and Sivasithamparam, K. 2006. Relationship between *Brassica napus* seedling and adult plant responses to *Leptosphaeria maculans is* determined by plant growth stage at inoculation and temperature regime. Field Crops Res. 96:428-437.

Lindhout, P. 2002. The perspectives of polygenic resistance in breeding for durable resistance. Euphytica 124:217–226.

Markham, J.E. and Hille, J. 2001. Host-selective toxins as agents of cell death in plant-fungus interactions. Mol. Plant Pathol. 2:220-239.

McDonald, B.A. and Linde, C. 2002. Pathogen population genetics, evolutionary potential, and durable resistance. Ann. Rev. Phytopath. 40: 349-379.

McMullen, M.P. and Markell, S.G. 2010. 2011 North Dakota Field Crop Fungicide Guide. N.D. State Univ. Ext. Serv. Rep. No. PP-622.

McNabb, W.M., van den Berg, C.G.J., and Rimmer, S.R. 1993.Comparison of inoculation methods for selection of plants resistant to *Leptosphaeria maculans* in *Brassica napus*. Can. J. Plant Sci. 73:1199-1207.

McVetty, P.B.E. and Scarth, R. 2002. Breeding for improved oil quality in *Brassica* oilseed species. J. Crop Prod. 5: 345-369.

Mendès-Pereira, E., Balesdent, M.H., Brun, H. and Rouxel, T. 2003. Molecular phylogeny of the *Leptosphaeria maculans–L. biglobosa* species complex. Mycol. Res. 107:1287–1304.

Mengistu, A., Rimmer, S.R., Koch, E., and Williams, P.H. 1991. Pathogenicity grouping of isolates of *Leptosphaeria maculans* on *Brassica napus* cultivars and their disease reaction profiles on rapid-cycling Brassicas. Plant Dis. 75:1279-1282.

Morales, V.M., Seguin-Swartz, G., and Taylor, J.L. 1993. Chromosome length polymorphisms in *Leptosphaeria maculans*. Phytopathology 83:503–509.

Munzel, U., and Bandelow, B. 1998. The use of parametric vs. nonparametric tests in the statistical evaluation of rating scales. Pharmacopsych. 31:222-224.

Northern Canola Growers Association. 2010. 2010 Canola County Estimates. Available from http://www.northerncanola.com. Accessed May 3, 2011.

Oliver, R. and Solomon, O. 2010. New developments in pathogenicity and virulence of necrotrophs. Curr. Op. Plant Biol. 13:415-419.

Painter, K. and Roe, D. 2007. Economics of Canola Production in the Pacific Northwest. Center for Sustaining Agriculture and Natural Resources Rep. No. WP 2007-17.

Parlevliet, J.E. 2002. Durability of resistance against fungal, bacterial and viral pathogens; present situation. Euphytica 124:147–156.

Pedras, M.S.C., Séguin-Swartz, G., and Abrams, S.R. 1990. Minor phytotoxins from the blackleg fungus *Phoma lingam*. Phytochem. 29:777-782.

Pedras, M.S.C. 2001. Phytotoxins from fungi causing blackleg disease on crucifers: isolation, structure determination, detection, and phytotoxic activity. Res. Devel. Phytochem. 5: 109-117.

Penaud, A., Bernard, C., Maisonneuve, C., PeÂreÁs, A., and Pilorge, Â. E. 1999. Decision rules for a chemical control of *Leptosphaeria maculans*. Rapeseed Congress, 1999. Canberra, Australia. http://www.regional.org.au/papers/index.htm. Accessed February 12, 2011.

Petrie G. A. 1978. Occurrence of a highly virulent strain of blackleg *(Leptosphaeria maculans)*. Can. Plant Dis. Surv. 21-25.

Petrie G A. 1986. Consequences of survival of *Leptosphaeria maculans* (blackleg) in canola stubble residue through an entire crop rotation sequence. Can. J. Plant Pathol. 8:353.

Pietravalle S., Lemarie S., and van den Bosch, F. 2006. Durability of resistance and cost of virulence. Eur. J. Plant Pathol. 114:107–116.

Pilet, M.L., Delourme, R., Renard, M., and Foisset, N.1998. Identification of loci contributing to quantitative field resistance to blackleg disease, causal agent *Leptosphaeria maculans*(Desm.) Ces.et de Not., in winter rapeseed (*Brassica napus* L.). Theor. Appl. Gen. 96:23-30.

Pilet, M. L., Duplan, G., Archipiano, M., Barret, P., Baron, C., Horvais, R., Tanguy, X., Lucas, M.O., Renard, M., and Delourme, R. 2001. Stability of QTL for field resistance to blackleg across two genetic backgrounds in oilseed rape. Crop Sci. 41:197–205.

Poggeler, S., 1999. Phylogenetic relationships between mating-type sequences from homothallic and heterothallic ascomycetes. Curr. Genet. 36: 222-231.

Pongam, P., Osborn, T.C., and Williams, P.H. 1999. Assesment of genetic variation among *Leptosphaeria maculans* isolates using pathogenicity data and AFLP analyses. Plant Dis. 83:149-154.

Potts, D.A., Rakow, G.W., and Males, D.R., 1999. Canola-quality *Brassica juncea*, a new oilseed crop for the Canadian prairies. New Horizons for an old crop. Proc 10th Intl rapeseed Congr., Canberra, Australia 1999.

Punithalingam, E., and Holliday, P. 1972. *Leptosphaeria maculans*. CMI Descriptions of Pathogenic Fungi and Bacteria. No. 331.

Raymer, P.L., Auld, D.L., and Mahler, K.A. 1990. Agronomy of canola in the United States. p. 25–35. In: F. Shahidi (ed.), Canola and rapeseed: Production, chemistry, nutrition, and processing technology. Van Nostrand Rhienhold, New York.

Rimmer, S.R. and van den Berg, C.G.J. 1992. Resistance of oilseed Brassica spp to blackleg caused by *Leptosphaeria maculans*. Can. J. Plant Pathol. 14:56-66.

Rouxel, T. and Balesdent, M.H. 2005. The stem canker (blackleg) fungus, *Leptosphaeria maculans*, enters the genomic era. Mol. Plant Pathol. 6:225–241.

Rouxel, T., Mendes-Pereira, E., Brun, H. and Balesdent, M.H. 2004.Species complex of fungal phytopathogens: the *Leptosphaeria maculans–L. biglobosa* case study. Mol. Plant Pathol. 6: 225–241.

Rouxel, T., Penaud, A., Pinochet, X., Brun, H., Gout, L., Delourme, R., Schmit, J., and Balesdent, M.H. 2003. A 10 year survey of populations of *Leptosphaeria maculans* in France indicates a rapid adaptation towards the Rlm1 resistance gene of oilseed rape. Eur. J. Plant Pathol. 109:871-881.

Roy, N. N. 1984. Interspecific transfer of *Brassica juncea*-type high blackleg resistance to *Brassica napus*. Euphytica 33:295-303.

Salam, M. U., Khangura, R. K., Diggle, A. J. and Barbetti, M. J. 2003. Blackleg sporacle: A model for predicting onset of pseudothecia maturity and seasonal ascospore showers in relation to blackleg of canola. Phytopathology 93:1073-1081.

Shah, D.A. and Madden, L.V. 2004. Nonparametric analysis of ordinal data in designed factorial experiments. Phytopathology 94:33-43.

Shoemaker, R.A. and Brun, H. 2001. The teleomorph of the weakly aggressive segregate of *Leptosphaeria maculans*. Can. J. Bot. 79:412–419.

Sjodin, C. and Glimelius, K. 1988. Screening for resistance to Blackleg *Phoma lingam* (Tode ex Fr.) Desm, within Brassicaceae. J. Phytopathology 123:322-332.

Sovero, M. 1993. Rapeseed, a new oilseed crop for the United States. p. 302–307. In: J. Janick and J.E. Simon (eds.), New crops. Wiley, New York.

Sprague, S.J., Balesdent, M.H., Brun, H., Hayden, H.L., Marcroft, S.J., Pinochet, X., Rouxel, T., and Howlett, B.J. 2006. Major gene resistance in *Brassica napus* (oilseed rape) is overcome by changes in virulence of populations of *Leptoshaeria maculans* in France and Australia. Eur. J. Plant Pathol.114:33

Stringam, G., Bansal, V., Thiagarajah, M., and Tewari, J. 1992. Genetic analysis of blackleg (*Leptosphaeria maculans*) resistance in *Brassica napus L.* using the doubled haploid method. Thirteen Eucarpia Congress, Angers, France, Posters Abstracts:213-214.

Struss, D., Bellin, U., and Röbbelen, G. 1991. Development of B genome chromosome addition lines of *Brassica napus* using different interspecific *Brassica* hybrids. Plant Breed. 106:204–214.

Su, Y. 2009. Double haploid production of canola (*Brassica napus* L.) with improved resistance to *Sclerotinia sclerotiorum* via microspore culture. M.S. Thesis. North Dakota State University. Fargo, ND. 78 p.

Toscano-Underwood, C., Huang, Y.J., Fitt, B.D.L., and Hall, A.M. 2003. Effects of temperature on maturation of pseudothecia of *Leptosphaeria maculans* and *L. biglobosa* on oilseed rape stem debris. Plant Pathol. 52:726-736.

Toscano-Underwood, C., West, J.S., Fitt, B.D.L., Todd, A.D., and Jedryckzka, M. 2001. Development of Phoma lesions on oilseed rape leaves inoculated with ascospores of A-group and B-group *Leptosphaeria maculans* (stem canker) at different temperatures and wetness durations. Plant Pathol. 5:28-41.

van den Bosch, F., and Gilligan, C. A. 2003.Measures of durability of resistance. Phytopathology 93:616-625.

Venn, L.A. 1979. The genetic control of sexual compatibility in *Leptosphaeria maculans*. Aust. J. Plant Path. 8: 5–6.

USDA-NASS. 2010. National Statistics for Canola. Available from http://www.nass.usda.gov/Data_and_Statistics/index.asp. Accessed February 9, 2011.

West, J. S. and Fitt, B.D.L. 2005. Population dynamics and dispersal of *Leptosphaeria maculans* (blackleg of canola). Aust. Plant Pathol. 34:457–461.

West, J.S., Kharbanda, P.D., Barbetti, M.J., and Fitt, B.D.L. 2001. Epidemiology and management of *Leptosphaeria maculans* (phoma stem canker) on oilseed rape in Australia, Canada, and Europe. Plant Pathol. 50:10-27.

West, J.S., Balesdent, M.H., Rouxel, T., Nancy, J.P., Huang, Y.J., Roux, J., Steed, J.M., Fitt, B.D.L. and Schmit, J. 2002. Colonization of winter oilseed rape tissues by A/Tox+ and B/Tox0 *Leptosphaeria maculans* (phoma stem canker) in France and England. Plant Pathol. 51:311–321.

Williams, P.H. 1992. Biology of *Leptosphaeria maculans*. Can. J. Plant Pathol. 14:30-5.

Wood, P. McR. and Barbetti, M.J. 1977. A study on the inoculation of rape seedlings with ascospores and pycnidiospores of the blackleg disease causal agent *Leptosphaeria maculans.* J. Aust. Institute Ag. Sci. 4:79-80.

Zabala, F. 2008. Screening the USDA-NGRP *Brassica rapa* collection for resistance to *Sclerotinia sclerotiorum.* MS Thesis. North Dakota State University, Fargo, ND.

Zhu, B. and Rimmer, S.R. 2003.Inheritance of resistance to *Leptosphaeria maculans* in two accessions of *Brassica napus.* Can. J. Plant Pathol. 25:98-103.

APPENDIX TABLES

A.1. Median, mean rank and estimated relative treatment effects for the severity of foliar symptoms on 227 Brassica rapa accessions based on their reaction to inoculation with three L. maculans isolates of PG3.

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
14	PI 319693	6	131.00	0.28	(0.050)	0.07	0.68
12	PI 263054	6	74.75	0.29	(0.050)	0.07	0.68
4	Ames 9251	6	151.88	0.31	(0.002)	0.29	0.33
48	PI 340187	6	67.13	0.31	(0.002)	0.29	0.33
64	Ames 9731	6	151.88	0.31	(0.002)	0.29	0.33
71	PI 347595	6	182.38	0.31	(0.002)	0.29	0.33
75	PI 347610	6	138.63	0.31	(0.002)	0.29	0.33
80	PI 347612	6	161.25	0.31	(0.002)	0.29	0.33
91	PI 352817	6	134.00	0.31	(0.002)	0.29	0.33
94	PI 352821	6	99.88	0.31	(0.002)	0.29	0.33
99	PI 347612	6	171.63	0.31	(0.033)	0.14	0.56
115	PI 633181	6	206.38	0.31	(0.002)	0.29	0.33
118	PI 597831	6	143.50	0.31	(0.033)	0.14	0.56
167	PI 352812	6	94.50	0.31	(0.002)	0.29	0.33
210	PI 458615	6	136.50	0.31	(0.002)	0.29	0.33
237	PI 370740	6	138.50	0.31	(0.002)	0.29	0.33
242	PI 169096	6	84.63	0.31	(0.033)	0.14	0.56
253	PI 426234	6	137.00	0.31	(0.002)	0.29	0.33
265	PI 174796	6	150.38	0.31	(0.002)	0.29	0.33
276	PI 426263	6	117.75	0.31	(0.002)	0.29	0.33
5	PI 183019	6	141.50	0.32	(0.031)	0.15	0.55
7	PI 319413	6	140.00	0.32	(0.031)	0.15	0.55
103	PI 430601	6	179.13	0.32	(0.031)	0.15	0.55
111	PI 352790	6	135.63	0.32	(0.031)	0.15	0.55
116	PI 426284	6	172.25	0.32	(0.031)	0.15	0.55
208	PI 370729	6	68.38	0.32	(0.031)	0.15	0.55
25	PI 426276	6	195.88	0.35	(0.044)	0.13	0.67
59	Ames 9706	6	174.75	0.35	(0.044)	0.13	0.67
63	PI 340194	6	137.38	0.35	(0.044)	0.13	0.67
69	PI 347607	6	167.00	0.35	(0.044)	0.13	0.67
73	Ames 9888	6	116.50	0.35	(0.044)	0.13	0.67
98	PI 633174	7	185.50	0.35	(0.044)	0.13	0.67
109	PI 633178	6	141.88	0.35	(0.044)	0.13	0.67

A.1. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
113	PI 352791	6	195.38	0.35	(0.044)	0.13	0.67
215	PI 370732	6	105.88	0.35	(0.044)	0.13	0.67
226	PI 426282	6	120.75	0.35	(0.044)	0.13	0.67
37	PI 340182	6	140.00	0.36	(0.042)	0.14	0.66
65	PI 347602	6	192.25	0.36	(0.042)	0.14	0.66
105	PI 347614	6	120.75	0.36	(0.042)	0.14	0.66
127	PI 419212	6	144.38	0.36	(0.042)	0.14	0.66
9	PI 183391	7	188.13	0.38	(0.039)	0.17	0.65
38	Ames 9411	6	169.63	0.38	(0.020)	0.26	0.52
42	Ames 9416	6	133.25	0.38	(0.020)	0.26	0.52
49	Ames 9495	6	120.75	0.38	(0.020)	0.26	0.52
70	Ames 9744	6	137.38	0.38	(0.020)	0.26	0.52
77	PI 426265	6	150.38	0.38	(0.020)	0.26	0.52
78	PI 347611	6	137.38	0.38	(0.020)	0.26	0.52
79	PI 426257	6	147.38	0.38	(0.020)	0.26	0.52
82	PI 426290	6	120.75	0.38	(0.020)	0.26	0.52
85	PI 426261	6	117.75	0.38	(0.020)	0.26	0.52
121	PI 352794	6	89.13	0.38	(0.020)	0.26	0.52
122	PI 419063	6	120.13	0.38	(0.039)	0.17	0.65
216	PI 426249	6	87.63	0.38	(0.020)	0.26	0.52
250	PI 426175	6	83.25	0.38	(0.020)	0.26	0.52
261	PI 537002	6	94.50	0.38	(0.020)	0.26	0.52
264	PI 426288	7	120.75	0.39	(0.053)	0.12	0.74
194	PI 164542	6	212.13	0.40	(0.051)	0.13	0.74
1	PI 312903	6	117.25	0.42	(0.033)	0.23	0.65
24	PI 314137	7	78.63	0.42	(0.033)	0.23	0.65
29	PI 198061	6	151.88	0.42	(0.033)	0.23	0.65
39	PI 207465	6	154.75	0.42	(0.033)	0.23	0.65
45	Ames 15492	6	140.13	0.42	(0.033)	0.23	0.65
52	Ames 9624	6	237.25	0.42	(0.033)	0.23	0.65
61	PI 426273	6	157.13	0.42	(0.033)	0.23	0.65
62	PI 347596	6	120.75	0.42	(0.033)	0.23	0.65
76	PI 633166	7	86.63	0.42	(0.033)	0.23	0.65
87	PI 426264	6	165.13	0.42	(0.033)	0.23	0.65
100	PI 370731	6	99.88	0.42	(0.033)	0.23	0.65
102	PI 347613	6	120.75	0.42	(0.033)	0.23	0.65

A.1. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
114	PI 391554	6	158.38	0.42	(0.033)	0.23	0.65
117	PI 352792	6	169.00	0.42	(0.033)	0.23	0.65
154	PI 426238	6	125.50	0.42	(0.033)	0.23	0.65
175	PI 426280	7	196.88	0.42	(0.033)	0.23	0.65
195	PI 179642	6	172.63	0.42	(0.033)	0.23	0.65
221	PI 169082	6	86.63	0.42	(0.033)	0.23	0.65
231	PI 370738	7	172.63	0.42	(0.033)	0.23	0.65
235	PI 169094	6	171.63	0.42	(0.033)	0.23	0.65
240	PI 370741	7	102.50	0.42	(0.033)	0.23	0.65
259	PI 174793	6	104.50	0.42	(0.033)	0.23	0.65
260	PI 426242	6	151.88	0.42	(0.033)	0.23	0.65
198	PI 352823	6	181.00	0.43	(0.044)	0.18	0.72
58	Ames 9677	7	151.88	0.45	(0.023)	0.30	0.61
68	PI 340196	6	160.63	0.45	(0.023)	0.30	0.61
220	PI 432375	6	147.38	0.45	(0.023)	0.30	0.61
66	PI 340195	6	147.63	0.46	(0.043)	0.21	0.73
130	PI 426172	6	137.50	0.46	(0.043)	0.21	0.73
212	PI 169070	6	86.63	0.46	(0.038)	0.23	0.71
223	PI 169088	7	99.00	0.46	(0.043)	0.21	0.73
101	PI 633175	6	147.38	0.47	(0.052)	0.17	0.78
147	PI 426235	6	218.00	0.47	(0.052)	0.17	0.78
165	PI 426270	6	47.00	0.47	(0.057)	0.16	0.81
197	PI 426266	6	107.38	0.47	(0.052)	0.18	0.78
222	PI 370735	7	106.38	0.47	(0.047)	0.20	0.76
192	PI 352821	6	226.00	0.48	(0.050)	0.19	0.78
11	PI 319417	7	140.00	0.49	(0.032)	0.29	0.70
18	PI 319694	7	117.75	0.49	(0.032)	0.29	0.70
30	Ames 9304	7	170.25	0.49	(0.032)	0.29	0.70
34	Ames 9390	6	131.00	0.49	(0.032)	0.29	0.70
54	PI 340189	7	80.00	0.49	(0.032)	0.29	0.70
81	PI 347599	6	168.50	0.49	(0.032)	0.29	0.70
90	PI 347609	6	135.50	0.49	(0.032)	0.29	0.70
92	PI 426255	6	120.75	0.49	(0.032)	0.29	0.70
96	PI 370728	6	191.00	0.49	(0.032)	0.29	0.70
104	PI 633176	6	103.88	0.49	(0.032)	0.29	0.70
108	PI 370737	6	124.25	0.49	(0.032)	0.29	0.70
112	PI 633180	6	81.50	0.49	(0.032)	0.29	0.70

A.1. Continued

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
183	PI 431573	6	168.13	0.49	(0.032)	0.29	0.70
184	PI 352818	6	143.38	0.49	(0.032)	0.29	0.70
219	PI 458972	6	107.38	0.49	(0.032)	0.29	0.70
227	PI 458976	7	227.13	0.49	(0.032)	0.29	0.70
232	PI 169093	6	154.38	0.49	(0.032)	0.29	0.70
239	PI 458984	7	86.63	0.49	(0.032)	0.29	0.70
243	PI 370742	6	124.25	0.49	(0.032)	0.29	0.70
245	PI 170032	7	118.25	0.49	(0.032)	0.29	0.70
255	PI 426236	6	135.13	0.49	(0.032)	0.29	0.70
262	PI 174799	6	104.50	0.49	(0.032)	0.29	0.70
166	PI 135821	7	44.38	0.50	(0.058)	0.17	0.83
178	PI 426292	6	146.88	0.50	(0.058)	0.17	0.83
107	PI 352789	7	86.63	0.52	(0.020)	0.38	0.65
196	PI 352822	6	129.38	0.52	(0.020)	0.38	0.65
17	Ames 9264	7	98.00	0.54	(0.038)	0.29	0.76
19	PI 183917	7	117.25	0.54	(0.038)	0.29	0.76
22	PI 323939	8	85.00	0.54	(0.044)	0.26	0.80
23	Ames 9285	7	151.88	0.54	(0.038)	0.29	0.76
28	Ames 9286	6	181.50	0.54	(0.038)	0.29	0.76
57	PI 34192	7	181.50	0.54	(0.038)	0.29	0.76
83	Ames 15943	7	161.38	0.54	(0.038)	0.29	0.76
86	PI 633170	6	209.13	0.54	(0.038)	0.29	0.76
88	PI 352807	6	98.00	0.54	(0.038)	0.29	0.76
97	PI 426287	7	151.38	0.54	(0.038)	0.29	0.76
110	PI 391547	7	102.50	0.54	(0.038)	0.29	0.76
119	PI 352793	6	182.13	0.54	(0.038)	0.29	0.76
129	PI 352798	7	251.13	0.54	(0.038)	0.29	0.76
144	PI 426286	7	144.50	0.54	(0.038)	0.29	0.76
146	PI 352805	6	178.00	0.54	(0.038)	0.29	0.76
156	PI 426277	7	137.50	0.54	(0.038)	0.29	0.76
172	PI 426259	6	117.25	0.54	(0.038)	0.29	0.76
181	PI 163498	6	106.38	0.54	(0.038)	0.29	0.76
189	PI 164468	6	178.00	0.54	(0.038)	0.29	0.76
190	PI 352820	6	102.75	0.54	(0.038)	0.29	0.76
193	PI 436560	6	245.25	0.54	(0.038)	0.29	0.76
218	PI 169081	6	138.50	0.54	(0.038)	0.29	0.76
225	PI 370736	6	103.75	0.54	(0.038)	0.29	0.76

A.1. Continued

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
241	PI 459020	6	86.63	0.54	(0.038)	0.29	0.76
244	PI 169097	7	138.50	0.54	(0.044)	0.26	0.80
254	PI 175608	6	127.13	0.54	(0.038)	0.29	0.76
263	PI 426244	7	150.38	0.54	(0.038)	0.29	0.76
269	PI 537010	7	107.38	0.54	(0.038)	0.29	0.76
270	PI 426248	6	140.50	0.54	(0.044)	0.26	0.80
275	PI 426254	7	151.88	0.54	(0.038)	0.29	0.76
277	PI 174805	7	136.50	0.54	(0.038)	0.29	0.76
148	PI 115885	6	117.75	0.55	(0.065)	0.17	0.88
257	PI 426238	8	65.75	0.55	(0.046)	0.26	0.81
157	PI 125798	7	158.75	0.56	(0.027)	0.38	0.73
170	PI 352813	6	212.13	0.56	(0.027)	0.38	0.73
206	PI 370028	7	140.50	0.56	(0.027)	0.38	0.73
238	PI 169095	7	98.00	0.56	(0.027)	0.38	0.73
252	PI 426173	6	116.25	0.56	(0.027)	0.38	0.73
143	PI 352804	6	135.63	0.57	(0.044)	0.28	0.82
180	PI 458989	6	148.38	0.57	(0.044)	0.28	0.82
142	PI 352803	6	106.00	0.59	(0.047)	0.27	0.84
149	PI 329025	7	151.38	0.59	(0.047)	0.27	0.84
161	PI 352810	6	151.38	0.59	(0.047)	0.27	0.84
163	PI 134692	7	160.25	0.59	(0.050)	0.26	0.85
169	PI 135871	6	107.38	0.59	(0.047)	0.27	0.84
179	PI 352816	6	188.75	0.59	(0.047)	0.27	0.84
182	PI 352817	6	125.25	0.59	(0.047)	0.27	0.84
204	PI 365643	7	74.88	0.59	(0.004)	0.57	0.62
236	PI 458983	8	116.25	0.59	(0.047)	0.27	0.84
267	PI 537009	7	156.25	0.59	(0.047)	0.27	0.84
228	PI 370737	7	158.25	0.60	(0.060)	0.22	0.89
47	Ames 9492	7	169.63	0.61	(0.031)	0.39	0.79
60	PI 340193	7	206.38	0.61	(0.031)	0.39	0.79
135	PI 175054	6	172.13	0.61	(0.049)	0.28	0.86
136	PI 426174	6	143.38	0.61	(0.038)	0.35	0.82
199	PI 165595	7	138.50	0.61	(0.031)	0.39	0.79
133	PI 352799	6	159.63	0.62	(0.052)	0.27	0.88
155	PI 426240	6	134.13	0.62	(0.052)	0.27	0.88
203	PI 165608	8	103.88	0.62	(0.052)	0.27	0.88
159	PI 426241	6	194.38	0.63	(0.054)	0.26	0.89

A.1. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
164	PI 426262	6	182.25	0.63	(0.054)	0.26	0.89
202	PI 426260	8	135.50	0.63	(0.054)	0.26	0.89
213	PI 370731	8	202.25	0.63	(0.054)	0.26	0.89
89	PI 633171	7	137.38	0.65	(0.033)	0.41	0.83
150	PI 175050	7	192.88	0.65	(0.033)	0.41	0.83
168	PI 426275	7	148.38	0.65	(0.033)	0.41	0.83
233	PI 458982	7	117.50	0.65	(0.033)	0.41	0.83
256	PI 173868	7	218.63	0.65	(0.033)	0.41	0.83
266	PI 426246	7	181.50	0.65	(0.033)	0.41	0.83
273	PI 174804	7	117.25	0.65	(0.033)	0.41	0.83
274	PI 426252	7	140.50	0.65	(0.033)	0.41	0.83
131	PI 633156	6	148.88	0.66	(0.039)	0.37	0.86
153	OI 352807	6	161.25	0.66	(0.039)	0.37	0.86
174	PI 162778	8	120.75	0.66	(0.039)	0.37	0.86
200	PI 443023	7	151.38	0.66	(0.039)	0.37	0.86
229	PI 169092	7	86.63	0.66	(0.039)	0.37	0.86
230	PI 458977	7	86.63	0.66	(0.039)	0.37	0.86
40	PI 426289	7	174.75	0.68	(0.015)	0.57	0.77
120	PI 419036	7	134.13	0.68	(0.015)	0.57	0.77
128	PI 426268	6	172.25	0.68	(0.041)	0.37	0.88
26	PI 324507	7	104.50	0.69	(0.037)	0.40	0.88
72	PI 347609	7	160.63	0.69	(0.037)	0.40	0.88
145	PI 633159	7	189.00	0.69	(0.037)	0.40	0.88
173	PI 352814	7	141.50	0.69	(0.037)	0.40	0.88
211	PI 175052	7	141.50	0.69	(0.037)	0.40	0.88
224	PI 458975	6	100.38	0.69	(0.037)	0.40	0.88
10	PI 183395	7	174.13	0.70	(0.039)	0.39	0.89
93	PI 347610	8	161.38	0.70	(0.039)	0.39	0.89
171	PI 426728	7	154.38	0.70	(0.039)	0.39	0.89
186	PI 164398	8	224.00	0.70	(0.045)	0.35	0.91
205	PI 269445	6	89.13	0.70	(0.039)	0.39	0.89
271	PI 426250	8	195.38	0.70	(0.039)	0.39	0.89
124	PI 470042	7	242.00	0.71	(0.041)	0.39	0.90
234	PI 370739	7	69.75	0.71	(0.022)	0.55	0.84
139	PI 633158	7	154.63	0.72	(0.040)	0.40	0.91
140	Ames 21757	7	161.38	0.72	(0.013)	0.63	0.80
188	PI 436552	7	205.38	0.72	(0.013)	0.63	0.80

A.1. Continued

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
126	PI 352797	6	192.00	0.73	(0.042)	0.39	0.92
137	PI 426175	7	161.25	0.73	(0.042)	0.39	0.92
177	PI 163496	7	110.25	0.73	(0.042)	0.39	0.92
158	PI 352809	7	160.25	0.75	(0.044)	0.38	0.93
160	PI 127440	6	112.38	0.75	(0.044)	0.38	0.93
162	PI 426242	7	131.50	0.75	(0.044)	0.38	0.93
272	PI 537011	8	86.63	0.75	(0.044)	0.38	0.93
15	PI 183664	7	118.25	0.76	(0.003)	0.75	0.78
16	Dk 3042	7	140.00	0.76	(0.003)	0.75	0.78
106	PI 370736	9	69.75	0.76	(0.045)	0.37	0.94
123	PI 419180	7	88.75	0.76	(0.003)	0.75	0.78
251	PI 173852	7	117.25	0.76	(0.003)	0.75	0.78
268	PI 174803	7	140.00	0.76	(0.018)	0.61	0.86
134	PI 633157	7	159.63	0.77	(0.044)	0.38	0.95
138	PI 352802	7	170.50	0.77	(0.046)	0.36	0.95
132	PI 426173	7	86.88	0.78	(0.024)	0.58	0.90
151	PI 116021	6	205.38	0.78	(0.045)	0.37	0.96
44	PI 340185	7	171.25	0.79	(0.021)	0.61	0.90
125	PI 352796	7	125.50	0.80	(0.024)	0.60	0.92
191	PI 164494	7	162.25	0.80	(0.024)	0.60	0.92
20	Ames 9267	8	132.00	0.81	(0.014)	0.70	0.89
185	PI 432364	7	107.38	0.83	(0.012)	0.74	0.90
246	PI 419063	8	106.38	0.85	(0.014)	0.72	0.92
152	PI 125795	8	151.38	0.86	(0.016)	0.71	0.94
201	PI 443024	8	47.00	0.86	(0.016)	0.71	0.94
214	PI 169074	9	68.38	0.88	(0.019)	0.68	0.96
21	PI 183919	8	116.25	0.90	(0.013)	0.77	0.96
53	PI 340191	8	120.75	0.91	(0.014)	0.76	0.97
187	PI 352819	8	191.88	0.91	(0.014)	0.76	0.97
176	PI 426258	7	191.13	0.92	(0.015)	0.74	0.98
8	Ames 9260	8	146.88	0.95	(0.005)	0.90	0.98

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ith accession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

A.2. Median, mean rank and estimated relative treatment effects for the severity of foliar symptoms on 227 *Brassica rapa* accessions based on their reaction to inoculation with one *L. maculans* isolate of PG 4.

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
1	PI 312903	7	89.50	0.28	(0.003)	0.26	0.30
2	PI 179863	7	89.50	0.28	(0.003)	0.26	0.30
9	PI 183391	6	16.00	0.28	(0.029)	0.13	0.51
27	PI 319413	7	89.50	0.28	(0.050)	0.07	0.67
51	PI 163947	7	208.50	0.28	(0.050)	0.07	0.67
57	PI 34192	7	89.50	0.28	(0.003)	0.26	0.30
60	PI 340193	7	16.00	0.28	(0.003)	0.26	0.30
72	PI 347609	7	3.00	0.28	(0.003)	0.26	0.30
88	PI 352807	7	89.50	0.28	(0.003)	0.26	0.30
94	PI 352821	7	149.00	0.28	(0.029)	0.13	0.51
103	PI 430601	7	40.00	0.28	(0.003)	0.26	0.30
198	PI 352823	7	270.50	0.28	(0.003)	0.26	0.30
204	PI 365643	7	89.50	0.28	(0.003)	0.26	0.30
216	PI 426249	7	40.00	0.28	(0.003)	0.26	0.30
79	PI 426257	8	16.00	0.29	(0.048)	0.08	0.66
98	PI 633174	7	16.00	0.29	(0.048)	0.08	0.66
192	PI 352821	8	89.50	0.29	(0.048)	0.08	0.66
56	PI 340195	7	89.50	0.30	(0.026)	0.15	0.50
63	PI 340194	7	40.00	0.30	(0.026)	0.15	0.50
78	PI347611	7	89.50	0.30	(0.026)	0.15	0.50
96	PI370728	7	40.00	0.30	(0.026)	0.15	0.50
5	PI183019	8	149.00	0.34	(0.034)	0.16	0.60
7	PI319413	7	16.00	0.34	(0.034)	0.16	0.60
23	Ames 9285	7	270.50	0.34	(0.018)	0.23	0.47
28	Ames 9286	7	89.50	0.34	(0.034)	0.16	0.60
30	Ames 9304	7	16.00	0.34	(0.034)	0.16	0.60
35	PI340181	7	208.50	0.34	(0.018)	0.23	0.47
37	PI340182	7	40.00	0.34	(0.018)	0.23	0.47
61	PI426273	7	89.50	0.34	(0.034)	0.16	0.60
80	PI347612	8	89.50	0.34	(0.044)	0.12	0.66
87	PI426264	7	89.50	0.34	(0.044)	0.12	0.66
89	PI633171	7	89.50	0.34	(0.018)	0.23	0.47
90	PI347609	7	149.00	0.34	(0.018)	0.23	0.47
91	PI352817	7	208.50	0.34	(0.018)	0.23	0.47
105	PI347614	8	89.50	0.34	(0.018)	0.23	0.47

A.2. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
107	PI352789	7	89.50	0.34	(0.018)	0.23	0.47
183	PI431573	7	89.50	0.34	(0.034)	0.16	0.60
206	PI370028	7	208.50	0.34	(0.018)	0.23	0.47
235	PI169094	7	149.00	0.34	(0.018)	0.23	0.47
241	PI459020	7	40.00	0.34	(0.044)	0.12	0.66
253	PI426234	8	208.50	0.34	(0.018)	0.23	0.47
273	PI174804	6	149.00	0.34	(0.044)	0.12	0.66
10	PI183395	8	40.00	0.35	(0.041)	0.14	0.65
50	PI340189	7	16.00	0.35	(0.041)	0.14	0.65
194	PI164542	7	89.50	0.35	(0.041)	0.14	0.65
249	PI173848	8	89.50	0.35	(0.041)	0.14	0.65
41	PI340184	8	208.50	0.36	(0.031)	0.18	0.58
83	Ames15943	7	149.00	0.36	(0.031)	0.18	0.58
104	PI633176	7	89.50	0.36	(0.031)	0.18	0.58
117	PI352792	7	208.50	0.36	(0.031)	0.18	0.58
6	PI314137	8	208.50	0.37	(0.048)	0.12	0.70
31	PI175085	7	89.50	0.40	(0.045)	0.16	0.71
66	PI340195	8	40.00	0.40	(0.035)	0.20	0.64
69	PI347607	8	89.50	0.40	(0.061)	0.11	0.79
70	Ames 9744	7	40.00	0.40	(0.035)	0.20	0.64
108	PI370737	8	40.00	0.40	(0.035)	0.20	0.64
150	PI175050	8	270.50	0.40	(0.035)	0.20	0.64
207	PI169061	8	208.50	0.40	(0.035)	0.20	0.64
226	PI426282	7	208.50	0.40	(0.035)	0.20	0.64
4	Ames 9251	7	89.50	0.41	(0.021)	0.28	0.55
114	PI391554	7	40.00	0.41	(0.021)	0.28	0.55
14	PI319693	7	40.00	0.42	(0.042)	0.18	0.70
34	Ames 9390	7	89.50	0.42	(0.042)	0.18	0.70
64	Ames 9731	8	149.00	0.42	(0.056)	0.13	0.78
242	PI169096	7	89.50	0.42	(0.042)	0.18	0.70
15	PI183664	7	89.50	0.46	(0.033)	0.26	0.68
26	PI324507	7	208.50	0.46	(0.033)	0.26	0.68
29	PI198061	7	16.00	0.46	(0.033)	0.26	0.68
47	Ames 9492	7	16.00	0.46	(0.033)	0.26	0.68
52	Ames 9624	7	208.50	0.46	(0.033)	0.26	0.68
93	PI347610	7	149.00	0.46	(0.033)	0.26	0.68
102	PI347613	8	89.50	0.46	(0.033)	0.26	0.68

A.2. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect		Treatment effect: Standard error		Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
113	PI352791	7	149.00	0.46	(	0.052	)	0.17	0.78
145	PI633159	7	254.50	0.46	(	0.033	)	0.26	0.68
175	PI426280	8	270.50	0.46	(	0.052	)	0.17	0.78
178	PI426292	8	208.50	0.46	(	0.052	)	0.17	0.78
208	PI370729	7	40.00	0.46	(	0.033	)	0.26	0.68
211	PI175052	7	149.00	0.46	(	0.033	)	0.26	0.68
212	PI169070	8	208.50	0.46	(	0.033	)	0.26	0.68
215	PI370732	8	89.50	0.46	(	0.033	)	0.26	0.68
220	PI432375	8	89.50	0.46	(	0.052	)	0.17	0.78
231	PI370738	8	149.00	0.46	(	0.033	)	0.26	0.68
237	PI370740	7	149.00	0.46	(	0.033	)	0.26	0.68
265	PI174796	7	89.50	0.46	(	0.052	)	0.17	0.78
275	PI426254	7	40.00	0.46	(	0.033	)	0.26	0.68
84	PI347605	8	89.50	0.47	(	0.018	)	0.35	0.59
127	PI419212	8	254.50	0.47	(	0.049	)	0.19	0.77
159	PI426241	8	254.50	0.47	(	0.049	)	0.19	0.77
180	PI458989	8	208.50	0.47	(	0.049	)	0.19	0.77
218	PI169081	8	208.50	0.47	(	0.049	)	0.19	0.77
223	PI169088	8	208.50	0.47	(	0 049	)	0.19	0.77
232	PI169093	8	208.50	0.47	(	0.018	)	0.35	0.59
182	PI352817	7	16.00	0.48	(	0.041	)	0.23	0.73
133	PI352799	8	208.50	0.51	(	0.044	)	0.24	0.77
193	PI436560	8	40.00	0.51	(	0.044	)	0.24	0.77
256	PI173868	7	208.50	0.51	(	0.044	)	0.24	0.77
25	PI426276	7	149.00	0.52	(	0.040	)	0.27	0.76
55	Ames 9668	8	40.00	0.52	(	0.040	)	0.27	0.76
86	PI633170	8	16.00	0.52	(	0.040	)	0.27	0.76
101	PI633175	8	149.00	0.52	(	0.040	)	0.27	0.76
185	PI432364	8	149.00	0.52	(	0.050	)	0.22	0.81
195	PI179642	8	149.00	0.52	(	0.040	)	0.27	0.76
230	PI458977	8	149.00	0.52	(	0.040	)	0.27	0.76
250	PI426175	7	208.50	0.52	(	0.040	)	0.27	0.76
264	PI426288	7	16.00	0.52	(	0.047	)	0.23	0.79
268	PI174803	7	89.50	0.52	(	0.040	)	0.27	0.76
16	Dk 3042	7	149.00	0.53	(	0.003	)	0.51	0.55
17	Ames 9264	7	208.50	0.53	(	0.028	)	0.34	0.71
19	PI183917	7	149.00	0.53	(	0.028	)	0.34	0.71

A.2. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
39	PI207465	8	149.00	0.53	(0.028)	0.34	0.71
40	PI426289	7	149.00	0.53	(0.028)	0.34	0.71
44	PI340185	8	254.50	0.53	(0.028)	0.34	0.71
65	PI347602	7	208.50	0.53	(0.028)	0.34	0.71
76	PI633166	8	208.50	0.53	(0.028)	0.34	0.71
92	PI426255	8	149.00	0.53	(0.028)	0.34	0.71
95	PI633173	8	40.00	0.53	(0.028)	0.34	0.71
97	PI426287	8	16.00	0.53	(0.059)	0.18	0.85
122	PI419063	8	270.50	0.53	(0.028)	0.34	0.71
188	PI436552	8	149.00	0.53	(0.028)	0.34	0.71
190	PI352820	8	254.50	0.53	(0.028)	0.34	0.71
209	PI169064	7	149.00	0.53	(0.059)	0.18	0.85
210	PI458615	7	89.50	0.53	(0.028)	0.34	0.71
259	PI174793	7	89.50	0.53	(0.028)	0.34	0.71
203	PI165608	7	89.50	0.54	(0.046)	0.25	0.80
22	PI323939	7	89.50	0.56	(0.068)	0.16	0.89
205	PI269445	8	89.50	0.56	(0.048)	0.26	0.83
165	PI426270	7	208.50	0.57	(0.039)	0.31	0.79
11	PI319417	8	208.50	0.58	(0.033)	0.36	0.78
18	PI319694	7	149.00	0.58	(0.033)	0.36	0.78
36	Ames 9396	7	89.50	0.58	(0.033)	0.36	0.78
77	PI426265	8	89.50	0.58	(0.033)	0.36	0.78
110	PI391547	7	89.50	0.58	(0.033)	0.36	0.78
121	PI352794	8	149.00	0.58	(0.033)	0.36	0.78
140	Ames21757	8	208.50	0.58	(0.033)	0.36	0.78
154	PI426238	8	270.50	0.58	(0.033)	0.36	0.78
162	PI426242	8	208.50	0.58	(0.033)	0.36	0.78
166	PI135821	8	254.50	0.58	(0.033)	0.36	0.78
169	PI135871	8	254.50	0.58	(0.033)	0.36	0.78
172	PI426259	8	208.50	0.58	(0.033)	0.36	0.78
179	PI352816	8	208.50	0.58	(0.033)	0.36	0.78
189	PI164468	8	149.00	0.58	(0.033)	0.36	0.78
228	PI370737	8	208.50	0.58	(0.042)	0.30	0.82
234	PI370739	7	149.00	0.58	(0.033)	0.36	0.78
238	PI169095	8	89.50	0.58	(0.033)	0.36	0.78
240	PI370741	7	89.50	0.58	(0.033)	0.36	0.78
244	PI169097	7	208.50	0.58	(0.050)	0.25	0.85

A.2. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
252	PI426173	8	149.00	0.58	(0.033)	0.36	0.78
255	PI426236	8	149.00	0.58	(0.033)	0.36	0.78
258	PI173871	7	149.00	0.58	(0.033)	0.36	0.78
260	PI426242	7	149.00	0.58	(0.050)	0.25	0.85
261	PI537002	8	208.50	0.58	(0.033)	0.36	0.78
266	PI426246	7	89.50	0.58	(0.050)	0.25	0.85
272	PI537011	7	16.00	0.58	(0.050)	0.25	0.85
274	PI426252	7	89.50	0.58	(0.033)	0.36	0.78
59	Ames 9706	7	89.50	0.59	(0.017)	0.47	0.70
158	PI352809	8	208.50	0.59	(0.049)	0.27	0.85
224	PI458975	8	89.50	0.59	(0.049)	0.27	0.85
197	PI426266	8	89.50	0.61	(0.060)	0.22	0.90
170	PI352813	8	208.50	0.62	(0.058)	0.24	0.90
200	PI443023	7	208.50	0.62	(0.058)	0.23	0.90
269	PI537010	8	208.50	0.62	(0.056)	0.24	0.89
131	PI633156	8	270.50	0.63	(0.041)	0.34	0.84
135	PI175054	8	208.50	0.63	(0.041)	0.34	0.84
146	PI352805	8	254.50	0.63	(0.041)	0.34	0.84
160	PI127440	8	208.50	0.63	(0.041)	0.34	0.84
24	PI314137	7	89.50	0.64	(0.043)	0.33	0.86
54	PI340189	8	89.50	0.64	(0.035)	0.39	0.83
112	PI633180	8	208.50	0.64	(0.035)	0.39	0.83
120	PI419036	7	208.50	0.64	(0.035)	0.39	0.83
124	PI470042	8	254.50	0.64	(0.035)	0.39	0.83
130	PI426172	8	254.50	0.64	(0.035)	0.39	0.83
173	PI352814	8	208.50	0.64	(0.035)	0.39	0.83
174	PI162778	8	16.00	0.64	(0.043)	0.33	0.86
202	PI426260	7	149.00	0.64	(0.035)	0.39	0.83
219	PI458972	8	208.50	0.64	(0.035)	0.39	0.83
221	PI169082	9	89.50	0.64	(0.043)	0.33	0.86
227	PI458976	7	89.50	0.64	(0.035)	0.39	0.83
239	PI458984	8	149.00	0.64	(0.035)	0.39	0.83
243	PI370742	8	89.50	0.64	(0.035)	0.39	0.83
247	PI171521	7	16.00	0.64	(0.035)	0.39	0.83
254	PI175608	8	208.50	0.64	(0.035)	0.39	0.83
42	Ames 9416	8	149.00	0.65	(0.019)	0.51	0.76
43	Ames 9474	8	89.50	0.65	(0.019)	0.51	0.76
118	PI597831	7	16.00	0.65	(0.019)	0.51	0.76

A.2. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
156	PI426277	8	208.50	0.65	(0.019)	0.51	0.76
161	PI352810	8	149.00	0.65	(0.019)	0.51	0.76
168	PI426275	8	208.50	0.65	(0.019)	0.51	0.76
233	PI458982	8	89.50	0.65	(0.019)	0.51	0.76
263	PI426244	7	89.50	0.65	(0.056)	0.26	0.90
45	Ames15492	9	40.00	0.68	(0.040)	0.38	0.88
144	PI426286	7	89.50	0.68	(0.040)	0.38	0.88
148	PI115885	9	208.50	0.68	(0.048)	0.32	0.90
236	PI458983	7	89.50	0.68	(0.048)	0.32	0.90
271	PI426250	7	89.50	0.68	(0.048)	0.32	0.90
196	PI352822	8	1.00	0.69	(0.028)	0.48	0.84
20	Ames 9267	8	208.50	0.70	(0.017)	0.58	0.80
53	PI340191	8	208.50	0.70	(0.042)	0.37	0.90
106	PI370736	7	89.50	0.70	(0.042)	0.37	0.90
126	PI352797	9	208.50	0.70	(0.042)	0.37	0.90
129	PI352798	8	208.50	0.70	(0.017)	0.58	0.80
132	PI426173	9	254.50	0.70	(0.042)	0.37	0.90
142	PI352803	9	270.50	0.70	(0.042)	0.37	0.90
164	PI426262	8	149.00	0.70	(0.042)	0.37	0.90
171	PI426728	9	208.50	0.70	(0.042)	0.37	0.90
181	PI163498	8	40.00	0.70	(0.017)	0.58	0.80
186	PI164398	8	254.50	0.70	(0.017)	0.58	0.80
199	PI165595	8	254.50	0.70	(0.042)	0.37	0.90
229	PI169092	8	208.50	0.70	(0.017)	0.58	0.80
267	PI537009	7	89.50	0.70	(0.042)	0.37	0.90
277	PI174805	7	149.00	0.70	(0.042)	0.37	0.90
257	PI426238	8	149.00	0.73	(0.044)	0.37	0.92
245	PI170032	7	208.50	0.74	(0.046)	0.36	0.93
136	PI426174	8	270.50	0.75	(0.024)	0.56	0.87
138	PI352802	9	270.50	0.75	(0.047)	0.35	0.94
147	PI426235	8	254.50	0.75	(0.024)	0.56	0.87
157	PI125798	8	208.50	0.75	(0.024)	0.56	0.87
163	PI134692	8	270.50	0.75	(0.024)	0.56	0.87
167	PI352812	8	149.00	0.75	(0.024)	0.56	0.87
201	PI443024	7	208.50	0.75	(0.047)	0.35	0.94
246	PI419063	8	208.50	0.75	(0.024)	0.56	0.87
137	PI426175	8	270.50	0.76	(0.026)	0.54	0.89
149	PI329025	8	89.50	0.76	(0.002)	0.74	0.78

A.2. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect		Treatment effect: Standard error		Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
155	PI426240	9	149.00	0.76	(	0.026	)	0.54	0.89
262	PI174799	8	40.00	0.76	(	0.002	)	0.74	0.78
270	PI426248	8	149.00	0.76	(	0.026	)	0.54	0.89
128	PI426268	9	208.50	0.79	(	0.027	)	0.55	0.92
21	PI183919	8	254.50	0.80	(	0.012	)	0.71	0.87
187	PI352819	8	89.50	0.80	(	0.012	)	0.71	0.87
139	PI633158	9	208.50	0.81	(	0.031	)	0.52	0.94
214	PI169074	8	208.50	0.81	(	0.031	)	0.52	0.94
177	PI163496	9	208.50	0.82	(	0.016	)	0.69	0.90
125	PI352796	8	208.50	0.85	(	0.014	)	0.72	0.92
134	PI633157	8	254.50	0.85	(	0.014	)	0.72	0.92
153	OI 352807	8	89.50	0.85	(	0.014	)	0.72	0.92
143	PI352804	9	254.50	0.86	(	0.016	)	0.71	0.94
176	PI426258	9	270.50	0.86	(	0.016	)	0.71	0.94
251	PI173852	8	208.50	0.86	(	0.016	)	0.71	0.94
8	Ames 9260	8	208.50	0.87	(	0.018	)	0.69	0.95
213	PI370731	8	208.50	0.87	(	0.018	)	0.69	0.95
191	PI164494	9	89.50	0.89	(	0.012	)	0.77	0.95
123	PI419180	9	208.50	0.90	(	0.014	)	0.76	0.96
151	PI116021	9	208.50	0.90	(	0.014	)	0.76	0.96
152	PI125795	9	254.50	0.91	(	0.015	)	0.75	0.97

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

A.3. Median, mean rank and estimated relative treatment effects for the severity of foliar symptoms on 80 *Brassica napus* accessions based on their reaction to inoculation with three *L. maculans* isolates of PG 3.

				Treatment effect				Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect		Standard error		Lower Limit	Upper Limit
5	Ames 19198	7	55.25	0.41	(	0.039	)	0.19	0.67
20	Ames 25116	7	56.00	0.41	(	0.039	)	0.19	0.67
39	PI 169080	7	55.25	0.41	(	0.039	)	0.19	0.67
45	PI 271452	7	99.63	0.41	(	0.039	)	0.19	0.67
46	PI 282571	6	55.25	0.41	(	0.039	)	0.19	0.67
48	PI 286418	7	79.13	0.41	(	0.026	)	0.25	0.58
63	PI 409022	7	92.00	0.41	(	0.039	)	0.19	0.67
72	PI 432395	7	37.38	0.41	(	0.039	)	0.19	0.67
78	PI 458924	7	69.88	0.41	(	0.039	)	0.19	0.67
79	PI 458935	8	103.00	0.41	(	0.039	)	0.19	0.67
85	PI 535865	6	39.25	0.41	(	0.039	)	0.19	0.67
86	PI 458949	6	27.13	0.41	(	0.039	)	0.19	0.67
90	PI 469930	7	55.13	0.41	(	0.039	)	0.19	0.67
98	PI 469803	6	44.38	0.41	(	0.039	)	0.19	0.67
130	PI 649145	7	61.25	0.41	(	0.039	)	0.19	0.67
4	Ames 19197	6	65.38	0.44	(	0.060	)	0.13	0.80
60	PI 365644	7	72.88	0.45	(	0.064	)	0.13	0.82
74	PI 436556	6	56.00	0.45	(	0.032	)	0.26	0.66
104	PI 490024	7	43.88	0.45	(	0.064	)	0.13	0.82
3	Ames 18935	7	60.38	0.46	(	0.033	)	0.25	0.67
18	Ames 25114	7	60.38	0.46	(	0.033	)	0.25	0.67
19	Ames 25115	7	67.38	0.46	(	0.033	)	0.25	0.67
28	Ames 26168	7	60.38	0.46	(	0.033	)	0.25	0.67
34	PI 391553	7	63.25	0.46	(	0.033	)	0.25	0.67
41	PI 250135	7	87.88	0.46	(	0.033	)	0.25	0.67
42	PI 26635	7	63.25	0.46	(	0.033	)	0.25	0.67
51	PI 305281	8	118.88	0.46	(	0.033	)	0.25	0.67
89	PI 458952	7	56.00	0.46	(	0.033	)	0.25	0.67
106	PI 537011	7	98.63	0.46	(	0.033	)	0.25	0.67
123	PI 633163	7	98.63	0.46	(	0.033	)	0.25	0.67
128	PI 633169	7	60.38	0.46	(	0.033	)	0.25	0.67
129	PI 649141	7	98.25	0.46	(	0.065	)	0.13	0.83
40	PI 221971	6	39.25	0.47	(	0.025	)	0.31	0.63
24	Ames 25120	7	69.88	0.48	(	0.053	)	0.18	0.79

A.3. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
25	Ames 26165	6	63.13	0.48	(0.053)	0.18	0.79
31	Ames 26626	6	63.13	0.48	(0.053)	0.18	0.79
100	PI 469832	6	42.75	0.48	(0.053)	0.18	0.79
35	PI 399418	7	72.88	0.49	(0.057)	0.18	0.81
58	PI 311732	6	39.25	0.49	(0.057)	0.18	0.81
88	PI 458951	7	80.00	0.49	(0.057)	0.18	0.81
97	PI 469791	6	56.13	0.49	(0.045)	0.22	0.76
125	PI 633165	7	82.38	0.49	(0.045)	0.22	0.76
10	Ames 19205	7	74.63	0.50	(0.024)	0.35	0.66
113	PI 537020	7	101.75	0.50	(0.024)	0.35	0.66
115	PI 603020	7	87.88	0.50	(0.024)	0.35	0.66
1	Ames 19204	7	72.00	0.53	(0.034)	0.31	0.73
6	Ames 19199	7	72.00	0.53	(0.034)	0.31	0.73
15	Ames 25111	7	72.00	0.53	(0.034)	0.31	0.73
27	Ames 26167	7	72.00	0.53	(0.034)	0.31	0.73
30	Ames 26171	7	72.00	0.53	(0.034)	0.31	0.73
37	PI 458944	7	72.00	0.53	(0.034)	0.31	0.73
43	PI 251614	6	60.38	0.53	(0.034)	0.31	0.73
53	PI 311727	7	63.25	0.53	(0.034)	0.31	0.73
54	PI 311728	7	93.75	0.53	(0.034)	0.31	0.73
55	PI 311729	7	72.00	0.53	(0.034)	0.31	0.73
57	PI 311731	7	72.00	0.53	(0.034)	0.31	0.73
80	PI 458939	6	44.38	0.53	(0.034)	0.31	0.73
83	PI 458946	7	56.00	0.53	(0.034)	0.31	0.73
103	PI 469863	6	56.00	0.53	(0.034)	0.31	0.73
65	PI 431572	7	55.25	0.55	(0.055)	0.22	0.84
2	Ames173847	7	76.25	0.57	(0.021)	0.43	0.70
47	PI 284859	7	55.25	0.57	(0.021)	0.43	0.70
102	PI 469857	7	61.25	0.57	(0.038)	0.32	0.79
107	PI 537012	7	85.38	0.57	(0.021)	0.43	0.70
111	PI 469920	7	60.38	0.57	(0.021)	0.43	0.70
116	PI 26628	7	79.13	0.57	(0.021)	0.43	0.70
127	PI 633168	7	88.88	0.57	(0.038)	0.32	0.79
61	PI 383422	6	45.25	0.59	(0.055)	0.24	0.87
126	PI 633167	7	87.88	0.59	(0.045)	0.30	0.83
66	PI 431574	7	38.50	0.61	(0.048)	0.29	0.85
120	PI 633160	7	74.63	0.61	(0.048)	0.29	0.85

A.3. Continued

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
122	PI 633162	6	48.50	0.61	(0.048)	0.29	0.85
38	PI 169075	7	87.88	0.64	(0.004)	0.62	0.67
71	PI 432394	6	10.13	0.64	(0.004)	0.62	0.67
75	PI 436557	6	39.25	0.64	(0.033)	0.41	0.82
84	PI 458947	7	72.00	0.64	(0.033)	0.41	0.82
109	PI 537014	7	67.75	0.64	(0.004)	0.62	0.67
110	PI 537015	6	22.25	0.64	(0.004)	0.62	0.67
119	PI 603027	6	39.25	0.64	(0.033)	0.41	0.82
121	PI 633161	7	79.13	0.64	(0.004)	0.62	0.67
52	PI 305282	7	113.38	0.65	(0.036)	0.39	0.85
32	Ames 26627	7	93.75	0.66	(0.051)	0.30	0.90
26	Ames 26166	8	96.25	0.67	(0.053)	0.29	0.91
44	PI 269449	7	72.00	0.67	(0.053)	0.29	0.91
7	Ames 19201	7	98.63	0.71	(0.020)	0.56	0.82
13	Ames 25109	7	101.75	0.71	(0.020)	0.56	0.82
21	Ames 25117	7	95.75	0.71	(0.020)	0.56	0.82
62	PI 384536	6	60.75	0.71	(0.020)	0.56	0.82
67	PI 432373	7	75.13	0.71	(0.020)	0.56	0.82
101	PI 469836	7	56.00	0.71	(0.020)	0.56	0.82
108	PI 537013	7	71.13	0.71	(0.020)	0.56	0.82
118	PI 603026	7	74.63	0.71	(0.020)	0.56	0.82
9	Ames 19203	7	94.75	0.72	(0.041)	0.40	0.91
16	Ames 25112	7	100.13	0.72	(0.024)	0.54	0.85
124	PI 26641	7	84.13	0.72	(0.024)	0.54	0.85
22	Ames 25118	7	110.63	0.74	(0.043)	0.39	0.92
23	Ames 25119	7	102.38	0.78	(0.023)	0.59	0.89
68	PI 432391	7	82.38	0.81	(0.027)	0.56	0.93
50	PI 305279	7	56.00	0.84	(0.020)	0.67	0.93
49	PI 305278	7	57.25	0.87	(0.023)	0.63	0.96
131	Dk 3042	8	132.13	0.97	(0.001)	0.95	0.98
11	Ames 21489	8	133.50	0.98	(0.002)	0.95	0.99

Standard errors (*se*) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, *se* can be roughly approximated by *se* / N, in which *se* is the standard error of the mean rank for the i^{th} accession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

A.4. Median, mean rank and estimated relative treatment effects for the severity of foliar symptoms on 80 *Brassica napus* accessions based on their reaction to inoculation with one *L. maculans* isolate of PG 4.

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
20	Ames 25116	7	44.63	0.33	(0.055)	0.09	0.72
89	PI 458952	7	35.75	0.33	(0.055)	0.09	0.72
43	PI 251614	7	60.25	0.35	(0.004)	0.32	0.38
48	PI 286418	7	76.63	0.35	(0.022)	0.22	0.51
54	PI 311728	8	74.38	0.35	(0.004)	0.32	0.38
59	PI 311733	7	25.50	0.35	(0.034)	0.16	0.60
83	PI 458946	8	88.25	0.35	(0.052)	0.11	0.72
91	PI 458954	7	64.00	0.35	(0.034)	0.16	0.60
97	PI 469791	7	64.63	0.35	(0.034)	0.16	0.60
129	PI 649141	8	103.13	0.36	(0.064)	0.08	0.78
8	Ames 19202	7	52.75	0.37	(0.029)	0.20	0.58
18	Ames 25114	7	52.75	0.37	(0.029)	0.20	0.58
19	Ames 25115	7	49.13	0.37	(0.045)	0.14	0.68
33	Ames 26653	7	51.00	0.37	(0.029)	0.20	0.58
117	PI 603024	7	70.63	0.37	(0.029)	0.20	0.58
123	PI 633163	8	87.63	0.37	(0.029)	0.20	0.58
127	PI 633168	8	82.38	0.37	(0.029)	0.20	0.58
128	PI 633169	7	49.13	0.37	(0.029)	0.20	0.58
96	PI 469761	7	35.88	0.38	(0.035)	0.18	0.62
70	PI 432393	8	68.88	0.39	(0.041)	0.17	0.67
77	PI 26637	8	88.25	0.39	(0.052)	0.13	0.73
41	PI 250135	8	98.00	0.40	(0.060)	0.12	0.78
72	PI 432395	7	51.63	0.40	(0.060)	0.12	0.78
17	Ames 25113	7	55.13	0.41	(0.049)	0.15	0.72
24	Ames 25120	7	58.00	0.41	(0.049)	0.15	0.72
45	PI 271452	7	83.13	0.41	(0.049)	0.15	0.72
88	PI 458951	8	97.13	0.41	(0.049)	0.15	0.72
98	PI 469803	7	38.88	0.41	(0.049)	0.15	0.72
125	PI 633165	7	70.50	0.41	(0.049)	0.15	0.72
130	PI 649145	7	50.63	0.41	(0.049)	0.15	0.72
4	Ames 19197	7	55.00	0.42	(0.040)	0.19	0.68
25	Ames 26165	7	56.63	0.42	(0.021)	0.29	0.56
26	Ames 26166	7	56.63	0.42	(0.021)	0.29	0.56
42	PI 26635	7	56.38	0.42	(0.021)	0.29	0.56

A.4. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
104	PI 490024	7	64.38	0.42	(0.040)	0.19	0.68
111	PI 469920	8	100.13	0.42	(0.021)	0.29	0.56
113	PI 537020	8	87.13	0.42	(0.021)	0.29	0.56
116	PI 26628	7	60.25	0.42	(0.021)	0.29	0.56
76	PI 443015	7	55.13	0.43	(0.044)	0.18	0.71
126	PI 633167	8	106.88	0.43	(0.044)	0.18	0.71
53	PI 311727	8	87.63	0.44	(0.035)	0.24	0.67
93	PI 469730	7	44.63	0.46	(0.068)	0.12	0.84
56	PI 311730	7	48.50	0.48	(0.037)	0.26	0.71
58	PI 311732	7	62.50	0.48	(0.051)	0.19	0.78
64	PI 431571	8	75.75	0.48	(0.037)	0.26	0.71
78	PI 458924	6	35.88	0.48	(0.037)	0.26	0.71
87	PI 458940	7	50.50	0.48	(0.037)	0.26	0.71
110	PI 537015	7	20.00	0.48	(0.037)	0.26	0.71
120	PI 633160	7	73.13	0.48	(0.064)	0.14	0.84
99	PI 469814	7	25.50	0.49	(0.024)	0.34	0.65
112	PI 537019	7	83.50	0.49	(0.024)	0.34	0.65
28	Ames 26168	7	69.13	0.50	(0.046)	0.23	0.77
75	PI 436557	7	35.88	0.50	(0.036)	0.28	0.72
81	PI 469882	7	48.88	0.50	(0.046)	0.23	0.77
115	PI 603020	7	67.63	0.51	(0.036)	0.29	0.73
40	PI 221971	7	41.00	0.52	(0.030)	0.32	0.70
74	PI 436556	7	56.63	0.52	(0.036)	0.30	0.74
68	PI 432391	8	91.75	0.53	(0.058)	0.19	0.84
103	PI 469863	7	58.88	0.53	(0.058)	0.19	0.84
7	Ames 19201	7	75.75	0.55	(0.036)	0.32	0.76
30	Ames 26171	7	75.75	0.55	(0.036)	0.32	0.76
31	Ames 26626	7	75.75	0.55	(0.036)	0.32	0.76
35	PI 399418	8	80.13	0.55	(0.053)	0.23	0.84
39	PI 169080	8	78.88	0.55	(0.036)	0.32	0.76
47	PI 284859	7	31.88	0.55	(0.036)	0.32	0.76
52	PI 305282	8	108.38	0.55	(0.036)	0.32	0.76
60	PI 365644	7	65.75	0.55	(0.036)	0.32	0.76
62	PI 384536	7	75.38	0.55	(0.036)	0.32	0.76
65	PI 431572	7	82.13	0.55	(0.036)	0.32	0.76
71	PI 432394	8	81.75	0.55	(0.036)	0.32	0.76
10	Ames 19205	7	74.75	0.56	(0.021)	0.42	0.69

A.4. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
109	PI 537014	7	53.63	0.56	(0.021)	0.42	0.69
38	PI 169075	7	85.25	0.58	(0.044)	0.29	0.82
69	PI 432392	8	112.13	0.60	(0.055)	0.25	0.87
90	PI 469930	7	78.00	0.60	(0.055)	0.25	0.87
122	PI 633162	7	51.38	0.60	(0.055)	0.25	0.87
3	Ames 18935	7	87.63	0.61	(0.043)	0.32	0.83
22	Ames 25118	8	87.63	0.61	(0.043)	0.32	0.83
44	PI 269449	7	48.50	0.61	(0.043)	0.32	0.83
51	PI 305281	8	90.63	0.61	(0.043)	0.32	0.83
86	PI 458949	7	25.50	0.61	(0.043)	0.32	0.83
118	PI 603026	7	56.63	0.61	(0.043)	0.32	0.83
1	Ames 19204	8	83.50	0.62	(0.030)	0.41	0.79
6	Ames 19199	7	81.00	0.62	(0.030)	0.41	0.79
36	PI 458941	7	82.13	0.62	(0.030)	0.41	0.79
63	PI 409022	8	93.38	0.62	(0.030)	0.41	0.79
79	PI 458935	8	98.00	0.62	(0.049)	0.29	0.87
107	PI 537012	8	107.38	0.62	(0.030)	0.41	0.79
108	PI 537013	8	72.00	0.62	(0.030)	0.41	0.79
9	Ames 19203	8	89.38	0.65	(0.038)	0.38	0.85
100	PI 469832	7	53.50	0.66	(0.054)	0.28	0.90
5	Ames 19198	7	88.38	0.68	(0.035)	0.42	0.86
13	Ames 25109	8	95.38	0.68	(0.035)	0.42	0.86
49	PI 305278	7	57.50	0.68	(0.035)	0.42	0.86
61	PI 383422	7	46.63	0.68	(0.035)	0.42	0.86
66	PI 431574	7	62.50	0.68	(0.035)	0.42	0.86
2	Ames173847	8	93.88	0.69	(0.017)	0.57	0.79
37	PI 458944	8	93.88	0.69	(0.017)	0.57	0.79
55	PI 311729	7	63.13	0.69	(0.017)	0.57	0.79
80	PI 458939	7	61.00	0.69	(0.017)	0.57	0.79
101	PI 469836	7	56.38	0.69	(0.017)	0.57	0.79
32	Ames26627	8	99.88	0.71	(0.056)	0.29	0.94
84	PI 458947	8	94.75	0.73	(0.037)	0.44	0.90
124	PI 26641	8	100.13	0.73	(0.037)	0.44	0.90
21	Ames25117	8	102.63	0.74	(0.019)	0.60	0.85
106	PI 537011	8	93.88	0.74	(0.019)	0.60	0.85
119	PI 603027	7	31.38	0.74	(0.019)	0.60	0.85
15	Ames 25111	8	104.25	0.78	(0.026)	0.56	0.90

A.4. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
102	PI 469857	7	46.88	0.78	(0.026)	0.56	0.90
121	PI 633161	7	58.88	0.78	(0.026)	0.56	0.90
16	Ames 25112	8	109.75	0.80	(0.017)	0.67	0.89
50	PI 305279	7	35.13	0.80	(0.017)	0.67	0.89
67	PI 432373	7	75.38	0.83	(0.021)	0.64	0.93
23	Ames 25119	8	117.13	0.86	(0.003)	0.84	0.88
131	Dk 3042	8	117.13	0.87	(0.003)	0.82	0.88
11	Ames21489	9	135.38	0.99	(0.001)	0.98	1.00

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

A.5. Median, mean rank and estimated relative treatment effects for the severity of foliar symptoms on 356 *Brassica juncea* accessions based on their reaction1 to inoculation with three *L. maculans* isolates of PG 3.

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
133	PI 390135	6	72.25	0.22	(0.059)	0.03	0.76
137	PI390139	6	157.50	0.22	(0.059)	0.03	0.76
186	PI 426335	6	131.88	0.22	(0.033)	0.07	0.52
187	PI 426336	5	43.00	0.22	(0.058)	0.03	0.74
79	PI250130	6	41.63	0.24	(0.031)	0.09	0.51
162	PI 426311	6	43.00	0.24	(0.031)	0.09	0.51
340	PI633077	6	128.75	0.24	(0.032)	0.08	0.51
400	PI 649125	6	189.75	0.24	(0.032)	0.08	0.51
56	PI 181034	6	151.25	0.25	(0.028)	0.11	0.49
130	PI370746	6	72.25	0.25	(0.049)	0.05	0.67
132	PI387819	6	72.25	0.25	(0.049)	0.05	0.67
138	PI 390140	5	194.50	0.25	(0.028)	0.11	0.49
144	PI 426292	6	72.25	0.25	(0.049)	0.05	0.67
188	PI 426337	6	72.25	0.25	(0.049)	0.05	0.67
204	PI 426353	6	128.50	0.25	(0.028)	0.11	0.49
210	PI 426359	6	132.00	0.25	(0.028)	0.11	0.49
218	PI 426367	6	128.25	0.25	(0.049)	0.05	0.67
252	PI426403	6	25.38	0.25	(0.028)	0.11	0.49
304	PI470082	6	83.38	0.25	(0.028)	0.11	0.49
313	PI 478332	6	274.00	0.25	(0.049)	0.05	0.67
316	PI478335	6	197.88	0.25	(0.028)	0.11	0.49
330	PI537008	6	154.25	0.25	(0.028)	0.11	0.49
352	PI633093	6	113.00	0.25	(0.049)	0.05	0.67
357	PI 633098	6	148.75	0.25	(0.028)	0.11	0.49
387	PI649112	6	197.88	0.25	(0.028)	0.11	0.49
394	PI649119	6	218.50	0.25	(0.028)	0.11	0.49
154	PI 426302	6	59.75	0.26	(0.030)	0.10	0.50
347	PI633088	6	113.00	0.26	(0.029)	0.11	0.50
181	PI426330	6	124.88	0.28	(0.025)	0.14	0.48
334	PI 603011	5	100.25	0.28	(0.025)	0.14	0.48
356	PI633097	6	238.50	0.28	(0.025)	0.14	0.48
364	PI633105	6	100.25	0.28	(0.025)	0.14	0.48
396	PI649121	6	163.75	0.28	(0.025)	0.14	0.48

A.5. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
117	PI340219	6	194.50	0.30	(0.022)	0.17	0.46
177	PI 426326	6	72.25	0.30	(0.037)	0.11	0.59
327	PI537005	6	83.63	0.30	(0.022)	0.17	0.46
322	PI 531268	6	208.50	0.31	(0.045)	0.09	0.66
209	PI426358	6	174.50	0.32	(0.042)	0.11	0.65
248	PI426399	6	111.63	0.32	(0.042)	0.11	0.65
286	PI458993	6	182.75	0.32	(0.042)	0.11	0.65
342	PI633083	6	119.25	0.32	(0.030)	0.16	0.55
359	PI633100	6	61.63	0.32	(0.042)	0.11	0.65
5	PI21754	6	126.00	0.33	(0.029)	0.16	0.55
373	PI 633114	6	151.88	0.33	(0.043)	0.11	0.65
55	PI181033	7	132.00	0.34	(0.025)	0.20	0.53
160	PI426308	6	186.75	0.34	(0.025)	0.20	0.53
207	PI426356	6	111.63	0.34	(0.040)	0.13	0.64
263	PI432381	6	174.50	0.34	(0.025)	0.20	0.53
312	PI478331	6	197.88	0.34	(0.025)	0.20	0.53
324	PI531270	6	197.88	0.34	(0.025)	0.20	0.53
326	PI537004	6	174.50	0.34	(0.025)	0.20	0.53
328	PI537006	6	182.75	0.34	(0.025)	0.20	0.53
333	PI549282	6	76.63	0.34	(0.025)	0.20	0.53
337	PI 603014	5	50.88	0.34	(0.025)	0.20	0.53
348	PI633089	6	240.50	0.34	(0.025)	0.20	0.53
372	PI633113	6	193.88	0.34	(0.025)	0.20	0.53
385	PI649110	6	126.00	0.34	(0.025)	0.20	0.53
391	PI 649116	6	123.63	0.34	(0.025)	0.20	0.53
397	PI649122	6	155.25	0.34	(0.025)	0.20	0.53
32	PI179644	6	258.25	0.36	(0.019)	0.24	0.50
116	PI340218	6	172.25	0.36	(0.019)	0.24	0.50
131	PI 379103	6	224.00	0.36	(0.019)	0.24	0.50
201	PI426350	6	213.00	0.36	(0.019)	0.24	0.50
216	PI426365	6	271.00	0.36	(0.051)	0.11	0.72
268	PI432386	6	238.50	0.36	(0.051)	0.11	0.72
272	PI432390	6	216.75	0.36	(0.019)	0.24	0.50
282	PI458942	6	124.38	0.36	(0.051)	0.11	0.72
318	PI478337	6	123.50	0.36	(0.036)	0.16	0.63
339	PI 603016	6	178.63	0.36	(0.019)	0.24	0.50
362	PI633103	6	281.25	0.36	(0.019)	0.24	0.50
211	PI426360	6	98.25	0.38	(0.049)	0.13	0.72

A.5. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect		Treatment effect: Standard error		Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
277	PI449439	6	172.25	0.38	(	0.049	)	0.13	0.72
283	PI458943	6	80.88	0.38	(	0.049	)	0.13	0.72
25	PI179183	7	192.25	0.39	(	0.050	)	0.13	0.74
196	PI426345	6	244.38	0.39	(	0.060	)	0.10	0.79
254	PI426405	6	181.38	0.39	(	0.050	)	0.13	0.74
344	PI633085	6	161.25	0.39	(	0.060	)	0.10	0.79
329	PI537007	6	215.00	0.40	(	0.045	)	0.15	0.71
156	PI426304	6	152.25	0.41	(	0.036	)	0.20	0.66
198	PI426347	6	198.25	0.41	(	0.036	)	0.20	0.66
247	PI426398	6	238.25	0.41	(	0.036	)	0.20	0.66
262	PI432380	6	257.13	0.41	(	0.036	)	0.20	0.66
294	PI459001	6	146.25	0.41	(	0.036	)	0.20	0.66
311	PI478330	6	104.63	0.41	(	0.036	)	0.20	0.66
378	PI649103	7	174.50	0.41	(	0.036	)	0.20	0.66
45	PI180264	6	245.00	0.43	(	0.002	)	0.41	0.44
67	PI192936	6	85.88	0.43	(	0.002	)	0.41	0.44
104	PI 340205	5	141.63	0.43	(	0.002	)	0.41	0.44
106	PI340207	6	257.50	0.43	(	0.002	)	0.41	0.44
108	PI340210	6	193.50	0.43	(	0.002	)	0.41	0.44
111	PI 340213	6	218.50	0.43	(	0.002	)	0.41	0.44
113	PI340215	6	202.38	0.43	(	0.002	)	0.41	0.44
119	PI 340221	5	245.00	0.43	(	0.002	)	0.41	0.44
127	PI 358591	5	265.75	0.43	(	0.002	)	0.41	0.44
128	PI370744	6	265.75	0.43	(	0.002	)	0.41	0.44
129	PI370745	6	154.25	0.43	(	0.002	)	0.41	0.44
136	PI390138	6	194.50	0.43	(	0.002	)	0.41	0.44
145	PI426293	6	240.50	0.43	(	0.002	)	0.41	0.44
152	PI426300	6	198.00	0.43	(	0.002	)	0.41	0.44
182	PI426331	6	139.00	0.43	(	0.031	)	0.24	0.64
190	PI426339	6	152.25	0.43	(	0.002	)	0.41	0.44
195	PI426344	6	154.25	0.43	(	0.002	)	0.41	0.44
203	PI426352	6	303.00	0.43	(	0.002	)	0.41	0.44
214	PI426363	6	112.75	0.43	(	0.002	)	0.41	0.44
256	PI 426407	6	45.88	0.43	(	0.002	)	0.41	0.44
257	PI426408	6	45.88	0.43	(	0.002	)	0.41	0.44
260	PI432378	6	194.50	0.43	(	0.002	)	0.41	0.44
267	PI432385	6	244.75	0.43	(	0.002	)	0.41	0.44
278	PI458927	6	276.25	0.43	(	0.002	)	0.41	0.44

A.5. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect		Standard error		Confidence Interval (95%): Lower Limit	Upper Limit
279	PI458928	6	194.50	0.43	(	0.002	)	0.41	0.44
284	PI458978	6	103.63	0.43	(	0.002	)	0.41	0.44
290	PI458997	6	124.00	0.43	(	0.002	)	0.41	0.44
292	PI458999	6	152.25	0.43	(	0.002	)	0.41	0.44
301	PI459008	6	45.88	0.43	(	0.002	)	0.41	0.44
341	PI 633078	6	151.88	0.43	(	0.002	)	0.41	0.44
345	PI633086	6	116.88	0.43	(	0.031	)	0.24	0.64
358	PI 633099	6	157.50	0.43	(	0.002	)	0.41	0.44
375	PI633116	7	257.13	0.43	(	0.031	)	0.24	0.64
402	PI 163497	6	214.25	0.43	(	0.002	)	0.41	0.44
85	PI250140	7	194.25	0.45	(	0.044	)	0.19	0.74
86	PI251239	6	151.88	0.45	(	0.044	)	0.19	0.74
97	PI288725	7	228.38	0.45	(	0.044	)	0.19	0.74
115	PI340217	6	187.25	0.45	(	0.044	)	0.19	0.74
146	PI 426294	6	147.63	0.45	(	0.054	)	0.15	0.79
171	PI426320	6	182.38	0.45	(	0.044	)	0.19	0.74
172	PI426321	6	142.13	0.45	(	0.054	)	0.15	0.79
174	PI426323	6	146.25	0.45	(	0.044	)	0.19	0.74
215	PI426364	6	106.13	0.45	(	0.044	)	0.19	0.74
223	PI426373	6	201.63	0.45	(	0.044	)	0.19	0.74
274	PI449436	6	174.50	0.45	(	0.044	)	0.19	0.74
314	PI478333	6	131.88	0.45	(	0.044	)	0.19	0.74
315	PI478334	6	157.63	0.45	(	0.044	)	0.19	0.74
320	PI500675	6	127.25	0.45	(	0.044	)	0.19	0.74
331	PI537018	6	154.25	0.45	(	0.054	)	0.15	0.79
343	PI633084	6	148.50	0.45	(	0.044	)	0.19	0.74
365	PI 633106	5	158.88	0.45	(	0.044	)	0.19	0.74
377	PI649102	6	107.63	0.45	(	0.044	)	0.19	0.74
383	PI649108	7	232.25	0.45	(	0.044	)	0.19	0.74
65	PI183117	7	202.38	0.46	(	0.062	)	0.13	0.83
285	PI458992	6	98.25	0.46	(	0.062	)	0.13	0.83
323	PI531269	6	111.63	0.46	(	0.062	)	0.13	0.83
8	PI163494	7	157.63	0.47	(	0.040	)	0.22	0.73
10	PI169077	7	215.88	0.47	(	0.040	)	0.22	0.73
17	PI173874	6	174.00	0.47	(	0.050	)	0.18	0.78
41	PI 179857	7	232.25	0.47	(	0.040	)	0.22	0.73
44	PI179862	6	241.38	0.47	(	0.040	)	0.22	0.73
84	PI250139	6	229.13	0.47	(	0.040	)	0.22	0.73

A.5. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
105	PI340206	6	197.88	0.47	(0.040)	0.22	0.73
149	PI426297	6	157.63	0.47	(0.040)	0.22	0.73
158	PI426306	6	152.25	0.47	(0.040)	0.22	0.73
179	PI426328	6	132.00	0.47	(0.040)	0.22	0.73
180	PI426329	6	127.75	0.47	(0.040)	0.22	0.73
222	PI426372	6	142.13	0.47	(0.040)	0.22	0.73
226	PI426376	6	263.38	0.47	(0.040)	0.22	0.73
270	PI432388	6	190.25	0.47	(0.040)	0.22	0.73
271	PI432389	6	220.75	0.47	(0.040)	0.22	0.73
309	PI478328	6	194.50	0.47	(0.040)	0.22	0.73
346	PI633087	6	144.50	0.47	(0.040)	0.22	0.73
19	PI175068	6	232.25	0.48	(0.059)	0.15	0.83
398	PI 649123	5	222.13	0.48	(0.071)	0.11	0.87
403	PI 175608	5	302.50	0.48	(0.041)	0.22	0.74
6	PI113310	7	210.88	0.50	(0.019)	0.37	0.63
61	PI 181043	7	145.00	0.50	(0.036)	0.27	0.73
72	PI211000	7	144.00	0.50	(0.019)	0.37	0.63
76	PI 215636	7	126.50	0.50	(0.019)	0.37	0.63
107	PI340209	6	174.50	0.50	(0.019)	0.37	0.63
110	PI340212	6	212.50	0.50	(0.019)	0.37	0.63
114	PI340216	6	190.50	0.50	(0.019)	0.37	0.63
135	PI 390137	5	257.13	0.50	(0.019)	0.37	0.63
163	PI426312	6	166.00	0.50	(0.019)	0.37	0.63
170	PI426319	6	225.00	0.50	(0.019)	0.37	0.63
236	PI426386	6	172.25	0.50	(0.019)	0.37	0.63
237	PI426387	6	118.50	0.50	(0.056)	0.18	0.83
265	PI432383	6	251.00	0.50	(0.019)	0.37	0.63
288	PI458995	6	163.75	0.50	(0.019)	0.37	0.63
317	PI478336	6	168.38	0.50	(0.068)	0.13	0.87
349	PI633090	7	221.38	0.50	(0.019)	0.37	0.63
351	PI 633092	6	194.50	0.50	(0.019)	0.37	0.63
386	PI649111	6	202.50	0.50	(0.019)	0.37	0.63
389	PI 649114	5	238.00	0.50	(0.096)	0.07	0.94
37	PI179654	6	178.00	0.51	(0.048)	0.22	0.80
219	PI426369	6	162.25	0.51	(0.048)	0.22	0.80
266	PI432384	6	355.63	0.51	(0.048)	0.22	0.80
306	PI478325	6	227.00	0.51	(0.048)	0.22	0.80
382	PI649107	6	147.63	0.51	(0.048)	0.22	0.80

A.5. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
388	PI649113	6	169.88	0.51	(0.048)	0.22	0.80
393	PI649118	6	224.75	0.51	(0.048)	0.22	0.80
95	PI286417	7	304.25	0.52	(0.065)	0.15	0.87
29	PI179636	7	162.38	0.53	(0.029)	0.33	0.72
35	PI179651	7	202.38	0.53	(0.029)	0.33	0.72
42	PI179858	7	151.88	0.53	(0.029)	0.33	0.72
50	PI180420	7	258.25	0.53	(0.029)	0.33	0.72
64	PI183115	7	152.25	0.53	(0.043)	0.26	0.79
73	PI212082	6	274.88	0.53	(0.029)	0.33	0.72
80	PI 250131	6	244.38	0.53	(0.029)	0.33	0.72
88	PI257240	7	307.38	0.53	(0.029)	0.33	0.72
98	PI288727	6	242.75	0.53	(0.029)	0.33	0.72
99	PI288730	6	200.13	0.53	(0.029)	0.33	0.72
109	PI340211	6	242.75	0.53	(0.029)	0.33	0.72
120	PI340223	6	190.25	0.53	(0.029)	0.33	0.72
121	PI346876	6	172.25	0.53	(0.029)	0.33	0.72
123	PI347616	6	265.75	0.53	(0.029)	0.33	0.72
143	PI426291	6	227.00	0.53	(0.029)	0.33	0.72
161	PI426310	6	111.63	0.53	(0.029)	0.33	0.72
168	PI426317	6	255.25	0.53	(0.029)	0.33	0.72
175	PI426324	6	154.25	0.53	(0.029)	0.33	0.72
183	PI426332	6	139.00	0.53	(0.029)	0.33	0.72
184	PI426333	6	154.25	0.53	(0.029)	0.33	0.72
185	PI426334	6	131.88	0.53	(0.029)	0.33	0.72
202	PI426351	6	204.75	0.53	(0.029)	0.33	0.72
221	PI426371	6	244.25	0.53	(0.029)	0.33	0.72
227	PI426377	6	242.25	0.53	(0.029)	0.33	0.72
230	PI426380	6	162.13	0.53	(0.029)	0.33	0.72
238	PI426388	6	131.88	0.53	(0.043)	0.26	0.79
240	PI426390	6	182.13	0.53	(0.029)	0.33	0.72
241	PI426391	6	227.00	0.53	(0.029)	0.33	0.72
242	PI426393	6	194.50	0.53	(0.029)	0.33	0.72
245	PI426396	6	308.75	0.53	(0.029)	0.33	0.72
264	PI432382	6	204.75	0.53	(0.029)	0.33	0.72
273	PI436559	6	174.50	0.53	(0.029)	0.33	0.72
280	PI458929	6	240.50	0.53	(0.029)	0.33	0.72
291	PI458998	6	132.00	0.53	(0.029)	0.33	0.72
293	PI459000	6	111.63	0.53	(0.043)	0.26	0.79

A.5. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
302	PI459009	6	111.63	0.53	(0.029)	0.33	0.72
310	PI478329	6	218.25	0.53	(0.029)	0.33	0.72
319	PI500651	6	111.63	0.53	(0.043)	0.26	0.79
355	PI633096	6	332.50	0.53	(0.029)	0.33	0.72
363	PI633104	6	288.50	0.53	(0.029)	0.33	0.72
368	PI633109	6	194.50	0.53	(0.029)	0.33	0.72
371	PI633112	6	257.13	0.53	(0.029)	0.33	0.72
395	PI649120	6	103.75	0.53	(0.029)	0.33	0.72
404	PI207465	6	271.00	0.53	(0.029)	0.33	0.72
89	PI269432	7	306.50	0.55	(0.052)	0.22	0.84
148	PI426296	7	253.63	0.55	(0.055)	0.21	0.85
151	PI 426299	6	151.88	0.55	(0.052)	0.22	0.84
169	PI426318	6	132.00	0.55	(0.052)	0.22	0.84
205	PI426354	6	172.38	0.55	(0.052)	0.22	0.84
213	PI426362	6	157.63	0.55	(0.052)	0.22	0.84
251	PI426402	6	157.63	0.55	(0.052)	0.22	0.84
234	PI426384	6	222.50	0.56	(0.113)	0.05	0.97
246	PI426397	6	212.50	0.56	(0.022)	0.41	0.71
30	PI179637	7	201.63	0.57	(0.039)	0.30	0.80
49	PI180417	7	306.50	0.57	(0.047)	0.26	0.84
102	PI323270	6	182.00	0.57	(0.047)	0.26	0.84
122	PI347615	6	111.63	0.57	(0.047)	0.26	0.84
141	PI 426178	7	213.63	0.57	(0.039)	0.30	0.80
275	PI449437	6	280.25	0.57	(0.047)	0.26	0.84
297	PI459004	6	194.50	0.57	(0.047)	0.26	0.84
153	PI426301	6	296.00	0.58	(0.058)	0.21	0.88
369	PI633110	7	246.50	0.58	(0.057)	0.21	0.87
38	PI179850	6	308.75	0.60	(0.052)	0.25	0.87
51	PI 180421	6	172.25	0.60	(0.029)	0.39	0.78
60	PI181042	6	216.25	0.60	(0.029)	0.39	0.78
70	PI209021	7	212.50	0.60	(0.029)	0.39	0.78
75	PI212970	7	194.50	0.60	(0.029)	0.39	0.78
100	PI311726	6	151.25	0.60	(0.029)	0.39	0.78
112	PI340214	6	214.25	0.60	(0.029)	0.39	0.78
140	PI 418956	5	182.13	0.60	(0.029)	0.39	0.78
157	PI426305	6	111.63	0.60	(0.029)	0.39	0.78
166	PI 426315	6	162.25	0.60	(0.029)	0.39	0.78
173	PI426322	6	154.25	0.60	(0.029)	0.39	0.78

A.5. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect		Treatment effect: Standard error		Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
199	PI426348	6	257.13	0.60	(	0.029	)	0.39	0.78
220	PI426370	6	244.25	0.60	(	0.029	)	0.39	0.78
225	PI426375	6	142.13	0.60	(	0.029	)	0.39	0.78
229	PI426379	6	132.00	0.60	(	0.029	)	0.39	0.78
232	PI426382	6	224.63	0.60	(	0.029	)	0.39	0.78
243	PI426394	6	224.63	0.60	(	0.029	)	0.39	0.78
269	PI432387	6	174.50	0.60	(	0.029	)	0.39	0.78
287	PI458994	7	182.00	0.60	(	0.029	)	0.39	0.78
295	PI459002	6	194.25	0.60	(	0.029	)	0.39	0.78
325	PI531271	7	244.38	0.60	(	0.029	)	0.39	0.78
208	PI426357	6	271.00	0.62	(	0.052	)	0.26	0.88
321	PI531267	6	244.38	0.62	(	0.052	)	0.26	0.88
361	PI633102	6	284.50	0.62	(	0.063	)	0.20	0.91
235	PI426385	6	227.00	0.63	(	0.036	)	0.37	0.83
3	Ames15649	6	142.13	0.64	(	0.034	)	0.39	0.83
12	PI169085	7	201.63	0.64	(	0.034	)	0.39	0.83
14	PI173865	6	244.25	0.64	(	0.034	)	0.39	0.83
16	PI173873	7	240.50	0.64	(	0.034	)	0.39	0.83
18	PI174801	7	257.13	0.64	(	0.034	)	0.39	0.83
20	PI175082	6	141.88	0.64	(	0.034	)	0.39	0.83
23	PI175607	6	184.63	0.64	(	0.034	)	0.39	0.83
24	PI176884	7	198.25	0.64	(	0.034	)	0.39	0.83
28	PI179635	7	276.75	0.64	(	0.034	)	0.39	0.83
33	PI179647	7	335.00	0.64	(	0.034	)	0.39	0.83
36	PI 179653	7	287.63	0.64	(	0.034	)	0.39	0.83
43	PI179859	6	258.25	0.64	(	0.034	)	0.39	0.83
53	PI181017	6	132.00	0.64	(	0.034	)	0.39	0.83
54	PI181026	7	220.50	0.64	(	0.034	)	0.39	0.83
58	PI181040	6	258.25	0.64	(	0.034	)	0.39	0.83
59	PI181041	7	232.75	0.64	(	0.034	)	0.39	0.83
62	PI182921	6	228.75	0.64	(	0.034	)	0.39	0.83
66	PI 183437	6	111.63	0.64	(	0.034	)	0.39	0.83
68	PI195553	6	290.38	0.64	(	0.034	)	0.39	0.83
69	PI208734	7	256.50	0.64	(	0.034	)	0.39	0.83
81	PI 250133	7	268.75	0.64	(	0.034	)	0.39	0.83
82	PI250134	7	293.00	0.64	(	0.034	)	0.39	0.83
83	PI250137	7	285.13	0.64	(	0.034	)	0.39	0.83
90	PI269448	6	195.88	0.64	(	0.034	)	0.39	0.83

A.5. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
91	PI 271442	7	320.88	0.64	(0.034)	0.39	0.83
92	PI271453	7	259.88	0.64	(0.034)	0.39	0.83
93	PI271455	6	284.25	0.64	(0.034)	0.39	0.83
101	PI311734	6	177.00	0.64	(0.034)	0.39	0.83
159	PI426307	7	182.13	0.64	(0.034)	0.39	0.83
165	PI426314	6	142.13	0.64	(0.034)	0.39	0.83
167	PI426316	6	264.00	0.64	(0.034)	0.39	0.83
193	PI426342	7	257.13	0.64	(0.058)	0.24	0.91
200	PI426349	7	310.13	0.64	(0.034)	0.39	0.83
206	PI426355	7	274.63	0.64	(0.034)	0.39	0.83
224	PI426374	7	206.25	0.64	(0.034)	0.39	0.83
228	PI426378	6	111.63	0.64	(0.034)	0.39	0.83
231	PI426381	6	228.38	0.64	(0.034)	0.39	0.83
239	PI426389	6	196.38	0.64	(0.034)	0.39	0.83
259	PI432377	7	148.75	0.64	(0.034)	0.39	0.83
261	PI432379	7	172.25	0.64	(0.034)	0.39	0.83
276	PI449438	7	293.00	0.64	(0.034)	0.39	0.83
296	PI459003	6	111.63	0.64	(0.034)	0.39	0.83
298	PI459005	6	257.13	0.64	(0.034)	0.39	0.83
299	PI459006	6	174.50	0.64	(0.034)	0.39	0.83
308	PI478327	6	194.50	0.64	(0.034)	0.39	0.83
332	PI537021	6	154.25	0.64	(0.034)	0.39	0.83
350	PI633091	6	227.00	0.64	(0.034)	0.39	0.83
354	PI633095	6	324.88	0.64	(0.034)	0.39	0.83
360	PI633101	7	290.75	0.64	(0.046)	0.31	0.87
381	PI649106	6	172.25	0.64	(0.034)	0.39	0.83
384	PI649109	6	172.25	0.64	(0.034)	0.39	0.83
1	Ames 9914	7	236.25	0.65	(0.054)	0.26	0.91
11	PI169078	6	204.50	0.67	(0.025)	0.48	0.81
15	PI173872	6	272.00	0.67	(0.040)	0.36	0.88
31	PI 179640	6	220.50	0.67	(0.040)	0.36	0.88
39	PI179854	6	327.25	0.67	(0.040)	0.36	0.88
52	PI180422	6	262.25	0.67	(0.040)	0.36	0.88
57	PI181035	6	196.25	0.67	(0.040)	0.36	0.88
74	PI212594	7	292.38	0.67	(0.040)	0.36	0.88
94	PI280637	6	264.50	0.67	(0.039)	0.37	0.87
124	PI347617	6	275.38	0.67	(0.025)	0.48	0.81
164	PI426313	7	221.88	0.67	(0.040)	0.36	0.88

A.5. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect		Treatment effect: Standard error		Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
22	PI175602	6	197.88	0.68	(	0.048	)	0.31	0.90
379	PI 649104	5	215.00	0.68	(	0.048	)	0.31	0.90
249	PI426400	7	317.88	0.70	(	0.028	)	0.49	0.86
250	PI426401	7	240.50	0.70	(	0.028	)	0.49	0.86
289	PI458996	7	363.25	0.70	(	0.076	)	0.16	0.96
300	PI459007	7	245.00	0.70	(	0.028	)	0.49	0.86
303	PI459010	7	194.50	0.70	(	0.028	)	0.49	0.86
305	PI470241	7	257.13	0.70	(	0.028	)	0.49	0.86
353	PI633094	7	281.25	0.70	(	0.028	)	0.49	0.86
376	PI649101	6	194.50	0.70	(	0.044	)	0.35	0.91
7	PI120923	6	284.50	0.71	(	0.051	)	0.30	0.93
71	PI 209781	6	321.00	0.71	(	0.052	)	0.30	0.93
34	PI179649	6	312.13	0.73	(	0.033	)	0.46	0.90
63	PI183112	6	305.63	0.73	(	0.033	)	0.46	0.90
4	Ames21749	8	278.88	0.74	(	0.029	)	0.50	0.89
87	PI254361	6	275.00	0.74	(	0.029	)	0.50	0.89
40	PI179855	7	204.88	0.77	(	0.033	)	0.48	0.92
258	PI432367	7	242.75	0.77	(	0.012	)	0.68	0.85
217	PI426366	7	355.63	0.78	(	0.034	)	0.47	0.93
233	PI426383	7	257.13	0.78	(	0.034	)	0.47	0.93
47	PI180267	6	319.25	0.80	(	0.018	)	0.65	0.90
96	PI 288724	6	233.13	0.80	(	0.036	)	0.46	0.95
370	PI633111	6	329.38	0.80	(	0.018	)	0.65	0.90
46	PI 180266	6	264.13	0.81	(	0.010	)	0.73	0.87
77	PI217516	6	257.13	0.81	(	0.037	)	0.44	0.96
307	PI478326	7	257.13	0.81	(	0.010	)	0.73	0.87
191	PI426340	7	307.50	0.82	(	0.038	)	0.43	0.96
253	PI426404	7	347.13	0.83	(	0.022	)	0.63	0.93
13	PI173857	6	314.63	0.84	(	0.016	)	0.70	0.93
26	PI 179191	7	301.13	0.84	(	0.016	)	0.70	0.93
27	PI179192	6	301.13	0.84	(	0.015	)	0.70	0.92
2	Ames15645	6	293.13	0.85	(	0.002	)	0.83	0.86
9	PI169076	6	304.25	0.85	(	0.002	)	0.83	0.86
48	PI180269	7	257.13	0.88	(	0.008	)	0.80	0.92
406	PI649162	6	314.63	0.88	(	0.008	)	0.80	0.92
244	PI426395	8	347.13	0.91	(	0.011	)	0.80	0.97
405	PI 426281	5	325.75	0.91	(	0.011	)	0.80	0.97
150	PI426298	7	348.50	0.92	(	0.012	)	0.79	0.97

A.5. Continued

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
176	PI426325	8	268.38	0.92	(0.012)	0.79	0.97
178	PI426327	8	268.38	0.92	(0.012)	0.79	0.97
407	Dk 3042	8	358.38	0.98	(0.001)	0.98	0.99
192	PI426341	7	385.75	0.99	(0.002)	0.96	1.00

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

A.6. Median, mean rank and estimated relative treatment effects for the severity of foliar symptoms on 356 *Brassica juncea* accessions based on their reaction to inoculation with one *L. maculans* isolate of PG 4.

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
67	PI192936	7	85.88	0.25	(0.025)	0.11	0.46
304	PI 470082	6	83.38	0.25	(0.025)	0.11	0.46
364	PI633105	7	100.25	0.25	(0.047)	0.06	0.66
392	PI649117	7	106.50	0.25	(0.025)	0.11	0.46
218	PI426367	7	128.25	0.26	(0.067)	0.03	0.80
327	PI537005	7	83.63	0.26	(0.039)	0.08	0.59
338	PI603015	7	108.25	0.27	(0.045)	0.07	0.64
181	PI 426330	7	124.88	0.28	(0.035)	0.11	0.57
211	PI426360	7	98.25	0.28	(0.035)	0.11	0.57
215	PI 426364	6	106.13	0.28	(0.022)	0.15	0.46
284	PI458978	7	103.63	0.28	(0.022)	0.15	0.46
285	PI 458992	6	98.25	0.28	(0.035)	0.11	0.57
311	PI478330	7	104.63	0.28	(0.035)	0.11	0.57
334	PI603011	7	100.25	0.28	(0.022)	0.15	0.46
347	PI633088	7	113.00	0.28	(0.035)	0.11	0.57
395	PI649120	7	103.75	0.28	(0.022)	0.15	0.46
66	PI 183437	7	111.63	0.31	(0.031)	0.14	0.55
76	PI 215636	7	126.50	0.31	(0.018)	0.21	0.44
122	PI347615	7	111.63	0.31	(0.031)	0.14	0.55
137	PI390139	7	157.50	0.31	(0.054)	0.07	0.72
157	PI426305	7	111.63	0.31	(0.031)	0.14	0.55
161	P426310	7	111.63	0.31	(0.031)	0.14	0.55
207	PI426356	7	111.63	0.31	(0.031)	0.14	0.55
228	PI426378	7	111.63	0.31	(0.031)	0.14	0.55
248	PI426399	7	111.63	0.31	(0.031)	0.14	0.55
290	PI458997	7	124.00	0.31	(0.018)	0.21	0.44
293	PI459000	7	111.63	0.31	(0.031)	0.14	0.55
296	PI459003	7	111.63	0.31	(0.031)	0.14	0.55
302	PI 459009	6	111.63	0.31	(0.031)	0.14	0.55
318	PI478337	7	123.50	0.31	(0.031)	0.14	0.55
319	PI 500651	7	111.63	0.31	(0.031)	0.14	0.55
323	PI531269	7	111.63	0.31	(0.031)	0.14	0.55
340	PI633077	7	128.75	0.31	(0.031)	0.14	0.55
342	PI633083	7	119.25	0.31	(0.031)	0.14	0.55
345	PI633086	7	116.88	0.31	(0.031)	0.14	0.55

A.6. Continued

				Treatment effect				Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect		Standard error		Lower Limit	Upper Limit
358	PI 633099	6	157.50	0.31	(	0.054	)	0.07	0.72
377	PI 649102	6	107.63	0.31	(	0.033	)	0.14	0.57
237	PI426387	7	118.50	0.32	(	0.032	)	0.14	0.57
336	PI 603013	6	113.13	0.32	(	0.055	)	0.08	0.73
5	PI21754	7	126.00	0.34	(	0.027	)	0.18	0.54
53	PI181017	7	132.00	0.34	(	0.027	)	0.18	0.54
55	PI181033	7	132.00	0.34	(	0.027	)	0.18	0.54
78	PI249555	7	141.25	0.34	(	0.052	)	0.10	0.72
169	PI426318	7	132.00	0.34	(	0.027	)	0.18	0.54
179	PI426328	7	132.00	0.34	(	0.027	)	0.18	0.54
180	PI426329	7	127.75	0.34	(	0.052	)	0.10	0.72
185	PI426334	7	131.88	0.34	(	0.027	)	0.18	0.54
186	PI 426335	7	131.88	0.34	(	0.027	)	0.18	0.54
210	PI426359	7	132.00	0.34	(	0.027	)	0.18	0.54
229	PI426379	7	132.00	0.34	(	0.027	)	0.18	0.54
238	PI426388	7	131.88	0.34	(	0.027	)	0.18	0.54
291	PI458998	7	132.00	0.34	(	0.027	)	0.18	0.54
314	PI478333	7	131.88	0.34	(	0.027	)	0.18	0.54
335	PI603012	7	136.63	0.34	(	0.052	)	0.10	0.72
385	PI649110	7	126.00	0.34	(	0.027	)	0.18	0.54
391	PI 649116	6	123.63	0.34	(	0.027	)	0.18	0.54
204	PI 426353	6	128.50	0.35	(	0.048	)	0.11	0.70
282	PI 458942	6	124.38	0.35	(	0.060	)	0.08	0.77
320	PI 500675	6	127.25	0.35	(	0.048	)	0.11	0.70
346	PI633087	7	144.50	0.35	(	0.048	)	0.11	0.70
374	PI633115	8	127.00	0.35	(	0.060	)	0.08	0.77
3	Ames15649	7	142.13	0.37	(	0.044	)	0.14	0.68
20	PI175082	7	141.88	0.37	(	0.044	)	0.14	0.68
64	PI183115	7	152.25	0.37	(	0.020	)	0.25	0.52
72	PI211000	8	144.00	0.37	(	0.020	)	0.25	0.52
108	PI340210	7	193.50	0.37	(	0.035	)	0.18	0.63
152	PI426300	7	198.00	0.37	(	0.035	)	0.18	0.63
156	PI 426304	7	152.25	0.37	(	0.020	)	0.25	0.52
158	PI426306	7	152.25	0.37	(	0.020	)	0.25	0.52
165	PI426314	7	142.13	0.37	(	0.044	)	0.14	0.68
172	PI426321	7	142.13	0.37	(	0.044	)	0.14	0.68
174	PI426323	7	146.25	0.37	(	0.020	)	0.25	0.52
182	PI426331	7	139.00	0.37	(	0.044	)	0.14	0.68

A.6. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect		Treatment effect: Standard error		Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
183	PI426332	7	139.00	0.37	(	0.044	)	0.14	0.68
190	PI426339	7	152.25	0.37	(	0.020	)	0.25	0.52
222	PI426372	7	142.13	0.37	(	0.044	)	0.14	0.68
225	PI426375	7	142.13	0.37	(	0.044	)	0.14	0.68
259	PI432377	7	148.75	0.37	(	0.020	)	0.25	0.52
292	PI458999	7	152.25	0.37	(	0.020	)	0.25	0.52
294	PI459001	7	146.25	0.37	(	0.020	)	0.25	0.52
343	PI633084	7	148.50	0.37	(	0.044	)	0.14	0.68
357	PI 633098	6	148.75	0.37	(	0.020	)	0.25	0.52
61	PI 181043	7	145.00	0.38	(	0.045	)	0.14	0.70
146	PI 426294	7	147.63	0.38	(	0.044	)	0.14	0.69
382	PI649107	7	147.63	0.38	(	0.044	)	0.14	0.69
8	PI163494	7	157.63	0.40	(	0.052	)	0.13	0.75
29	PI179636	8	162.38	0.40	(	0.039	)	0.18	0.68
42	PI179858	7	151.88	0.40	(	0.027	)	0.24	0.59
56	PI 181034	7	151.25	0.40	(	0.052	)	0.13	0.75
86	PI 251239	7	151.88	0.40	(	0.027	)	0.24	0.59
100	PI311726	7	151.25	0.40	(	0.052	)	0.13	0.75
129	PI370745	7	154.25	0.40	(	0.027	)	0.24	0.59
149	PI426297	7	157.63	0.40	(	0.052	)	0.13	0.75
151	PI 426299	7	151.88	0.40	(	0.027	)	0.24	0.59
166	PI 426315	7	162.25	0.40	(	0.039	)	0.18	0.68
173	PI426322	7	154.25	0.40	(	0.027	)	0.24	0.59
175	PI426324	7	154.25	0.40	(	0.027	)	0.24	0.59
184	PI426333	7	154.25	0.40	(	0.027	)	0.24	0.59
195	PI426344	7	154.25	0.40	(	0.027	)	0.24	0.59
213	PI426362	7	157.63	0.40	(	0.052	)	0.13	0.75
219	PI426369	7	162.25	0.40	(	0.039	)	0.18	0.68
230	PI426380	7	162.13	0.40	(	0.039	)	0.18	0.68
251	PI426402	7	157.63	0.40	(	0.052	)	0.13	0.75
288	PI458995	7	163.75	0.40	(	0.027	)	0.24	0.59
315	PI478334	7	157.63	0.40	(	0.052	)	0.13	0.75
330	PI537008	7	154.25	0.40	(	0.027	)	0.24	0.59
331	PI537018	7	154.25	0.40	(	0.027	)	0.24	0.59
332	PI537021	7	154.25	0.40	(	0.027	)	0.24	0.59
341	PI 633078	6	151.88	0.40	(	0.027	)	0.24	0.59
344	PI633085	7	161.25	0.40	(	0.052	)	0.13	0.75
365	PI 633106	6	158.88	0.40	(	0.052	)	0.13	0.75

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
373	PI633114	7	151.88	0.40	(0.027)	0.24	0.59
396	PI649121	7	163.75	0.40	(0.027)	0.24	0.59
397	PI649122	7	155.25	0.40	(0.039)	0.18	0.68
205	PI426354	7	172.38	0.43	(0.052)	0.15	0.77
37	PI179654	7	178.00	0.44	(0.048)	0.17	0.75
51	PI 180421	7	172.25	0.44	(0.018)	0.32	0.56
101	PI311734	7	177.00	0.44	(0.034)	0.23	0.67
107	PI340209	7	174.50	0.44	(0.018)	0.32	0.56
116	PI340218	7	172.25	0.44	(0.018)	0.32	0.56
121	PI346876	7	172.25	0.44	(0.018)	0.32	0.56
163	PI426312	7	166.00	0.44	(0.034)	0.23	0.67
209	PI426358	7	174.50	0.44	(0.018)	0.32	0.56
236	PI426386	7	172.25	0.44	(0.018)	0.32	0.56
261	PI432379	7	172.25	0.44	(0.018)	0.32	0.56
263	PI432381	7	174.50	0.44	(0.018)	0.32	0.56
269	PI432387	7	174.50	0.44	(0.018)	0.32	0.56
273	PI436559	7	174.50	0.44	(0.018)	0.32	0.56
274	PI449436	7	174.50	0.44	(0.018)	0.32	0.56
277	PI449439	7	172.25	0.44	(0.018)	0.32	0.56
286	PI458993	7	182.75	0.44	(0.034)	0.23	0.67
299	PI459006	7	174.50	0.44	(0.018)	0.32	0.56
326	PI 537004	6	174.50	0.44	(0.018)	0.32	0.56
328	PI537006	7	182.75	0.44	(0.034)	0.23	0.67
378	PI649103	7	174.50	0.44	(0.018)	0.32	0.56
381	PI649106	7	172.25	0.44	(0.018)	0.32	0.56
384	PI649109	7	172.25	0.44	(0.018)	0.32	0.56
317	PI 478336	6	168.38	0.45	(0.072)	0.10	0.86
23	PI175607	7	184.63	0.46	(0.053)	0.16	0.79
254	PI426405	7	181.38	0.46	(0.070)	0.11	0.86
17	PI173874	7	174.00	0.47	(0.037)	0.24	0.71
24	PI176884	7	198.25	0.47	(0.043)	0.22	0.74
57	PI181035	7	196.25	0.47	(0.043)	0.22	0.74
140	PI 418956	6	182.13	0.47	(0.037)	0.24	0.71
159	PI426307	7	182.13	0.47	(0.037)	0.24	0.71
171	PI426320	7	182.38	0.47	(0.037)	0.24	0.71
198	PI426347	7	198.25	0.47	(0.043)	0.22	0.74
240	PI426390	7	182.13	0.47	(0.037)	0.24	0.71
339	PI603016	7	178.63	0.47	(0.058)	0.15	0.81

A.6. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect		Treatment effect: Standard error		Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
388	PI649113	7	169.88	0.47	(	0.037	)	0.24	0.71
400	PI 649125	6	189.75	0.47	(	0.037	)	0.24	0.71
367	PI633108	7	187.88	0.49	(	0.063	)	0.15	0.85
12	PI169085	8	201.63	0.50	(	0.063	)	0.15	0.85
22	PI175602	7	197.88	0.50	(	0.044	)	0.23	0.77
25	PI179183	7	192.25	0.50	(	0.041	)	0.24	0.76
30	PI179637	7	201.63	0.50	(	0.063	)	0.15	0.85
75	PI212970	8	194.50	0.50	(	0.002	)	0.48	0.51
85	PI250140	7	194.25	0.50	(	0.029	)	0.31	0.69
90	PI269448	7	195.88	0.50	(	0.044	)	0.23	0.77
102	PI323270	7	182.00	0.50	(	0.044	)	0.23	0.77
104	PI 340205	6	141.63	0.50	(	0.039	)	0.18	0.68
105	PI340206	7	197.88	0.50	(	0.044	)	0.23	0.77
115	PI340217	7	187.25	0.50	(	0.049	)	0.20	0.80
117	PI340219	7	194.50	0.50	(	0.002	)	0.48	0.51
120	PI340223	7	190.25	0.50	(	0.029	)	0.31	0.69
136	PI390138	7	194.50	0.50	(	0.002	)	0.48	0.51
138	PI390140	7	194.50	0.50	(	0.002	)	0.48	0.51
160	PI426308	7	186.75	0.50	(	0.044	)	0.23	0.77
201	PI426350	7	213.00	0.50	(	0.041	)	0.24	0.76
202	PI426351	7	204.75	0.50	(	0.029	)	0.31	0.69
223	PI426373	7	201.63	0.50	(	0.063	)	0.15	0.85
224	PI426374	7	206.25	0.50	(	0.053	)	0.19	0.81
234	PI426384	7	222.50	0.50	(	0.109	)	0.05	0.95
242	PI426393	7	194.50	0.50	(	0.002	)	0.48	0.51
260	PI432378	7	194.50	0.50	(	0.002	)	0.48	0.51
264	PI432382	7	204.75	0.50	(	0.029	)	0.31	0.69
270	PI432388	7	190.25	0.50	(	0.029	)	0.31	0.69
279	PI458928	7	194.50	0.50	(	0.002	)	0.48	0.51
287	PI458994	7	182.00	0.50	(	0.044	)	0.23	0.77
295	PI459002	7	194.25	0.50	(	0.029	)	0.31	0.69
297	PI459004	7	194.50	0.50	(	0.002	)	0.48	0.51
303	PI459010	7	194.50	0.50	(	0.002	)	0.48	0.51
308	PI478327	7	194.50	0.50	(	0.002	)	0.48	0.51
309	PI478328	7	194.50	0.50	(	0.002	)	0.48	0.51
312	PI478331	7	197.88	0.50	(	0.044	)	0.23	0.77
316	PI478335	7	197.88	0.50	(	0.044	)	0.23	0.77
324	PI531270	7	197.88	0.50	(	0.044	)	0.23	0.77

A.6. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect		Treatment effect: Standard error		Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
351	PI 633092	6	194.50	0.50	(	0.002	)	0.48	0.51
368	PI633109	7	194.50	0.50	(	0.002	)	0.48	0.51
376	PI649101	7	194.50	0.50	(	0.002	)	0.48	0.51
386	PI649111	7	202.50	0.50	(	0.029	)	0.31	0.69
387	PI649112	7	197.88	0.50	(	0.044	)	0.23	0.77
389	PI 649114	6	238.00	0.50	(	0.002	)	0.48	0.51
322	PI531268	7	208.50	0.51	(	0.063	)	0.16	0.86
114	PI340216	7	190.50	0.52	(	0.050	)	0.22	0.81
372	PI633113	7	193.88	0.52	(	0.057	)	0.18	0.84
11	PI169078	7	204.50	0.53	(	0.042	)	0.26	0.78
31	PI 179640	7	220.50	0.53	(	0.037	)	0.29	0.76
35	PI179651	8	202.38	0.53	(	0.037	)	0.29	0.76
54	PI181026	8	220.50	0.53	(	0.037	)	0.29	0.76
60	PI181042	7	216.25	0.53	(	0.037	)	0.29	0.76
99	PI288730	7	200.13	0.53	(	0.042	)	0.26	0.78
111	PI 340213	7	218.50	0.53	(	0.037	)	0.29	0.76
113	PI340215	7	202.38	0.53	(	0.037	)	0.29	0.76
239	PI426389	7	196.38	0.53	(	0.037	)	0.29	0.76
310	PI478329	7	218.25	0.53	(	0.037	)	0.29	0.76
329	PI537007	7	215.00	0.53	(	0.042	)	0.26	0.78
379	PI649104	7	215.00	0.53	(	0.042	)	0.26	0.78
394	PI649119	7	218.50	0.53	(	0.037	)	0.29	0.76
62	PI182921	7	228.75	0.54	(	0.047	)	0.24	0.81
65	PI183117	8	202.38	0.54	(	0.054	)	0.21	0.84
164	PI426313	7	221.88	0.54	(	0.058	)	0.19	0.85
6	PI113310	8	210.88	0.56	(	0.043	)	0.27	0.81
10	PI169077	8	215.88	0.56	(	0.048	)	0.25	0.83
40	PI179855	8	204.88	0.56	(	0.043	)	0.27	0.81
70	PI209021	8	212.50	0.56	(	0.018	)	0.44	0.68
96	PI 288724	8	233.13	0.56	(	0.062	)	0.18	0.88
97	PI288725	7	228.38	0.56	(	0.048	)	0.25	0.83
110	PI340212	7	212.50	0.56	(	0.018	)	0.44	0.68
112	PI340214	7	214.25	0.56	(	0.018	)	0.44	0.68
141	PI 426178	7	213.63	0.56	(	0.044	)	0.27	0.81
170	PI426319	7	225.00	0.56	(	0.018	)	0.44	0.68
231	PI426381	7	228.38	0.56	(	0.048	)	0.25	0.83
246	PI426397	7	212.50	0.56	(	0.018	)	0.44	0.68
271	PI432389	7	220.75	0.56	(	0.034	)	0.33	0.77

A.6. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect		Standard error		Confidence Interval (95%): Lower Limit	Upper Limit
349	PI633090	7	221.38	0.56	(	0.043	)	0.27	0.81
393	PI649118	7	224.75	0.56	(	0.018	)	0.44	0.68
402	PI163497	7	214.25	0.56	(	0.018	)	0.44	0.68
197	PI426346	7	242.25	0.57	(	0.052	)	0.23	0.85
227	PI426377	7	242.25	0.57	(	0.052	)	0.23	0.85
131	PI 379103	6	224.00	0.59	(	0.052	)	0.24	0.86
1	Ames 9914	8	236.25	0.60	(	0.040	)	0.32	0.82
14	PI173865	7	244.25	0.60	(	0.052	)	0.25	0.87
16	PI173873	8	240.50	0.60	(	0.028	)	0.40	0.77
59	PI181041	7	232.75	0.60	(	0.052	)	0.25	0.87
143	PI426291	7	227.00	0.60	(	0.028	)	0.40	0.77
145	PI426293	7	240.50	0.60	(	0.028	)	0.40	0.77
220	PI426370	7	244.25	0.60	(	0.052	)	0.25	0.87
221	PI426371	7	244.25	0.60	(	0.052	)	0.25	0.87
232	PI426382	7	224.63	0.60	(	0.028	)	0.40	0.77
235	PI426385	7	227.00	0.60	(	0.028	)	0.40	0.77
241	PI426391	7	227.00	0.60	(	0.028	)	0.40	0.77
243	PI426394	7	224.63	0.60	(	0.028	)	0.40	0.77
247	PI426398	7	238.25	0.60	(	0.040	)	0.32	0.82
250	PI426401	7	240.50	0.60	(	0.028	)	0.40	0.77
265	PI432383	7	251.00	0.60	(	0.040	)	0.32	0.82
268	PI432386	7	238.50	0.60	(	0.028	)	0.40	0.77
272	PI432390	7	216.75	0.60	(	0.040	)	0.32	0.82
280	PI458929	7	240.50	0.60	(	0.028	)	0.40	0.77
306	PI478325	7	227.00	0.60	(	0.028	)	0.40	0.77
348	PI633089	7	240.50	0.60	(	0.028	)	0.40	0.77
350	PI633091	7	227.00	0.60	(	0.028	)	0.40	0.77
356	PI633097	7	238.50	0.60	(	0.028	)	0.40	0.77
369	PI633110	8	246.50	0.60	(	0.040	)	0.32	0.82
398	PI649123	7	222.13	0.60	(	0.052	)	0.25	0.87
19	PI175068	7	232.25	0.62	(	0.021	)	0.47	0.75
41	PI 179857	8	232.25	0.62	(	0.021	)	0.47	0.75
44	PI179862	7	241.38	0.62	(	0.044	)	0.31	0.86
84	PI250139	8	229.13	0.62	(	0.056	)	0.24	0.89
98	PI288727	7	242.75	0.62	(	0.021	)	0.47	0.75
109	PI340211	7	242.75	0.62	(	0.021	)	0.47	0.75
168	PI426317	7	255.25	0.62	(	0.021	)	0.47	0.75
189	PI426338	7	274.00	0.62	(	0.036	)	0.37	0.83

A.6. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
255	PI426406	7	274.00	0.62	(0.036)	0.37	0.83
258	PI432367	7	242.75	0.62	(0.021)	0.47	0.75
267	PI432385	7	244.75	0.62	(0.021)	0.47	0.75
313	PI478332	7	274.00	0.62	(0.036)	0.37	0.83
383	PI649108	7	232.25	0.62	(0.021)	0.47	0.75
52	PI180422	7	262.25	0.63	(0.044)	0.31	0.86
94	PI280637	8	264.50	0.63	(0.044)	0.31	0.86
32	PI179644	7	258.25	0.66	(0.027)	0.45	0.82
43	PI179859	7	258.25	0.66	(0.027)	0.45	0.82
45	PI180264	8	245.00	0.66	(0.027)	0.45	0.82
50	PI180420	8	258.25	0.66	(0.027)	0.45	0.82
58	PI181040	7	258.25	0.66	(0.027)	0.45	0.82
69	PI208734	7	256.50	0.66	(0.027)	0.45	0.82
80	PI 250131	6	244.38	0.66	(0.027)	0.45	0.82
81	PI 250133	7	268.75	0.66	(0.027)	0.45	0.82
92	PI271453	8	259.88	0.66	(0.052)	0.28	0.91
106	PI340207	7	257.50	0.66	(0.027)	0.45	0.82
119	PI 340221	6	245.00	0.66	(0.027)	0.45	0.82
148	PI426296	7	253.63	0.66	(0.049)	0.30	0.90
167	PI426316	7	264.00	0.66	(0.052)	0.28	0.91
196	PI426345	7	244.38	0.66	(0.027)	0.45	0.82
208	PI426357	7	271.00	0.66	(0.027)	0.45	0.82
216	PI426365	7	271.00	0.66	(0.027)	0.45	0.82
300	PI459007	8	245.00	0.66	(0.027)	0.45	0.82
321	PI531267	7	244.38	0.66	(0.027)	0.45	0.82
325	PI531271	7	244.38	0.66	(0.027)	0.45	0.82
380	PI649105	7	240.13	0.66	(0.049)	0.30	0.90
404	PI 207465	6	271.00	0.66	(0.027)	0.45	0.82
226	PI426376	8	263.38	0.68	(0.033)	0.43	0.86
353	PI633094	8	281.25	0.68	(0.033)	0.43	0.86
362	PI633103	7	281.25	0.68	(0.033)	0.43	0.86
4	Ames21749	8	278.88	0.69	(0.043)	0.36	0.90
7	PI120923	7	284.50	0.69	(0.032)	0.44	0.86
18	PI174801	8	257.13	0.69	(0.032)	0.44	0.86
48	PI180269	8	257.13	0.69	(0.032)	0.44	0.86
77	PI217516	7	257.13	0.69	(0.032)	0.44	0.86
87	PI254361	7	275.00	0.69	(0.018)	0.55	0.80
93	PI271455	8	284.25	0.69	(0.043)	0.36	0.90

A.6. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect		Treatment effect: Standard error		Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
135	PI 390137	5	257.13	0.69	(	0.032	)	0.44	0.86
193	PI426342	7	257.13	0.69	(	0.032	)	0.44	0.86
199	PI426348	7	257.13	0.69	(	0.032	)	0.44	0.86
203	PI426352	7	303.00	0.69	(	0.055	)	0.27	0.93
233	PI426383	8	257.13	0.69	(	0.032	)	0.44	0.86
262	PI432380	7	257.13	0.69	(	0.032	)	0.44	0.86
275	PI449437	7	280.25	0.69	(	0.043	)	0.36	0.90
298	PI459005	7	257.13	0.69	(	0.032	)	0.44	0.86
305	PI470241	8	257.13	0.69	(	0.032	)	0.44	0.86
307	PI478326	8	257.13	0.69	(	0.032	)	0.44	0.86
361	PI633102	7	284.50	0.69	(	0.032	)	0.44	0.86
371	PI633112	7	257.13	0.69	(	0.032	)	0.44	0.86
375	PI633116	7	257.13	0.69	(	0.032	)	0.44	0.86
15	PI173872	7	272.00	0.70	(	0.054	)	0.28	0.93
28	PI179635	8	276.75	0.70	(	0.054	)	0.28	0.93
2	Ames15645	8	293.13	0.72	(	0.036	)	0.43	0.89
46	PI 180266	7	264.13	0.72	(	0.036	)	0.43	0.89
73	PI212082	7	274.88	0.72	(	0.023	)	0.54	0.85
83	PI250137	8	285.13	0.72	(	0.046	)	0.35	0.92
123	PI347616	7	265.75	0.72	(	0.037	)	0.42	0.90
127	PI 358591	5	265.75	0.72	(	0.037	)	0.42	0.90
128	PI370744	7	265.75	0.72	(	0.037	)	0.42	0.90
176	PI426325	8	268.38	0.72	(	0.037	)	0.42	0.90
178	PI426327	8	268.38	0.72	(	0.037	)	0.42	0.90
206	PI426355	8	274.63	0.72	(	0.023	)	0.54	0.85
278	PI458927	7	276.25	0.72	(	0.023	)	0.54	0.85
360	PI633101	8	290.75	0.72	(	0.023	)	0.54	0.85
363	PI633104	7	288.50	0.72	(	0.023	)	0.54	0.85
74	PI212594	7	292.38	0.73	(	0.045	)	0.36	0.93
124	PI347617	8	275.38	0.74	(	0.040	)	0.41	0.92
63	PI183112	7	305.63	0.75	(	0.047	)	0.34	0.95
82	PI250134	7	293.00	0.75	(	0.003	)	0.73	0.77
276	PI449438	7	293.00	0.75	(	0.003	)	0.73	0.77
9	PI169076	7	304.25	0.76	(	0.026	)	0.54	0.89
26	PI 179191	7	301.13	0.76	(	0.026	)	0.54	0.89
36	PI 179653	8	287.63	0.76	(	0.026	)	0.54	0.89
68	PI195553	7	290.38	0.76	(	0.026	)	0.54	0.89
95	PI286417	8	304.25	0.76	(	0.026	)	0.54	0.89

A.6. Continued

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
403	PI 175608	6	302.50	0.76	(0.026)	0.54	0.89
34	PI179649	8	312.13	0.78	(0.050)	0.32	0.96
38	PI179850	8	308.75	0.78	(0.010)	0.71	0.85
49	PI180417	8	306.50	0.78	(0.010)	0.71	0.85
88	PI257240	8	307.38	0.78	(0.029)	0.52	0.92
89	PI269432	8	306.50	0.78	(0.010)	0.71	0.85
153	PI426301	8	296.00	0.78	(0.030)	0.51	0.92
245	PI426396	8	308.75	0.78	(0.010)	0.71	0.85
13	PI173857	7	314.63	0.79	(0.028)	0.54	0.92
27	PI179192	7	301.13	0.79	(0.028)	0.54	0.92
406	PI649162	7	314.63	0.79	(0.028)	0.54	0.92
191	PI426340	8	307.50	0.81	(0.033)	0.49	0.95
200	PI426349	8	310.13	0.81	(0.030)	0.52	0.94
354	PI633095	8	324.88	0.81	(0.033)	0.49	0.95
47	PI180267	7	319.25	0.82	(0.011)	0.73	0.89
91	PI 271442	7	320.88	0.82	(0.011)	0.73	0.89
249	PI426400	8	317.88	0.82	(0.011)	0.73	0.89
405	PI 426281	6	325.75	0.82	(0.031)	0.52	0.95
39	PI179854	7	327.25	0.84	(0.016)	0.70	0.92
71	PI 209781	7	321.00	0.84	(0.033)	0.48	0.97
355	PI633096	7	332.50	0.84	(0.016)	0.70	0.92
370	PI633111	7	329.38	0.84	(0.016)	0.70	0.92
33	PI179647	7	335.00	0.85	(0.010)	0.77	0.91
244	PI426395	8	347.13	0.89	(0.002)	0.88	0.90
253	PI426404	8	347.13	0.89	(0.002)	0.88	0.90
289	PI458996	8	363.25	0.89	(0.002)	0.88	0.90
150	PI426298	8	348.50	0.90	(0.016)	0.73	0.97
217	PI426366	8	355.63	0.91	(0.006)	0.86	0.95
266	PI432384	8	355.63	0.91	(0.006)	0.86	0.95
407	Dk 3042	8	358.38	0.91	(0.007)	0.85	0.95
192	PI426341	8	385.75	0.94	(0.015)	0.72	0.99

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

A.7. Median, mean rank and estimated relative treatment effects for the severity of foliar symptoms on 54 commercial canola cultivars based on their reaction to inoculation with three *Leptosphaeria maculans* isolates of PG 3.

				Treatment effect		Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect	Standard error	Lower Limit	Upper Limit
37	Croplan Hyclass 906P	6	23.00	0.32	(0.036)	0.13	0.59
29	Canterra SWK5352RR	7	24.63	0.33	(0.020)	0.21	0.48
75	Monsanto DKL52-41Plus	7	24.63	0.33	(0.020)	0.21	0.48
5	Agriprogress 30503-B6	7	25.88	0.35	(0.043)	0.13	0.66
7	Agriprogress 30217-C7	6	28.13	0.36	(0.031)	0.18	0.58
28	Cargill V 2010	7	27.88	0.36	(0.031)	0.18	0.58
21	Brett Young 4414RR	8	29.25	0.38	(0.048)	0.13	0.72
25	Cargill V2018	7	30.00	0.40	(0.023)	0.26	0.56
38	Croplan Hyclass 906	7	30.63	0.40	(0.023)	0.26	0.56
41	Croplan Hyclass 410	7	30.50	0.40	(0.023)	0.26	0.56
31	Canterra 1818	7	31.38	0.43	(0.031)	0.24	0.64
74	Monsanto G75449	7	31.38	0.43	(0.046)	0.17	0.73
13	Agriprogress 30611-C7	7	36.25	0.46	(0.036)	0.24	0.70
11	Agriprogress 30412-B6	7	36.50	0.47	(0.020)	0.34	0.60
33	Canterra 30507-B6	7	35.63	0.47	(0.020)	0.34	0.60
56	Mycogen Seeds G2X0023	7	35.00	0.47	(0.020)	0.34	0.60
3	Agriprogress 30416-B6	7	41.00	0.54	(0.004)	0.51	0.57
4	Agriprogress 30423-C7	7	41.00	0.54	(0.004)	0.51	0.57
18	Bayer Invigor 8440	7	41.00	0.54	(0.004)	0.51	0.57
39	Croplan Hyclass 712	7	41.00	0.54	(0.004)	0.51	0.57
55	Mycogen Seeds DN051874	7	41.00	0.54	(0.004)	0.51	0.57
58	Mycogen Seeds Nexera 845 Cl	7	41.00	0.54	(0.004)	0.51	0.57
71	Monsanto G72003	7	41.00	0.54	(0.004)	0.51	0.57
79	Proseed 2066	7	41.00	0.54	(0.004)	0.51	0.57
81	Pioneer 45H28	7	41.00	0.54	(0.004)	0.51	0.57
26	Cargill V1037	7	42.38	0.57	(0.038)	0.31	0.79
15	Agriprogress 30214-C7	8	46.00	0.60	(0.018)	0.48	0.72
64	Mycogen Seeds DN0 51505	7	46.13	0.60	(0.018)	0.48	0.72
73	Monsanto G72021	7	46.13	0.60	(0.018)	0.48	0.72
78	Proseed 30 Caliber	7	46.13	0.60	(0.018)	0.48	0.72
27	Cargill V1035	7	47.75	0.63	(0.027)	0.44	0.79
36	Croplan Hyclass 924	7	47.75	0.63	(0.027)	0.44	0.79
51	Mycogen Seeds G2X0043	8	51.13	0.67	(0.020)	0.51	0.79
57	Mycogen Seeds Nexera 830 CL	8	50.25	0.67	(0.020)	0.51	0.79
63	Mycogen Seeds DN051493	7	49.75	0.67	(0.020)	0.51	0.79

A.7. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
66	Monsanto Z4409	8	53.00	0.70	(0.027)	0.49	0.84
67	Monsanto G75011	8	52.38	0.70	(0.027)	0.49	0.84
69	Monsanto G67012	7	52.88	0.70	(0.027)	0.49	0.84
42	Dekalb IS7145	7	55.50	0.73	(0.031)	0.48	0.89
54	Mycogen Seeds G2X0044	8	55.38	0.73	(0.018)	0.59	0.83
12	Agriprogress 30408-C7	8	56.63	0.76	(0.022)	0.58	0.88
59	Mycogen Seeds DN051607	8	57.88	0.76	(0.022)	0.58	0.88
68	Monsanto G72061	7	57.38	0.76	(0.022)	0.58	0.88
48	Integra Seed IX087121R	8	60.38	0.79	(0.025)	0.57	0.91
32	Canterra 30120-B6	8	62.38	0.82	(0.009)	0.75	0.88
43	Dekalb 52-41	8	65.00	0.86	(0.010)	0.77	0.91
53	Mycogen Seeds G2X0024	8	67.13	0.87	(0.014)	0.74	0.94
47	IntegraSeed IX08-7321R	8	66.88	0.89	(0.009)	0.81	0.93
62	Mycogen Seeds DN051535	8	67.50	0.89	(0.009)	0.81	0.93
45	Dekalb DKL72-55	8	70.38	0.91	(0.012)	0.78	0.96
83	Dk3242 1	8	69.38	0.92	(0.002)	0.90	0.93
44	Dekalb IS3057	8	71.63	0.94	(0.005)	0.89	0.96
52	Mycogen Seeds G2X0022	8	71.63	0.94	(0.005)	0.89	0.96
72	Monsanto G64034	8	71.63	0.94	(0.005)	0.89	0.96

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ithaccession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).

A.8. Median, mean rank and estimated relative treatment effects for the severity of foliar symptoms on 54 commercial canola cultivars based on their reaction to inoculation with one *Leptosphaeria maculans* isolate of PG 4.

				Treatment effect				Confidence Interval (95%)	
Accession number	Name	Median Disease Rating	Mean Rank	Treatment relative effect		Standard error		Lower Limit	Upper Limit
33	Canterra 30507-B6	7	31.63	0.40	(	0.021	)	0.27	0.55
74	Monsanto G75449	7	30.38	0.40	(	0.021	)	0.27	0.55
79	Proseed 2066	8	31.00	0.40	(	0.021	)	0.27	0.55
81	Pioneer 45H28	8	30.63	0.40	(	0.021	)	0.27	0.55
17	Bayer Invigor 5440	8	30.50	0.41	(	0.037	)	0.19	0.67
3	Agriprogress 30416-B6	8	36.13	0.47	(	0.018	)	0.35	0.59
5	Agriprogress 30503-B6	8	34.88	0.47	(	0.018	)	0.35	0.59
7	Agriprogress 30217-C7	7	35.88	0.47	(	0.018	)	0.35	0.59
11	Agriprogress 30412-B6	7	35.25	0.47	(	0.036	)	0.25	0.70
18	Bayer Invigor 8440	8	35.63	0.47	(	0.036	)	0.25	0.70
26	Cargill V1037	7	34.88	0.47	(	0.036	)	0.25	0.70
38	Croplan Hyclass 906	8	35.25	0.47	(	0.018	)	0.35	0.59
46	Interstate 1005	8	35.25	0.47	(	0.018	)	0.35	0.59
76	Proseed 50 Caliber	7	36.25	0.47	(	0.036	)	0.25	0.70
4	Agriprogress 30423-C7	8	41.13	0.54	(	0.030	)	0.33	0.73
27	Cargill V1035	7	40.38	0.54	(	0.030	)	0.33	0.73
15	Agriprogress 30214-C7	8	45.38	0.60	(	0.019	)	0.46	0.72
55	Mycogen Seeds DN051874	8	45.38	0.60	(	0.019	)	0.46	0.72
58	Mycogen Seeds Nexera 845 Cl	8	46.25	0.60	(	0.019	)	0.46	0.72
64	Mycogen Seeds DN0 51505	8	45.38	0.60	(	0.019	)	0.46	0.72
66	Monsanto Z4409	8	45.38	0.60	(	0.019	)	0.46	0.72
73	Monsanto G72021	8	46.25	0.60	(	0.019	)	0.46	0.72
68	Monsanto G72061	8	48.00	0.64	(	0.030	)	0.42	0.81
51	Mycogen Seeds G2X0043	8	51.25	0.67	(	0.022	)	0.50	0.80
59	Mycogen Seeds DN051607	8	49.88	0.67	(	0.022	)	0.50	0.80
69	Monsanto G67012	8	49.88	0.67	(	0.022	)	0.50	0.80
28	Cargill V 2010	8	53.38	0.71	(	0.042	)	0.37	0.91
42	Dekalb IS7145	8	55.75	0.74	(	0.019	)	0.59	0.84
43	Dekalb 52-41	8	55.75	0.74	(	0.019	)	0.59	0.84
54	Mycogen Seeds G2X0044	8	55.75	0.74	(	0.019	)	0.59	0.84
56	Mycogen Seeds G2X0023	8	54.88	0.74	(	0.019	)	0.59	0.84
57	Mycogen Seeds Nexera 830 CL	8	54.88	0.74	(	0.019	)	0.59	0.84
78	Proseed 30 Caliber	8	55.75	0.74	(	0.019	)	0.59	0.84
48	Integra Seed IX087121R	9	59.38	0.77	(	0.025	)	0.56	0.90
12	Agriprogress 30408-C7	8	60.75	0.80	(	0.003	)	0.78	0.82

A.8. Continued

Accession number	Name	Median Disease Rating	Mean Rank	Treatment effect: Treatment relative effect	Treatment effect: Standard error	Confidence Interval (95%): Lower Limit	Confidence Interval (95%): Upper Limit
32	Canterra 30120-B6	8	60.75	0.80	(0.003)	0.78	0.82
36	Croplan Hyclass 924	8	60.75	0.80	(0.003)	0.78	0.82
39	Croplan Hyclass 712	8	60.75	0.80	(0.003)	0.78	0.82
63	Mycogen Seeds DN051493	8	60.75	0.80	(0.003)	0.78	0.82
67	Monsanto G75011	8	60.75	0.80	(0.003)	0.78	0.82
83	Dk3242	8	60.75	0.80	(0.003)	0.78	0.82
47	IntegraSeed IX08-7321R	8	63.88	0.84	(0.011)	0.75	0.90
53	Mycogen Seeds G2X0024	8	63.88	0.84	(0.011)	0.75	0.90
62	Mycogen Seeds DN051535	8	63.88	0.84	(0.011)	0.75	0.90
45	Dekalb DKL72-55	9	68.63	0.89	(0.014)	0.75	0.95
44	Dekalb IS3057	9	70.63	0.93	(0.012)	0.79	0.98
52	Mycogen Seeds G2X0022	9	71.38	0.93	(0.012)	0.79	0.98
72	Monsanto G64034	9	74.63	0.98	(0.002)	0.96	0.99

Standard errors (se) are given in brackets after the estimates, which were determined based on output of the SAS macro. In general, if the SAS macro is not available, se can be roughly approximated by se / N, in which se is the standard error of the mean rank for the ith accession (treatment) as determined in the MIXED procedure of SAS with the LSMEANS option (SAS Institute, Cary, NC).