HOST-PATHOGEN STUDIES OF COMMON RUST OF MAIZE IN SOUTH AFRICA

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"One must learn by doing the thing, for though you think you know it, you have no certainty until you try"

Aristotle

CONTENTS

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PREFACE

Zea mays L. (maize or corn) is one of the most important food crops worldwide and is used for livestock feed, as a staple food for humans, and in many industrial products such as starch, oil and protein, alcoholic beverages, food sweeteners and fuel. Maize is equally important in South Africa where 10.6 million tons were produced on 3.87 million hectares in the 1999/2000 season. Maize is attacked by many diseases, among which common rust, caused by the fungus *Puccinia sorghi* Schwein. Common rust is widely distributed throughout maize-growing regions of the world, and often causes economic losses. In South Africa, significant losses may occur in areas where the disease is severe, in particular the mist belt and production areas in KwaZulu-Natal. The disease has not been studied intensively in South Africa. The recent occurrence of common rust epidemics on certain hybrids, and a perception that the disease is increasing in importance in South Africa, inspired this study.

The first chapter serves as a general overview of *P. sorghi* including occurrence of the disease, taxonomy, economic significance, environmental conditions and disease control. The second chapter is dedicated to the occurrence of different spore stages of *P. sorghi* in South Africa. Although the macrocyclic life-cycle has been known for many years, these early illustrated publications are difficult to obtain. Chapter 2 thus provides images and micrographs of the spore stages, fungal structures and symptoms, as well as an account of the occurrence of aecial infections on *Oxalis corniculata*, the alternate host for *P. sorghi*.

In chapter 3 historic and current maize germplasm of PANNAR Seed Company (Pty.) Ltd., were screened to determine the level of resistance to common rust in their genetic stocks. To obtain information on the economic significance of the disease, the effects of different fungicides on yield of maize cultivars, grown in two environments where common rust occurs annually, were investigated over two seasons (chapter 4). In chapter 5 the inheritance of *Rp* genes effective to South African pathotypes of *P. sorghi* were studied. The objective was to determine expression of *Rp* genes in segregating populations, thus providing information on the ease of selecting for resistance in seedlings. The dissertation was compiled as a collection of independent articles. Therefore, some repetition was unavoidable.

CHAPTER 1

AN OVERVIEW OF COMMON RUST OF MAIZE

INTRODUCTION

Plant diseases continue to play a major limiting role in food production, particularly in intensively managed agricultural crops. Concerns about food quality, environmental safety and pesticide resistance have dictated the need for alternative pest management techniques such as breeding for resistance.

Maize diseases show a high degree of spatial and temporal variability (Carlson & Main, 1976). This variability causes uncertainty in decision making with regard to disease management, in particular application of fungicides. Financial risks further complicate this uncertainty. These risks are often unknown to seed companies or farmers when the decisions to apply control measures are made, because the specific diseases that may occur during the growing season, their intensity, rate of development and economic damage, cannot be projected with a high degree of certainty. Better knowledge about the diseases would benefit farmers by enabling them to make more informed decisions.

In favourable environments, foliar diseases such as common maize rust, caused by *Puccinia sorghi* Schwein., can be economically damaging (Pataky, 1987a). Inoculum quantities (especially urediniospores), level of host plant resistance and environmental conditions are three major factors influencing rust epidemics. Moreover, the introduction of rust susceptible maize hybrids can contribute to the high inoculum pressure (Pataky & Headrick, 1989). Rust is a problem throughout the main maize producing areas of the world including South Africa, and particularly in KwaZulu-Natal, Mpumalanga and the North West province. Except for a report by Kaiser & Nowel (1983) who noted yield losses of up to 26.9% in KwaZulu-Natal, no data on the influence of this disease in South Africa are available.

The aim of this chapter was to give an overview of the common rust - maize pathosystem.

OCCURRENCE AND ECONOMIC IMPORTANCE

Occurrence and severity of *P. sorghi* depend largely on the environment. Favourable climatic conditions during a growing season will frequently result in common rust epidemics (Wegulo *et al.*, 1998). Severe epidemics can therefore be expected to occur in the eastern, more humid regions of South Africa. Severe epidemics have likewise been encountered in the upper Midwest of the USA (Pataky & Headrick, 1989; Pataky & Eastburn, 1993). Common rust has been reported as a serious sweet corn disease in the USA, in particular in Hawaii, Wisconsin, Minnesota, Illinois, New York, California and southern and central Florida (Pataky, 1987a; 1987b; Pataky & Eastburn, 1993; Hu & Hulbert, 1996; Hu, Webb & Hulbert, 1997). Common rust severity was also reported to be higher in more tropical regions where infection occurred at earlier growth stages (Hooker, 1985).

The economic and social impact resulting from crop losses following plant disease epidemics is one of the dominant influences on research. Several researchers (Kaiser & Nowel, 1983, Pataky, 1987; Pataky & Eastburn, 1993) have assessed the effects of *P. sorghi* infection on yield and quality of both maize and sweet corn. The main effect is a reduction in grain yield, due to a reduction in kernel size. However, reductions in plant height, fresh plant weight, ear length, ear diameter, oil content and protein content, as well as an increase in the occurrence of stalk rots were reported by Hooker (1985). The latter author also noted that when sweet corn infections occurred in mid-season, *P. sorghi* rarely caused significant yield reductions.

Yield losses of 30-40% were reported on sweet corn by Pataky & Mosely (1995) and losses of almost 50% were observed by Groth *et al.* (1983). Yields of sweet corn are reduced by about 0.6% for each 1% rust severity at harvest (Pataky & Eastburn, 1993). In central Illinois, rust severity ranged from 15 to 40% and from 25 to 80% on moderately susceptible and susceptible hybrids, respectively (Pataky & Eastburn, 1993).

Russel (1965) compared resistant near-isogenic lines with their susceptible counterparts. Disease severity was measured at 50 days post-anthesis as the percentage leaf area covered with rust pustules. Severity values of 10, 30, 50, 60 and 70% resulted in yield reductions of 4, 6,15, 21 and 24%, respectively (Russell, 1965). In Argentina yield increases of 17.3-18.6% were observed where hybrids were protected from rust infection by the application of foliar fungicides (Martines, 1977). In Hawaii, a severity of 80% resulted in an average reduction of 35% in grain yield (Kim & Brewbaker, 1976) but reductions as high as 75% were recorded in susceptible hybrids. Yield losses approaching 32% were reported as a result from *P. sorghi* infection in India (Sharma *et al.,* 1982).

Crop losses occur due to a loss in photosynthetic leaf area, therefore, rust reduces both the net amount of radiation intercepted and radiation use efficiency, as well as impairs the translocation of photosynthates to the developing ear (Wegulo *et al.,* 1997). Physiological and metabolic changes in host tissues infected by rust fungi were described by Durbin (1984). The rate of photosynthesis in infected leaves is higher than in healthy leaves and photosynthates may accumulate in infected ones. This accumulation is due to an increased movement of solutes towards the infection site whereas translocation away from the site is decreased. In stripe rust (*P. striiforms* f. sp. *tritici*) on wheat, a reduction of 99% in the translocation of ^{14}C occurred in infected leaves over a 3 h period, thus creating an efficient sink (Durbin, 1984).

These effects of pathogens cause a reduction in the accumulation of dry matter in seed, resulting in reduced yields. Host resistance to *P. sorghi* greatly influences the level of disease severity, and thus the yield loss. Results published by Groth *et al.* (1983) showed that yield and quality losses due to rust can be high. They also found that secondary ears were more severely affected by rust than primary ears, and that total losses in yield and quality may be reached on secondary ears.

TAXONOMY AND NOMENCLATURE

Puccinia sorghi belongs to the genus *Puccinia* Pers.:Pers. of the Pucciniaceae. Members of the Pucciniaceae are heteroecious and belong to the order Uredinales of the class Basidiomycetes. Although this rust does not occur on sorghum, it was named *P. sorghi* in 1832 because Schweinitz thought he was working with sorghum leaves (Parmelee & Savile, 1986).

Synonyms for the common rust pathogen according to Laundon & Waterston (1964) are:

= *Puccinia sorghi* Schwein, 1832

= *Puccinia maydis* Bèrenger, 1845

= *Puccinia zeae* Bèrenger, 1851

= *Aecidium oxalidis* Thuem., 1876

= *Tilletia epiphylla* Berk. & Br., 1882

= *Dicaeoma sorghi* (Schwein.) Kuntze, 1898

SYMPTOMS ON MAIZE PLANTS

Rust symptoms can be observed on almost all photosynthetic tissues of maize plants, but are most prevalent on the leaves, especially towards the late vegetative growth stages, approaching tasseling or maturity (White, 1999). Stems, inflorescences and ears/cobs are also affected. Affected plant stages thus include the flowering-, fruiting-, seedling-, and the vegetative growth stages. The size and number of pustules are influenced by the susceptibility of the specific cultivars.

Puccinia sorghi infections are characterized by the presence of typical brown to cinnamon-brown rust pustules (uredinia) which occur on both leaf surfaces (White, 1999). Pustules are usually round to elongated with an approximate equal frequency on both the upper and lower leaf surfaces. The initial symptoms appear as small chlorotic areas. As the uredinia develop, they become erumpent, splitting the epidermal tissue to expose masses of powdery urediniospores, each capable of infecting a susceptible host. Spores often collect in the whorls of plants, resulting in a band of infection across the leaf. When the disease is severe, large areas of the leaves and leaf sheaths can become necrotic. These pustules become brownish-black, due to teliospore development, as the plant matures. Severe chlorosis and necrosis of the leaves and leaf sheaths may occur. These symptoms will be discussed in more detail in Chapter 2.

DISEASE CYCLE

Teliospores germinate in the winter to form basidia on which small, thin-walled, hyaline, haploid basidiospores are produced. These basidiospores germinate, penetrate the leaves of creeping sorrel (*Oxalis corniculata*) and form pycnia containing pycniospores on both sides of the leaf (Evans, 1923; Hooker & Yarwood, 1966). Pycniospores fuse with receptive hyphae of the opposite mating type initiating the aecial stage on the lower surface of *Oxalis* leaves. The binucleate aeciospores in the "cluster-cups" are windborne and infect susceptible maize leaves. These infections give rise to urediniospores, the repeating stage of the fungus (White, 1999).

In most temperate areas of the world, the fungus does not infect *Oxalis* and persists on living maize plants (White, 1999). If the weather is favourable, the fungus can complete its life cycle on maize in five to seven days (Esterhuysen, Trench & Wilkinson, 1992).

SPORE MORPHOLOGY

Terminology of spore states is based on morphology and ontogeny. The ontogenic system emphasizes positions of the spore states in the life cycle, whereas the morphological system emphasizes the morphology of the spores as the basis for defining states, and for classification of genera and species in rust fungi (White, 1999).Teliospores are amphigenous, scattered or grouped (Arthur, 1962). The teliospores are oblong or ellipsoid, 16-23 X 29-45 µm, rounded or obtuse both above and below, and are slightly constricted at the septum. The wall is a dark chestnut–brown colour and is 1-2 µm thick at the sides and 5-7 µm thick above. The pedicel is colourless, except near the spore, and is once or twice the length of the spore (Arthur, 1962). Cells of teliospores are binucleate, and the two haploid nuclei only fuse just prior to germination to form the diploid phase of the fungus (Smith & White, 1988). Pycnia occur on both sides of the leaves of *Oxalis* (alternative host of *P. sorghi*), grouped on an area up to 0.5 mm in diameter in the center of the spot (Laundon & Waterston, 1964) and pycniospores are exuded in a gelatinous mass. Aecia occur on the underside of *Oxalis* leaves only, surrounding the pycnia in a zone up to 2 mm wide (Laundon & Waterston, 1964) and are 18-26 X 13-19 µm. Aeciaspores are mostly globoid or ellipsoid, their walls are 1-1.5 µm thick, and pale yellowish and verrucose (Cummins, 1971). The urediniospores are amphigenous, scattered, oblong or elongate, pulverulent and measure 23-29 X 26-32 µm (Cummins, 1971). The wall of the urediniospores is cinnamon-brown, 1.5-2 µm thick, finely and moderately echinulate (Arthur, 1962), and have three or four equatorial germ pores (Cummins, 1971). Two of the three known rusts that occur on *Zea mays* are compared in Table 1 (Parmelee & Savile, 1986).

Table 1: Comparison of spore characteristics in *Puccinia sorghi* and *P. polysora* (Parmelee & Savile, 1986)

	P. sorghi	***P. polysora***
Urediniospores		
shape	usually globoid	usually ellipsoid
max. length	30(-33)µm	(35-)37-40(-44)µm
pores	3-4(-5) with internal ring	(3-)4-6(-7) slight or no internal ring
hilum	rugulose	smooth
Telia	pulvinate, soon naked, black	locular, long covered, plumbeous
Teliospore apex	3.5-8.0µm thick	1.5-4.0µm thick
Pedicel	18-95(-120)µm, firm	8-38µm, delicate

ENVIRONMENTAL CONDITIONS

Disease spread can be very rapid under favourable environmental conditions. Common rust development on sweet corn is greatly influenced by night temperatures (Headrick & Pataky, 1986). Very few uredinia develop when night temperatures are 32°C and higher (Headrick & Pataky, 1986) but uredinium formation is increased when night temperatures range between 8-24°C.

The minimum and maximum temperatures for infection under fluctuating conditions appear to represent a wider range than those under constant conditions (Headrick & Pataky, 1986). When day temperatures were moderate, night temperatures of 32°C, continued to inhibit uredinial formation. Headrick & Pataky (1986) also reported that little to no rust developed at a constant temperature of 8°C, but increasing day temperatures (16-22°C) may result in disease.

Pataky (1986) observed the maximum number of uredinia on seedlings of several sweet corn hybrids to occur at 19-20 days post-inoculation. The optimal mist period for infection was about 12 h (Pataky, 1986), but other research showed dew periods longer than 6-12 h to increase infection structure formation (Mahindapala, 1978) and pustule density (Hollier & King, 1985).

Mahindapala (1978) found a dew period of at least 3-4 h necessary for the initiation of infection structure formation, and proved germination and germ tube growth of *P. sorghi* to occur at relative humidities of 98.5-100%. It can be perceived that night temperatures and dew period will be important components in the development of a common rust-forecasting model.

INFECTION PROCESS

Different degrees of susceptibility and resistance are expressed within the maize-common rust pathosystem (Hooker, 1967) which influence the infection process. Urediniospore germ tube growth is directional towards the stoma and may be a thigmotropic response to the plant surface (Littlefield & Heath, 1979). Hughes & Rijkenberg (1985) reported that germ tubes grow randomly towards the stoma and not by orientating itself along gross structural features. Once the stoma has been encountered, induction of the appressorium takes place (Fig 1). An infection peg forms between the guard cells and gives rise to a substomatal vesicle. From the substomatal vesicle an infection hypha is formed, which then initiates the haustorium mother cell in the intercellular space. Eventually morphologically distinct secondary infection hyphae develop from the substomatal vesicle on the proximal side of the primary hypha septum (Hughes & Rijkenberg, 1985). All intercellular growth arises from the secondary hyphae. A haustorium develops from the haustorium mother cell and invaginates the host mesophyll cell to facilitate nutrient exchange (Fig 1) (Littlefield & Heath, 1979). In a susceptible host a large number of spores germinate on the plant surface and the pathogen is not restricted by host factors throughout the disease cycle. Sub-optimal development was observed in a resistant host where the plant suppresses growth of the pathogen (Hooker, 1967).

DISEASE MANAGEMENT

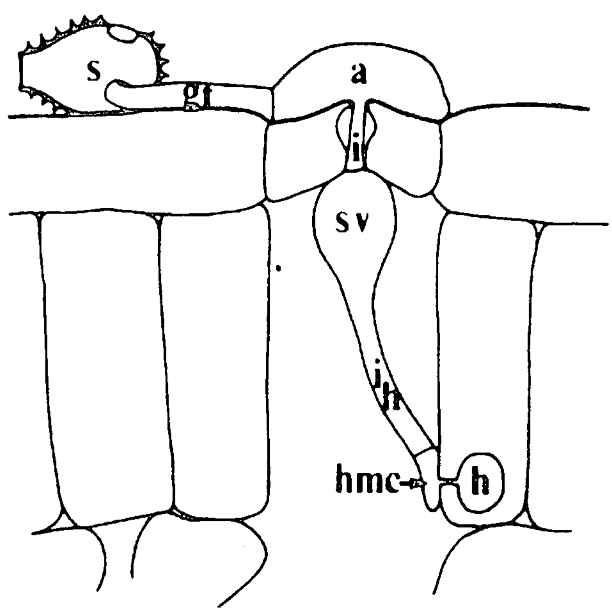
Control of common rust is achieved mainly by breeding for resistance or by the application of foliar fungicides.

Resistance

Resistance and susceptibility are measured by the amount of rust (disease severity) that occurs on a specific genotype (Pataky & Headrick, 1989). Common rust severity on maize can be reduced by hypersensitive (*Rp* gene) or partial resistance (Gingera, Davis & Groth, 1995).

Figure 1. Diagrammatic representation of a cross section of a leaf showing the infection structures[a] typically derived from a urediniospore on the leaf surface (Littlefield & Heath, 1979)

[a] s – Urediniospore gt – germ tube a – appressorium
i – infection peg sv – substomal vesicle ih – infection hypha
hmc – haustorium mother cell h – haustorium


s
gt
a
i
sv
ih
hmc
h

Hypersensitive resistance

More than 100 sources of resistance to the common rust fungus were identified in maize lines during the 1950's and 1960's (Hooker & Russel, 1962; Hagan & Hooker, 1965; Wilkinson & Hooker, 1968). Twenty-four dominant factors (genes or alleles) were differentiated among these maize lines, by a spectrum of rust isolates to which they conferred resistance, and by their placement on the maize genetic linkage map (Hulbert, Lyons & Bennetzen, 1991). These genes for resistance can be linked to three areas of the maize genome – a cluster of loci on chromosome 10 (*Rp1*, *Rp5* and *Rp6*) and two other possible complex loci on chromosomes 3 (*Rp3*) and 4 (*Rp4*)(Hulbert *et al.,* 1991).

The *Rp1* complex maps 25 cm from the centromere on the short arm of chromosome 10 (Bennetzen, Blevins & Ellingboe, 1988). It was one of the first loci demonstrated to be composed of multiple genes along with the M-locus for rust resistance in flax (Shepherd & Mayo, 1972). Two other resistance factors, mapping more than a unit away, were labelled *Rp5* and *Rp6*, and recombined frequently with one or more of the *Rp1* alleles (Hulbert & Bennetzen, 1991). Most, but not all, of the *Rp* genes are dominant, with the resistant homozygotes being phenotypically indistinguishable from the heterozygotes (Hulbert, 1997). The *Rp8* locus, with unique patterns of inheritance, was identified in a line of unknown pedigree (Delaney, Webb & Hulbert, 1998). Analysis with restriction fragment length polymorphism (RFLP) showed that the *Rp8* locus was on the long arm of chromosome 6 (Delaney *et al.,* 1998). This locus is unusual in that only certain heterozygous allelic combinations confers rust resistance (Delaney *et al.,* 1998).

Resistance controlled by *Rp* genes are generally associated with a hypersensitive reaction (HR), although the phenotype varies considerably (Hulbert, 1997). The HR associated with the different genes varies in the rate at which cells die following inoculation, and in the number of cells that become necrotic. The different genes also vary considerably in the consistency of the HR on a single leaf, and some resistance genes commonly condition mixed reaction types (Hulbert, 1997).

According to Pataky *et al.* (1998) *Rp* genes are used in nearly 33% of new sweet corn hybrids. This resistance is expressed qualitatively as chlorotic or necrotic flecks, with little or no formation of urediniospores (Pataky & Headrick, 1989). Despite the high levels of rust resistance conditioned by single genes, the HR has generally been non-durable, with maize being no exception. Resistance due to the *Rp1-D* gene has broken down in hybrids tested in Argentina, Hawaii, Mexico and South Africa (Pataky *et al.*, 2001).

The Z infection type of common rust on maize, proposed by Van Dyke & Hooker (1969), represents lesions where leaf tips are typically hypersensitive, while those at the leaf bases appear as normal pustules. This Z-type reaction appears to be more influenced by light than by temperature. Experimental evidence suggests that age and maturation of leaf tissue determine Z-type reactions. Older, mature tissues are resistant and younger tissues, or tissue with delayed maturation, are susceptible (Van Dyke & Hooker, 1969). Van Dyke and Hooker (1969) reported that while lack of light before and after inoculation increased susceptibility, temperature did not change the Z-reaction.

Pathogenic variation

Pathogenic variation in *P. sorghi* has frequently been reported, e.g. by Bergquist & Pryor (1984), Hulbert *et al.* (1991), Hu & Hulbert (1996), Pataky (2000), Pate & Pataky (2000) and Pataky *et al.* (2001). A study conducted by Fato (2000) showed that seven different pathotypes occurred in South Africa. Variation occurred throughout South Africa, with four of the seven pathotypes isolated in KwaZulu-Natal. Resistance genes remaining effective in South Africa are *Rp1-C*, *Rp1-G*, *Rp1-L*, *Rp3-D* and *Rp3-F* (Fato, 2000). In Hawaii some of the *Rp1* alleles were quickly overcome and breeders had to resort to other sources of resistance (Groth, Pataky & Gingera, 1992). More specifically, virulence for the *Rp1-D* resistance in Argentina, Hawaii, Mexico and South Africa (Pataky *et al.*, 2001) further illustrates the non-durability of single gene resistance.

Virulence identification becomes less useful when pathogenic variability increases (Groth, Pataky & Gingera, 1992). Since surveys have not been done extensively in South Africa, the spatial and temporal variability of *P. sorghi* is not known. In areas where the life-cycle is completed on *Oxalis corniculata* it can be expected that sexual recombination will contribute to variability. The aecial stage is not known to occur in North America and central Mexico is therefore considered to be the source of common rust inoculum for the midwestern United States (Pataky *et al.*, 2001). The first report of the aecial stage of *P. sorghi* in South Africa was by Arthur (1904), followed by Evans (1923). Despite these early records no information on the epidemiological significance of life-cycle completion in South Africa could be found.

Partial resistance

Resistance to common rust may also be expressed as a delayed first pustule appearance. This may function to reduce inoculum production progressively throughout the season and limit the total number of reproductive cycles of common rust (Gingera *et al.*, 1995), hence reducing the rate of the epidemic. Partial resistance is also expressed as reductions in the number of lesions, number of sporulating uredinia, size of uredinia and urediniospore production (Pataky, 1986). During the growing season, differences between epidemics on partially resistant and susceptible hybrids may become greater, even though all hybrids would become more resistant with age (Headrick & Pataky, 1987). Partial resistance is usually most discernable on mature plants and has been referred to as adult plant resistance (Hooker & Russel, 1962), but it is also detectable in seedlings (Pataky, 1986).

Likewise, evaluations of sweetcorn hybrids in field experiments have shown that differences in partial resistance to *P. sorghi* can be detected among genotypes at various plant growth stages (Headrick & Pataky, 1985). Predictive models developed for common rust should therefore include the growth stage and partial resistance level of the host (Headrick & Pataky, 1987).

The need for fungicide treatments on partially resistant and susceptible hybrids differs depending on host growth stage at the time of infection (Pataky & Mosely, 1995). The effect of gross morphology of the host on the micro-environment, may also be a factor in the adult plant resistance reaction. Before tasselling, leaf whorls provide a moist, protected environment conducive to urediniospore germination and infection of the plant. After tasselling, whorls are not present and urediniospores are exposed to desiccation and ultraviolet radiation, which could reduce their viability (Headrick & Pataky,1987).

Differences in rust severity approximately three weeks after inoculation were smaller when partially resistant and susceptible genotypes were inoculated at adult-plant stages, than when plants were inoculated at seedling stages (Pataky, 1986). Partial resistance, specifically during the adult plant stages, is therefore considered an important component in the management of common rust on maize (Headrick & Pataky,1987).

The maize lethal leaf spot 1 (lls1) mutation causes the formation of large, spreading necrotic lesions that eventually consume the leaves and kill the plant (Simmons *et al.,* 1998). When plants with the lls1 mutant were inoculated with *P. sorghi*, fewer pustules formed than on wild type siblings and pustule size was often smaller. This reduction ranged from 52 – 85%, with an average of 70% (Simmons *et al.,* 1998). The usefulness of this is not clear, because the plant suffers loss of photosynthetic leaf area in both cases (with or without lls 1).

Chemical control

Fungicides

When disease pressure is moderate to severe, fungicides are sometimes used to control rust (Dillard & Seem, 1990). However, net returns may vary from year to year because of i) variation in climatic conditions; ii) different levels of disease; and iii) planting of different hybrids each year (Wegulo *et al.,* 1997).

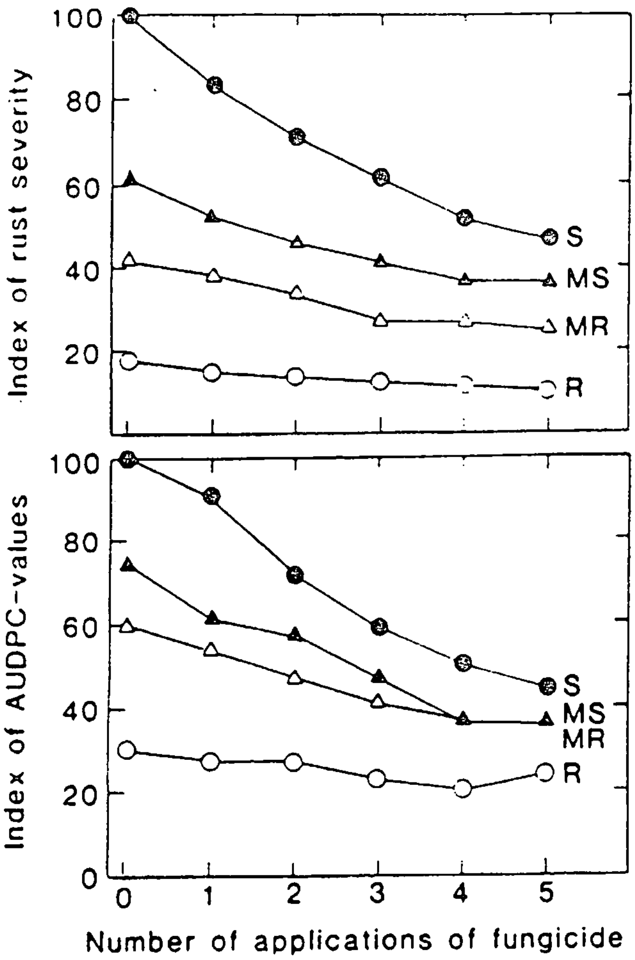
When conditions are favourable for development of common rust (cool, wet weather) foliar applications of chlorothalonil, mancozeb or propiconazole may minimize yield losses in seed production of hybrid corn (Wegulo *et al.,* 1998). Wegulo *et al.* (1997) suggested that the best disease control can be achieved when a fungicide spray program starts early (at low disease severity levels) and sprays are continued for at least three consecutive applications. Pataky (1987b) found an inverse relationship between the number of mancozeb or propiconazole applications and common rust severity on hybrid sweet corn. Figure 2 shows the effectiveness of fungicide applications on common rust (Pataky & Eastburn, 1993).

The choice of fungicide is important, but the levels of net return will depend on factors such as fungicide costs, number and frequency of applications, disease intensity, and the growth stage at which fungicide sprays are initiated (Wegulo *et al.*, 1997). Kaiser & Nowell (1983) reported that mancozeb and bitertanol were most efficient in controlling *P. sorghi* in South Africa. Because of an apparent stimulatory effect on maize, the mancozeb treatment also yielded slightly higher than the genetic control (Kaiser & Nowell, 1983). At present no fungicide is officially registered for common rust control in South Africa. However, labels of certain compounds registered against other foliar diseases mention the fact that common rust will also be controlled.

Foliar fertiliser sprays

Induced systemic resistance may add to the management of diseases in agricultural crops. Systemic protection, expressed as a reduction in the total number of pustules of *P. sorghi* which developed on maize upper leaves, was induced by sprays of various NPK (nitrogen, phosphorus and potassium) fertilisers on the lower leaves (Reuveni, Reuveni & Agapov, 1995). However, the value of such sprays needs confirmation. According to Reuveni & Reuveni (1998) the effectiveness of foliar fertilizers is limited by a number of factors, including nutrient-specific element type and degree of mineral uptake, or inability to supply the required amount of nutrients.

Figure 2. Indices of rust severity and AUDPC values for hybrids which received zero to five applications of fungicides (Pataky & Eastburn, 1993). "S" - susceptible, "MS" - moderately susceptible, "MR" - moderately resistant and "R" - resistant.


Index of rust severity
Index of AUDPC-values
Number of applications of fungicide
S
MS
MR
R
0
1
2
3
4
5
20
40
60
80
100

Action threshold

The sporadic occurrence of rust epidemics and the practice of routine fungicide applications in maize suggested the need for a prediction model or forecast system, aimed at improving chemical efficacy and increasing economic returns in maize (Headrick & Pataky, 1986). To prevent damaging levels of disease prior to harvest and to reduce the rate of epidemic development, an action threshold is needed to enable growers to apply timely control measures. Similar thresholds have been developed for stripe rust of wheat in Australia (Brown & Holmes, 1983). Dillard & Seem (1990) developed an action threshold of 80% incidence, prior to tasselling as a starting level for fungicide sprays (e.g. mancozeb) to avoid crop loss in processing sweetcorn.

Research by Pataky & Eastburn (1993) supported the action threshold proposed by Dillard & Seem (1990). This action threshold, however, was only for cultivars in the moderately resistant category. For susceptible and moderately susceptible hybrids a threshold of 40 – 60% would be appropriate, because severity is relatively constant from 20 – 60% incidence, but increases more rapidly after 40% incidence (Pataky & Headrick, 1988).

CONCLUSION

Based on recent experience of common maize rust epidemics in South Africa, more directed research on this disease is warranted. Although fungicides provide a short-term option for control of common rust, the development of resistant cultivars remains the most attractive management strategy. High costs of fungicides and applications, lower net income, and environmental hazards associated with chemical sprays justify efforts to breed for common rust resistance in South Africa. Moreover, the fact that no fungicide has official registration for common rust control in South Africa complicates spray recommendations.

With the exception of production areas in the humid eastern parts of South

Africa, partial resistance alone should be effective in most field situations. Even though some rust development can be anticipated on partially resistant genotypes, severity should remain below damaging levels in most seasons. Maize breeders and pathologists should focus on the identification of breeding lines with durable resistance. If monogenic *Rp* sources are used, these genes should be protected in appropriate genetic backgrounds. Traditional and molecular methods of transferring and following resistance in breeding populations are important and should be optimized. Ideally annual surveys of virulence adaptation in the pathogen must be conducted, allowing breeders to screen their material to prevailing pathotypes of *P. sorghi*.

To equip farmers with scientifically tested rust management strategies, chemical companies should seek registration of effective products. Action thresholds provide proper timing of the first fungicide application and prevent unnecessary applications. Unless rapid progress is made in breeding locally adapted cultivars with sufficient levels of resistance, research on the establishment of such thresholds in South Africa should be conducted.

Demand for high-yielding maize cultivars resistant to common rust, competition among seed companies, and collaborative research efforts between commercial and public institutions should hopefully result in acceptable, disease-resistant hybrids.

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CHAPTER 2

DESCRIPTION OF SPORE STAGES OF *PUCCINIA SORGHI* IN SOUTH AFRICA

ABSTRACT

The life cycle of *Puccinia sorghi* Schwein., a heteroecious fungus, consists of five well-defined spore stages. The uredinial and telial stages are completed on the primary maize host whereas pycnial and aecial stages occur on *Oxalis corniculata* (creeping sorrel), a perennial and widespread weed. Although the sexual phase of maize rust has been known to occur in South Africa for many years, its importance in creating pathogenic variability in local maize production areas has not been studied. In preliminary experiments the requirements for infection of *O. corniculata* were determined and the different spore stages and associated fungal structures described. Surface-sterilized disks of maize leaves containing telia were placed on water agar plates and inverted over *O. corniculata* plants covered with a settling tower. Removal of plants at different time intervals showed that 6 h of high humidity at 19-21°C were sufficient for germination of teliospores and infection of the alternate host by basidiospores. Light microscopy of plastic and wax embedded *O. corniculata* leaf sections, as well as scanning electron microscopy, provided detailed descriptions of the pycnia, containing receptive hyphae and spermatia, and aecia with aeciospores. The detection of aecial infections on *O. corniculata* in KwaZulu-Natal in 2000 and 2001, suggested that sexual recombination plays an important role in generating new variants of *P. sorghi* in South Africa.

INTRODUCTION

Common rust, caused by *Puccinia sorghi* Schwein., is found throughout most maize producing areas in the world. Disease incidence and severity have increased over recent years (Dillard & Seem, 1990), qualifying common rust as a major disease of maize. The life-cycle of this heteroecious fungus consists of five well-defined spore stages, viz. urediniospores, teliospores, basidiospores, pycniospores and aeciospores. The disease cycle of *P. sorghi* varies from region to region. In tropical and subtropical regions where maize is grown throughout the year, the pathogen reproduces by means of the repeating uredinial stage on successive crops. In areas where maize is grown principally as a summer crop, the pathogen can overwinter as teliospores on maize residue, and subsequently infect young maize plants by means of aeciospores produced on the alternate host (Evans, 1923; Mains, 1934). Additionally, infections of common rust can be caused by exotic wind-borne urediniospores.

Uredinia and telia occur only on *Zea mays* L. subsp. *mexicana* (Schrad.) Iltis (*Euchlaena mexicana* Schrad. (teosinte)), *Z. perennis* (Hitchc.) Reeves & Mangelsd., and *Zea mays* L. (Laundon & Waterston, 1964). Teosinte has been reported to occur in South Africa (Doidge, 1950), but is not common. The pycnial and aecial stages may occur on 30 species of *Oxalis* (some of these by artificial inoculation only), including *Oxalis corniculata* (creeping sorrel) (Fig 1), which is a perennial and widespread weed, not only in South Africa (Botha, 2001), but world-wide (Laundon & Waterston, 1964). According to Botha (2001) creeping sorrel is particularly common in gardens, sports fields and disturbed areas.

In South Africa the aecial stage was found as early as 1876 on *Oxalis bowiei* Lindl. near Somerset East in the Cape Province (now Eastern Cape) (Arthur, 1904). Some years later Evans (1923) reported the aecial stage of *P. sorghi* on *O. corniculata*. Despite the completion of the sexual stage in South Africa for many years, its role in the epidemiology of the disease has never been studied. The first study on pathogenic variation in *P. sorghi* in South Africa revealed seven pathotypes

Figure 1: *Oxalis corniculata* (creeping sorrel) on which the aecial stage of *Puccinia sorghi* occurs

(Fato, 2000), however, the contribution of sexual recombination to the formation of these variants is not known.

Due to the limited accessibility of illustrations (Evans, 1923) of the life-cycle of *P. sorghi*, the objective of this study was to provide detailed microscopic and schematic images of the different spore stages found in South Africa. Furthermore, a survey was conducted during the major maize producing areas to determine the extent of aecial infections on *O. corniculata*.

MATERIALS AND METHODS

Infection of *Oxalis* plants

Maize leaves containing telia were obtained from fields near Greytown, South Africa in May 2000. Telial collections were stored in a sealed plastic jar at 4°C until needed. The surface of the maize leaf disks were sterilized with 3.5% sodium hypochlorite (1% solution) for 1 min and rinsed with distilled water. These disks were then placed on water agar plates and inverted over mature *O. corniculata* plants covered with a settling tower (Morin, Auld & Brown, 1993). To maintain high humidity, pots covered with settling towers were then put in a dew-simulation chamber at 21-22°C. Plants (two pots per treatment) were removed from the dew chamber after 6, 12, 18, 24, 30, 36 and 42 h incubation. Dew covered plants were dried in fan-circulated air for about 2 h. These plants were then placed in a greenhouse cubicle at 18-22°C. The efficiency of different incubation periods was confirmed in three independent experiments.

Microscopy

Leaves with symptoms (pycnia as well as aecia) were prepared for wax and plastic embedding for light microscopy, and for scanning electron microscopy. For wax imbedding the material was fixed in 3% gluteraldehyde for 18 h and then washed in distilled water. The tertiary butylalcohol (TBA)-method (Gray, 1958) was used to dehydrate the plant material before embedding in Histosec-wax (melting point 56-60

°C). After a soaking period of 24 h, a Jung microtome was used to cut 10 μm slices. Slices were stained differentially with Safranine and Fast Green and mounted in Entellan (Johansen, 1940; Sass, 1958).

Material prepared for plastic embedding was also fixed in 3% gluteraldehyde and rinsed twice in a 0.1 M phosphate buffer-solution. Material was post fixed in 1% osmium tetroxide in a 0.1 M phosphate buffer for 2 h. After rinsing with phosphate buffer, the material was dehydrated in 30%, 50%, 70%, 95%, and 100% ethanol solutions for 30 min, respectively before being epoxy impregnated and polymerised for 8 h at 70 °C. Cross section slices (3 μm) were made with glass knives in a LKB Ultratome III microtome. Sections were stained with 0.05% Toluïdine blue.

Leaf material for scanning electron microscopy was cut into 5 mm sections and fixated in 3% gluteraldehyde for 24 h. Leaf pieces were washed twice in 0.05 M phosphate buffer and post-fixed in 2% osmium tetroxide. Fixatives were dissolved in 0.05 M phosphate buffer (pH = 6.8-7.2). The material was subsequently dehydrated for 30 minutes in 30%, 50%, 70% and 95% ethanol, respectively, left overnight in 100% ethanol, and dried in a Polaron critical point dryer. A Bio-Rad system was used to coat the material with gold/palladium. Specimens were viewed with a JEOL WINSEM JSM-6400 scanning microscope operating at 5 kV.

Survey

During June and July 2001 a survey was conducted in the main maize producing areas of South Africa to determine the occurrence of *O. corniculata* and the aecial stage of *P. sorghi*. Seventy survey stops were made along a route of approximately 7 000 km. At each stop maize fields were inspected for the occurrence of telia and *O. corniculata*, with or without aecial infections. Intensively surveyed areas included the mistbelt and cooler eastern production areas in KwaZulu-Natal, Northern Province and Mpumalanga.

RESULTS AND DISCUSSION

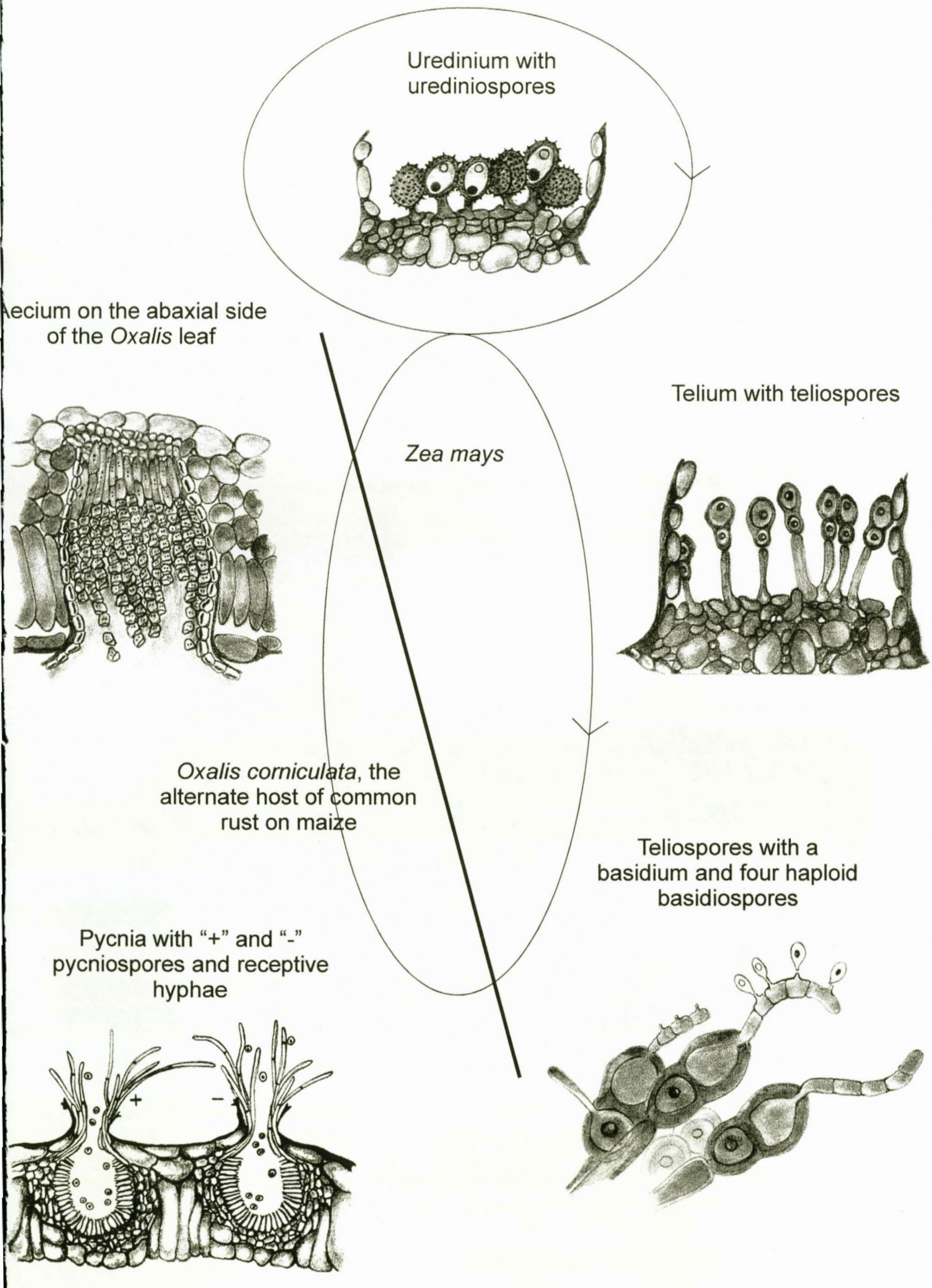
From detailed images on microscopy slides and micrographs the life cycle of *P. sorghi* was illustrated (Fig 2). Pycnia (=spermogonia) (stage 0), containing receptive hyphae and pycniospores (Figs 3 A, B and C), were observed on both sides of *Oxalis* leaves, six days after inoculation. Pycnia, exuding droplets of nectar, grouped in an area up to 0.5 mm in diameter in the center of the lesion, similar to the descriptions of Laundon & Waterston (1964), were frequently brushed to facilitate spermatization. After fusion (plasmogamy) of the "+" and "-" mating types, contained in either the pycniospores (=spermatia) and receptive hyphae, aecial formation (stage 1) takes place in a zone up to 2 mm wide surrounding the pycnia (Laundon & Waterston, 1964).

In the present study aecia containing aeciospores were observed exclusively on the abaxial surface of leaves (Figs 3 D - F). These dikaryotic spores (also called transfer spores) are mostly globoid or ellipsoid, with 1-1.5 µm thick walls, light-yellow in colour with a verrucose surface (Cummins, 1971). Aeciospores are dispersed through the air to a receptive maize plant, where infection can take place to form the dikaryotic uredinial stage (stage 2). In the present study uredinial symptoms were observed 12 days after the inoculation of maize plants with aeciospores from *Oxalis* leaves (Figs 3 G - I).

Urediniospores, borne in uredinia (Figs 3 G - H), act as repeating vegetative summer spores to spread the pathogen on and among maize plants. These spores are unicellular, pedicellate, amphigenous, scattered, oblong or elongate, and pulverulent (Cummins, 1971). The wall of the urediniospore is cinnamon-brown, 1.5-2 µm thick, finely to moderately echinulate (Arthur, 1962), and have three or four equatorial germ pores (Cummins, 1971). Specialized infection structures, namely the appressorium, infection peg, substomatal vesicle and infection hypha, develop during this stage and are responsible for successful penetration of the susceptible maize host (Littlefield & Heath, 1979).

Dikaryotic teliospores (stage 3) can be observed as early as 29 days after inoculation with urediniospores (Pataky, 1986). Cells of teliospores are binucleate, but

Figure 2: Spore stages occurring during the life-cycle of *Puccinia sorghi*



Life-cycle of *Puccinia sorghi* on *Zea mays* and *Oxalis corniculata*

prior to germination, the two haploid nuclei fuse to form the diploid phase of the fungus (Smith & White, 1988). Teliospores are two-celled, oblong to ellipsoid, rounded both at the apex and base, and slightly constricted at the septum (Figs 3 J and K). The wall of the teliospore is a dark chestnut–brown in colour and is 1-2 µm thick at the sides and 5-7 µm thick at the top. The pedicel is once or twice the length of the spore and is colourless, except near the spore (Arthur, 1962).

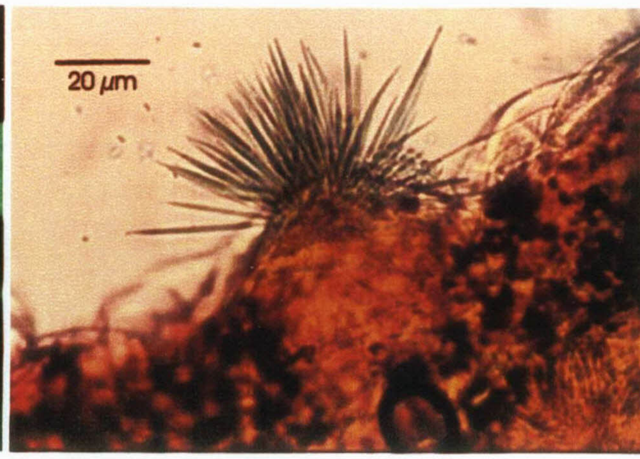
Teliospores germinate to form a promycelium (basidium) bearing four haploid, thin-walled basidiospores (stage 4) of + and - mating types on sterigmata (Fig 3 L). Basidiospores are liberated from the sterigmata by abjection, and air currents spread these short-lived spores to leaves of creeping sorrel, where they germinate and penetrate the leaf surface.

Mendgen (1984) reported that basidium formation, and formation and discharge of basidiospores occur after 4-6 h at 18°C. Results of the present study were in accordance with this report. Following artificial inoculation, successful pycnial and aecial infections developed on all *Oxalis* plants retrieved from the dew chamber, showing that 6 h of high humidity was sufficient for teliospore germination, basidiospore formation, and infection of the alternate host (Figs 3 K, L and M). Although infection of *Oxalis* was easily achieved under controlled conditions, it can be assumed that the age and viability of teliospores, as well as duration of high humidity periods in nature, will also influence the successful infection of *Oxalis* plants. In several rust pathosystems teliospores will only germinate after a dormancy period (Mendgen, 1984; Anikster, 1986). However, Anikster (1986) reported that most teliospores lose germinability when exposed to natural outdoor conditions for 1 yr.

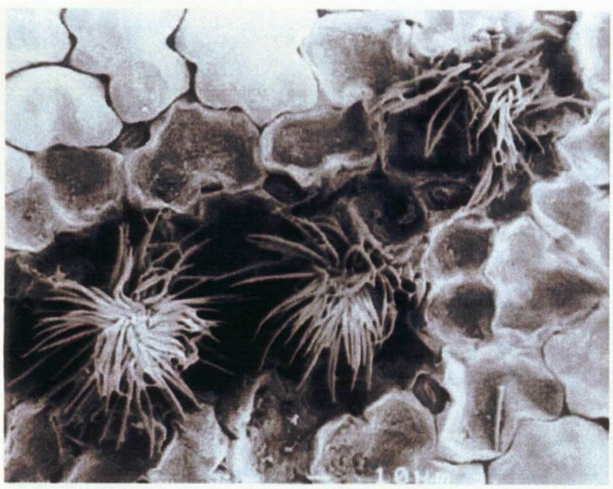
Measurements of the different spore sizes of *P. sorghi* obtained in natural and artifical inoculations in South Africa correlated well with those previously reported (Table 1).

Figure 3: The five different spore stages of *Puccinia sorghi* : A : Pycnia on *Oxalis corniculata;* B: Pycnium with pycniospores and receptive hyphae (400X); C : Scanning electron micrograph of pycnia on *O. corniculata*; D : Cross section of a wax-imbedded *Oxalis* leaf with a pycnium (top) and an aecium (bottom); E: Aecia on an *O. corniculata* leaf (22X); F: Scanning electron micrograph of aecia on an *Oxalis* leaf; G+H: Uredinia on maize leaves; I : Scanning electron micrograph of a uredinium and urediniospores; J : Telia on a maize leaf; K : Teliospores viewed with a light microscope (200X); L : Four basidiospores on a basidium (200X).

A



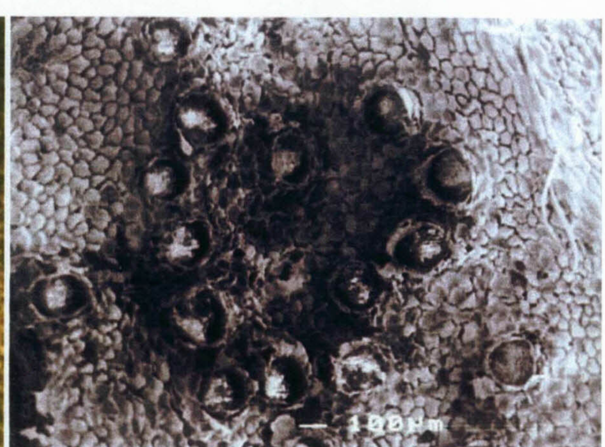
B



C

D

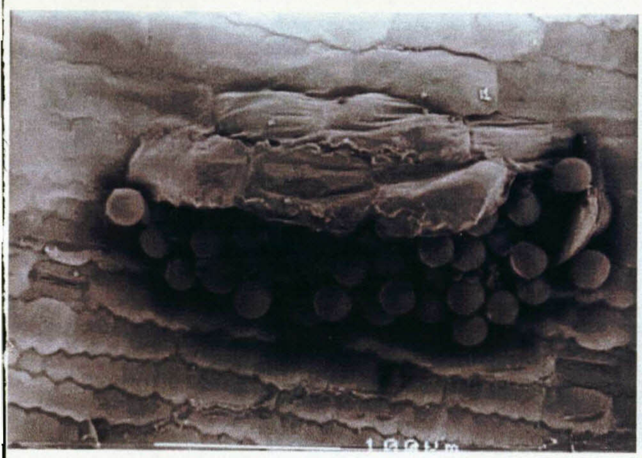
E



F

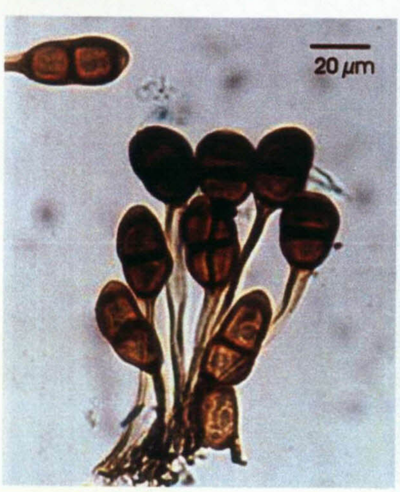
G

H

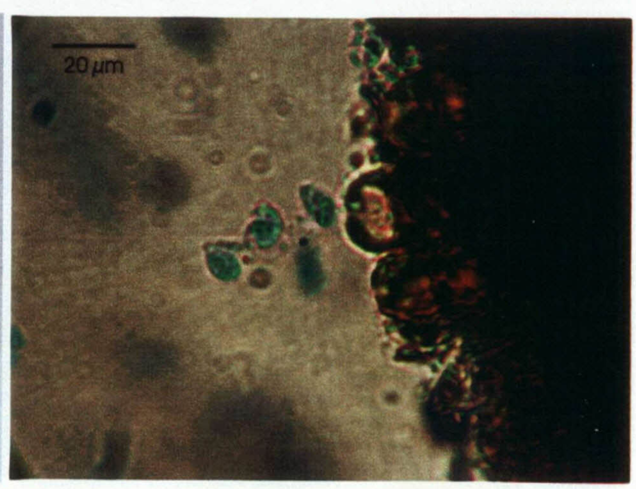


I

J



K



L

Table 1: Measurements of the different spores of *Puccinia sorghi*

	Literature[a]	**Own measurements**
Teliospores	16-23 x 29-45 µm	20-25 x 37-42.5 µm
Pycniospores	no information	2-3 x 3-4 µm
Aeciospores	13-19 x 18-26 µm	17.5-30 x 20-22.5 µm
Urediniospores	23-29 x 26-32 µm	27.5-30 x 27.5-30 µm

[a] Cummings (1971).

Table 2: The occurrence of *Oxalis corniculata* and the aecial stage of *Puccinia sorghi* in maize producing areas in South Africa during June-July 2001

No	Locality	*O. corniculata*	Aecia	Comments
	KWAZULU-NATAL			
1	Greytown - Chailey	✓	✓	severe infection, telia
2	Greytown - Redgates	✓	✓	high infection, telia
3	Karkloof stop 1	✓	✗	telia
4	Karkloof stop 2	✓	✓	severe infection, telia
5	Karkloof stop 3	✓	✗	telia
6	Cedara	✓	✓	severe infection, telia
7	Bloedrivier stop 1	✗	✗	
8	Bloedrivier stop 2	✗	✗	
9	Vryheid industrial	✗	✗	
10	Vryheid Hill	✗	✗	
11	Scheepers Nek	✗	✗	
12	Botha's Pass	✗	✗	
13	Utrecht	✗	✗	
14	Glencoe	✗	✗	
15	Colenso stop 1	✗	✗	
16	Colenso stop 2	✓	✗	few plants
17	Colenso stop 3	✓	✗	few plants
18	Weenen	✗	✗	
19	Rosetta	✗	✗	
20	Sani Pass	✓	✓	severe infection, telia
21	Himeville	✓	✓	severe infection, telia
22	Underberg	✓	✓	severe infection, telia
23	Underberg/Bulwer	✗	✗	telia
24	Arthurs Seat (Loskop)	✗	✗	
25	Lone tree hill (Loskop)	✗	✗	
26	Tree hill (Bergville)	✗	✗	

Table 2 (cont.)

No	Locality	*O. corniculata*	Aecia	Comments
27	Bergville	✗	✗	
70	Makatini	✗	✗	
	FREE STATE			
28	Clarens	✗	✗	
29	Attanada (Senekal/Winburg)	✗	✗	
67	Billerbekshoek	✗	✗	
68	Wesselsbron	✗	✗	
	MPUMALANGA			
30	Koppiesfontein (Petit)	✗	✗	
31	Delmas stop 1	✗	✗	telia
32	Delmas stop 2	✗	✗	telia
33	Delmas stop 3	✗	✗	telia
34	Arnot (Middelburg)	✗	✗	
35	Wonderfontein (Middelburg)	✗	✗	
36	Dullstroom	✗	✗	
37	Kwaggashoek (Lydenburg)	✗	✗	
38	Finsburg (Lydenburg)	✗	✗	
49	Nelspruit	✓	✗	
50	Carolina/Belfast	✗	✗	telia
51	Carolina	✗	✗	telia
52	Breyten	✗	✗	
53	Volksrust	✗	✗	
54	Perdekop	✗	✗	
47	White River	✓	✗	few plants
55	Standerton	✗	✗	
56	Balfour	✗	✗	
57	Bloekomspruit	✗	✗	
58	Vereniging	✗	✗	
69	Piet Retief	✗	✗	

Table 2 (cont.)

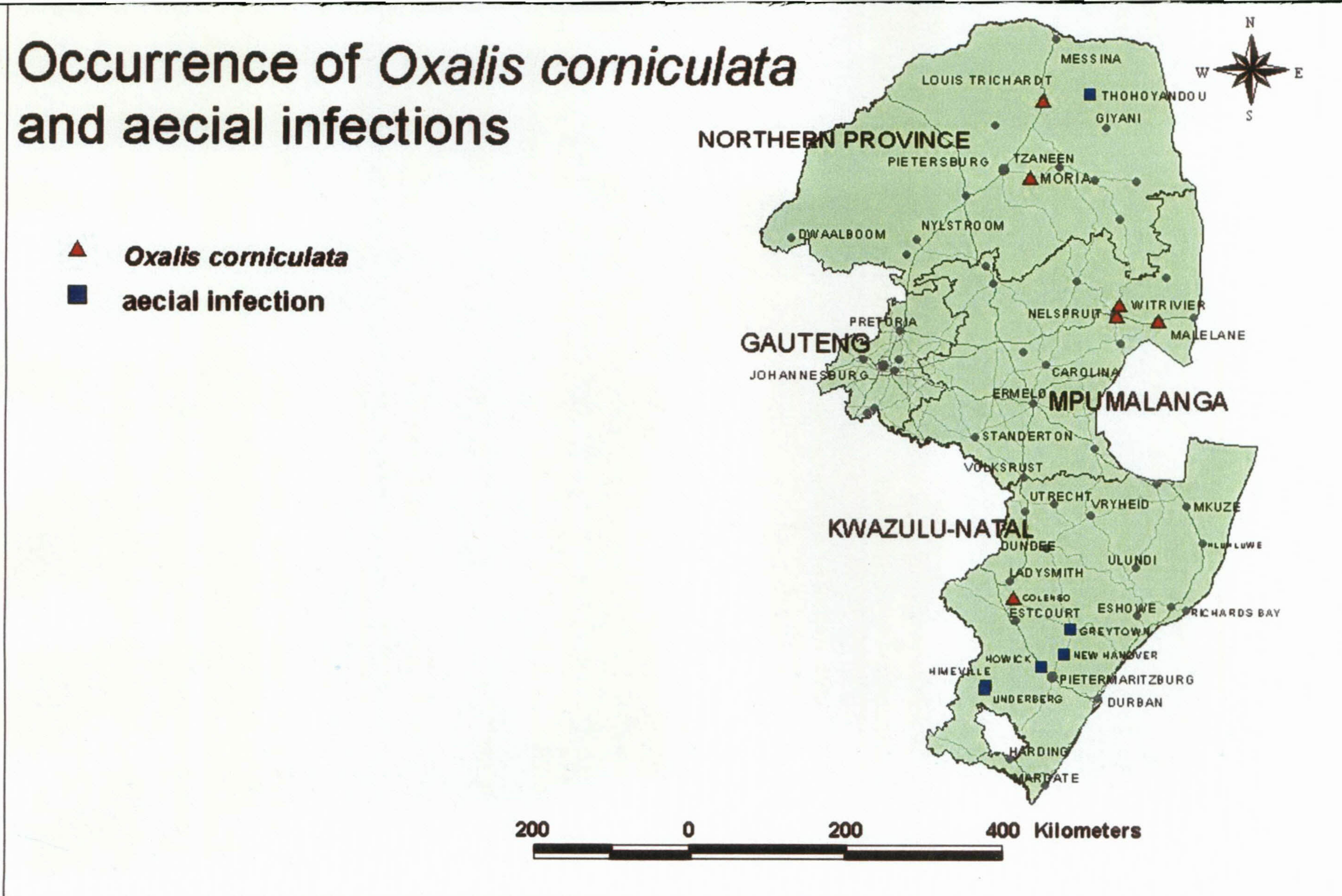
	NORTHERN PROVINCE			
39	Mooketsi (Tzaneen)	✗	✗	
40	Mulima (Louis Trichard)	✓	✗	
41	Lwamundo (Thoyandou)	✓	✓	low infection
42	Madzivhandila (Thoyandou)	✓	✗	few plants
43	Spitskop (Monare)	✓	✗	
44	Letsitele	✗	✗	
45	Dingleydale (Bushbuck Ridge)	✗	✗	
46	Burgershall (Hazyview)	✓	✗	few plants
48	Malelane	✓	✗	
	NORTHWEST PROVINCE			
59	Hartbeesfontein	✗	✗	telia
60	Coligny	✗	✗	
61	Grootpan stop 1	✗	✗	telia
62	Grootpan stop 2	✗	✗	telia
63	Grootpan stop 3	✗	✗	telia
64	Lichtenburg	✗	✗	telia
65	Ottosdal	✗	✗	

✗ = absent
✓ = present
severe infection = aecia frequently observed
telia = telia present on maize residue

The detection of aecia on *O. corniculata* (specimen PREM 57281, Plant Protection Research Institute, Pretoria) in KwaZulu-Natal in June 2000 suggested that sexual recombination may play a role in generating new variants of *P. sorghi* in South Africa. Results from the *Oxalis* survey conducted in 2001 appear in Table 2. *Oxalis corniculata* was found in most areas, but often in gardens and not maize fields. In KwaZulu-Natal (highest incidence), Northern Province and Mpumalanga, *Oxalis* plants were found in maize fields. The most severe aecial infections were observed at Karkloof and Himeville in KwaZulu-Natal. Besides KwaZulu-Natal the aecial stage of *P. sorghi* was found only at Thohoyandou in the Northern Province (Fig. 4). At the time of the survey most maize fields had been harvested, preventing the observation of telia.

Further studies in South Africa should refine the minimum dew requirements for teliospore germination and determine which areas, in synchronization with maize cropping cycles, experience suitable climatic conditions for infection of creeping sorrel, and subsequently maize plants. Likewise, the viability of overwintered teliospores in maize debris should be determined at different time intervals. In this regard Mendgen (1984) reported that teliospore germination in *P. sorghi* is non-uniform, as some spores would germinate at once and some only after months. Although more work is needed to establish the role of aecia in initiating uredinial infections of maize crops, it appears that the life-cycle of *P. sorghi* is frequently completed in KwaZulu-Natal. If the *Oxalis* infections synchronise with maize crops, new pathotypes could arise specifically from this region. This is supported by the data of Fato (2000), who detected four of the seven pathotypes in KwaZulu-Natal.

Figure 4: Areas surveyed in South Africa to determine the occurrence of *Oxalis corniculata* and the aecial stage of *Puccinia sorghi*


Occurrence of Oxalis corniculata and aecial infections
Oxalis corniculata
aecial infection
N
W
E
S
NORTHERN PROVINCE
GAUTENG
MPUMALANGA
KWAZULU-NATAL
MESSINA
LOUIS TRICHARDT
THOHOYANDOU
GIYANI
PIETERSBURG
TZANEEN
MORIA
DWAALBOOM
NYLSTROOM
PRETORIA
JOHANNESBURG
NELSPRUIT
WITRIVIER
MALELANE
CAROLINA
ERMELO
STANDERTON
VOLKSRUST
UTRECHT
VRYHEID
MKUZE
DUNDEE
ULUNDI
LADYSMITH
COLENSO
ESTCOURT
ESHOWE
RICHARDS BAY
GREYTOWN
NEW HANOVER
HOWICK
HIMEVILLE
PIETERMARITZBURG
UNDERBERG
DURBAN
HARDING
MARGATE
200
0
200
400 Kilometers

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CHAPTER 3

RESISTANCE TO *PUCCINIA SORGHI* IN A COLLECTION OF MAIZE LINES

ABSTRACT

Puccinia sorghi is usually controlled by the use of disease-resistant hybrids and foliar applications of fungicides. Two forms of resistance, specific resistance (pathotype-specific or vertical) and general resistance (pathotype-non-specific or horizontal), have been observed in maize. A study was conducted to screen historic and current maize germplasm maintained by PANNAR for response to common rust in a controlled and field environment. High levels of resistance were detected in certain entries, but considering the number of lines screened, resistance to *P. sorghi* was not common in PANNAR germ plasm.

INTRODUCTION

In South Africa the distribution of common rust of maize (caused by *Puccinia sorghi* Schwein.) varies depending on primary inoculum, climate, and host genotype. The most severe infections occur towards the humid eastern production areas (Fato, 2000). According to yield loss data reported from Hawaii, the disease can be extremely damaging and should not be underestimated (Kim & Brewbaker, 1976). To contribute to sustainable maize production in South Africa it is important that risk factors such as common rust be controlled.

Puccinia sorghi is usually controlled by the use of disease-resistant hybrids, and foliar applications of fungicides. Resistance is the most cost-effective management theme. Two forms of resistance to common rust have been observed in maize. Firstly, specific resistance (pathotype-specific or vertical) is monogenic and usually inherited as a dominant trait. Phenotypically it is characterized by hypersensitive, fleck-type reactions on maize plants. The second form, general resistance (pathotype-non-specific or horizontal), conditions a reduction in the number and size of lesions, and less leaf necrosis and chlorosis (Kim & Brewbaker, 1977).

In South Africa, PANNAR (Pty) Ltd. is a privately owned seed company which, as a principal seed supplier, has the major share of the local yellow and white maize market. The company's head office based in Greytown in KwaZulu-Natal, South Africa, is involved in the breeding, development and marketing of maize hybrids. In addition to the local market, maize hybrids are also developed for and marketed in the rest of Africa, USA, Argentina and Europe. Since limited information was available on the status of resistance to *P. sorghi*, a preliminary study was conducted to screen historic and current maize germ plasm maintained by PANNAR.

MATERIALS AND METHODS

Inoculum preparation

Inoculum of the *P. sorghi* pathotypes identified by Fato (2000) was increased on a rust-susceptible hybrid, PHB 3394. Plants for inoculum multiplication were grown in 1-liter-capacity pots (approximately 10 plants per pot). Eleven days after planting 50 ml of a maleic hydracide (0.1 g/1 liter dist. water) solution were applied as a soil drench per pot to retard plant development and enhance sporulation (Knott, 1989). Fourteen days after sowing (approximately five leaves visible) plants were inoculated by atomizing a suspension of urediniospores in light mineral oil onto leaves. Following inoculation, plants were placed in a dew-simulation chamber at 25°C for 16 h to facilitate spore germination and infection. On completion of the dew period plants were dried for about 2 h before placement in a glasshouse where a day/night temperature cycle of 25°C/15°C was maintained. When pathotypes were increased separately, plants inoculated with different isolates were kept in smaller compartments. Rust spores were collected when abundant sporulation occurred and either used in a next cycle of inoculation, or dried for two days before storage at –76°C in cryotubes. In most cases freshly collected spores were used to infect maize seedlings.

Seedling tests

Seedling tests were done at 20°C to 25°C in a glasshouse. Maize lines were grown in sterilized soil in seedling cones (50 x 50 x 100 mm). Two seeds of each line were sown per cone. Trays (675 x 345 x 100 mm) contained 72 cones. Plants were fertilized on a weekly basis by applying 10 g/l (3:2:1 (25) + 0.5% Zn)(50 ml/cone) fertilizer. Plants were inoculated 14 days after sowing (five to six leaves visible) with an equal mixture of the seven pathotypes of *P. sorghi*.

A compressor and a low pressure spray gun, operating at 1.5 kPa, were used to inoculate the plants. Spores were suspended in sterile, distilled water with the aid of an adjuvant (Tween 20 [0.02 ml/250 ml water]). Excess moisture on inoculated plants was dried at room temperature before trays were placed in a dew chamber for 16 h. Infection types were rated after 10-14 days according to a 1-4 scale (Table 1) (Fig 1 A-F).

In total, 2594 lines were screened in this manner for their reaction to *P. sorghi*. Based on the number of lines, inoculations were conducted on 11 different occasions. These lines represent the viable entries in the maize germplasm collection of PANNAR Seed, accumulated over 40 years. Depending on the breeding objectives these lines represent accessions obtained for yield potential, agronomic adaptation, quality attributes, and disease or insect resistance.

A set of lines containing individual *Rp* genes, and a set of advanced white and yellow lines used by PANNAR for breeding purposes, were screened against individual pathotypes of *P. sorghi* (Table 2). Inoculation procedures were the same as described above.

Field tests

The same collection of maize lines screened during the seedling stage was planted at Greytown in 2000. Two row plots, spaced 90 cm apart and containing 10 plants per row, were planted for each entry. Since severe natural infection occurred, no inoculations were made. In the field a 1-9 rating scale (Table 3) was used to assess host response to common rust during anthesis (Fig 1 G-M). Entries were also classified as resistant (R), moderately resistant (MR), moderate (M), moderately susceptible (MS) and susceptible (S) (Pataky & Eastburn, 1993).

Figure 1: Infection types observed at the seedling (Table 1) and adult (Table 3) stages. Seedling reactions: A: uninfected control, B: infection type 1, C: 2, D: 3, E: 4, F: mixed infection type. Adult reactions: G: 1, H: 2, I: 3, J: 4, K:5, L: 6, M: 7.

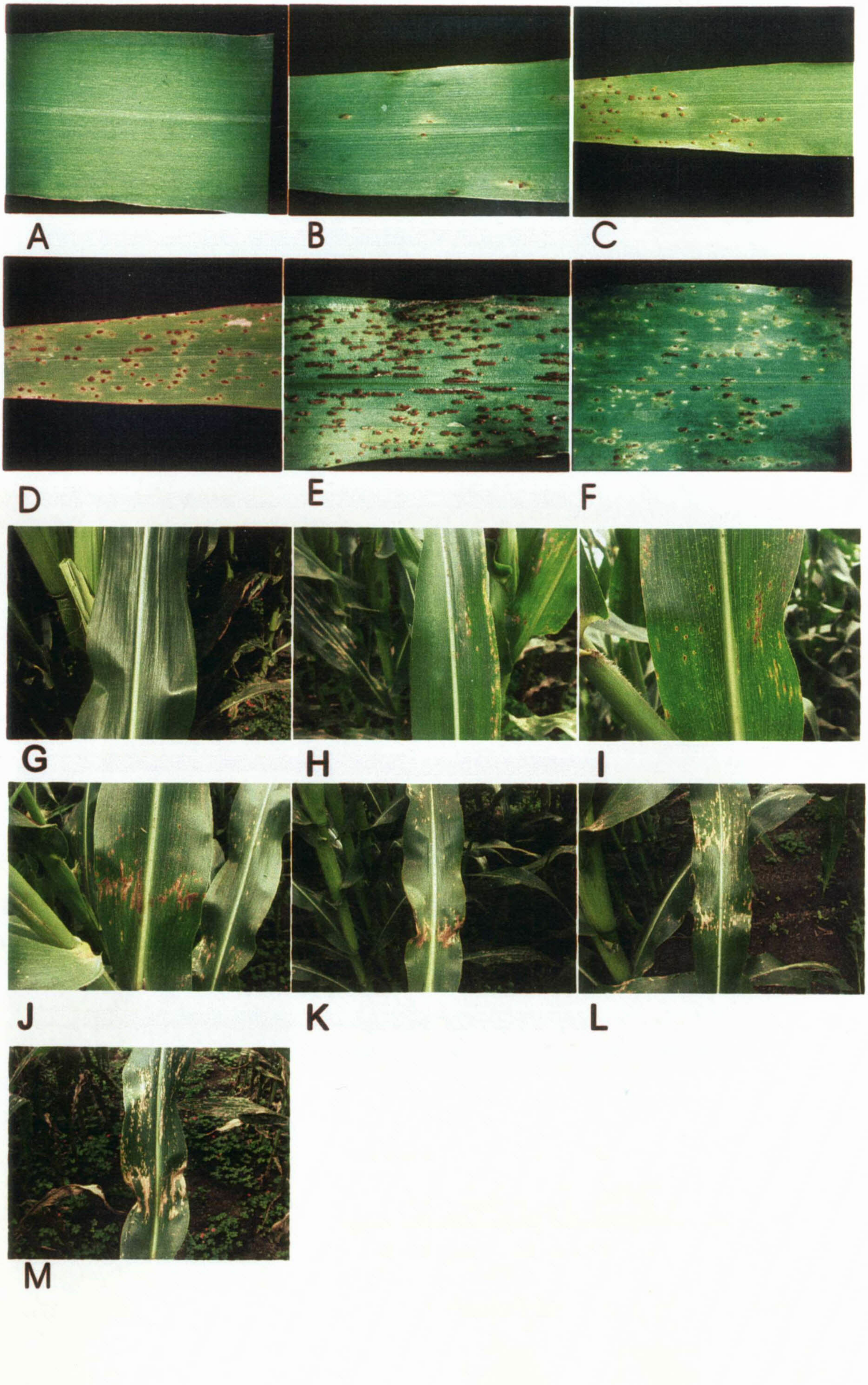

A
B
C
D
E
F
G
H
I
J
K
L
M

Table 1: Description of seedling infection types produced by *Puccinia sorghi* in pathogenicity studies on maize (modified from Hooker, 1985)

Infection type	Symptom description
;	Small chlorotic flecks
1	Small pustules surrounded by necrotic tissue
2	Small pustules surrounded by chlorotic tissue
3	Medium sized sporulating pustules without chlorosis
4	Large sporulating pustules
C	Chlorotic areas associated with infection sites
N	Necrotic areas associated with infection sites

Table 2: White and yellow maize lines screened with a mixture and separately with the different pathotypes of *Puccinia sorghi*

		Pathotypes of *Puccinia sorghi*						
Source	**Mixture**	**GT 1**	**GT 2**	**GT 3**	**GT 4**	**4-2-1**	**34-2-1**	**35-1**
PLY1	;2	;2	;2	2	3^+	2	;2	;2
PLY2	;3	;	;3	;1	2	2	;1	;1
PLY3	;2	3	;3	;1	;1	;1	;	;1
PLY4	;3	2	2	2	2	;3	;3	;3
PLY7	;3	;	3^+	1	;1	3	;2	;
PLY8	;2	;	2^+	;1	;1	3	;2	;1
PLY9	;	;	;1	;1	;	;	;	;
PLY10	;	;	;2	;1	;	;	;	;
PLY12	;2	;	4	;1	;1	;2	3^+	3
PLY13	;1	3	;2	2	3	;1	;1	;
PLY14	;1	;1	3^+	;1	;	;1	;	;
PLY15	;1	NG	NG	;	NG	3	;2	;2
PLY16	;2	;	3	;2	2	3	;2	;
PLY17	;3	3	2	2	2^+	3^+	3^+	4
PLY18	;2	3	2^+	NG	3	3	3	3
PLY20	;3	;1	4	;1	;1	3^+	;2	;1
PLY21	;1^C	;	;3	;1	;2	;2	;2	1P;/1P3
PLY22	;2	1	;3	2	3^+	;2	;2	3
PLY23	;1	1	3	1	2	;3	;1	;
PLY25	;2	;2	2^+	3	3	;2	;1	3^+
PLY26	;1	3	;3	2^+	2^+	;1	;3	3^+
PLY27	;2	4	3	3	3	3	3	4
PLY28	;3	3	3	3	3	;3	3^+	3
PLY29	;1^C	2^+	;2^+	2	2	2	2^+	3
PLY31	;2	3	4	4	4	3	3	2
PLW3	;	;	;1	;	;	;1	;	;
PLW4	;1	NG	;2^+	;2	3	;	NG	;
PLW5	;1	;2^C	;3	;1	2	;^{C}	;^{C}	;
PLW6	;2	3	3^+	2	3^+	3^+	3	;3
PLW7	;2	3	3^+	1	4	3^C	3	;3
PLW8	;2^{CN}	;2	;3	2	4	;1	;2	3
PLW9	;2	3	3	2^+	3^+	;1	;2	2^+
PLW10	;3	2	3	2	3^+	3	2	2
PLW11	;2	3^+	2	2^+	3^+	2^+	;2	3
PLW12	;2	3	;3	3	3	;2	3	3
PLW13	;3	3	;2	3	3	;1	;2	;2
PLW14	;3	3	4	3^+	3	3	;2	3
PLW15	;2	3^+	3	3	3	3	2	3
PLW16	;2	2^+	3	3	4	3	3	;2
PLW17	;2	1	3	2	3	2	2	3
PLW18	;1	2	3^+	2	3^+	;2	2	;2
PLW19	;3	3	4	3	NG	3	3^+	NG
PLW20	;2	3	;	3	;2	;	;2	3^+
PLW21	;2	3	3^+	3	3	;2	2^+	3
PLW23	;3^C	4	3	3^+	3	3	;1	3
PLW24	;1^{CN}	3	;1	2	3	;1^{CN}	;1^{CN}	;2
PLW25	;3	1	3^+	3	3^+	3	3^+	3
PLW26	;1	;	;	;	;	;^{C}	;	NG
PLW27	;1	;	;	2	;1	;	;1	;3

* NG - Not germinated, "C" - Chlorosis, "N" - Necrosis

Table 3: Description key for maize reaction to *Puccinia sorghi* at the post silking stage (modified from Davis, Randle & Groth, 1988)

Rating	% Leaf area affected	Description
1	0	Immune response; no visible disease although hypersensitive flecks may be present
2	1	One to five single pustules present
3	5	Five to fifteen single pustules present plus evidence of a banding pattern
4	10	Numerous single pustules present plus a well-defined banding pattern
5	20	Up to two well defined banding patterns with numerous single pustules present
6	35	Leaf margins becoming necrotic with numerous single pustules present plus up to two well defined banding patterns
7	50	Numerous single pustules, banding patterns, and necrotic margins well defined
8	80	All leaf tissue necrotic except for the center of leaf
9	96	All leaf tissue necrotic except for the for mid-rib adjoining the leaf tissue

RESULTS AND DISCUSSION

The protocol used in the seedling tests allowed for consistent levels of infection, satisfactory disease development and accurate separation of infection types. Screening of the differentials showed that the isolates used corresponded with the data of Fato (2000) (Table 4). The results are summarized in Table 5 whereas the common rust reactions of all individual lines are shown in Appendix 1.

Most of the lines have major genes for resistance to the pathotypes of *P. sorghi* used. This was evident from the many fleck type reactions observed in seedling evaluations. In total 611 lines were completely resistant during the seedling stage (infection type range ; to ;1) (Fig 2A, Table 5). A further 1573 lines showed fleck and susceptible-type pustules on the same plant, indicating a resistance gene effective to some pathotype(s) but not to others. Based on the occurrence of high infection types (5 to 6 range), 410 lines were rated as susceptible to common rust.

In the field 562 lines were rated as resistant (1 to 6MR range) (Fig 2B, Table 5). A comparison of responses showed that not all entries displaying seedling resistance were rated accordingly in the field. Only 185 lines showed resistance in the field as well as in the seedling stage, and 349 lines showed complete susceptibility in both stages (Table 5). In the field 426 lines, rated resistant as seedlings, were susceptible in the adult stage. Most probably unidentified pathotypes of *P. sorghi* occurred in the field, suggesting that further surveys are necessary to determine pathogenic variability. Sixty-one lines were susceptible as seedlings but resistant in the field (Table 5). This indicated that not all pathotypes occurred in the Greytown area where these lines were tested, or possibly that these lines contain adult-plant resistance.

High levels of resistance were detected in entries such as numbers 23-48, 83 and 84 (Appendix 1). In the group that showed mixed seedling reactions, 316 lines were resistant in the field whereas 1257 were susceptible (Table 5). The majority of entries (2032 lines) were susceptible, or sustained significant leaf damage in the field. Results of the yellow and white lines screened as seedlings with a mixture or individual pathotypes of *P. sorghi* are given in Table 2.

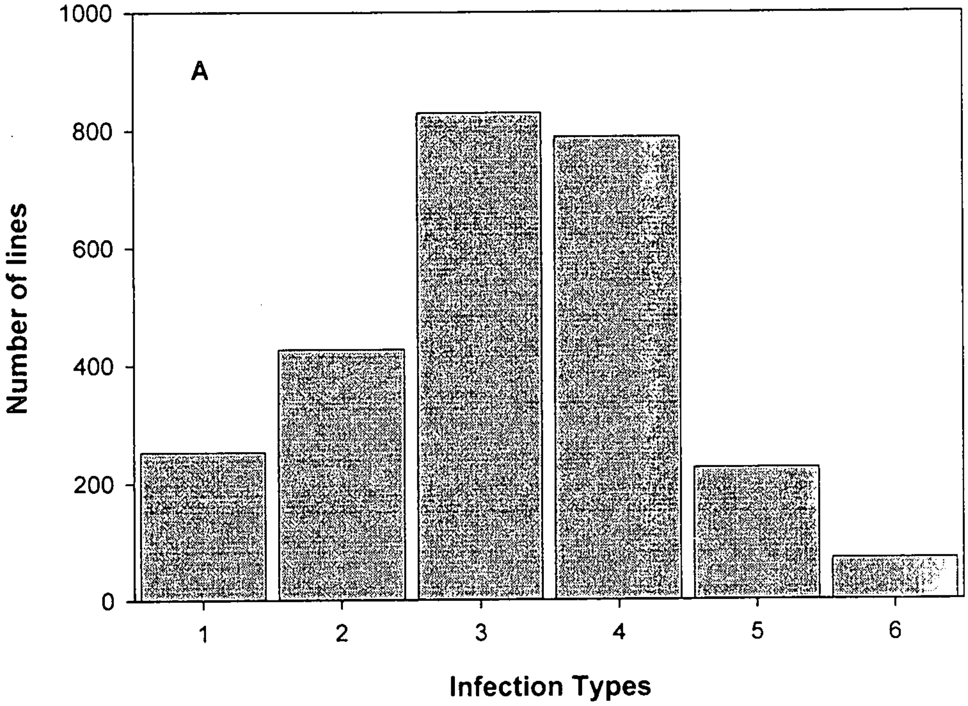
Table 4: Infection types of maize rust differentials to seven pathotypes of *Puccinia sorghi* known in South Africa

SOURCE	GENE	GT1	GT2	GT3	GT4	4-2-1	34-2-1	35-1
1.V20487	*Rp1a*	;	;	3	3	;	;1	4
2. V20489	*Rp1a*	;	;	3	;2	;	;1	3+
3. V20491	*Rp1b*	;1	3+	;1	;1	;3	;1	;1
4. V20493	*Rp1c*	;	;c	2	2	;	;1	3+
5. V20495	*Rp1c*	;	;1	;1	;1	;	;	;1
6. V20499	*Rp1d*	;	4	;1	1	3	;2	;1
7. V20503	*Rp1f*	1pust ;	;1	2+	2	;	;1	3
8. V20505	*Rp1g*	;	;	;1	;	;	;	;
9. V20507	*Rp1h*	;	3+	;1	;1	3	;2	;
10. V20509	*Rp1i*	1pust ;	4	1	;1	3	;2	;
11. V20511	*Rp1j*	;	;	3	;2	;1	;1	1P; / 1P3
12. V20515	*Rp1k*	;1	4	;2	1	3	;2	;1
13. V20515	*Rp1l*	;	;	;2	;	;	;	;
14. V20517	*Rp1m*	;1	;3	;1	;1	3	3+	;
15. V20519	*Rp1n*	;	3+	;1	;1	;2	;2	;1
16. V20521	*Rp3a*	3	3+	2	3	;2	3	;1
17. V20523	*Rp3b*	3+	3	2	3	3	3	3+
18. V20525	*Rp3b*	;	;1	3	3	;	;1	3+
19. V20527	*Rp3c*	;c	;	3	3	;	;	3+
20. V20529	*Rp3d*	;	;	;1	;	;	;	;
21 V20531	*Rp3e*	;	;	2	2	;	;1	3
22. V20533	*Rp3f*	;	;	;1	;	;	;	;
23. V20535	*Rp4a*	;3	3+	2	3	;2	;2	;1
24. V20537	*Rp4b*	;	3	;3	3	3	;3	;1
25 PHB 3394	Control	3	3+	3+	3+	3	3+	3+

"C" - Chlorosis

Figure 2: A) Distribution of maize lines according to their reaction to *Puccinia sorghi*. Seedling response categories (1-6) are defined by : 1 = [0 - ;^{CN}] , 2 = [; - 1^{+CN}], 3 = [;2 - 2^{+CN}] , 4 = [;3 - ;4] , 5 = [3 - 3^{+CN}] and 6 = [4 - 4^{+CN}], with "C" as chlorosis and "N" as necrosis.

B) Distribution of maize lines according to their reaction type (R - resistant [chlorotic flecks]; MR - moderately resistant [more flecks than pustules]; MS - moderately susceptible [more pustules than flecks] and S - susceptible [only pustules]). Variation within reaction type class was rated on a 1-9 scale.


A
Number of lines
1000
800
600
400
200
0
1
2
3
4
5
6
Infection Types

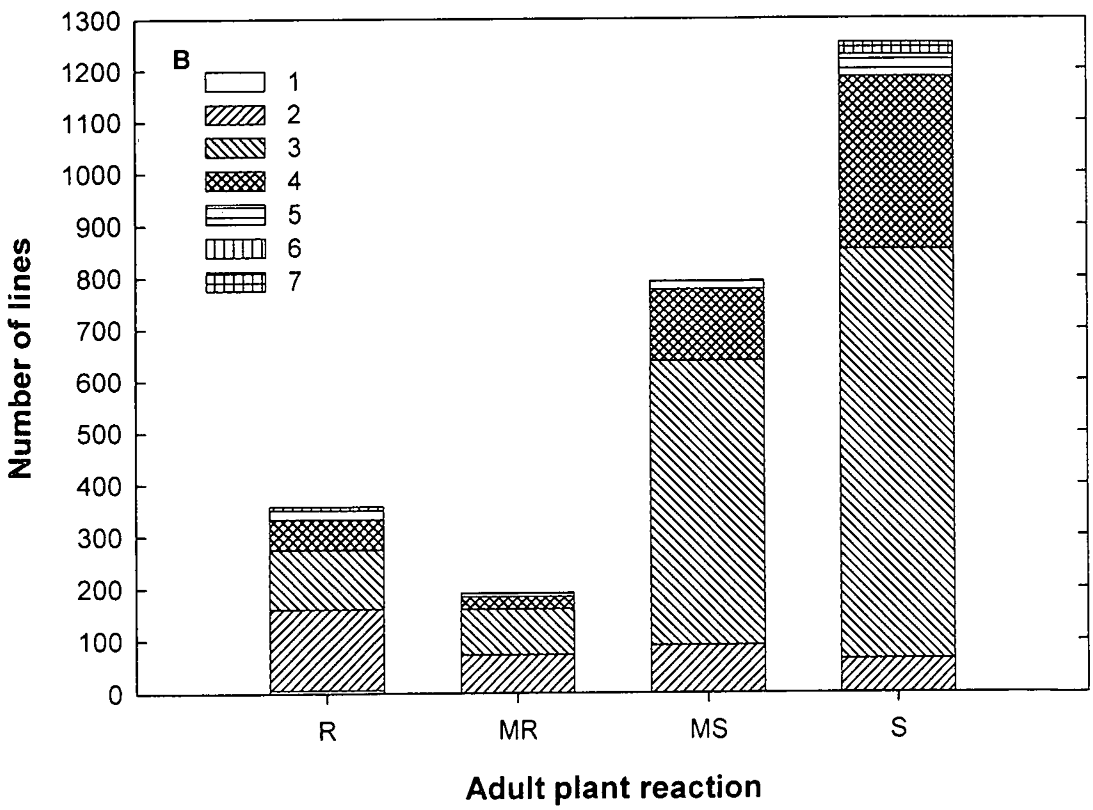

B
1
2
3
4
5
6
7
Number of lines
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
R
MR
MS
S
Adult plant reaction

Table 5: Seedling and adult-plant reaction (divided into 6 response groups) to *Puccinia sorghi* in a collection of 2594 maize lines

Response group	Seedling reaction	Adult reaction	Number of lines
1	Resistant[a]	Resistant[b]	185
2	Mixed reaction[c]	Resistant	316
3	Mixed reaction	Susceptible[d]	1257
4	Susceptible[e]	Resistant	61
5	Susceptible	Susceptible	349
6	Resistant	Susceptible	426
Total			2594

[a] - Infection types 0; to ;1 (0-4 scale).

[b] - Infection types 0, 1, 2R, 2MR, 3R, 3MR, 4R, 4MR, 5R, 5MR, 6R and 6MR.

[c] - Resistant and susceptible infection types on same leaf.

[d] - Infection types 2S, 2MS, 3S, 3MS, 4S, 4MS, 5S, 5MS, 6S, 6MS, 7S and 7MS.

[e] - Infection types 2 to 4 (0 to 4 scale).

Lines PLY 9, 10, and PLW 3, 26, were resistant to all pathotypes and PLY 18, 27, 28, 31 and PLW 6, 12, 14-16, 19 susceptible (Table 2).

Considering the summarized data, resistance to common rust was not common in PANNAR germ plasm. This was not unexpected in view of the fact that the collection has been compiled to include various other traits. Up to now very little emphasis was placed on a rust resistance breeding program as such for South Africa. Although maize breeders and pathologists record rust severity whenever the disease occurs naturally in field plots, and this information is used in selection, a focused common rust breeding program is needed. This entails the continued monitoring of virulence adaptation in *P. sorghi*, as well as more comprehensive testing of resistant lines. It is important that those lines identified as resistant in both seedling and field tests be confirmed as such in multilocational field trials. A detailed pedigree analysis (PANNAR confidential information) of promising lines identified in this study could also indicate if resistance can be related to certain parents. Procedures to quantify partial resistance, and to select for this resistance form in the field or glasshouse, should be optimized. Should durable (polygenic) resistance be commonly used in breeding, the need for virulence surveys in *P. sorghi* will become less.

Breeders should use sources of effective seedling resistance with circumspect. Based on the hypersensitive expression of low infection types these sources appear to be monogenic for common rust resistance. If resistance in these lines is indeed based on single genes it can not be assumed to remain durable. The use of such sources in genetic backgrounds with pathotype-non-specific resistance will be more sensible from a durability point of view. Confirming resistance genes in inbreds will also allow breeders to combine genes in hybrids rather than exposing them as single genes to a potentially flexible rust population.

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CHAPTER 4

CHEMICAL CONTROL OF *PUCCINIA SORGHI* ON MAIZE IN SOUTH AFRICA

ABSTRACT

To study the impact of common rust (*Puccinia sorghi*) on yield of maize (*Zea mays*), as well as the efficacy of different fungicides, field experiments were conducted at Greytown and Delmas in the 1999/2000 and 2000/2001 seasons. Treatments included six commercial hybrids, three fungicides used in combinations, viz. Eria® (carbendazim/difenoconazole) (150/75 g a.i /ha), Amistar® (azoxystrobin) (75 g a.i/ha) and Flint® (trifloxystrobin) (50 g a.i/ha), and an unsprayed control. Fungicides were applied between 66-83 days after planting, depending on the season. In a second spray, Eria® was applied as a follow-up on all fungicide-treated plots. No pustule formation was observed on maize hybrids sprayed with Amistar®, but foliage showed significant necrosis where colonization had taken place prior to spraying. In unsprayed plots rust development was most severe on PHB 3394 whereas PAN 6710 was most resistant. In the 1999/2000 season yield losses up to 2.1 ton/ha at Delmas and 2.06 ton/ha at Greytown were observed. At Delmas and Greytown, respectively, yield losses up to 2.1 and 2.39 ton/ha were encountered in the 2000/2001 season. At Greytown grey leaf spot appeared late in the season and influenced yield in unsprayed plots. This study showed that fungicides controlled common rust and increased yield of maize hybrids. Results were, however, influenced by location and hybrid genotype.

INTRODUCTION

In the production of agricultural crops plant diseases continue to play a major limiting role. Foliar diseases of crops destroy photosynthetic leaf area which, in turn, reduces the amount of radiation intercepted, subsequently influencing crop productivity (Wegulo *et al.*, 1997). Genetic resistance to disease is generally considered the most cost-effective way of controlling diseases. The amount of disease is, however, dependent on the nature of the host genotype, virulence in the pathogen, environment and production practices (Reuveni & Reuveni, 1998). Although resistance breeding remains important, the breakdown of resistance genes, e.g. the *Rp1-D* gene for resistance to *Puccinia sorghi* (Pataky *et al.,* 2001), can under certain circumstances necessitate a short-term control measure such as fungicide application. Cultural practices such as no-till may also lead to more volunteer plants and an increase in primary inoculum of *P. sorghi* (Sumner, Doupnik & Boosalis, 1981). In South Africa the planting of susceptible maize hybrids has emphasized the importance of chemical rust control.

In areas where common rust epidemics require emergency control actions, or where yields warrant chemical control costs, fungicide application is a useful management practice. Pataky (1987) reported an inverse relationship between the number of fungicide applications and common rust severity. The choice of fungicide, application time and frequency, and coverage of foliage will have an effect on the level of control achieved (Wegulo *et al.,* 1997). Wegulo *et al.* (1997) reported that three consecutive applications after common rust detection resulted in the greatest net returns, depending on the specific situation. The earlier the applications were made, the more profitable the spray program became. Wegulo *et al.* (1998) reported that five applications of mancozeb or propiconazole reduced common rust by 55% on a susceptible host.

An action threshold was formulated to enable farmers to properly time fungicide application, thus reducing the rate of epidemic development and preventing damaging levels of disease (Dillard & Seem, 1990b). For sweet corn, an action threshold of 80%

incidence prior to tasseling, or six uredinia per leaf, was suggested by Dillard & Seem (1990 a,b) for moderately resistant hybrids. For susceptible and moderately susceptible hybrids a threshold of 40–60% was suggested as disease severity is relatively constant between 20% and 60% disease incidence (Pataky & Headrick, 1988).

In South Africa, common rust epidemics have been known to occur recently, in particular on maize hybrids marketed by international seed companies. These hybrids are popular in terms of yield and adaption, but lack resistance to *P. sorghi*. At present no fungicide has been registered in South Africa to control common rust as such. However, recommendations of several compounds applied to control foliar diseases of maize state that common rust will also be controlled. In this study the effect of fungicides was investigated on common rust and yield of maize hybrids in two environments.

MATERIALS AND METHODS

1999/2000

The maize hybrids PAN 6727, PAN 6335, PAN 6573, PAN 6710, PAN 6242 and PAN 6716, were planted at Greytown and Delmas according to a 6 x 3 factorial treatment design with four replicates. Hybrids were considered as main-plots and spray treatments as sub-plots. In Greytown plots consisted of two 4.4-m rows spaced 90 cm apart, giving a population of 50 000 plants per ha. In Delmas plots consisted of two 6.1-m rows spaced 90 cm apart, giving 36 000 plants per ha. Spray treatments consisted of two fungicides and an unsprayed control. Applications were made by a knapsack sprayer calibrated to apply the recommended rates. The fungicides Eria® (carbendazim/difenoconazole, 150/75 g a.i /ha) and Flint® (trifloxystrobin, 50 g a.i/ha) were applied individually at 83 days after planting, followed by an Eria® treatment on all fungicide-sprayed plots 29 days later.

Rating of natural common rust severity was done according to a 1-9 scale

(Chapter 3: Table 2) during anthesis. The plots were harvested 205 days after planting and grain yield determined. Plot yield was converted to ton/ha before being analyzed for variance using NCSS 2000 Statistical Software for Windows.

2000/2001

The experiment was repeated with some modifications (6 x 4 factorial design) at the same sites in 2000/2001. PAN 6716 was replaced by PHB 3394, a rust-susceptible hybrid, and Amistar® (azoxystrobin, 75 g a.i./ha), recently registered for the control of grey leaf spot (*Cercospora zea-maydis*), was added as a third fungicide treatment. Similar to the previous season, two fungicide sprays were applied, an early spray at 66 days after planting, followed by an Eria® application three weeks later. Unsprayed plots of each hybrid served as control treatments. The Delmas trial was artificially inoculated at the 9-10 leaf stage with a mixture of *P. sorghi* pathotypes. Inoculation was done by spraying plots with urediniospores suspended in light mineral oil (approximately 1 mg spores/ml), using an ultra-low volume hand-held sprayer, as well as by injecting a spore/distilled water suspension into whorls of plants. Due to an early and uniform occurrence of common rust at Greytown, this trial was not artificially infected. Common rust ratings of treatments were done according to the 1-9 scale during anthesis.

RESULTS

1999/2000

Common rust ratings recorded at Delmas and Greytown are given in Fig 1A + B. At Delmas ratings in unsprayed control plots varied between 20% (PAN 6727 and PAN 6335) and 5% (PAN 6242). At Greytown common rust ratings in control plots ranged between 15% (PAN 6727 and PAN 6335) and 5% (PAN 6242 and PAN 6717). According to the rating system used and excepting PAN 6727, fungicide applications did not reduce common rust substantially at any of these sites. None of the fungicide treatments prevented sporulation, but a reduction was noticed in infection type.

At Delmas hybrids differed significantly ($P < 0.0001$) but neither treatments nor the interaction between hybrids and treatments were significant sources of variation. Over treatments, PAN 6242 produced the highest yield (7.91 t/ha) and PAN 6727 the lowest (5.76 t/ha) (Fig 2A). The best yield response (increase of 37.06% [1.99 t/ha]) was obtained for PAN 6727 and the lowest (0.94 t/ha [8.8%]) for PAN 6242 (Fig 3A). Differences in yield between sprayed and unsprayed treatments are shown in Fig 4A.

At Greytown hybrids ($P < 0.000565$), treatments ($P < 0.000737$) and their interaction ($P < 0.018174$) were significant sources of variation. PAN 6335 yielded the highest (13.84 t/ha) and PAN 6710 yielded the lowest (11.93 t/ha) (Fig 2B). Overall PAN 6335 responded the best (2.06 t/ha yield increase [16.52%]) to fungicide applications (Fig 3A). For PAN 6710 the unsprayed control surprisingly yielded 0.15 t/ha more [-1.25%] than in the fungicide treatments (Fig 3A). Over hybrids, the Flint® and Eria® treatments increased yield with 6.13% and 7.25% with respect to the unsprayed control. Differences in yield between sprayed and unsprayed treatments are shown in Fig 4B. In individual cultivar/fungicide treatments, the highest increase in yield (17.96%) was obtained from PAN 6335 sprayed with Flint®+Eria®.

Figure 1: Rust reactions (0-96% scale) observed on maize hybrids in different fungicide treatments at Delmas (A) and Greytown (B) during the 1999/2000 season

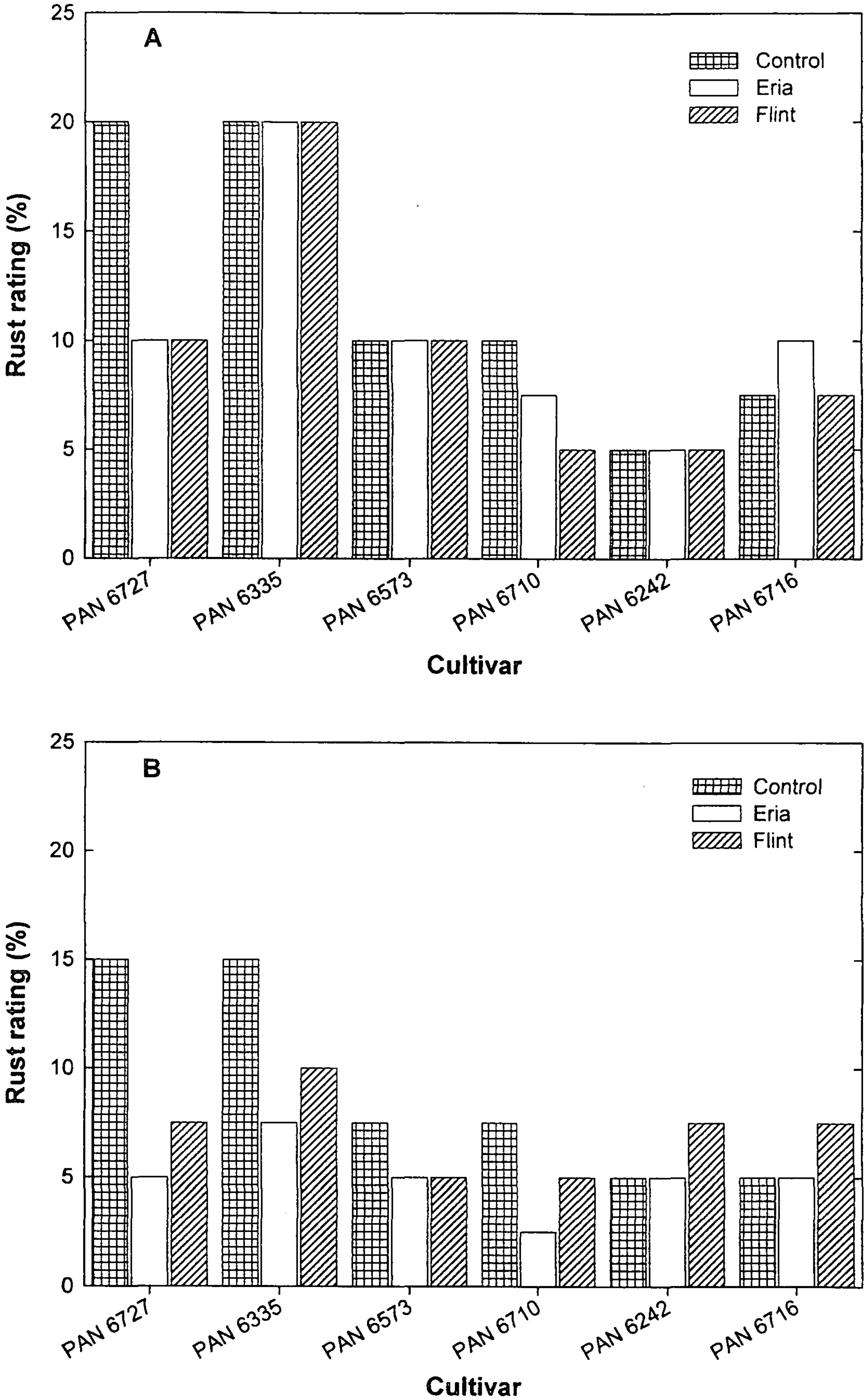

25
20
15
10
5
0
A
Control
Eria
Flint
Rust rating (%)
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PAN 6716
Cultivar
B
Control
Eria
Flint
Rust rating (%)
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PAN 6716
Cultivar

Figure 2: Yield response (t/ha) of six maize hybrids sprayed with two fungicides at Delmas (A) and Greytown (B), during the 1999/2000 season. Error bars indicate standard deviations.

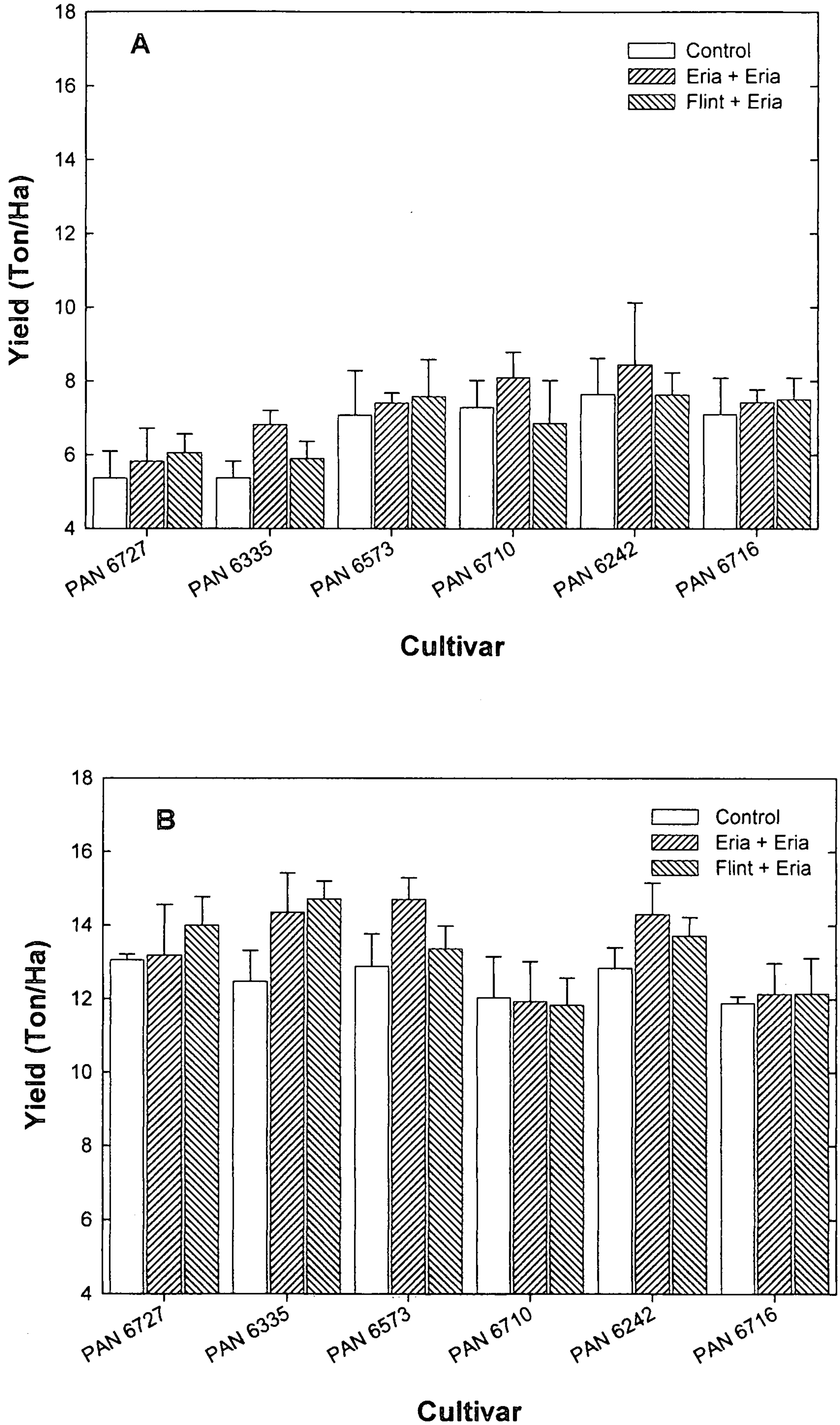
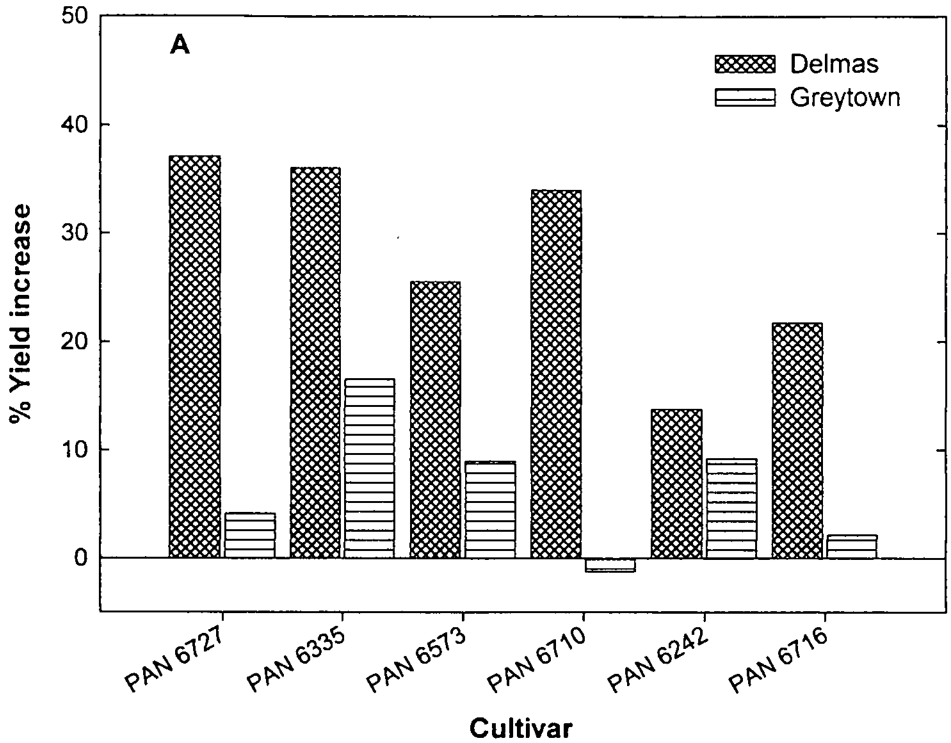

A
Control
Eria + Eria
Flint + Eria
Yield (Ton/Ha)
18
16
14
12
10
8
6
4
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PAN 6716
Cultivar
B
Control
Eria + Eria
Flint + Eria
Yield (Ton/Ha)
18
16
14
12
10
8
6
4
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PAN 6716
Cultivar

Figure 3: Mean yield increase (%) obtained in different maize cultivars with fungicide applications at Delmas and Greytown for the 1999/2000 (A) and 2000/2001 (B) seasons


A
Delmas
Greytown
% Yield increase
50
40
30
20
10
0
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PAN 6716
Cultivar

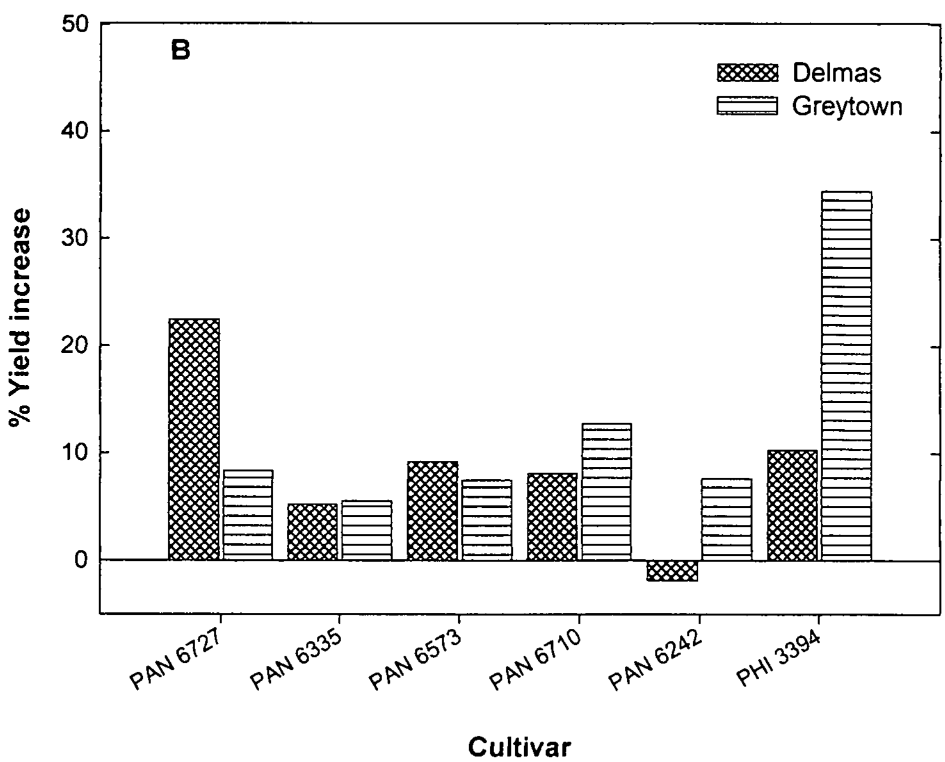
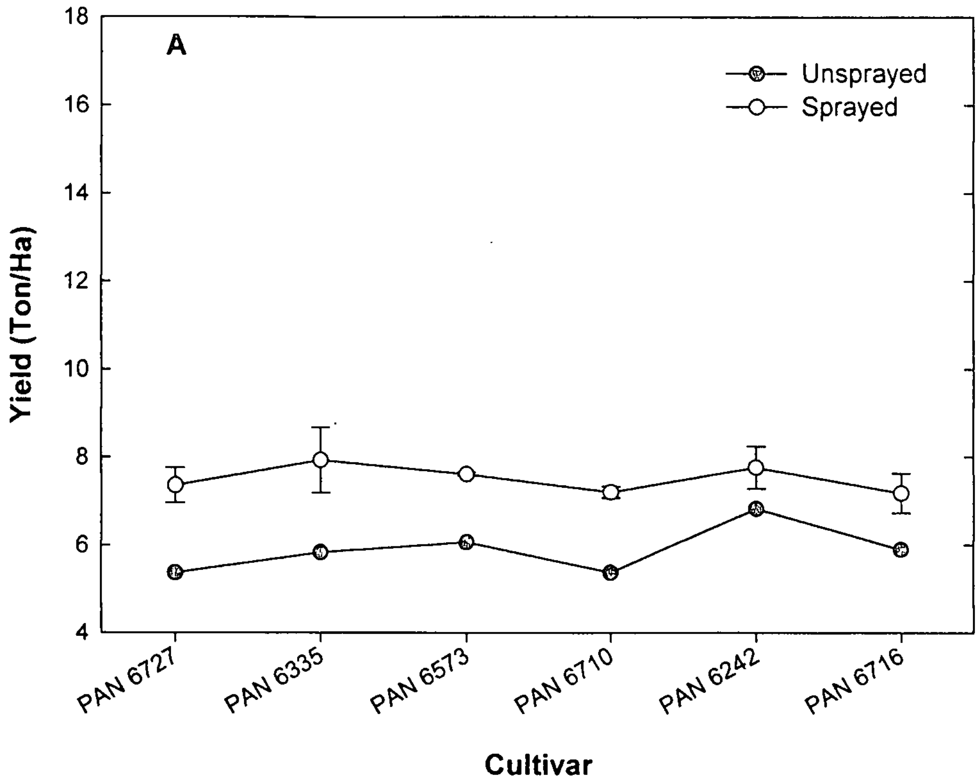
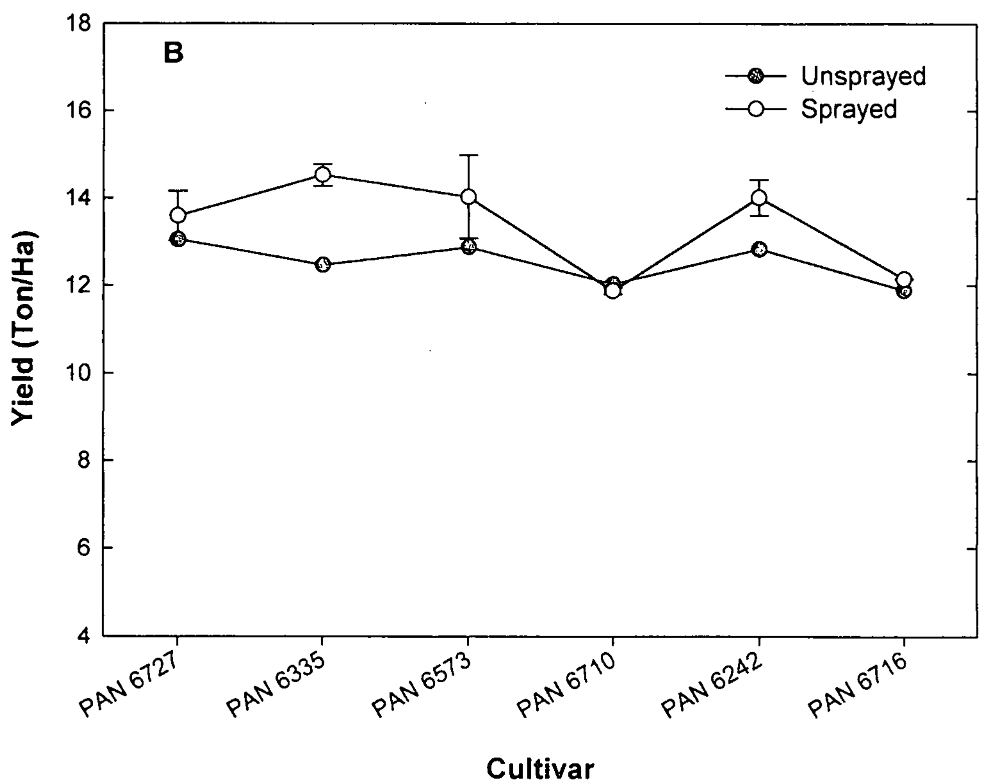

B
Delmas
Greytown
% Yield increase
50
40
30
20
10
0
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PHI 3394
Cultivar

Figure 4: The mean differences between sprayed (mean of the two treatments) and unsprayed (control) treatments on maize hybrids at Delmas (A) and Greytown (B) during the 1999/2000 season. Error bars indicate standard deviations.


A
Unsprayed
Sprayed
Yield (Ton/Ha)
18
16
14
12
10
8
6
4
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PAN 6716
Cultivar


B
Unsprayed
Sprayed
Yield (Ton/Ha)
18
16
14
12
10
8
6
4
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PAN 6716
Cultivar

2000/2001

In unsprayed plots at Delmas, PHB 3394 was most susceptible followed by PAN 6335, PAN 6573 and PAN 6242 (Fig 5A). According to the rust severity at Greytown PHB 3394, PAN 6242 and PAN 6727 were rated most susceptible (Fig 5B). Differences in rust severity between sprayed and unsprayed plots were more apparent at Delmas, but ratings varied between 10% and 15% at Greytown. Amistar®+Eria® was the only treatment that sufficiently inhibited sporulation, but necrosis of leaf tissue still occurred (Fig 6 A + B).

Similar to the previous season at Delmas, only hybrids differed significantly ($P < 0.00885$) according to the analysis of variance. PHB 3394 produced the lowest yield (7.75 t/ha) over treatments and PAN 6710 the highest (8.71 t/ha) (Fig 7A). The mean yield of cultivars was increased by 0.66 t/ha (8.89%) over fungicide treatments (Fig 8A). Similar to the previous season, PAN 6727 showed the highest response (22.46% [1.60 t/ha]), and PAN 6242 the lowest response (-1.88% [-0.16 t/ha]) to fungicide treatments (Fig 3B).

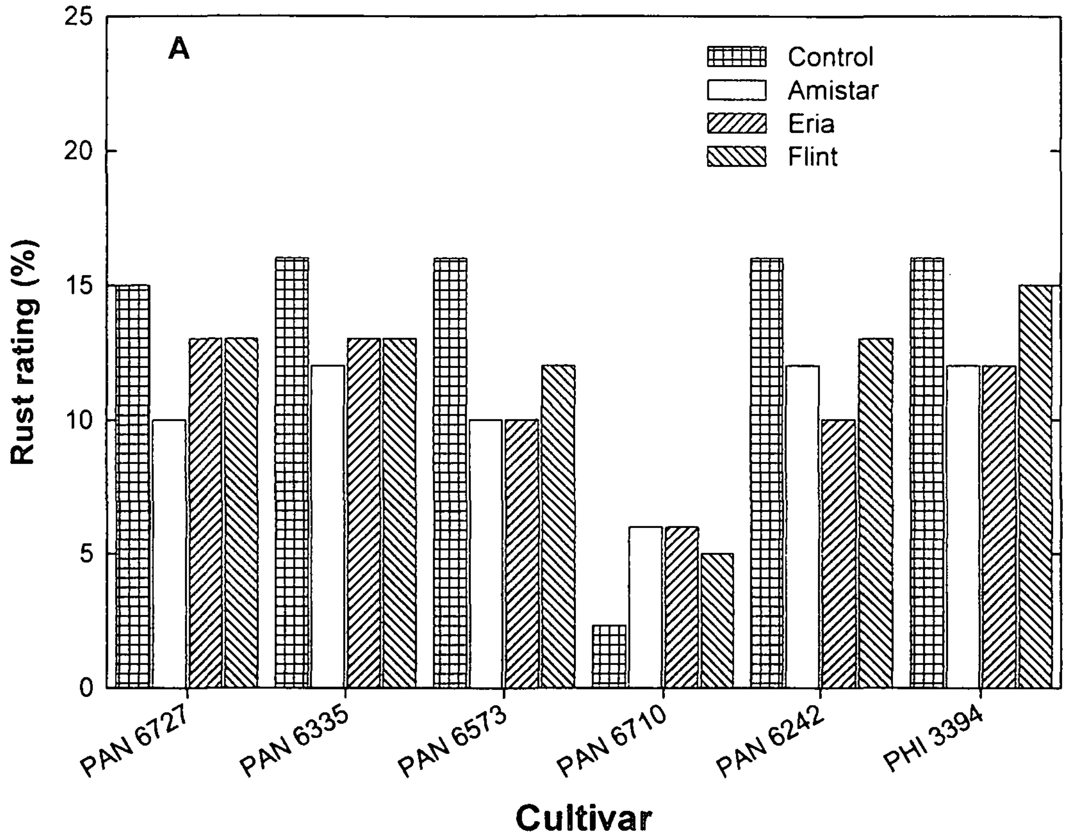
At Greytown treatments ($P < 0.021588$) and hybrids ($P < 0.000164$) differed significantly, but not their interaction. At Greytown PAN 6727 yielded the highest (13.69 t/ha) and PHB 3394, as in Delmas, produced the lowest yield (8.76 t/ha) (Fig 7B).The cultivars responded with a mean 1.25 t/ha yield increase (12.67%) to fungicides (Fig 8B). PHB 3394 showed the best mean response (34.39% [2.39 t/ha yield increase]) to fungicide treatment compared to 5.52% (0.68 t/ha) in PAN 6335 (Fig 3B). The hybrids showed the best response (10.06%) to the Amistar® + Eria® treatment followed by the Flint® + Eria® treatment (11.56%) and then the Eria® + Eria® treatment (4.24%). At Greytown grey leaf spot (GLS) appeared late in the season and most probably influenced yield in the control plots. Amistar® was recently registered in South Africa against GLS, explaining the significant influence of this fungicide on yield.

DISCUSSION

This study showed that fungicides, in particular Eria®+Eria® or Amistar®+Eria®, have a positive effect on yield of commercial hybrids. Considering the economics of fungicide applications on maize, it has been estimated that a combined Amistar® plus Eria® aerial spray amounted to R463-10 per ha during the 2000/2001 season (F.J. Kloppers, personal communication). At an average maize price of R1000 per ton, the farmer thus has to protect, in comparison with an unsprayed field, approximately 0.5 t/ha to recover chemical control costs. At Delmas yield increases up to 2.1 t/ha were realised in the absence of other leaf spot diseases, indicating that fungicide applications were profitable. However, based on the lack of marked differences in rust severity between sprayed and unsprayed plots, it was not clear if yield differences can be entirely ascribed to common rust control. A concern in this regard is that the 1-9 rust assessment scheme does not reflect actual damage and that percentage diseased tissue would be more appropriate. Except for GLS at Greytown in the second season, no other diseases were conspicuous among plots. It should be kept in mind that fungicides contribute to plant health in general, and that stem and possibly root rots, without clear symptoms and signs, may also have been influenced by foliar applications. Benefits of foliar sprays aimed at common rust thus include control of other diseases, in particular lodging and head rot, and less inoculum carry-over to the next season. Grain quality may also be improved.

It was clear that yield loss studies due to common rust, in the absence of other foliar diseases, are difficult. Some environments seen as high-risk rust areas are also prone to GLS infections and the individual effects of these two diseases are difficult to separate. With better control of humidity, such as micro-irrigation systems

Figure 5: Rust reactions (1-9 scale) observed on maize hybrids in different fungicide treatments at Delmas (A) and Greytown (B) during the 2000/2001 season.


A
Control
Amistar
Eria
Flint
Rust rating (%)
25
20
15
10
5
0
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PHI 3394
Cultivar

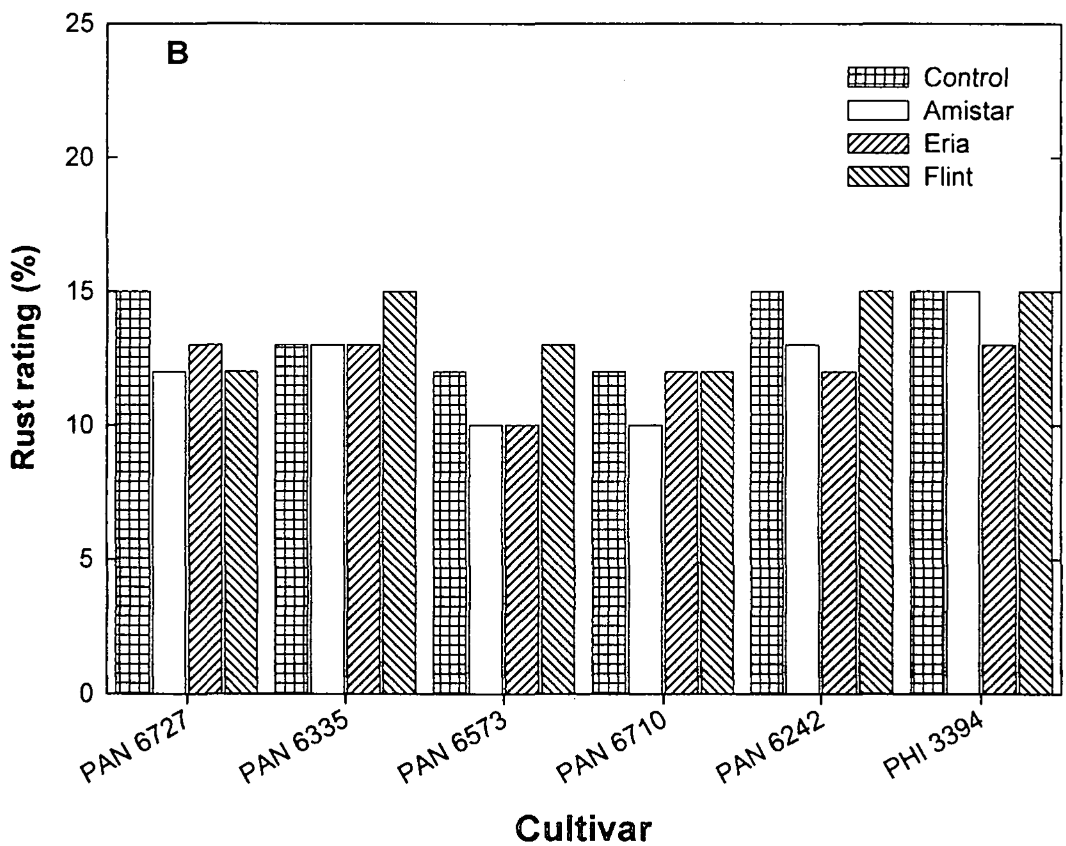

B
Control
Amistar
Eria
Flint
Rust rating (%)
25
20
15
10
5
0
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PHI 3394
Cultivar

Figure 6: Inhibition of *Puccinia sorghi* sporulation by Amistar®+Eria® on maize leaves (A) compared to less effective control (B).

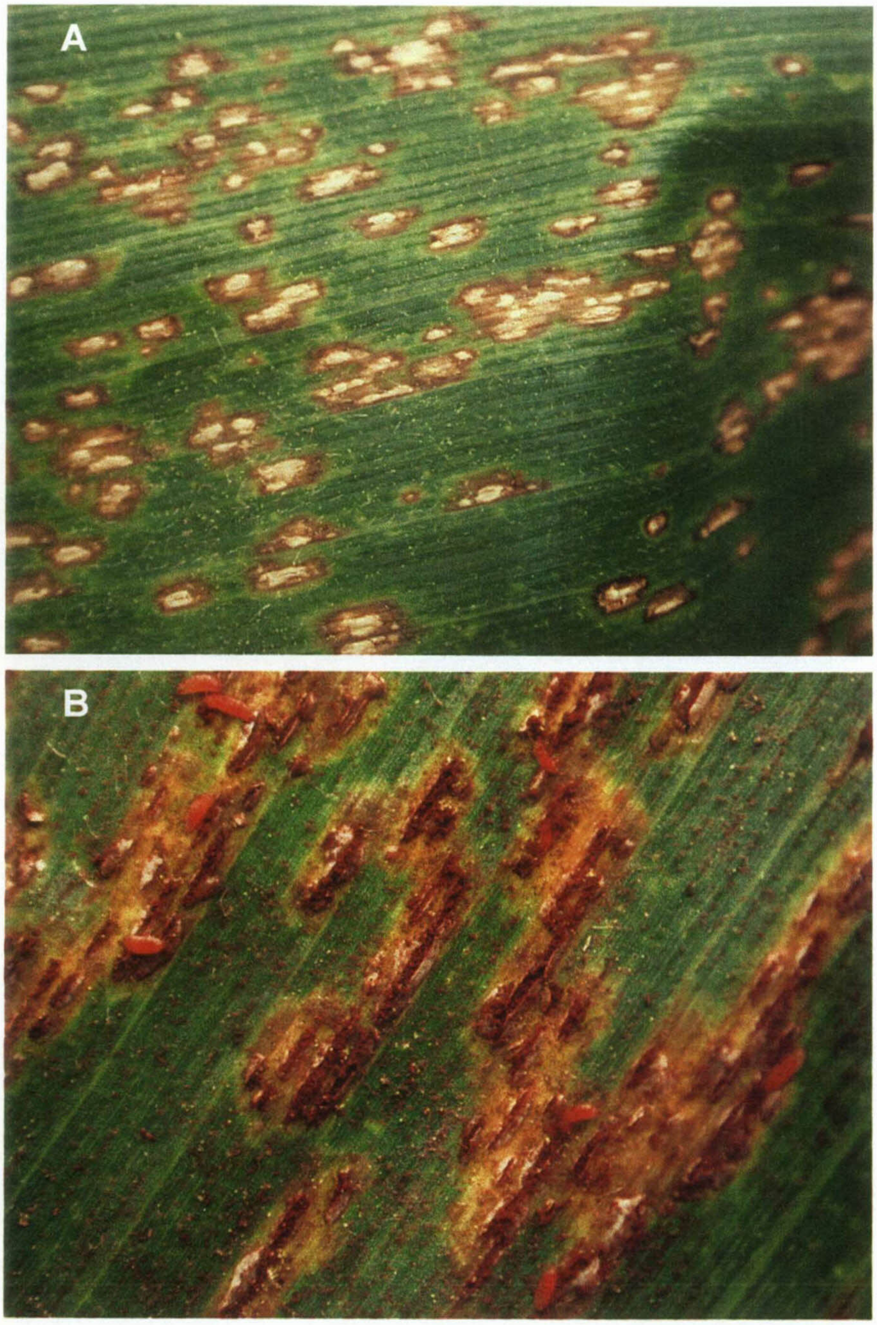
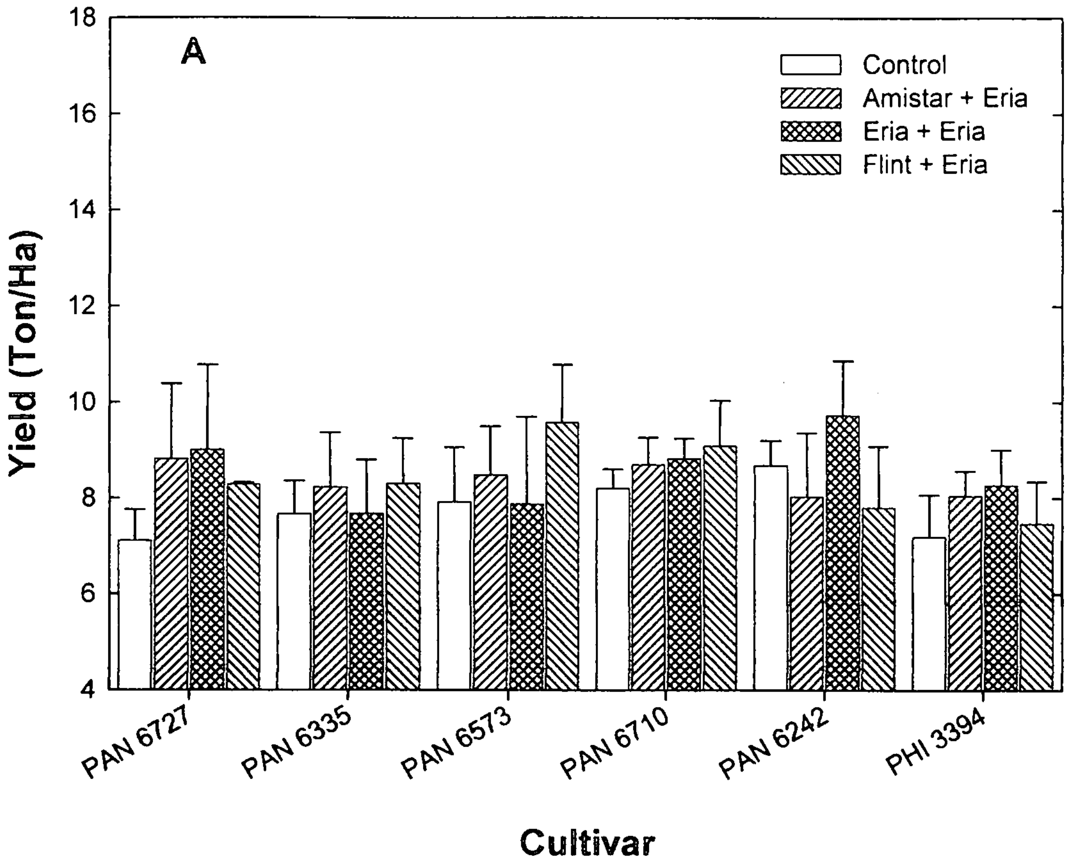

A
B

Figure 7: Yield (t/ha) of six maize hybrids sprayed with two fungicides at Delmas (A) and Greytown (B) during the 2000/2001 season. Error bars indicate standard deviations.


A
Control
Amistar + Eria
Eria + Eria
Flint + Eria
Yield (Ton/Ha)
Cultivar
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PHI 3394

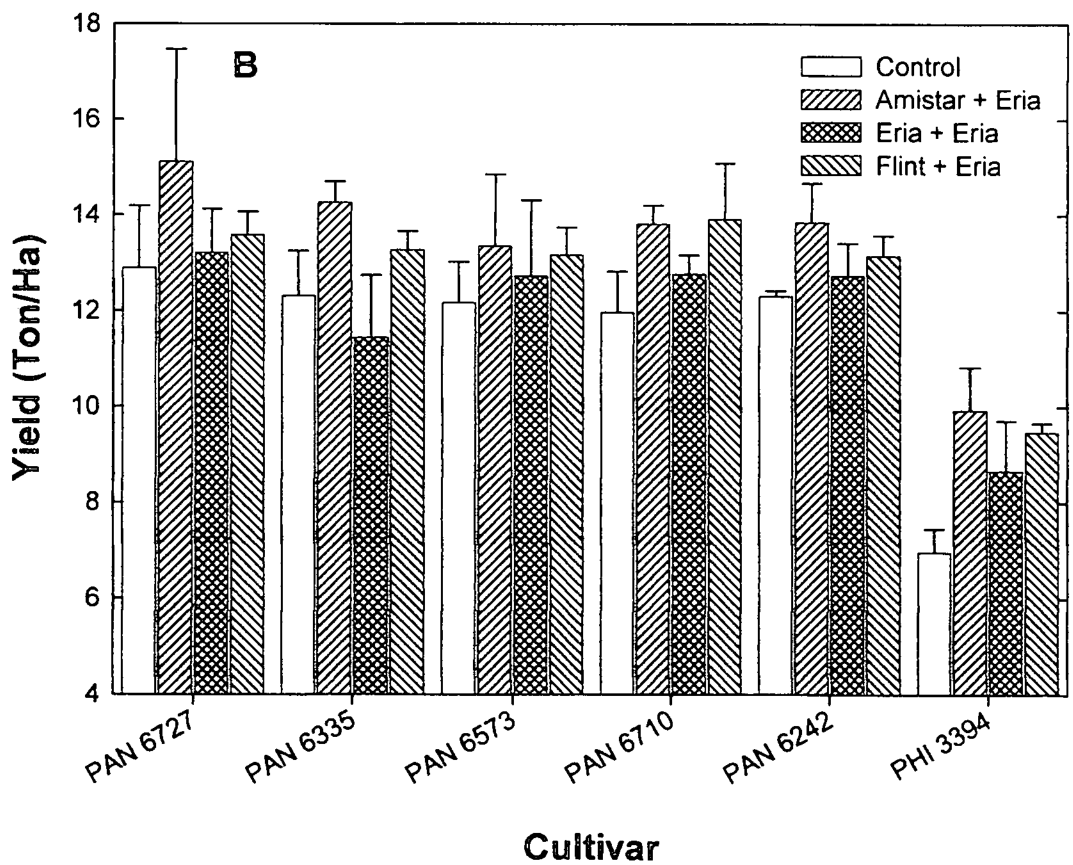
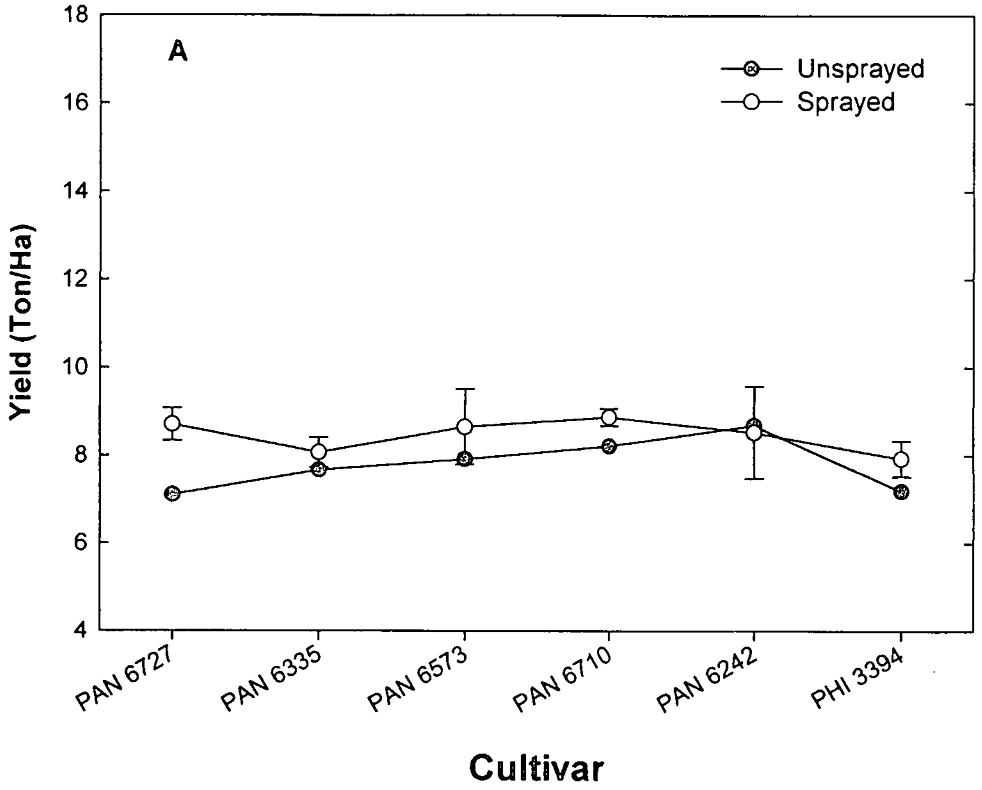
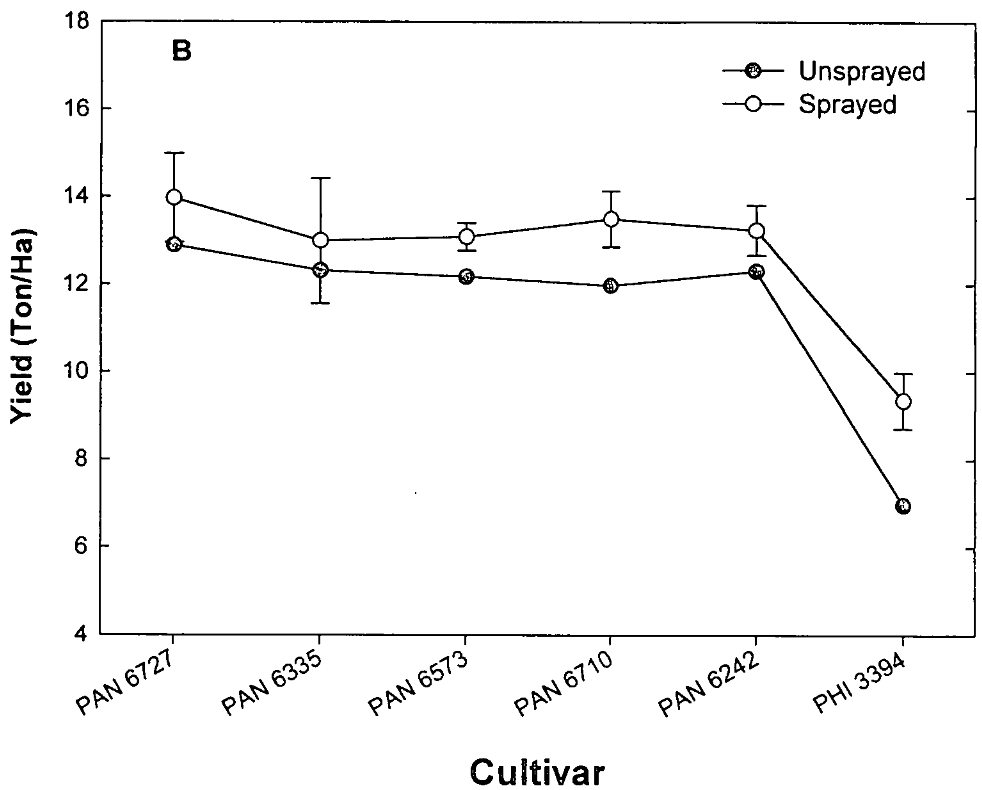

B
Control
Amistar + Eria
Eria + Eria
Flint + Eria
Yield (Ton/Ha)
Cultivar
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PHI 3394

Figure 8: The mean differences between sprayed (mean of the two treatments) and unsprayed (control) treatments on maize hybrids at Delmas (A) and Greytown (B) during the 2000/2001 season. Error bars indicate standard deviations.


A
Unsprayed
Sprayed
Yield (Ton/Ha)
18
16
14
12
10
8
6
4
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PHI 3394
Cultivar


B
Unsprayed
Sprayed
Yield (Ton/Ha)
18
16
14
12
10
8
6
4
PAN 6727
PAN 6335
PAN 6573
PAN 6710
PAN 6242
PHI 3394
Cultivar

providing leaf wetness at regular intervals at dryer, non-GLS sites, more refined common rust studies should be possible. Resistance of hybrids also influences the need for and effectivity of fungicides (Pataky & Eastburn, 1993) and genotypes should be carefully selected for yield loss studies.

To allow specific recommendations for chemical control of common rust, it is important that chemical companies seek official registration of products. Several compounds, most notably those in the triazole (Kuck, Scheinpflug & Pontzen, 1995) and strobilurin (Shaner & Buechley, 2000) groups, have a proven efficacy against *Puccinia* spp. Additionally, more efficient recommendations for rust control can be formulated within the stipulations and protection of the South African Act on Agricultural Remedies (no. 36 of 1947).

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Phytopathology 83:1046-1051.

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Sumner, D.R., Doupnik, B. & Boosalis, M.G. 1981. Effects of reduced tillage and multiple cropping on plant diseases. *Annu. Rev. Phytopathol.* 19:167-187.

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CHAPTER 5

INHERITANCE OF *RP* GENES IN SOUTH AFRICAN MAIZE GERMPLASM

ABSTRACT

Pyramiding of major *Rp* genes for resistance to common rust into a single line can enhance the durability of resistance and extend the effective lifetime of pathotype-specific resistance. This study was done to investigate the inheritance of the *Rp* genes effective to pathotypes previously identified in South Africa. Furthermore, the influence of yellow or white seed colour on heritability was studied. *Rp1-A, Rp1-C, Rp1-G, Rp1-L, Rp3-D, Rp3-E* and *Rp3-F* were inherited as single dominant genes for resistance to pathotype Gt1 of *Puccinia sorghi*. Segregation ratios in the F2 populations of Inbred1 X *Rp 1-L* and Inbred1 X *Rp 3-F* deviated significantly from the expected 3:1. Chi-square tests for homogeneity showed that, as expected, seed colour did not influence inheritance of *Rp1-A, Rp1-C, Rp1-G, Rp1-L, Rp3-D and Rp3-E*. Based on the clear expression of low infection types resistant plants should be selected with ease in segregating populations.

INTRODUCTION

Common rust (*Puccinia sorghi* Schwein.) is widely distributed on maize in South Africa. Although fungicide applications provide control options in the short-term, breeding for rust resistance is becoming increasingly important. Breeding for common rust resistance involves the identification of resistance sources, the characterization of expression and inheritance, and their incorporation into elite lines.

Resistance to common rust can either be race-specific, i.e. resistance effective against certain pathotypes, or race-nonspecific, when resistance is effective against all known pathotypes. More than 100 sources of resistance to *P. sorghi* were identified in maize lines during the 1950's and 1960's (Hooker & Russel, 1962; Hagan & Hooker, 1965; Wilkinson & Hooker, 1968). Twenty-four dominant genes were differentiated among these maize lines by a spectrum of rust isolates to which they conferred resistance and by their respective chromosomal positions (Hulbert, Lyons & Bennetzen, 1991). These genes for resistance are linked to three areas of the maize genome – a cluster of loci on chromosome 10 (*Rp*1, *Rp*5 and *Rp*6) and two other possibly complex loci on chromosomes 3 (*Rp*3) and 4 (*Rp*4)(Hulbert *et al.,* 1991). The *Rp1* locus consists of 14 genes (*Rp1a - Rp1n*) (Hulbert, Sudupak & Hong, 1993) . *Rp5* and *Rp6* mapped about one to two map units away from *Rp1* (Wilkinson & Hooker, 1968).

Durability of resistance is an important consideration in resistance breeding. The *Rp1-D* gene was used by most sweet corn breeders in the United States because of its effectiveness to *P. sorghi* (Pataky, 1987; Hulbert, 1997). However, in multi-locational testing Pataky *et al.* (2001) reported virulence for this gene in Argentina, Hawaii, Mexico and South Africa. Despite the development of virulence for single gene resistance, pyramiding of different genes into a single line or hybrid may enhance the durability of resistance (Hu, Webb & Hulbert, 1997) and extend the effective lifetime of pathotype-specific resistance (Hu & Hulbert, 1996).

Resistance which does not show interaction with different pathogen isolates may be more durable than simply inherited genes (Vanderplank, 1968). This type of resistance is quantitative in expression and has been reported to be controlled by several, or as few as two genes (Headrick & Pataky, 1987). Due to its multigenic nature partial resistance has been more difficult to transfer than simply inherited resistance (Brown, Juvik, & Pataky, 2001).

Considering the ephemeral nature of single gene resistance, but also aiming to use all potential sources of resistance in common rust resistance breeding in South Africa, a study was done to investigate the inheritance of *Rp* genes effective to pathotypes previously identified. The objective was to determine expression of *Rp* genes in segregating populations, thus providing information on the ease of selecting for resistance in seedlings. This set of material was also identified for marker-assisted breeding, however, the actual development of DNA markers falls beyond the scope of this investigation.

MATERIALS AND METHODS

Inoculum of *P. sorghi* isolate GT1 was propagated on a rust-susceptible hybrid, PHB 3394. To retard plant development and enhance sporulation (Knott, 1989), PHB 3394 plants were treated with maleic hydracide (0.1g/1l dist. water, 50 ml per pot) 12 days after planting. Plants were inoculated two days later (approximately five leaves visible) by applying urediniospores suspended in light mineral oil to leaves. Plants were then placed in a dew-simulation chamber at 25°C for 16 h. Upon completion of the high humidity period, plants were placed in a glasshouse at 15-25°C. Rust spores were collected after 14 days and used for inoculation of segregating materials.

F2 seed of seven crosses between common rust differential maize lines, each with a known *Rp* resistance gene, and a rust-susceptible line (Inbred1) (inbred code confidential) (Table 1), were obtained from the PANNAR Seed Company. The F2 progeny and parental lines were planted in sterilized soil in seedling trays (675 mm x 345 mm x 100 mm), each containing 72 cones of 50 mm x 50 mm. Fertilizer (10 g/l (3:2:1 (25) N:P:K + 0.5% Zn) was applied (50 ml/cone) on a weekly basis. Plants were inoculated 14 days after sowing (five to six leaves visible) with freshly harvested spores of isolate Gt1 (avirulent to *Rp1-A; Rp1-B; Rp1-C; Rp1-D; Rp1-F; Rp1-G; Rp1-H; Rp1-I; Rp1-J; Rp1-K; Rp3-B; Rp3-C; Rp3-D; Rp3-E; Rp4-B*) / virulent to (*Rp3-A; Rp3-B; Rp4-*

A) of *P. sorghi.* Spores were suspended in sterile water with an adjuvant, Tween 20 (0.02 ml/250 ml sterile water) and applied to leaves by means of a compressor-operated low pressure spray gun. Inoculated plants were dried at room temperature before they were placed in the dew chamber for 16 h. Infection types were rated after 12 days on a 1-4 scale (Chapter 3: Table 1). To determine whether genetic background influenced the inheritance and expression of *Rp* genes, white and yellow seeded F2 progeny were tested separately.

Standard chi-square analyses were conducted to determine conformation of observed segregation ratios to that expected for single gene inheritance. In an academic exercise to determine whether seed colour influenced inheritance, and if these populations can be pooled, ratios observed for yellow and white seeded populations were tested for homogeneity of samples (Steel & Torrie, 1980).

In each cross 10 F2 plants (five resistant and five susceptible to common rust), as well as the parental lines, were transplanted with the aim of DNA extraction. Infected leaves were removed at the time of transplanting. Three weeks later leaf material of each accession was collected and ground with a mortar and pestle in liquid nitrogen. Extraction buffer (5 M NaCl, 1M Tris-HCl, 0.25M EDYA, 20% SDS) was added and placed in a waterbath (65°C) for 1½ h. Chloroform:iso-amylalcohol (24:1) was added and centrifuged. The supernatant was transferred to a new tube, absolute ethanol added, and placed at 4 C overnight. DNA was washed in 70 % ethanol and placed in sterile saline water. After extraction, the concentration and purity of the DNA were determined. The DNA has been kept at -20°C until further research on DNA markers is initiated.

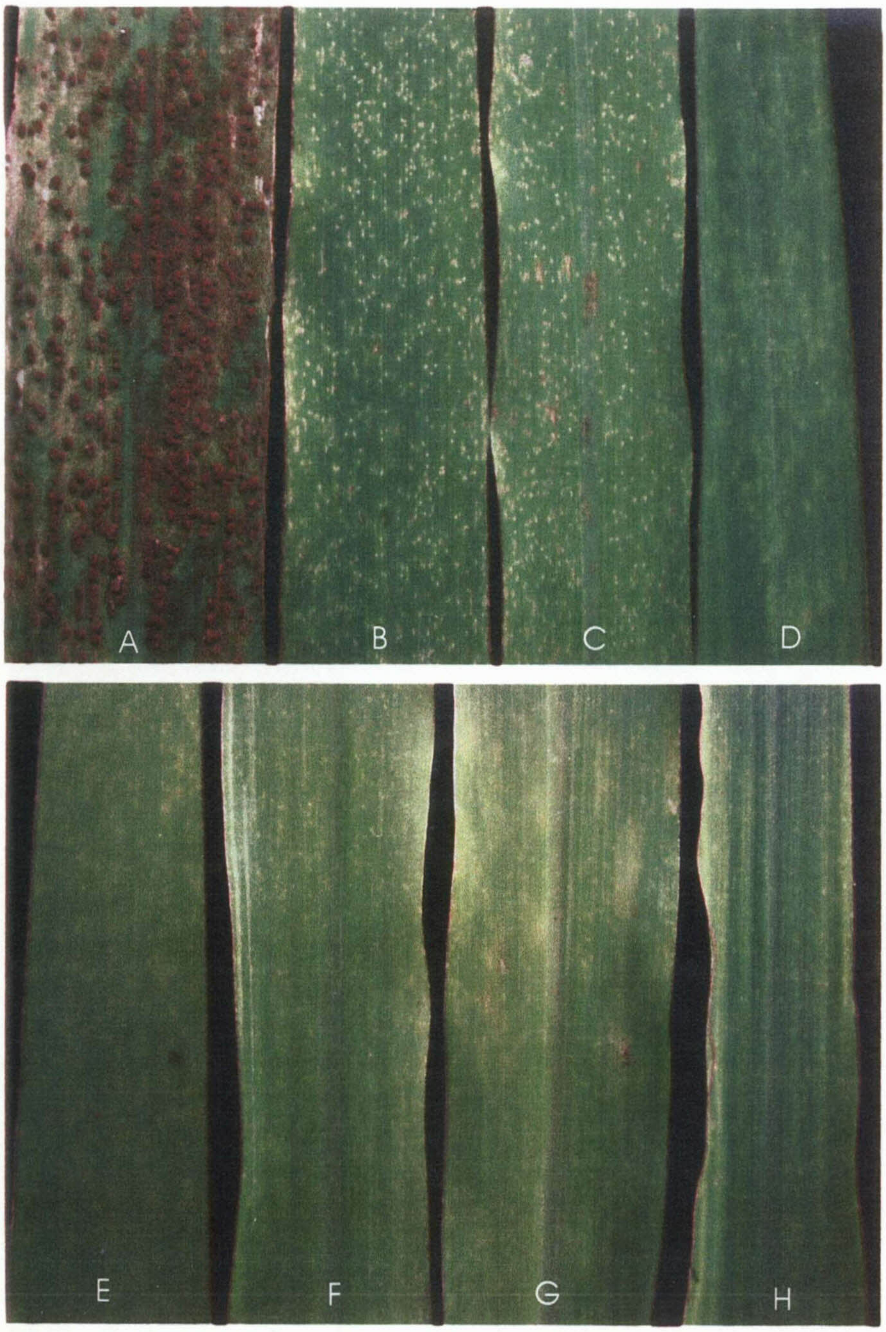
RESULTS AND DISCUSSION

The resistance phenotype of genes *Rp1-A, Rp1-C, Rp1-G, Rp1-L, Rp3-D, Rp3-E* and *Rp3-F* to isolate Gt1 of *P. sorghi* is shown in Fig 1. Infection types of resistant F2 segregates were similar to their respective *Rp* parents, except for the occasional occurrence of plants displaying an intermediate response in crosses between Inbred1 and *Rp1-G, Rp1-L, Rp3-D, Rp3-E* and *Rp3-F* (Table 1). Susceptible segregates produced infection types in the 3 to 4 range. For analysis plants in the intermediate group were considered resistant.

Testing the observed segregation ratios against that expected for a single dominant gene showed that all genes except *Rp1-L* (white) and *Rp3-F* (white) segregated according to a 3 resistant : 1 susceptible ratio (Table 1). In the Inbred1 x *Rp1-L* cross an excess of susceptible plants occurred (57 R : 28 S, $\chi^2_{3:1} = 4.8$) whereas in Inbred1 x *Rp 3-F* only a few susceptible plants were observed (44 R : 6 S, $\chi^2_{3:1} = 3.23$). Tests for homogeneity confirmed that pooling of white and yellow-seeded populations was appropriate for all *Rp* genes. When pooled ratios were tested for single gene inheritance, only Inbred1 x *Rp 1-L* progeny deviated significantly ($\chi^2_{3:1} = 3.56$). Considering resistant and susceptible segregates across *Rp* genes, single gene inheritance was again confirmed (907 R : 310 S, $\chi^2_{3:1} = 0.145$). The present data showed that single *Rp* genes should be managed with ease in a maize breeding program, provided that appropriate pathotypes are available to select target genes.

With a few exceptions in cereal rust pathosystems, e.g. the *Lr34*, *Yr18* and *Sr2* genes for leaf, stripe and stem rust resistance in wheat, monogenic resistance has not been durable. However, examples exist where stacking of single genes has provided effective protection against diseases (Pedersen & Leath, 1988; Braun, Rajaram & Van Ginkel, 1996; Kloppers & Pretorius, 1997). Thus, with proper management, single genes may continue to have value in breeding for resistance to common rust. Maize breeders should develop breeding lines with different *Rp* genes which could then be combined in the hybrid genotype. Traditional and molecular techniques can be employed to transfer and confirm effective *Rp* genes in the desired backgrounds. A culture collection of *P. sorghi* with different specificities to the *Rp* spectrum can facilitate detection of genes through conventional infection studies. Furthermore, advances in molecular markers for disease resistance provide new possibilities of combining and following genes in breeding populations.

Figure 1: Infection types of *Puccinia sorghi* on parental maize lines used in the *Rp* gene inheritance study. A: susceptible parent (Inbred1); B - H: Parents with resistant genes *Rp*1-A, *Rp1-C, Rp1-G, Rp1-L, Rp3-D, Rp3-E* and *Rp3-F* respectively.


A
B
C
D
E
F
G
H

In this regard Hu & Hulbert (1996) provided evidence of DNA markers proximal to the *Rp 1* locus. Considerable effort, however, will be required to backcross *Rp* genes, maintain *P. sorghi* isolates, and to identify and apply markers in combining rust resistance genes in individual lines.

To conclude, South African maize breeders should determine which genes have potential as members of an *Rp* pyramid, or in combination with partial resistance, and develop protocols to select for these genes in an efficient way. The provision of maize DNA obtained from different resistant and susceptible progenies in this study may serve as a step towards finding appropriate molecular markers.

Table 1: Segregation of the common rust resistance genes *Rp1-A, Rp1-C, Rp1-G, Rp1-L, Rp3-D, Rp3-E* and *Rp3-F* in crosses with maize line Inbred1 to isolate GT1 of *Puccinia sorghi*

		F2 segregation classes			Expected	
Cross	**Population**	**Resistant**	**Intermediate**	**Susceptible**	**ratio**	X^2
Inbred1 x 1-A	White	59	0	14	3:1	1.32
	Yellow	65	0	20	3:1	0.10
	Pooled	124	0	34	3:1	1.02
Inbred1 x 1-C	White	66	0	30	3:1	2.00
	Yellow	66	0	22	3:1	0.00
	Pooled	132	0	52	3:1	1.04
Inbred1 x 1-G	White	65	1	28	3:1	1.72
	Yellow	63	0	23	3:1	0.14
	Pooled	128	1	51	3:1	1.45
Inbred1 x 1-L	White	55	2	28	3:1	4.80*
	Yellow	64	0	26	3:1	0.24
	Pooled	119	2	54	3:1	3.56*
Inbred1 x 3-D	White	75	4	17	3:1	0.50
	Yellow	67	2	25	3:1	0.70
	Pooled	142	6	42	3:1	0.01
Inbred1 x 3-E	White	72	3	20	3:1	0.03
	Yellow	61	0	24	3:1	0.47
	Pooled	133	3	44	3:1	0.12
Inbred1 x 3-F	White	43	1	6	3:1	3.23*
	Yellow	73	0	27	3:1	0.21
	Pooled	116	1	33	3:1	0.44
Total		894	13	310	3:1	0.15

*Deviated significantly from expected 3:1 ratio.

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SUMMARY

Maize (*Zea mays* L.) is one of South Africa's most important grain crops because of its significance as a staple diet among a large proportion of the population. Maize is also an important component of livestock feed and is used in the manufacturing of several industrial products. Observations during the past few seasons showed an increased occurrence of common rust, caused by the fungus *Puccinia sorghi* Schwein. This gave rise to questions from maize producers and researchers regarding the epidemiology, economic impact and control measures of the disease.

The spore stages of this macro-cyclic fungus, as they occur on both the primary (maize) and alternate (*Oxalis corniculata*, creeping sorrel) hosts in South Africa, were described. Detailed schematic illustrations as well as microscopic records of the five spore stages were prepared. A survey was done to determine the occurrence of the sexual stage on creeping sorrel in the main maize producing areas in South Africa. Most aecial infections were observed in KwaZulu-Natal, implying this region to be a source of new recombinant pathotypes. On request of the PANNAR Seed Company (Pty) Ltd., all viable maize accessions in their germ plasm collection were tested for reaction to common rust infection. Out of 2594 lines only 185 were resistant in the glasshouse as well as in the field, while 426 were resistant in the glasshouse but not in the field. This information should help PANNAR to make certain decisions about rust resistance or susceptibility in their breeding material.

Spray trials with different fungicides and maize cultivars showed that positive yield increases can be obtained. Eria®+Eria® and Amistar®+Eria® showed the best results. The effects of fungicides were, however, dependent on the level of adult plant resistance, locality, as well as the occurrence of other diseases.

Even though maize breeders realize that single gene resistance does not ensure long-term protection against rust, breeding approaches allow combination of such genes with non-specific adult plant resistance. The inheritance of *Rp1-A, Rp1-C, Rp1-G, Rp1-L, Rp3-D, Rp3-E* and *Rp3-F* in F2 progenies were studied to provide breeders with information on the ease of following single genes in segregating populations. Although all the genes indicated monogenic inheritance, F2 segregation ratios from crosses inbred 1 X *Rp 1-L* and inbred 1 X *Rp 3-F* differed significantly from the

expected 3 resistant : 1 susceptible ratio. Chi-square tests for homogeneity showed that white and yellow seed colour did not, as expected, influence the inheritance of *Rp1-A*, *Rp1-C*, *Rp1-G*, *Rp1-L*, *Rp3-D* and *Rp3-E*. Based on the distinct expression of infection types, breeders should be able to efficiently select for these genes in cultivar development.

OPSOMMING

Mielies (*Zea mays* L.) is een van Suid Afrika se belangrikste graangewasse omdat baie mense daarvan afhanklik is vir stapelvoedsel. Mielies is voorts 'n belangrike komponent in dierevoeding en word ook as grondstof vir die vervaardiging van industriële produkte gebruik. Waarnemings die afgelope paar seisoene het duidelik getoon dat gewone roes, veroorsaak deur die swam *Puccinia sorghi* Schwein., meer algemeen voorkom. Hierdie voorkoms het vrae vanaf mielieprodusente en -navorsers laat ontstaan oor die epidemiologie van die siekte, die ekonomiese impak en beheermaatreëls.

In hierdie studie is die spoorstadia van *ie a rosi liese s am P. sorghi* op beide die primêre (mielies) en alternatiewe gashere (*Oxalis corniculata*, ranksuring) beskryf. Gedetailleerde skematiese illustrasies sowel as mikroskopiese rekords van die vyf spoorstadia is voorberei. 'n Opname wat gedoen is om die voorkoms van die geslagtelike fase en ranksuring in die belangrikste mielieproduserende gebiede in Suid Afrika te bepaal, het gewys dat KwaZulu-Natal waarskynlik die grootste bron is van nuwe, rekombinante patotipes. Op versoek van die PANNAR Saadmaatskappy Edms. (Bpk) is alle lewenskragtige mielie-aanwinste in hulle kiemplasmaversameling vir reaksie tot roesinfeksie getoets. Uit 'n totaal van 2594 lyne was 185 bestand in beide die glashuis- en veldevaluasies, terwyl 'n verdere 426 weerstand in die glashuis, maar nie in die veld, getoon het nie. Hierdie inligting stel PANNAR instaat om sekere aannames oor roesweerstand of -vatbaarheid in hulle teelmateriaal te maak.

In spuitproewe met verskillende mieliekultivars is aangetoon dat positiewe opbrengsverhogings verkry kan word met fungisiedtoedienings. Eria® + Eria® en Amistar® + Eria® behandelings het die beste resultate getoon. Opbrengste van kultivars is met tot 2.97 t/ha (42.7%) verhoog. Die effek wat fungisiedes op kultivars het is egter afhanklik van die vlak van volwasseplantweerstand, omgewing en ook die voorkoms van siektes bo en behalwe gewone roes.

Alhoewel mielietelers besef dat enkelgeenweerstand nie noodwendig langdurige beskerming teen roes sal verleen nie, maak hedendaagse tegnologie dit moontlik om sulke gene met nie-spesifieke, volwasseplantweerstand te kombineer. Ten einde inligting aan telers te voorsien oor die gemak waarmee enkelgene in segregerende

populasies gevolg kan word, is die oorwerwing van *Rp1-A, Rp1-C, Rp1-G, Rp1-L, Rp3-D, Rp3-E* en *Rp3-F* in F2 nageslagte bestudeer. Al die gene is as dominante enkelgene oorgeërf, alhoewel F2 segregasieverhoudings van die kruisings lyn 1 X *Rp 1-L* en lyn 1 X *Rp 3-F* betekenisvol vanaf die verwagte 3 bestand : 1 vatbaar afgewyk het. Chi-kwadraattoetse vir homogenisiteit het gewys dat, soos verwag, geel of wit saadkleur nie die oorwerwing van *Rp1-A, Rp1-C, Rp1-G, Rp1-L, Rp3-D* en *Rp3-E* beïnvloed het nie. Op grond van die duidelike uitdrukking van infeksietipes op roesbestande plante behoort telers hierdie gene maklik in kultivarontwikkeling te kan volg.

Appendix 1: Seedling and adult-plant reaction to *Puccinia sorghi* in a collection of 2594 maize lines. Response groups are defined by: 1: lines resistant at both the seedling and adult plant stages; 2: lines with mixed reactions at the seedling stage and resistant at the adult plant stage; 3: lines with mixed reactions at the seedling stage and susceptible at the adult stage; 4: lines susceptible as seedlings, resistant as adult plants; 5: lines susceptible at both growth stages and 6: lines resistant as seedlings and susceptible as adult plants

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1	1	U42771	1	2	MS
2	1	T60302	1	3	MS
3	1	Q21052	;	2	MR
4	1	VD31909	;	2	MR
5	1	U20290	;	2	MR
6	1	U20381	;	2	MR
7	1	WG19795	;	2	MR
8	1	WG19807	;	2	MR
9	1	W12010	;	2	MR
10	1	W12018	;	2	MR
11	1	W10831	;	2	MR
12	1	T31342b	;	2	MR
13	1	T70084	;	2	MS
14	1	WK88845	;	2	MS
15	1	P60010	;	2	MS
16	1	WD32019	;	2	MS
17	1	U20133	;	2	MS
18	1	U20153	;	2	MS
19	1	T65242	;	2	MS
20	1	T65040-2	;	2	MS
21	1	WG19839	;	2	MS
22	1	R47651	;	2	MS
23	1	OD14901	;	2	R
24	1	VD32087	;	2	R
25	1	VD31941	;	2	R
26	1	Q28701	;	2	R
27	1	U20041	;	2	R
28	1	Q28684	;	2	R
29	1	V20252	;	2	R
30	1	U20323	;	2	R
31	1	T65541-1	;	2	R
32	1	N21223	;	2	R
33	1	Q54367	;	2	R
34	1	S40079	;	2	R
35	1	S40080	;	2	R
36	1	W10621	;	2	R
37	1	U42716	;	2	R
38	1	U42821	;	2	R
39	1	WG19815	;	2	R
40	1	W12029	;	2	R
41	1	W12033	;	2	R
42	1	W12035	;	2	R
43	1	W12225	;	2	R
44	1	R47124	;	2	R
45	1	V56586	;	2	R
46	1	W10839	;	2	R
47	1	W10854	;	2	R
48	1	WG18338	;	2	R
49	1	S64129	;	3	MR
50	1	S64172	;	3	MR
51	1	UK77773	;	3	MR
52	1	UK77769	;	3	MR
53	1	U30340	;	3	MR
54	1	WD24441	;	3	MR
55	1	WG19793	;	3	MR
56	1	R43389	;	3	MR
57	1	T34973	;	3	MR
58	1	O54322	;	3	R
59	1	U20218	;	3	R
60	1	U30365	;	3	R
61	1	VWD361	;	3	R
62	1	WD28461	;	3	R
63	1	WD28701	;	3	R
64	1	WD24336	;	3	R
65	1	WD28390	;	3	R
66	1	WD28405	;	3	R
67	1	WD24171	;	3	R
68	1	20271T	;	3	R
69	1	VG54781	;	3	R
70	1	S54816-2	;	3	R

Appendix 1 (Cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
71	1	R61032	;	3	R
72	1	SD29490	;	4	MR
73	1	22907U	;	4	MR
74	1	N51186	;	4	R
75	1	U30361	;	4	R
76	1	22440V	;	4	R
77	1	22722U	;	4	R
78	1	U20326	;	4	R
79	1	N21213	;	4	R
80	1	WK88846	;	5	R
81	1	U30327	;	5	R
82	1	O54347a	;	6	R
83	1	WD28356	;1	1	
84	1	WD32002	;1	1	
85	1	S64101	;1	2	MR
86	1	WK88860	;1	2	MR
87	1	N51427	;1	2	MR
88	1	U30328	;1	2	MR
89	1	WD28389	;1	2	MR
90	1	R50745	;1	2	MR
91	1	Q21158	;1	2	MR
92	1	U20058	;1	2	MR
93	1	Q21352	;1	2	MR
94	1	Q21363	;1	2	MR
95	1	V20250	;1	2	MR
96	1	U20314	;1	2	MR
97	1	R61913	;1	2	MR
98	1	S33199	;1	2	MR
99	1	WG19829	;1	2	MR
100	1	W10822	;1	2	MR
101	1	W10842	;1	2	MR
102	1	W10849	;1	2	MR
103	1	W10768	;1	2	MR
104	1	T70123	;1	2	R
105	1	WK88857	;1	2	R
106	1	U42767	;1	2	R
107	1	U30326	;1	2	R
108	1	U30355	;1	2	R
109	1	U30372	;1	2	R
110	1	23089U	;1	2	R
111	1	22447V	;1	2	R
112	1	WD24301	;1	2	R
113	1	WD28387	;1	2	R
114	1	22460V	;1	2	R
115	1	12079U	;1	2	R
116	1	WD11217	;1	2	R
117	1	WD31945	;1	2	R
118	1	SD31457	;1	2	R
119	1	UD31671	;1	2	R
120	1	T60359	;1	2	R
121	1	U20053	;1	2	R
122	1	U20236	;1	2	R
123	1	U20068	;1	2	R
124	1	Q21325	;1	2	R
125	1	P60068	;1	2	R
126	1	S54216-2	;1	2	R
127	1	U20299	;1	2	R
128	1	U20384	;1	2	R
129	1	R61860	;1	2	R
130	1	WG18334	;1	2	R
131	1	W10838	;1	2	R
132	1	T31343b	;1	2	R
133	1	S64087	;1	3	MR
134	1	T70126	;1	3	MR
135	1	25424S	;1	3	MR
136	1	VDW131	;1	3	MR
137	1	VD31942	;1	3	MR
138	1	U20367	;1	3	MR
139	1	W10836	;1	3	MR
140	1	S64169	;1	3	R
141	1	N51470	;1	3	R
142	1	U30319	;1	3	R
143	1	SD29533	;1	3	R
144	1	WD11163	;1	3	R
145	1	WD28412	;1	3	R
146	1	26096V	;1	3	R
147	1	12070U	;1	3	R
148	1	VDW143	;1	3	R
149	1	VDW66	;1	3	R
150	1	WD28339	;1	3	R
151	1	N51484	;1	3	R
152	1	U20047	;1	3	R
153	1	Q21348	;1	3	R
154	1	T60467	;1	3	R

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
155	1	S54290	;1	3	R
156	1	Q21511	;1	3	R
157	1	T90198	;1	3	R
158	1	W10769	;1	3	R
159	1	O54354	;1	4	MR
160	1	U20318	;1	4	MR
161	1	S64149	;1	4	R
162	1	25518S	;1	4	R
163	1	VWD2328	;1	4	R
164	1	WD31915	;1	4	R
165	1	Q21170	;1	4	R
166	1	WG19334	;1	4	R
167	1	R50801	;1	5	R
168	1	Q21199	;1	5	R
169	1	S30921	;1+	2	MR
170	1	WK88707	;1+	3	R
171	1	23178S	;C	2	R
172	1	T60199	;C	2	R
173	1	P60104	;C	3	R
174	1	S30890	;C	3	R
175	1	N21155	;C	3	R
176	1	S33306	;CN	2	MR
177	1	VD31913	;CN	2	R
178	1	U20042	;CN	2	R
179	1	S64006	;CN	3	MR
180	1	WD28345	;CN	3	MR
181	1	WD28408	;CN	3	R
182	1	S64157	;CN	4	R
183	1	U20030	;CN	4	R
184	1	Q61234	;CN	5	R
185	1	WD28407	CN	2	R
186	2	25528S	;1	5	MR
187	2	U30316	;1	6	R
188	2	WD31987	;1	6	R
189	2	VD38436	;1C	1	
190	2	Q28772	;1C	2	MR
191	2	WD28417	;1C	2	R
192	2	J1038	;1C	3	R
193	2	P60176	;1C	3	R
194	2	I21744	;1C	4	R
195	2	U30325	;1C	3	MR
196	2	Q26084	;1C	3	R

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
197	2	WD28409	;1CN	2	R
198	2	Q21192	;1CN	2	R
199	2	T90224	;1CN	2	R
200	2	UD38711	;1CN	3	R
201	2	P40007	;1CN	3	R
202	2	S33230	;1CN	3	R
203	2	WD28416	;1CN	4	R
204	2	TD31334	;1CN	4	R
205	2	WK88703	;1CN	5	R
206	2	QD31768	;1CN	6	R
207	2	S64037	;2	1	
208	2	T69970	;2	1	
209	2	S64005	;2	2	MR
210	2	S64009	;2	2	MR
211	2	S64072	;2	2	MR
212	2	S63977	;2	2	MR
213	2	T70156	;2	2	MR
214	2	T70174	;2	2	MR
215	2	WK88706	;2	2	MR
216	2	VD31920	;2	2	MR
217	2	N13698	;2	2	MR
218	2	U20109	;2	2	MR
219	2	T11101	;2	2	MR
220	2	W12214	;2	2	MR
221	2	WG18268	;2	2	MR
222	2	W10823	;2	2	MR
260	2	T69940	;2	3	MR
261	2	T70048	;2	3	MR
262	2	T70141	;2	3	MR
263	2	T70162	;2	3	MR
264	2	S64150	;2	3	MR
265	2	S64178	;2	3	MR
266	2	U30317	;2	3.	MR
267	2	U30367	;2	3	MR
268	2	WD24473	;2	3	MR
269	2	WD28340	;2	3	MR
270	2	RD31118	;2	3	MR
271	2	Q28665	;2	3	MR
272	2	U77181	;2	3	R
273	2	T69931	;2	3	R
274	2	VK65319	;2	3	R
275	2	UK77740	;2	3	R

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
276	2	VD22286	;2	3	R
277	2	RD11441	;2	3	R
278	2	WD24431	;2	3	R
279	2	20251T	;2	3	R
280	2	UD11235	;2	3	R
281	2	SD31453	;2	3	R
282	2	N51481	;2	3	R
283	2	P60081	;2	3	R
284	2	Q51885	;2	3	R
285	2	R61755	;2	3	R
286	2	WG19264	;2	3	R
287	2	25524S	;2	4	MR
288	2	WD24482	;2	4	MR
289	2	T70045	;2	4	R
290	2	U30364	;2	4	R
291	2	T20409	;2	4	R
292	2	20413T	;2	4	R
293	2	25462S	;2	4	R
294	2	25169V	;2	4	R
295	2	WD106	;2	4	R
296	2	U20289	;2	4	R
297	2	S33294	;2	4	R
298	2	W10808	;2	4	R
299	2	20229T	;2	5	MR
300	2	WD24485	;2	5	MR
301	2	T70147	;2	5	R
302	2	N51177	;2	5	R
303	2	25132V	;2	5	R
304	2	WD31930	;2	5	R
305	2	R61072	;2	6	R
306	2	T69964	;2+	1	
307	2	WK88728	;2+	2	MR
308	2	VK65323	;2+	2	MR
309	2	S64003	;2+	2	R
310	2	T70207	;2+	2	R
311	2	WK88865	;2+	2	R
312	2	J1029	;2+	2	R
313	2	S64078	;2+	3	MR
314	2	S64181	;2+	3	MR
315	2	WK88863	;2+	3	MR
316	2	U30344	;2+	3	MR
317	2	M61436	;2+	3	MR
318	2	WD28351	;2+	3	MR
319	2	QD19931	;2+	3	MR
320	2	S64090	;2+	3	R
321	2	WK88716	;2+	3	R
322	2	WK88736	;2+	3	R
323	2	UK77731	;2+	3	R
324	2	UK77725	;2+	3	R
325	2	TD27107	;2+	3	R
326	2	WD24421	;2+	3	R
327	2	WD513	;2+	3	R
328	2	WD28402	;2+	3	R
329	2	WD23976	;2+	3	R
330	2	WK88853	;2+	4	MR
331	2	Q61196	;2+	4	MR
332	2	WK88856	;2+	4	R
333	2	U30331	;2+	4	R
334	2	25512S	;2+	4	R
335	2	20247T	;2+	4	R
336	2	UK77780	;2+	5	R
337	2	19961R	;2+C	2	MR
338	2	SD29530	;2+C	3	MR
339	2	VK65293	;2+C	4	MR
340	2	VK65294	;2+C	4	R
341	2	WK88741	;2+C	4	R
342	2	23202U	;2+CN	4	R
343	2	RD31152	;2C	2	R
344	2	WD356	;2C	3	MR
345	2	QD31824	;2C	3	MR
346	2	WK88705	;2C	3	R
347	2	WK88715	;2C	3	R
348	2	N31134	;2C	3	R
349	2	WD24416	;2C	3	R
350	2	RD31141	;2C	3	R
351	2	S54261	;2C	3	R
352	2	OD27600	;2C	4	R
353	2	TD31266	;2C	4	R
354	2	SD31500	;2C	4	R
355	2	UD31679	;2C	4	R
356	2	WD31986	;2CN	2	R
357	2	N21227	;2CN	2	R
358	2	T70135	;2CN	3	MR
359	2	I21965	;2CN	3	MR

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
360	2	T70144	;2CN	3	R
361	2	R50748	;2CN	3	R
362	2	U44621	;2CN	3	R
363	2	U773886	;3	2	MR
364	2	T69928	;3	2	MR
365	2	T70054	;3	2	MR
366	2	UK77782	;3	2	MR
367	2	R50734	;3	2	MR
368	2	U20110	;3	2	MR
369	2	V20114	;3	2	MR
370	2	T60472	;3	2	MR
371	2	T60491	;3	2	MR
372	2	S60604	;3	2	MR
373	2	V56594	;3	2	MR
374	2	V56605	;3	2	MR
375	2	T34947	;3	2	MR
376	2	T70051	;3	2	R
377	2	T70063	;3	2	R
378	2	T70096	;3	2	R
379	2	VK65248	;3	2	R
380	2	UK77744	;3	2	R
381	2	WD28410	;3	2	R
382	2	WD24066	;3	2	R
383	2	QD31762	;3	2	R
384	2	WD12112	;3	2	R
385	2	UD31689	;3	2	R
386	2	R50756	;3	2	R
387	2	Q28669	;3	2	R
388	2	Q21254	;3	2	R
389	2	Q28766	;3	2	R
390	2	U20056	;3	2	R
391	2	T65064	;3	2	R
392	2	N21095	;3	2	R
393	2	V56530	;3	2	R
394	2	R42436	;3	2	R
395	2	WG18339	;3	2	R
396	2	S64093	;3	3	MR
397	2	T69892	;3	3	MR
398	2	T69988	;3	3	MR
399	2	T70024	;3	3	MR
400	2	T70030	;3	3	MR
401	2	U77812	;3	3	MR

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
402	2	VK65251	;3	3	MR
403	2	WK88727	;3	3	MR
404	2	S64171	;3	3	MR
405	2	S64177	;3	3	MR
406	2	UK77742	;3	3	MR
407	2	UK77729	;3	3	MR
408	2	WK88836	;3	3	MR
409	2	WK88861	;3	3	MR
410	2	WK88864	;3	3	MR
411	2	VDW81	;3	3	MR
412	2	UD31697	;3	3	MR
413	2	T70009	;3	3	R
414	2	UK77764	;3	3	R
415	2	WK88866	;3	3	R
416	2	T60586	;3	3	R
417	2	U30368	;3	3	R
418	2	U30337	;3	3	R
419	2	U30312	;3	3	R
420	2	WD28392	;3	3	R
421	2	25368S	;3	3	R
422	2	29761T	;3	3	R
423	2	WD28403	;3	3	R
424	2	WD28406	;3	3	R
425	2	25340S	;3	3	R
426	2	22854U	;3	3	R
427	2	WD24121	;3	3	R
428	2	QD31764	;3	3	R
429	2	UD31726	;3	3	R
430	2	R61094	;3	3	R
431	2	WG19803	;3	3	R
432	2	S64070	;3	4	MR
433	2	WK88718	;3	4	MR
434	2	WK88743	;3	4	MR
435	2	UK77758	;3	4	MR
436	2	M61435	;3	4	MR
437	2	SD23166	;3	4	MR
438	2	U30313	;3	4	R
439	2	I21947	;3	4	R
440	2	11271R	;3	4	R
441	2	SD25288	;3	4	R
442	2	25342S	;3	4	R
443	2	20365T	;3	4	R

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
444	2	WD24191	;3	4	R
445	2	WD11223	;3	4	R
446	2	VD31997	;3	4	R
447	2	T60476	;3	4	R
448	2	U77821	;3	5	R
449	2	VK65246	;3	5	R
450	2	WK88737	;3	5	R
451	2	WD24256	;3	5	R
452	2	WD28349	;3	5	R
453	2	U44538	;3	6	MR
454	2	U77802	;3	6	R
455	2	37MW	;3+	2	MR
456	2	U77801	;3+	2	MR
457	2	S64049	;3+	3	MR
458	2	WK88840	;3+	3	MR
459	2	N51174	;3+	3	MR
460	2	S64050	;3+	3	R
461	2	S64018	;3+	4	MR
462	2	S64022	;3+	4	MR
463	2	T20407	;3+	4	MR
464	2	UK77749	;3+	4	R
465	2	TD27072	;3+	4	R
466	2	WK88735	;3C	2	MR
467	2	UK77765	;3C	2	R
468	2	S30909	;3C	2	R
469	2	P50064	;3C	2	R
470	2	O54375	;3C	2	R
471	2	TD20167	;3C	3	MR
472	2	29682T	;3C	3	MR
473	2	WK88742	;3C	3	R
474	2	WK88740	;3C	4	MR
475	2	TD31267	;3C	2	R
476	2	VD31966	;3C	3	MR
477	2	I21841	;3C	3	R
478	2	WD23986	;3C	4	MR
479	2	H21735	;3C	4	R
480	2	T69979	;3CN	2	R
481	2	T70075	;3CN	2	R
482	2	WK88702	;3CN	2	R
483	2	Q28655	;3CN	2	R
484	2	T70069	;3CN	3	MR
485	2	20417T	;3CN	3	MR
486	2	S64152	;3CN	3	R
487	2	N31077	;3CN	5	R
488	2	T70192	;4	2	MR
489	2	V20265	;4	2	MR
490	2	T70081	;4	2	R
491	2	UK77721	;4	2	R
492	2	R30198	;4	2	R
493	2	W10773	;4	3	MR
494	2	T70060	;4	3	R
495	2	VD25026	;4	3	R
496	2	WK88850	;4	4	MR
497	2	U77726	;4	4	R
498	2	U30338	;4	4	R
499	2	T36419	;4	4	R
500	2	WG19821	;4C	2	R
501	2	H21791	1P;2 1P3	3	R
502	3	N31002	;1C	3	MS
503	3	VD22455	;1C	3	MS
504	3	WD24451	;1C	3	MS
505	3	VD31948	;1C	3	MS
506	3	VDW46	;1C	3	S
507	3	VD31960	;1C	3	S
508	3	WD31976	;1C	3	S
509	3	VD31918	;1C	4	MS
510	3	T60331	;1C	2	MS
511	3	U20097	;1C	3	MS
512	3	TD11376	;1C	3	S
513	3	WD28347	;1C	4	MS
514	3	S60531	;1C	4	S
515	3	VWD459	;1CN	2	MS
516	3	WD31956	;1CN	2	MS
517	3	Q21185	;1CN	2	MS
518	3	W12939	;1CN	2	MS
519	3	S25515	;1CN	2	MS
520	3	I21952	;1CN	3	MS
521	3	WD28385	;1CN	3	MS
522	3	TD31332	;1CN	3	MS
523	3	TD31345	;1CN	3	MS
524	3	S54262-2	;1CN	3	MS
525	3	N21241	;1CN	3	MS
526	3	Q51875	;1CN	3	MS
527	3	U44630	;1CN	3	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
528	3	22446V	;1CN	3	S
529	3	WD32022	;1CN	3	S
530	3	P60051	;1CN	3	S
531	3	P60115	;1CN	3	S
532	3	R30430	;1CN	3	S
533	3	U20120	;1CN	3	S
534	3	S54700	;1CN	3	S
535	3	S61460	;1CN	3	S
536	3	S33090	;1CN	3	S
537	3	S33300	;1CN	3	S
538	3	S33311	;1CN	3	S
539	3	WG19824	;1CN	3	S
540	3	QD31774	;1CN	4	MS
541	3	WD32000	;1CN	4	MS
542	3	Q28809	;1CN	4	S
543	3	S61418	;1CN	4	S
544	3	T69967	;2	2	MS
545	3	T69973	;2	2	MS
546	3	UK77776	;2	2	MS
547	3	25157V	;2	2	MS
548	3	20291T	;2	2	MS
549	3	VD31991	;2	2	MS
550	3	N51573	;2	2	MS
551	3	Q28717	;2	2	MS
552	3	T65444	;2	2	MS
553	3	N21125	;2	2	MS
554	3	Q51851	;2	2	MS
555	3	R61092	;2	2	MS
556	3	S40081	;2	2	MS
557	3	W10559	;2	2	MS
558	3	V56560	;2	2	MS
559	3	V54084	;2	2	MS
560	3	V56567	;2	2	MS
561	3	V56433	;2	2	MS
562	3	S64029	;2	2	S
563	3	20328T	;2	2	S
564	3	WD38211	;2	2	S
565	3	WD31989	;2	2	S
566	3	U20035	;2	2	S
567	3	Q21350	;2	2	S
568	3	U20156	;2	2	S
569	3	U20400	;2	2	S
570	3	W10806	;2	2	S
571	3	W10825	;2	2	S
572	3	W10850	;2	2	S
573	3	S64007	;2	3	MS
574	3	T69886	;2	3	MS
575	3	UK77763	;2	3	MS
576	3	UK77762	;2	3	MS
577	3	UK77753	;2	3	MS
578	3	UK77747	;2	3	MS
579	3	WK88833	;2	3	MS
580	3	WK88869	;2	3	MS
581	3	WD24161	;2	3	MS
582	3	WD28418	;2	3	MS
583	3	20046T	;2	3	MS
584	3	25414S	;2	3	MS
585	3	25450S	;2	3	MS
586	3	29727U	;2	3	MS
587	3	20253T	;2	3	MS
588	3	20312T	;2	3	MS
589	3	WD24221	;2	3	MS
590	3	VDW186	;2	3	MS
591	3	WD28305	;2	3	MS
592	3	WD28312	;2	3	MS
593	3	WD13251	;2	3	MS
594	3	SD31595	;2	3	MS
595	3	TD31263	;2	3	MS
596	3	RD31125	;2	3	MS
597	3	RD31040	;2	3	MS
598	3	WD12109	;2	3	MS
599	3	UD19181	;2	3	MS
600	3	32043V	;2	3	MS
601	3	WD31901	;2	3	MS
602	3	WD31936	;2	3	MS
603	3	WD31938	;2	3	MS
604	3	WD19791	;2	3	MS
605	3	VD31917	;2	3	MS
606	3	WD31992	;2	3	MS
607	3	Q40517	;2	3	MS
608	3	R50816	;2	3	MS
609	3	Q28700	;2	3	MS
610	3	U44601	;2	3	MS
611	3	N51338	;2	3	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction	Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
612	3	U20034	;2	3	MS	654	3	W12021	;2	3	MS
613	3	Q28691	;2	3	MS	655	3	WG19361	;2	3	MS
614	3	P60265	;2	3	MS	656	3	W12028	;2	3	MS
615	3	Q21172	;2	3	MS	657	3	W12046	;2	3	MS
616	3	U20088	;2	3	MS	658	3	W10584	;2	3	MS
617	3	U20100	;2	3	MS	659	3	V54437	;2	3	MS
618	3	V20263	;2	3	MS	660	3	T36652	;2	3	MS
619	3	U20102	;2	3	MS	661	3	T36691	;2	3	MS
620	3	U20287	;2	3	MS	662	3	T36705	;2	3	MS
621	3	U20162	;2	3	MS	663	3	V56537	;2	3	MS
622	3	T60492	;2	3	MS	664	3	W10763	;2	3	MS
623	3	U20294	;2	3	MS	665	3	V56550	;2	3	MS
624	3	U20296	;2	3	MS	666	3	V54070	;2	3	MS
625	3	T64561-1	;2	3	MS	667	3	V56566	;2	3	MS
626	3	U20328	;2	3	MS	668	3	V54098	;2	3	MS
627	3	U20331	;2	3	MS	669	3	V56572	;2	3	MS
628	3	U20345	;2	3	MS	670	3	V54160	;2	3	MS
629	3	S54084	;2	3	MS	671	3	V56612	;2	3	MS
630	3	U20366	;2	3	MS	672	3	W10801	;2	3	MS
631	3	U20368	;2	3	MS	673	3	W10810	;2	3	MS
632	3	U20382	;2	3	MS	674	3	W10837	;2	3	MS
633	3	T65348	;2	3	MS	675	3	W10856	;2	3	MS
634	3	Q21499	;2	3	MS	676	3	R43333	;2	3	MS
635	3	P40183	;2	3	MS	677	3	V56428	;2	3	MS
636	3	N21222	;2	3	MS	678	3	U42449b	;2	3	MS
637	3	N21229	;2	3	MS	679	3	T31341b	;2	3	MS
638	3	N21187	;2	3	MS	680	3	V54754	;2	3	MS
639	3	P40271	;2	3	MS	681	3	V53888	;2	3	MS
640	3	P40031	;2	3	MS	682	3	U42479b	;2	3	MS
641	3	Q51830	;2	3	MS	683	3	T70177	;2	3	S
642	3	P40073	;2	3	MS	684	3	UK77777	;2	3	S
643	3	Q51864	;2	3	MS	685	3	U30370	;2	3	S
644	3	Q51929	;2	3	MS	686	3	U30304	;2	3	S
645	3	Q51967	;2	3	MS	687	3	U30306	;2	3	S
646	3	R61014	;2	3	MS	688	3	J1037	;2	3	S
647	3	R61958	;2	3	MS	689	3	20423T	;2	3	S
648	3	S33057	;2	3	MS	690	3	WD11166	;2	3	S
649	3	S33207	;2	3	MS	691	3	WD28386	;2	3	S
650	3	T90022	;2	3	MS	692	3	WD28414	;2	3	S
651	3	WG19833	;2	3	MS	693	3	11166V	;2	3	S
652	3	WG19835	;2	3	MS	694	3	25422S	;2	3	S
653	3	W12020	;2	3	MS	695	3	25464S	;2	3	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction	Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
696	3	25476S	;2	3	S	737	3	WD31998	;2	3	S
697	3	20233T	;2	3	S	738	3	R50728	;2	3	S
698	3	20239T	;2	3	S	739	3	R50781	;2	3	S
699	3	25164V	;2	3	S	740	3	R50806	;2	3	S
700	3	20287T	;2	3	S	741	3	R50809	;2	3	S
701	3	20305T	;2	3	S	742	3	R50811	;2	3	S
702	3	WD24061	;2	3	S	743	3	N51302	;2	3	S
703	3	VWD71	;2	3	S	744	3	Q28619	;2	3	S
704	3	VWD86WC	;2	3	S	745	3	N51223	;2	3	S
705	3	WD24261	;2	3	S	746	3	Q28720	;2	3	S
706	3	QD19151	;2	3	S	747	3	Q28723	;2	3	S
707	3	VD32061	;2	3	S	748	3	U20027	;2	3	S
708	3	31248T	;2	3	S	749	3	Q21098	;2	3	S
709	3	QD31760	;2	3	S	750	3	Q28661	;2	3	S
710	3	QD31780	;2	3	S	751	3	P60241	;2	3	S
711	3	QD31741	;2	3	S	752	3	Q21132	;2	3	S
712	3	QD31742	;2	3	S	753	3	U20039	;2	3	S
713	3	QD31743	;2	3	S	754	3	Q28739	;2	3	S
714	3	RD31140	;2	3	S	755	3	P60272	;2	3	S
715	3	UD11244	;2	3	S	756	3	T60099	;2	3	S
716	3	VD33921	;2	3	S	757	3	U20226	;2	3	S
717	3	UD31802	;2	3	S	758	3	Q21113	;2	3	S
718	3	VD12109	;2	3	S	759	3	U20232	;2	3	S
719	3	UD31711	;2	3	S	760	3	Q28799	;2	3	S
720	3	VD31999	;2	3	S	761	3	Q21313	;2	3	S
721	3	VD32010	;2	3	S	762	3	N51243	;2	3	S
722	3	WD31921	;2	3	S	763	3	U20098	;2	3	S
723	3	WD31948	;2	3	S	764	3	V20264	;2	3	S
724	3	SD31465	;2	3	S	765	3	U20142	;2	3	S
725	3	SD31488	;2	3	S	766	3	U20147	;2	3	S
726	3	VD11238	;2	3	S	767	3	U20154	;2	3	S
727	3	VD11256	;2	3	S	768	3	U20164	;2	3	S
728	3	WD32039	;2	3	S	769	3	U20165	;2	3	S
729	3	UD31673	;2	3	S	770	3	S54169	;2	3	S
730	3	UD31686	;2	3	S	771	3	S54221-1	;2	3	S
731	3	VD31908	;2	3	S	772	3	S54671	;2	3	S
732	3	VD31924	;2	3	S	773	3	S54712-1	;2	3	S
733	3	VD31929	;2	3	S	774	3	T60487	;2	3	S
734	3	VD31953	;2	3	S	775	3	U20417	;2	3	S
735	3	VD31954	;2	3	S	776	3	U20418	;2	3	S
736	3	VD31970	;2	3	S	777	3	R35383	;2	3	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
778	3	U20341	;2	3	S
779	3	S54052-3	;2	3	S
780	3	S54067	;2	3	S
781	3	S54078	;2	3	S
782	3	U20362	;2	3	S
783	3	U20365	;2	3	S
784	3	S54379-1	;2	3	S
785	3	U20377	;2	3	S
786	3	S54397	;2	3	S
787	3	T64418-1	;2	3	S
788	3	T65407-2	;2	3	S
789	3	T65414-2	;2	3	S
790	3	T64623	;2	3	S
791	3	T64711	;2	3	S
792	3	T64866-1	;2	3	S
793	3	T65040-1	;2	3	S
794	3	T65481-1	;2	3	S
795	3	P40193	;2	3	S
796	3	N21188	;2	3	S
797	3	P40230	;2	3	S
798	3	P40061	;2	3	S
799	3	P40086	;2	3	S
800	3	P40105	;2	3	S
801	3	Q51943	;2	3	S
802	3	Q51944	;2	3	S
803	3	Q51950	;2	3	S
804	3	R61033	;2	3	S
805	3	R61106	;2	3	S
806	3	R61424	;2	3	S
807	3	Q52462	;2	3	S
808	3	R61756	;2	3	S
809	3	Q54868	;2	3	S
810	3	S61072	;2	3	S
811	3	S60411	;2	3	S
812	3	S60429	;2	3	S
813	3	S60505	;2	3	S
814	3	S60770	;2	3	S
815	3	S33043	;2	3	S
816	3	S33185	;2	3	S
817	3	S33268	;2	3	S
818	3	S33276	;2	3	S
819	3	S33340	;2	3	S
820	3	S33373	;2	3	S
821	3	S33379	;2	3	S
822	3	S40084	;2	3	S
823	3	W10625	;2	3	S
824	3	WG18324	;2	3	S
825	3	V53962	;2	3	S
826	3	W13142	;2	3	S
827	3	U42488b	;2	3	S
828	3	WG19816	;2	3	S
829	3	WG19818	;2	3	S
830	3	W12043	;2	3	S
831	3	W12197	;2	3	S
832	3	R42751	;2	3	S
833	3	T36658	;2	3	S
834	3	T36660	;2	3	S
835	3	R46612	;2	3	S
836	3	T36695	;2	3	S
837	3	T34964	;2	3	S
838	3	V56532	;2	3	S
839	3	W10764	;2	3	S
840	3	V56568	;2	3	S
841	3	V56569	;2	3	S
842	3	V56579	;2	3	S
843	3	V56596	;2	3	S
844	3	V56614	;2	3	S
845	3	WG17236	;2	3	S
846	3	WG17248	;2	3	S
847	3	W10830	;2	3	S
848	3	W10840	;2	3	S
849	3	W10841	;2	3	S
850	3	R43038	;2	3	S
851	3	R40181	;2	3	S
852	3	W10784	;2	3	S
853	3	R40299	;2	3	S
854	3	T30302	;2	3	S
855	3	T30310	;2	3	S
856	3	R47694	;2	3	S
857	3	U42471b	;2	3	S
858	3	U42473a	;2	3	S
859	3	T90032	;2	3	S
860	3	R48417a	;2	3	S
861	3	R40145	;2	3	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction	Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
862	3	R48425a	;2	3	S	904	3	12064U	;2	4	S
863	3	R40150	;2	3	S	905	3	12076U	;2	4	S
864	3	U44754	;2	3	S	906	3	WD28571	;2	4	S
865	3	S25485	;2	3	S	907	3	25520S	;2	4	S
866	3	T31350c	;2	3	S	908	3	20257T	;2	4	S
867	3	S25517	;2	3	S	909	3	22380V	;2	4	S
868	3	U47440	;2	3	S	910	3	20332T	;2	4	S
869	3	U42484a	;2	3	S	911	3	WD23996	;2	4	S
870	3	W10722	;2	3	S	912	3	VWD111	;2	4	S
871	3	S64073	;2	4	MS	913	3	WD28302	;2	4	S
872	3	S64091	;2	4	MS	914	3	WD28326	;2	4	S
873	3	WK88841	;2	4	MS	915	3	WD28328	;2	4	S
874	3	N51369	;2	4	MS	916	3	WD28337	;2	4	S
875	3	VG49958	;2	4	MS	917	3	QD19291	;2	4	S
876	3	23058U	;2	4	MS	918	3	QD31785	;2	4	S
877	3	22913U	;2	4	MS	919	3	UD31798	;2	4	S
878	3	WD28322	;2	4	MS	920	3	WD32028	;2	4	S
879	3	QD31730	;2	4	MS	921	3	VD32115	;2	4	S
880	3	VD32036	;2	4	MS	922	3	VD31992	;2	4	S
881	3	UD31707	;2	4	MS	923	3	WD31907	;2	4	S
882	3	R50770	;2	4	MS	924	3	WD32020	;2	4	S
883	3	U20031	;2	4	MS	925	3	VD19501	;2	4	S
884	3	U20234	;2	4	MS	926	3	VD31926	;2	4	S
885	3	Q21305	;2	4	MS	927	3	VD31964	;2	4	S
886	3	U20131	;2	4	MS	928	3	WD31996	;2	4	S
887	3	U20149	;2	4	MS	929	3	R50769	;2	4	S
888	3	S54083	;2	4	MS	930	3	N51504	;2	4	S
889	3	T64504	;2	4	MS	931	3	U20015	;2	4	S
890	3	P60427	;2	4	MS	932	3	U20018	;2	4	S
891	3	T36310	;2	4	MS	933	3	N51572	;2	4	S
892	3	U42719	;2	4	MS	934	3	Q28623	;2	4	S
893	3	U42817	;2	4	MS	935	3	N51596	;2	4	S
894	3	V54635	;2	4	MS	936	3	P60230	;2	4	S
895	3	U42445a	;2	4	MS	937	3	Q21161	;2	4	S
896	3	W10760	;2	4	MS	938	3	Q28650	;2	4	S
897	3	W10757	;2	4	MS	939	3	Q21321	;2	4	S
898	3	V56434	;2	4	MS	940	3	T60182	;2	4	S
899	3	T70003	;2	4	S	941	3	Q21332	;2	4	S
900	3	WK88746	;2	4	S	942	3	U20150	;2	4	S
901	3	UK77783	;2	4	S	943	3	S54701	;2	4	S
902	3	UK77751	;2	4	S	944	3	U20320	;2	4	S
903	3	TD20411	;2	4	S	945	3	U20394	;2	4	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
946	3	T64683-2	;2	4	S
947	3	R36135	;2	4	S
948	3	Q51847	;2	4	S
949	3	Q51900	;2	4	S
950	3	U44624	;2	4	S
951	3	T36313	;2	4	S
952	3	R61043	;2	4	S
953	3	S60506	;2	4	S
954	3	S33192	;2	4	S
955	3	S33244	;2	4	S
956	3	S33320	;2	4	S
957	3	S40071	;2	4	S
958	3	W10776	;2	4	S
959	3	U40217	;2	4	S
960	3	T36661	;2	4	S
961	3	V56575	;2	4	S
962	3	W10821	;2	4	S
963	3	T34972	;2	4	S
964	3	W11445	;2	4	S
965	3	T64408	;2	5	MS
966	3	WK88726	;2	5	S
967	3	WD24126	;2	5	S
968	3	WD28303	;2	5	S
969	3	WD28355	;2	5	S
970	3	WD31908	;2	5	S
971	3	WD31909	;2	5	S
972	3	WD31919	;2	5	S
973	3	N51310	;2	5	S
974	3	U20335	;2	5	S
975	3	U20397	;2	5	S
976	3	T36676	;2	5	S
977	3	25434S	;2	6	S
978	3	U20396	;2	6	S
979	3	U20398	;2	6	S
980	3	U20104	;2	7	S
981	3	P40286	;2	7	S
982	3	S64052	;2+	2	MS
983	3	M61407	;2+	2	MS
984	3	WD24436	;2+	2	MS
985	3	S64028	;2+	2	S
986	3	WK88732	;2+	2	S
987	3	WK88858	;2+	2	S
988	3	T70099	;2+	3	MS
989	3	U77811	;2+	3	MS
990	3	WK88711	;2+	3	MS
991	3	S64168	;2+	3	MS
992	3	S64173	;2+	3	MS
993	3	S64180	;2+	3	MS
994	3	WK88832	;2+	3	MS
995	3	WK88842	;2+	3	MS
996	3	WK88854	;2+	3	MS
997	3	U20013	;2+	3	MS
998	3	O54206	;2+	3	MS
999	3	U30345	;2+	3	MS
1000	3	VG49957	;2+	3	MS
1001	3	WD28681	;2+	3	MS
1002	3	WD28393	;2+	3	MS
1003	3	20289T	;2+	3	MS
1004	3	S64033	;2+	3	S
1005	3	WK88729	;2+	3	S
1006	3	WK88745	;2+	3	S
1007	3	N51070	;2+	3	S
1008	3	U30347	;2+	3	S
1009	3	N31087	;2+	3	S
1010	3	WD28381	;2+	3	S
1011	3	20099T	;2+	3	S
1012	3	WD24519	;2+	3	S
1013	3	20345T	;2+	3	S
1014	3	WD24251	;2+	3	S
1015	3	WD28317	;2+	3	S
1016	3	RD31100	;2+	3	S
1017	3	QD31740	;2+	3	S
1018	3	SD31416	;2+	3	S
1019	3	QD31787	;2+	3	S
1020	3	RD31150	;2+	3	S
1021	3	VD31969	;2+	3	S
1022	3	R50742	;2+	3	S
1023	3	R50775	;2+	3	S
1024	3	R50780	;2+	3	S
1025	3	R50808	;2+	3	S
1026	3	Q21097	;2+	3	S
1027	3	WK88721	;2+	4	MS
1028	3	T60018	;2+	4	MS
1029	3	VD34451	;2+	4	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1030	3	QD31839	;2+	4	MS
1031	3	U77798	;2+	4	S
1032	3	VK65381	;2+	4	S
1033	3	U30309	;2+	4	S
1034	3	VD22296	;2+	4	S
1035	3	WD24356	;2+	4	S
1036	3	22375V	;2+	4	S
1037	3	WD28336	;2+	4	S
1038	3	QD31786	;2+	4	S
1039	3	SD31655	;2+	4	S
1040	3	VD31944	;2+	4	S
1041	3	N31116	;2+	3	MS
1042	3	WD28327	;2+	3	MS
1043	3	O44771	;2+	3	S
1044	3	N31122	;2+C	3	MS
1045	3	RD11301	;2+C	3	MS
1046	3	UK77767	;2+C	4	S
1047	3	S30928	;2+CN	4	S
1048	3	SD33061	;2+CN	5	S
1049	3	S64014	;2C	2	MS
1050	3	S64089	;2C	2	MS
1051	3	T70015	;2C	2	MS
1052	3	WK88734	;2C	2	MS
1053	3	W12927	;2C	2	MS
1054	3	U20051	;2C	2	S
1055	3	T70129	;2C	3	MS
1056	3	24706	;2C	3	MS
1057	3	TD20405	;2C	3	MS
1058	3	25492S	;2C	3	MS
1059	3	37141Q	;2C	3	MS
1060	3	SD31499	;2C	3	MS
1061	3	WD31968	;2C	3	MS
1062	3	P60096	;2C	3	MS
1063	3	UK77788	;2C	3	S
1064	3	N31089	;2C	3	S
1065	3	N31123	;2C	3	S
1066	3	WD24456	;2C	3	S
1067	3	25428S	;2C	3	S
1068	3	UD31693	;2C	3	S
1069	3	R50796	;2C	3	S
1070	3	Q28696	;2C	3	S
1071	3	Q28760	;2C	3	S
1072	3	T65448	;2C	3	S
1073	3	WG19806	;2C	3	S
1074	3	W12637	;2C	3	S
1075	3	WD31935	;2C	4	MS
1076	3	S30933	;2C	4	S
1077	3	VDW56	;2C	4	S
1078	3	WD28376	;2C	4	S
1079	3	VD31906	;2C	4	S
1080	3	VD31923	;2C	4	S
1081	3	S61370	;2CN	2	MS
1082	3	W10779	;2CN	2	MS
1083	3	WK88870	;2CN	3	MS
1084	3	TD41945	;2CN	3	MS
1085	3	SD11501	;2CN	3	MS
1086	3	25336S	;2CN	3	MS
1087	3	RD11511	;2CN	3	MS
1088	3	QD31754	;2CN	3	MS
1089	3	VD31928	;2CN	3	MS
1090	3	U20052	;2CN	3	MS
1091	3	P40216	;2CN	3	MS
1092	3	S60570	;2CN	3	MS
1093	3	WD28346	;2CN	3	S
1094	3	UD19251	;2CN	3	S
1095	3	QD31771	;2CN	3	S
1096	3	VD31961	;2CN	3	S
1097	3	Q28797	;2CN	3	S
1098	3	U20072	;2CN	3	S
1099	3	U20344	;2CN	3	S
1100	3	Q51969	;2CN	3	S
1101	3	U42472b	;2CN	3	S
1102	3	SD31592	;2CN	4	S
1103	3	SD31462	;2CN	4	S
1104	3	VD32075	;2CN	4	S
1105	3	T20158	;2CN	4	S
1106	3	WD23991	;2CN	5	S
1107	3	S63969	;3	2	MS
1108	3	S63970	;3	2	MS
1109	3	5CP	;3	2	MS
1110	3	UK77743	;3	2	MS
1111	3	WK88852	;3	2	MS
1112	3	25430S	;3	2	MS
1113	3	20324T	;3	2	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1114	3	T60107	;3	2	MS
1115	3	Q28757	;3	2	MS
1116	3	Q28793	;3	2	MS
1117	3	Q28795	;3	2	MS
1118	3	T60482	;3	2	MS
1119	3	T65081-2	;3	2	MS
1120	3	U44620	;3	2	MS
1121	3	P40093	;3	2	MS
1122	3	WG19328	;3	2	MS
1123	3	W11481	;3	2	MS
1124	3	S25507	;3	2	MS
1125	3	WD24511	;3	2	S
1126	3	QD31763	;3	2	S
1127	3	TD11164	;3	2	S
1128	3	R50754	;3	2	S
1129	3	N51341	;3	2	S
1130	3	S54240-3	;3	2	S
1131	3	Q51951	;3	2	S
1132	3	U44625	;3	2	S
1133	3	T36701	;3	2	S
1134	3	V56595	;3	2	S
1135	3	U42478b	;3	2	S
1136	3	S25490	;3	2	S
1137	3	S63975	;3	3	MS
1138	3	T69982	;3	3	MS
1139	3	T69985	;3	3	MS
1140	3	T69994	;3	3	MS
1141	3	T70078	;3	3	MS
1142	3	41MW	;3	3	MS
1143	3	1NP	;3	3	MS
1144	3	U77819	;3	3	MS
1145	3	U77814	;3	3	MS
1146	3	VK65249	;3	3	MS
1147	3	U77797	;3	3	MS
1148	3	U77795	;3	3	MS
1149	3	WK88704	;3	3	MS
1150	3	WK88710	;3	3	MS
1151	3	WK88719	;3	3	MS
1152	3	VK65275	;3	3	MS
1153	3	WK88747	;3	3	MS
1154	3	WK88748	;3	3	MS
1155	3	WK88750	;3	3	MS

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1156	3	S64151	;3	3	MS
1157	3	S64161	;3	3	MS
1158	3	VK65321	;3	3	MS
1159	3	VK65324	;3	3	MS
1160	3	UK77722	;3	3	MS
1161	3	WK88834	;3	3	MS
1162	3	WK88838	;3	3	MS
1163	3	WK88847	;3	3	MS
1164	3	WK88868	;3	3	MS
1165	3	WK88871	;3	3	MS
1166	3	WK88875	;3	3	MS
1167	3	H20612	;3	3	MS
1168	3	S30922	;3	3	MS
1169	3	M61337	;3	3	MS
1170	3	U30343	;3	3	MS
1171	3	S30924	;3	3	MS
1172	3	Q61226	;3	3	MS
1173	3	RD11381	;3	3	MS
1174	3	WD28423	;3	3	MS
1175	3	22436V	;3	3	MS
1176	3	WD28396	;3	3	MS
1177	3	WD28401	;3	3	MS
1178	3	WD28357	;3	3	MS
1179	3	22768U	;3	3	MS
1180	3	20326T	;3	3	MS
1181	3	20375T	;3	3	MS
1182	3	WD28341	;3	3	MS
1183	3	VD19641	;3	3	MS
1184	3	QD31745	;3	3	MS
1185	3	QD31744	;3	3	MS
1186	3	RD31121	;3	3	MS
1187	3	UD31836	;3	3	MS
1188	3	SD31509	;3	3	MS
1189	3	VD32035	;3	3	MS
1190	3	SD31430	;3	3	MS
1191	3	TD11154	;3	3	MS
1192	3	SD31445	;3	3	MS
1193	3	VD19701	;3	3	MS
1194	3	31813U	;3	3	MS
1195	3	UD31815	;3	3	MS
1196	3	UD31817	;3	3	MS
1197	3	WD11226	;3	3	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1198	3	VD32000	;3	3	MS
1199	3	WD31916	;3	3	MS
1200	3	WD31923	;3	3	MS
1201	3	WD31924	;3	3	MS
1202	3	SD31482	;3	3	MS
1203	3	UD32109	;3	3	MS
1204	3	VD32073	;3	3	MS
1205	3	UD31781	;3	3	MS
1206	3	WD32088	;3	3	MS
1207	3	VD31933	;3	3	MS
1208	3	VD31967	;3	3	MS
1209	3	WD31971	;3	3	MS
1210	3	Q40726	;3	3	MS
1211	3	R50800	;3	3	MS
1212	3	P60198	;3	3	MS
1213	3	U20020	;3	3	MS
1214	3	Q28735	;3	3	MS
1215	3	Q21144	;3	3	MS
1216	3	Q28745	;3	3	MS
1217	3	P60274	;3	3	MS
1218	3	U20050	;3	3	MS
1219	3	Q28773	;3	3	MS
1220	3	T90184	;3	3	MS
1221	3	U20075	;3	3	MS
1222	3	N51239	;3	3	MS
1223	3	N51240	;3	3	MS
1224	3	T60216	;3	3	MS
1225	3	U20099	;3	3	MS
1226	3	U20113	;3	3	MS
1227	3	U20123	;3	3	MS
1228	3	U20144	;3	3	MS
1229	3	T60479	;3	3	MS
1230	3	T60484	;3	3	MS
1231	3	S54709	;3	3	MS
1232	3	U20422	;3	3	MS
1233	3	S54094	;3	3	MS
1234	3	S54115-2	;3	3	MS
1235	3	S54740	;3	3	MS
1236	3	Q26075	;3	3	MS
1237	3	P64988	;3	3	MS
1238	3	P40182	;3	3	MS
1239	3	N21150	;3	3	MS
1240	3	P40248	;3	3	MS
1241	3	T36308	;3	3	MS
1242	3	T36317	;3	3	MS
1243	3	S33250	;3	3	MS
1244	3	U42715	;3	3	MS
1245	3	V54971	;3	3	MS
1246	3	WG19792	;3	3	MS
1247	3	WG19827	;3	3	MS
1248	3	W12051	;3	3	MS
1249	3	W12203	;3	3	MS
1250	3	W12221	;3	3	MS
1251	3	T36669	;3	3	MS
1252	3	V54028	;3	3	MS
1253	3	V56555	;3	3	MS
1254	3	W10765	;3	3	MS
1255	3	V56573	;3	3	MS
1256	3	V56584	;3	3	MS
1257	3	V56600	;3	3	MS
1258	3	W10805	;3	3	MS
1259	3	W10818	;3	3	MS
1260	3	W10846	;3	3	MS
1261	3	W10847	;3	3	MS
1262	3	W10786	;3	3	MS
1263	3	U42452b	;3	3	MS
1264	3	U42512	;3	3	MS
1265	3	U42135	;3	3	MS
1266	3	WG18343	;3	3	MS
1267	3	U77684	;3	3	S
1268	3	T69955	;3	3	S
1269	3	U77792	;3	3	S
1270	3	WK88709	;3	3	S
1271	3	UK77768	;3	3	S
1272	3	UK77733	;3	3	S
1273	3	U30314	;3	3	S
1274	3	M61446	;3	3	S
1275	3	VD25006	;3	3	S
1276	3	20415T	;3	3	S
1277	3	WD24156	;3	3	S
1278	3	25376S	;3	3	S
1279	3	11088T	;3	3	S
1280	3	25410S	;3	3	S
1281	3	22563U	;3	3	S
1282	3	20301T	;3	3	S
1283	3	12085WD	;3	3	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1284	3	WD28360	;3	3	S
1285	3	VWD115	;3	3	S
1286	3	WD24036	;3	3	S
1287	3	WD28307	;3	3	S
1288	3	WD28310	;3	3	S
1289	3	WD28318	;3	3	S
1290	3	OD15241	;3	3	S
1291	3	VD33441	;3	3	S
1292	3	QD19301	;3	3	S
1293	3	WD19371	;3	3	S
1294	3	QD31759	;3	3	S
1295	3	OD31550	;3	3	S
1296	3	VD38101	;3	3	S
1297	3	WD4141	;3	3	S
1298	3	WD13301	;3	3	S
1299	3	VD38031	;3	3	S
1300	3	TD19531	;3	3	S
1301	3	VD33961	;3	3	S
1302	3	UD31816	;3	3	S
1303	3	VWD2332	;3	3	S
1304	3	UD31710	;3	3	S
1305	3	WD11232	;3	3	S
1306	3	UD31735	;3	3	S
1307	3	SD19436	;3	3	S
1308	3	QD31810	;3	3	S
1309	3	SD31425	;3	3	S
1310	3	VD31995	;3	3	S
1311	3	VD31996	;3	3	S
1312	3	VD31998	;3	3	S
1313	3	VD32004	;3	3	S
1314	3	VD32007	;3	3	S
1315	3	WD31928	;3	3	S
1316	3	WD31932	;3	3	S
1317	3	WD31937	;3	3	S
1318	3	WD31946	;3	3	S
1319	3	WD31949	;3	3	S
1320	3	SD31455	;3	3	S
1321	3	SD31459	;3	3	S
1322	3	SD31463	;3	3	S
1323	3	SD31477	;3	3	S
1324	3	VD34141	;3	3	S
1325	3	TD31333	;3	3	S
1326	3	UD31663	;3	3	S
1327	3	UD31665	;3	3	S
1328	3	UD31674	;3	3	S
1329	3	UD31675	;3	3	S
1330	3	UD31685	;3	3	S
1331	3	VD31937	;3	3	S
1332	3	VD31956	;3	3	S
1333	3	VD31968	;3	3	S
1334	3	Q28702	;3	3	S
1335	3	N51311	;3	3	S
1336	3	N51327	;3	3	S
1337	3	Q28721	;3	3	S
1338	3	P60225	;3	3	S
1339	3	Q28656	;3	3	S
1340	3	P60257	;3	3	S
1341	3	Q21165	;3	3	S
1342	3	Q28778	;3	3	S
1343	3	Q28784	;3	3	S
1344	3	N51236	;3	3	S
1345	3	Q21354	;3	3	S
1346	3	U20091	;3	3	S
1347	3	R30458	;3	3	S
1348	3	U20107	;3	3	S
1349	3	U20108	;3	3	S
1350	3	U20111	;3	3	S
1351	3	V20115	;3	3	S
1352	3	V20117	;3	3	S
1353	3	U20157	;3	3	S
1354	3	U20286	;3	3	S
1355	3	S54168-2	;3	3	S
1356	3	T60474	;3	3	S
1357	3	T60497	;3	3	S
1358	3	U20293	;3	3	S
1359	3	U20298	;3	3	S
1360	3	U20300	;3	3	S
1361	3	U20325	;3	3	S
1362	3	U20327	;3	3	S
1363	3	U20338	;3	3	S
1364	3	S54029-2	;3	3	S
1365	3	S54079-3	;3	3	S
1366	3	U20348	;3	3	S
1367	3	S54380-1	;3	3	S
1368	3	U20383	;3	3	S
1369	3	U20388	;3	3	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1370	3	U20393	;3	3	S
1371	3	T64340-1	;3	3	S
1372	3	T65141-2	;3	3	S
1373	3	T65442-1	;3	3	S
1374	3	T65442-2	;3	3	S
1375	3	T65460-1	;3	3	S
1376	3	T65503	;3	3	S
1377	3	Q21490	;3	3	S
1378	3	Q21491	;3	3	S
1379	3	Q21503	;3	3	S
1380	3	P60487	;3	3	S
1381	3	P64946	;3	3	S
1382	3	P40175	;3	3	S
1383	3	N21151	;3	3	S
1384	3	P40206	;3	3	S
1385	3	P40294	;3	3	S
1386	3	P40022	;3	3	S
1387	3	P40026	;3	3	S
1388	3	P40059	;3	3	S
1389	3	Q51863	;3	3	S
1390	3	P40082	;3	3	S
1391	3	Q51906	;3	3	S
1392	3	Q51930	;3	3	S
1393	3	Q51977	;3	3	S
1394	3	R61089	;3	3	S
1395	3	R61103	;3	3	S
1396	3	R61390	;3	3	S
1397	3	S61165	;3	3	S
1398	3	S33044	;3	3	S
1399	3	S33106	;3	3	S
1400	3	S33313	;3	3	S
1401	3	U42711	;3	3	S
1402	3	V54970	;3	3	S
1403	3	U42488a	;3	3	S
1404	3	WG19267	;3	3	S
1405	3	WG19810	;3	3	S
1406	3	WG19812	;3	3	S
1407	3	WG19817	;3	3	S
1408	3	W12036	;3	3	S
1409	3	W12041	;3	3	S
1410	3	W12049	;3	3	S
1411	3	W12220	;3	3	S
1412	3	T36679	;3	3	S
1413	3	T36688	;3	3	S
1414	3	T36689	;3	3	S
1415	3	T36694	;3	3	S
1416	3	T36699	;3	3	S
1417	3	V54012	;3	3	S
1418	3	V56529	;3	3	S
1419	3	W12678	;3	3	S
1420	3	V54062	;3	3	S
1421	3	V56553	;3	3	S
1422	3	V56562	;3	3	S
1423	3	V56564	;3	3	S
1424	3	V54136	;3	3	S
1425	3	W10766	;3	3	S
1426	3	V56592	;3	3	S
1427	3	W10820	;3	3	S
1428	3	R43372	;3	3	S
1429	3	R43362	;3	3	S
1430	3	T34977	;3	3	S
1431	3	W11201	;3	3	S
1432	3	U42450b	;3	3	S
1433	3	U42454b	;3	3	S
1434	3	W10791	;3	3	S
1435	3	V53886	;3	3	S
1436	3	U42509	;3	3	S
1437	3	W10755	;3	3	S
1438	3	U42476a	;3	3	S
1439	3	WG18271	;3	3	S
1440	3	T31346c	;3	3	S
1441	3	T36748	;3	3	S
1442	3	R40168	;3	3	S
1443	3	T31348a	;3	3	S
1444	3	V56376	;3	3	S
1445	3	T31351b	;3	3	S
1446	3	U42484b	;3	3	S
1447	3	W10702	;3	3	S
1448	3	WG18341	;3	3	S
1449	3	WG18345	;3	3	S
1450	3	T70042	;3	4	MS
1451	3	S64156	;3	4	MS
1452	3	UK77766	;3	4	MS
1453	3	UK77756	;3	4	MS
1454	3	UK77746	;3	4	MS
1455	3	UK77737	;3	4	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction	Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1456	3	WK88843	;3	4	MS	1499	3	OD38417	;3	4	S
1457	3	WK88855	;3	4	MS	1500	3	SD31408	;3	4	S
1458	3	T60293	;3	4	MS	1501	3	31721Q	;3	4	S
1459	3	VD25021	;3	4	MS	1502	3	QD31779	;3	4	S
1460	3	WD28309	;3	4	MS	1503	3	OD31520	;3	4	S
1461	3	WD28311	;3	4	MS	1504	3	RD31136	;3	4	S
1462	3	VD34481	;3	4	MS	1505	3	UD31799	;3	4	S
1463	3	QD31713	;3	4	MS	1506	3	TD11152	;3	4	S
1464	3	WD4101	;3	4	MS	1507	3	SD31444	;3	4	S
1465	3	WD31917	;3	4	MS	1508	3	VD32038	;3	4	S
1466	3	UD31688	;3	4	MS	1509	3	31811U	;3	4	S
1467	3	VD31945	;3	4	MS	1510	3	WD38126	;3	4	S
1468	3	Q28706	;3	4	MS	1511	3	UD31705	;3	4	S
1469	3	U20103	;3	4	MS	1512	3	UD38661	;3	4	S
1470	3	V20116	;3	4	MS	1513	3	WD31906	;3	4	S
1471	3	P60426	;3	4	MS	1514	3	WD31913	;3	4	S
1472	3	N21142	;3	4	MS	1515	3	WD31926	;3	4	S
1473	3	N21232	;3	4	MS	1516	3	SD31479	;3	4	S
1474	3	S33075	;3	4	MS	1517	3	UD31677	;3	4	S
1475	3	WG19263	;3	4	MS	1518	3	VD31931	;3	4	S
1476	3	U43000-92	;3	4	MS	1519	3	VD31962	;3	4	S
1477	3	V56585	;3	4	MS	1520	3	WD31985	;3	4	S
1478	3	W10790	;3	4	MS	1521	3	N51213	;3	4	S
1479	3	T36750	;3	4	MS	1522	3	U20024	;3	4	S
1480	3	U44761	;3	4	MS	1523	3	U20026	;3	4	S
1481	3	S63980	;3	4	S	1524	3	U20220	;3	4	S
1482	3	S64065	;3	4	S	1525	3	Q21188	;3	4	S
1483	3	U77810	;3	4	S	1526	3	T60389	;3	4	S
1484	3	U77808	;3	4	S	1527	3	U20275	;3	4	S
1485	3	UK77784	;3	4	S	1528	3	U20146	;3	4	S
1486	3	UK77770	;3	4	S	1529	3	U20148	;3	4	S
1487	3	WK88872	;3	4	S	1530	3	T60466	;3	4	S
1488	3	O54329	;3	4	S	1531	3	S54047	;3	4	S
1489	3	Q61227	;3	4	S	1532	3	U20347	;3	4	S
1490	3	25036V	;3	4	S	1533	3	U20355	;3	4	S
1491	3	TD11090	;3	4	S	1534	3	U20373	;3	4	S
1492	3	TD11098	;3	4	S	1535	3	T65460-2	;3	4	S
1493	3	WD24466	;3	4	S	1536	3	T65630	;3	4	S
1494	3	WD28361	;3	4	S	1537	3	T65487	;3	4	S
1495	3	20363T	;3	4	S	1538	3	Q21481	;3	4	S
1496	3	WD28666	;3	4	S	1539	3	N21025	;3	4	S
1497	3	VWD155	;3	4	S	1540	3	P40190	;3	4	S
1498	3	WD28335	;3	4	S	1541	3	P40280	;3	4	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1542	3	P40098	;3	4	S
1543	3	P40128	;3	4	S
1544	3	Q51914	;3	4	S
1545	3	Q51965	;3	4	S
1546	3	T11029	;3	4	S
1547	3	R61068	;3	4	S
1548	3	U44627	;3	4	S
1549	3	S60839	;3	4	S
1550	3	S60952	;3	4	S
1551	3	S61499	;3	4	S
1552	3	S33070	;3	4	S
1553	3	S33089	;3	4	S
1554	3	W10777	;3	4	S
1555	3	T20139	;3	4	S
1556	3	W10775	;3	4	S
1557	3	U42822	;3	4	S
1558	3	U42855	;3	4	S
1559	3	U42857	;3	4	S
1560	3	WG19266	;3	4	S
1561	3	WG19790	;3	4	S
1562	3	WG19830	;3	4	S
1563	3	W12216	;3	4	S
1564	3	W12219	;3	4	S
1565	3	T34968	;3	4	S
1566	3	V56565	;3	4	S
1567	3	V56603	;3	4	S
1568	3	W10804	;3	4	S
1569	3	W10812	;3	4	S
1570	3	R43054c	;3	4	S
1571	3	U44760	;3	4	S
1572	3	T69958	;3	5	MS
1573	3	VD23261	;3	5	MS
1574	3	20373T	;3	5	S
1575	3	WD28314	;3	5	S
1576	3	UD13251	;3	5	S
1577	3	SD31468	;3	5	S
1578	3	UD31680	;3	5	S
1579	3	WD31974	;3	5	S
1580	3	U20090	;3	5	S
1581	3	U20105	;3	5	S
1582	3	U20392	;3	5	S
1583	3	N21204	;3	5	S
1584	3	WD12106	;3	6	S
1585	3	R50777	;3	6	S
1586	3	T65468	;3	6	S
1587	3	P60442	;3	6	S
1588	3	N21178	;3	6	S
1589	3	P40220	;3	6	S
1590	3	P40262	;3	6	S
1591	3	25480S	;3	7	S
1592	3	U20319	;3	7	S
1593	3	T36307	;3	7	S
1594	3	WK89684	;3+	2	MS
1595	3	S64086	;3+	2	MS
1596	3	VK65252	;3+	2	MS
1597	3	T69991	;3+	3	MS
1598	3	T70090	;3+	3	MS
1599	3	T70105	;3+	3	MS
1600	3	WK88749	;3+	3	MS
1601	3	WK89636	;3+	3	MS
1602	3	UK77748	;3+	3	MS
1603	3	WK88844	;3+	3	MS
1604	3	Q21044	;3+	3	MS
1605	3	O54317	;3+	3	MS
1606	3	11178V	;3+	3	MS
1607	3	WD19141	;3+	3	MS
1608	3	QD31773	;3+	3	MS
1609	3	VD31904	;3+	3	MS
1610	3	WK88874	;3+	3	S
1611	3	23192U	;3+	3	S
1612	3	20330T	;3+	3	S
1613	3	SD31486	;3+	3	S
1614	3	WD32045	;3+	3	S
1615	3	S63995	;3+	4	MS
1616	3	S64094	;3+	4	MS
1617	3	T69934	;3+	4	MS
1618	3	U77806	;3+	4	MS
1619	3	WK88848	;3+	4	MS
1620	3	H21336	;3+	4	MS
1621	3	RD31134	;3+	4	MS
1622	3	T69937	;3+	4	S
1623	3	WK88744	;3+	4	S
1624	3	U20007	;3+	4	S
1625	3	VD31958	;3+	4	S
1626	3	U20045	;3+	5	MS
1627	3	U77796	;3+C	3	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction	Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1628	3	N31076	;3+CN	4	MS	1671	3	U20112	;3CN	4	S
1629	3	U77688	;3C	2	MS	1672	3	U44629	;3CN	4	S
1630	3	WK88713	;3C	2	MS	1673	3	U20062	;4	2	MS
1631	3	S64166	;3C	3	MS	1674	3	U77793	;4	3	MS
1632	3	S30913	;3C	3	MS	1675	3	UK77739	;4	3	MS
1633	3	WD28421	;3C	3	MS	1676	3	VD34691	;4	3	MS
1634	3	WD25951	;3C	3	MS	1677	3	VD31994	;4	3	MS
1635	3	U20029	;3C	3	MS	1678	3	Q21109	;4	3	MS
1636	3	PD11531	;3C	3	S	1679	3	T60483	;4	3	MS
1637	3	VWD447	;3C	3	S	1680	3	U20385	;4	3	MS
1638	3	WD28319	;3C	3	S	1681	3	P64958	;4	3	MS
1639	3	WD28323	;3C	3	S	1682	3	R60929	;4	3	MS
1640	3	WD32051	;3C	3	S	1683	3	P40099	;4	3	MS
1641	3	T30298	;3C	3	S	1684	3	U42441b	;4	3	MS
1642	3	28783VD	;3C	4	MS	1685	3	WG19787	;4	3	MS
1643	3	SD29501	;3C	4	MS	1686	3	WK88878	;4	3	S
1644	3	VD33541	;3C	4	MS	1687	3	J1061	;4	3	S
1645	3	S30910	;3C	4	S	1688	3	U30310	;4	3	S
1646	3	N31073	;3C	4	S	1689	3	VD22276	;4	3	S
1647	3	WG19785	;3C	4	S	1690	3	WD28379	;4	3	S
1648	3	S30923	;3C	2	S	1691	3	TD20207	;4	3	S
1649	3	TD31262	;3C	2	S	1692	3	RD12311	;4	3	S
1650	3	H21733 a	;3C	3	S	1693	3	TD11160	;4	3	S
1651	3	H21799	;3C	3	S	1694	3	WD32123	;4	3	S
1652	3	VD31971	;3C	3	S	1695	3	WD31912	;4	3	S
1653	3	S30926	;3C	4	S	1696	3	WD31942	;4	3	S
1654	3	VD31934	;3C	4	S	1697	3	VD32092	;4	3	S
1655	3	P60023	;3C	5	MS	1698	3	VD31910	;4	3	S
1656	3	WD19531	;3CN	2	MS	1699	3	VD31939	;4	3	S
1657	3	VK65235	;3CN	3	MS	1700	3	Q28754	;4	3	S
1658	3	VK65327	;3CN	3	MS	1701	3	Q28798	;4	3	S
1659	3	SD31404	;3CN	3	MS	1702	3	Q21322	;4	3	S
1660	3	VD34731	;3CN	3	MS	1703	3	Q21326	;4	3	S
1661	3	SD31437	;3CN	3	MS	1704	3	U20092	;4	3	S
1662	3	VD34431	;3CN	3	S	1705	3	T60221	;4	3	S
1663	3	R30436	;3CN	3	S	1706	3	T60227	;4	3	S
1664	3	S54029-1	;3CN	3	S	1707	3	S54648	;4	3	S
1665	3	R61009	;3CN	3	S	1708	3	T64202	;4	3	S
1666	3	W12045	;3CN	3	S	1709	3	T64937	;4	3	S
1667	3	R48433b	;3CN	3	S	1710	3	T64938	;4	3	S
1668	3	U42769	;3CN	3	S	1711	3	P64916	;4	3	S
1669	3	H20966	;3CN	4	MS	1712	3	Q52246	;4	3	S
1670	3	VD25011	;3CN	4	MS	1713	3	Q54928	;4	3	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction	Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1714	3	S61294	;4	3	S	1757	3	T90014	;4CN	6	S
1715	3	S60412	;4	3	S	1758	3	WD28330	1P;1P1	3	MS
1716	3	WG19804	;4	3	S	1759	4	T36668	2	2	MR
1717	3	V56593	;4	3	S	1760	4	U42514	2	2	MR
1718	3	V54170	;4	3	S	1761	4	SD31464	2	2	R
1719	3	WG18340	;4	3	S	1762	4	W12013	2	2	R
1720	3	WK88730	;4	4	MS	1763	4	W12215	2	2	R
1721	3	UD31702	;4	4	MS	1764	4	W12224	2	2	R
1722	3	WD31955	;4	4	MS	1765	4	V56540	2	2	R
1723	3	R50760	;4	4	MS	1766	4	U42469a	2	2	R
1724	3	Q40656	;4	4	MS	1767	4	R43312	2	3	MR
1725	3	UK77774	;4	4	S	1768	4	23085U	2	4	R
1726	3	WK88880	;4	4	S	1769	4	S64053	3	2	MR
1727	3	TWD1586	;4	4	S	1770	4	T70183	3	2	R
1728	3	TD20190	;4	4	S	1771	4	25366S	3	2	R
1729	3	VD11220	;4	4	S	1772	4	W10807	3	2	R
1730	3	UD31699	;4	4	S	1773	4	U44752	3	2	R
1731	3	VD31988	;4	4	S	1774	4	T69976	3	3	MR
1732	3	VD32003	;4	4	S	1775	4	T70057	3	3	MR
1733	3	WD31904	;4	4	S	1776	4	T70189	3	3	MR
1734	3	WD31918	;4	4	S	1777	4	T70225	3	3	MR
1735	3	VD31927	;4	4	S	1778	4	U77822	3	3	MR
1736	3	VD31951	;4	4	S	1779	4	U77815	3	3	MR
1737	3	VD31952	;4	4	S	1780	4	Q21050	3	3	MR
1738	3	WD31967	;4	4	S	1781	4	QD19951	3	3	MR
1739	3	N13726	;4	4	S	1782	4	S64062	3	3	R
1740	3	U20267	;4	4	S	1783	4	WD28383	3	3	R
1741	3	Q26077	;4	4	S	1784	4	20377T	3	3	R
1742	3	P40288	;4	4	S	1785	4	WD31961	3	3	R
1743	3	Q51840	;4	4	S	1786	4	R46606	3	3	R
1744	3	P40127	;4	4	S	1787	4	W10851	3	3	R
1745	3	S60387	;4	4	S	1788	4	S64056	3	4	MR
1746	3	S60606	;4	4	S	1789	4	UK77771	3	4	MR
1747	3	T90012	;4	4	S	1790	4	S64080	3	4	R
1748	3	T90016	;4	4	S	1791	4	H21704	3	4	R
1749	3	WG19811	;4	4	S	1792	4	20340T	3	4	R
1750	3	S25508	;4	4	S	1793	4	25468S	3	5	MR
1751	3	T60475	;4	5	MS	1794	4	WD31941	3	6	R
1752	3	U44599	;4	5	S	1795	4	UK77730	4	2	R
1753	3	UD31759	;4	6	S	1796	4	N51171	4	2	R
1754	3	N31086	;4C	3	MS	1797	4	Q51887	4	2	R
1755	3	R50784	;4C	3	S	1798	4	20349T	4	3	R
1756	3	N31133	;4CN	4	S	1799	4	TD41949	4	6	MR

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1800	4	U20354	;	2	R
1801	4	UD11208	1CN	3	MR
1802	4	T70000	2+	3	MR
1803	4	U44539	2+	3	MR
1804	4	QD31822	2+	3	MR
1805	4	22441V	2+	3	R
1806	4	T70222	3+	2	R
1807	4	N51429	3+	2	R
1808	4	U77818	3+	3	MR
1809	4	WK88708	3+	3	MR
1810	4	WK88877	3+	3	MR
1811	4	UD19131	3+	3	MR
1812	4	U77825	3+	3	MS
1813	4	S64138	3+	3	R
1814	4	S63971	3+	4	MR
1815	4	UK77732	3C	3	MR
1816	4	UK77728	3C	3	MR
1817	4	WK88733	3CN	2	MR
1818	4	UK77779	3CN	6	R
1819	4	TD41957	4C	3	R
1820	5	R48413a	1	3	S
1821	5	U77789	2	2	MS
1822	5	U20332	2	2	MS
1823	5	T36728	2	2	MS
1824	5	W10758	2	2	S
1825	5	T70165	2	3	MS
1826	5	T70168	2	3	MS
1827	5	T70213	2	3	MS
1828	5	SD12507	2	3	MS
1829	5	RD12331	2	3	MS
1830	5	W12053	2	3	MS
1831	5	T36662	2	3	MS
1832	5	T36692	2	3	MS
1833	5	T36704	2	3	MS
1834	5	W10827	2	3	MS
1835	5	T30308	2	3	MS
1836	5	T31341a	2	3	MS
1837	5	U42458b	2	3	MS
1838	5	R47662	2	3	MS
1839	5	T31351a	2	3	MS
1840	5	S64045	2	3	S
1841	5	WD28300	2	3	S
1842	5	WD28334	2	3	S
1843	5	SD31576	2	3	S
1844	5	SD31448	2	3	S
1845	5	UD31763	2	3	S
1846	5	UD31773	2	3	S
1847	5	WD31963	2	3	S
1848	5	UD31666	2	3	S
1849	5	VD31905	2	3	S
1850	5	N51505	2	3	S
1851	5	U20361	2	3	S
1852	5	U42500	2	3	S
1853	5	W12039	2	3	S
1854	5	WG19325	2	3	S
1855	5	W12213	2	3	S
1856	5	U42444b	2	3	S
1857	5	T36659	2	3	S
1858	5	T36667	2	3	S
1859	5	T36685	2	3	S
1860	5	T34959	2	3	S
1861	5	W13350	2	3	S
1862	5	U42614	2	3	S
1863	5	U42602	2	3	S
1864	5	V56547	2	3	S
1865	5	V56551	2	3	S
1866	5	V56610	2	3	S
1867	5	W10803	2	3	S
1868	5	W10811	2	3	S
1869	5	W10814	2	3	S
1870	5	W10843	2	3	S
1871	5	R42243	2	3	S
1872	5	U42812	2	3	S
1873	5	U42593	2	3	S
1874	5	WG18337	2	3	S
1875	5	R48444a	2	3	S
1876	5	T31345a	2	3	S
1877	5	U42464b	2	3	S
1878	5	R48413b	2	3	S
1879	5	WG18270	2	3	S
1880	5	R48420b	2	3	S
1881	5	QD31835	2	4	MS
1882	5	W12016	2	4	MS
1883	5	W12032	2	4	MS
1884	5	W13349	2	4	MS
1885	5	R42926	2	4	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1886	5	R48432b	2	4	MS
1887	5	S64109	2	4	S
1888	5	WD28301	2	4	S
1889	5	QD19541	2	4	S
1890	5	N51502	2	4	S
1891	5	S62032	2	4	S
1892	5	V56602	2	4	S
1893	5	V56611	2	4	S
1894	5	W10845	2	4	S
1895	5	U42775	2	4	S
1896	5	V53929	2	4	S
1897	5	S25542	2	4	S
1898	5	S63976	2	5	S
1899	5	T31344b	2	5	S
1900	5	T70087	3	2	MS
1901	5	V20261	3	2	MS
1902	5	W12011	3	2	MS
1903	5	S64041	3	2	S
1904	5	V56548	3	2	S
1905	5	V54118	3	2	S
1906	5	T70195	3	3	MS
1907	5	T70201	3	3	MS
1908	5	U77824	3	3	MS
1909	5	U77823	3	3	MS
1910	5	WK88701	3	3	MS
1911	5	R1786	3	3	MS
1912	5	N51143	3	3	MS
1913	5	25137V	3	3	MS
1914	5	20293T	3	3	MS
1915	5	WD28324	3	3	MS
1916	5	UD19541	3	3	MS
1917	5	SD31415	3	3	MS
1918	5	TD31264	3	3	MS
1919	5	UD11247	3	3	MS
1920	5	UD31727	3	3	MS
1921	5	T60488	3	3	MS
1922	5	P64970	3	3	MS
1923	5	N21233	3	3	MS
1924	5	T20165	3	3	MS
1925	5	WG19819	3	3	MS
1926	5	W12012	3	3	MS
1927	5	W12037	3	3	MS
1928	5	W12038	3	3	MS
1929	5	W12052	3	3	MS
1930	5	T36674	3	3	MS
1931	5	V56539	3	3	MS
1932	5	V54048	3	3	MS
1933	5	V56557	3	3	MS
1934	5	V56604	3	3	MS
1935	5	V56608	3	3	MS
1936	5	W10800	3	3	MS
1937	5	W10813	3	3	MS
1938	5	V54688	3	3	MS
1939	5	V53931	3	3	MS
1940	5	W10767	3	3	MS
1941	5	U42621	3	3	MS
1942	5	U42474b	3	3	MS
1943	5	U42479a	3	3	MS
1944	5	T70006	3	3	S
1945	5	T70180	3	3	S
1946	5	U77817	3	3	S
1947	5	WK88699	3	3	S
1948	5	S64170	3	3	S
1949	5	Q21048	3	3	S
1950	5	11090T	3	3	S
1951	5	WD24246	3	3	S
1952	5	QD19131	3	3	S
1953	5	QD31765	3	3	S
1954	5	QD31825	3	3	S
1955	5	SD31427	3	3	S
1956	5	QD31838	3	3	S
1957	5	VD11244	3	3	S
1958	5	WD31962	3	3	S
1959	5	UD31657	3	3	S
1960	5	WD31973	3	3	S
1961	5	Q28755	3	3	S
1962	5	U20343	3	3	S
1963	5	S54264-2	3	3	S
1964	5	N21154	3	3	S
1965	5	N21172	3	3	S
1966	5	P40043	3	3	S
1967	5	R61011	3	3	S
1968	5	T20159	3	3	S
1969	5	WG19820	3	3	S
1970	5	W12014	3	3	S
1971	5	W12015	3	3	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
1972	5	W12022	3	3	S
1973	5	W12023	3	3	S
1974	5	W12024	3	3	S
1975	5	W12025	3	3	S
1976	5	W12026	3	3	S
1977	5	W12030	3	3	S
1978	5	W12042	3	3	S
1979	5	W12050	3	3	S
1980	5	W12199	3	3	S
1981	5	T36655	3	3	S
1982	5	T36656	3	3	S
1983	5	T36702	3	3	S
1984	5	T36707	3	3	S
1985	5	U42608	3	3	S
1986	5	V56533	3	3	S
1987	5	V54030	3	3	S
1988	5	V56538	3	3	S
1989	5	V56577	3	3	S
1990	5	V56588	3	3	S
1991	5	V56607	3	3	S
1992	5	V54176	3	3	S
1993	5	W10834	3	3	S
1994	5	R43050	3	3	S
1995	5	T34974	3	3	S
1996	5	R43340	3	3	S
1997	5	W10785	3	3	S
1998	5	R40306	3	3	S
1999	5	R40308	3	3	S
2000	5	U42459a	3	3	S
2001	5	WG18269	3	3	S
2002	5	U42460b	3	3	S
2003	5	T31344a	3	3	S
2004	5	R47675	3	3	S
2005	5	U41183	3	3	S
2006	5	S25520	3	3	S
2007	5	WG18342	3	3	S
2008	5	U77687	3	4	MS
2009	5	20307T	3	4	MS
2010	5	31800U	3	4	MS
2011	5	N21248	3	4	MS
2012	5	WG19323	3	4	MS
2013	5	W10858	3	4	MS
2014	5	W10687	3	4	MS
2015	5	W10787	3	4	MS
2016	5	U42477b	3	4	MS
2017	5	T31350b	3	4	MS
2018	5	T70204	3	4	S
2019	5	N51188	3	4	S
2020	5	UD31797	3	4	S
2021	5	QD31841	3	4	S
2022	5	SD31481	3	4	S
2023	5	Q21160	3	4	S
2024	5	U20411	3	4	S
2025	5	P64976	3	4	S
2026	5	N21020	3	4	S
2027	5	Q51671	3	4	S
2028	5	N21194	3	4	S
2029	5	R60909	3	4	S
2030	5	Q51955	3	4	S
2031	5	U41198	3	4	S
2032	5	T20270	3	4	S
2033	5	T20275	3	4	S
2034	5	T20164	3	4	S
2035	5	WG19794	3	4	S
2036	5	W12009	3	4	S
2037	5	W12205	3	4	S
2038	5	WG19339	3	4	S
2039	5	WG18335	3	4	S
2040	5	R46652	3	4	S
2041	5	V56541	3	4	S
2042	5	W10802	3	4	S
2043	5	W10853	3	4	S
2044	5	R48416b	3	4	S
2045	5	W12928	3	4	S
2046	5	69925T	3	5	MS
2047	5	29132WD	3	5	S
2048	5	U20316	3	5	S
2049	5	P40238	3	7	S
2050	5	V54132	4	2	S
2051	5	T70219	4	3	MS
2052	5	42062Q	4	3	MS
2053	5	RD31058	4	3	MS
2054	5	37341Q	4	3	MS
2055	5	WD31925	4	3	MS
2056	5	P64928	4	3	MS
2057	5	P64952	4	3	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction	Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
2058	5	S60243	4	3	MS	2101	5	VD32006	4	4	S
2059	5	WK88882	4	3	S	2102	5	VD31922	4	4	S
2060	5	24707L	4	3	S	2103	5	U20402	4	4	S
2061	5	11084T	4	3	S	2104	5	P60462	4	4	S
2062	5	20269T	4	3	S	2105	5	Q21495	4	4	S
2063	5	24176WD	4	3	S	2106	5	N21244	4	4	S
2064	5	WD19091	4	3	S	2107	5	S33380	4	4	S
2065	5	TD11126	4	3	S	2108	5	T20151	4	4	S
2066	5	RD31096	4	3	S	2109	5	U42483a	4	4	S
2067	5	WD4151	4	3	S	2110	5	W11174	4	4	S
2068	5	VD31990	4	3	S	2111	5	29580T	4	5	MS
2069	5	UD31669	4	3	S	2112	5	WD31905	4	5	S
2070	5	Q28715	4	3	S	2113	5	SD31461	4	5	S
2071	5	Q21157	4	3	S	2114	5	T70186	2+	2	MS
2072	5	U20222	4	3	S	2115	5	QD31843	2+	2	S
2073	5	T60191	4	3	S	2116	5	O54341a	2+	3	MS
2074	5	U20137	4	3	S	2117	5	OD31521	2+	3	MS
2075	5	U20387	4	3	S	2118	5	RD31144	2+	3	MS
2076	5	U20407	4	3	S	2119	5	QD31751	2+	3	S
2077	5	T65234	4	3	S	2120	5	QD31775	2+	3	S
2078	5	P60463	4	3	S	2121	5	SD31429	2+	3	S
2079	5	P64934	4	3	S	2122	5	RD11431	2+	4	S
2080	5	P64940	4	3	S	2123	5	UD19141	2+C	3	S
2081	5	P40102	4	3	S	2124	5	UD31692	2C	3	MS
2082	5	P40117	4	3	S	2125	5	W10771	2C	3	S
2083	5	WG19265	4	3	S	2126	5	S64105	2C	4	S
2084	5	WG19805	4	3	S	2127	5	T36654	2CN	3	MS
2085	5	WG19808	4	3	S	2128	5	T36653	2CN	3	S
2086	5	V56591	4	3	S	2129	5	I22055 B	2CN	4	S
2087	5	W10788	4	3	S	2130	5	U77813	3+	3	MS
2088	5	W10789	4	3	S	2131	5	WK88712	3+	3	MS
2089	5	U42477a	4	3	S	2132	5	S64159	3+	3	MS
2090	5	WG18344	4	3	S	2133	5	WD19611	3+	3	MS
2091	5	T70033	4	4	MS	2134	5	UK77786	3+	3	S
2092	5	U77800	4	4	MS	2135	5	UK77760	3+	3	S
2093	5	UD31706	4	4	MS	2136	5	WD11190	3+	3	S
2094	5	Q21156	4	4	MS	2137	5	WD19161	3+	3	S
2095	5	T60485	4	4	MS	2138	5	UDA	3+	3	S
2096	5	U42448b	4	4	MS	2139	5	U77826	3+	4	MS
2097	5	VK65388	4	4	S	2140	5	VK65367	3+	4	MS
2098	5	UK77772	4	4	S	2141	5	T69952	3+	4	S
2099	5	TD20170	4	4	S	2142	5	T70036	3+	4	S
2100	5	UD19121	4	4	S	2143	5	VK65280	3+	4	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
2144	5	UK77781	3+	4	S
2145	5	TD27086	3+	4	S
2146	5	VD34491	3+	4	S
2147	5	VK65277	3+	5	MS
2148	5	VK65328	3+	5	MS
2149	5	S64059	3+	5	S
2150	5	U77803	3+	5	S
2151	5	U42474a	3C	2	MS
2152	5	T70021	3C	3	MS
2153	5	UK77785	3C	3	MS
2154	5	WK88881	3C	3	S
2155	5	T31342c	3C	3	S
2156	5	W10697	3C	3	S
2157	5	Q21046	3C	4	MS
2158	5	WG19797	3C	4	MS
2159	5	S25502	3C	4	MS
2160	5	VK65279	3C	4	S
2161	5	W10756	3C	4	S
2162	5	R43129	3CN	3	MS
2163	5	WG18323	3CN	3	S
2164	5	WD24446	3CN	4	S
2165	5	P40057	3CN	4	S
2166	5	S40088	3CN	4	S
2167	5	WG19798	4C	3	MS
2168	5	Q51791	4CN	3	S
2169	6	U30351	;	2	S
2170	6	Q28742	;	2	S
2171	6	U20309	;	2	S
2172	6	U20423	;	2	S
2173	6	U20426	;	2	S
2174	6	U20427	;	2	S
2175	6	Q21435	;	2	S
2176	6	R61810	;	2	S
2177	6	W10623	;	2	S
2178	6	W12034	;	2	S
2179	6	T69946	;	3	MS
2180	6	WK88700	;	3	MS
2181	6	Q21036	;	3	MS
2182	6	N51453	;	3	MS
2183	6	U30348	;	3	MS
2184	6	P60370	;	3	MS
2185	6	TD22236	;	3	MS
2186	6	25420S	;	3	MS
2187	6	22365V	;	3	MS
2188	6	20361T	;	3	MS
2189	6	WD24056	;	3	MS
2190	6	WD28304	;	3	MS
2191	6	WD28342	;	3	MS
2192	6	WD28344	;	3	MS
2193	6	WD31939	;	3	MS
2194	6	TD31359	;	3	MS
2195	6	WD31997	;	3	MS
2196	6	WD32004	;	3	MS
2197	6	WD32006	;	3	MS
2198	6	N51232	;	3	MS
2199	6	U20064	;	3	MS
2200	6	T60401	;	3	MS
2201	6	V20246	;	3	MS
2202	6	U20284	;	3	MS
2203	6	T60495	;	3	MS
2204	6	U20369	;	3	MS
2205	6	U20376	;	3	MS
2206	6	U20389	;	3	MS
2207	6	U20412	;	3	MS
2208	6	U20413	;	3	MS
2209	6	P40084	;	3	MS
2210	6	S60458	;	3	MS
2211	6	S60494	;	3	MS
2212	6	WG18329	;	3	MS
2213	6	U42724	;	3	MS
2214	6	WG19799	;	3	MS
2215	6	WG19801	;	3	MS
2216	6	WG19802	;	3	MS
2217	6	WG19831	;	3	MS
2218	6	W12019	;	3	MS
2219	6	W12047	;	3	MS
2220	6	S64167	;	3	S
2221	6	P60041	;	3	S
2222	6	U30369	;	3	S
2223	6	S30914	;	3	S
2224	6	N31099	;	3	S
2225	6	WD28413	;	3	S
2226	6	20336T	;	3	S
2227	6	29166WD	;	3	S
2228	6	WD28348	;	3	S
2229	6	WD28352	;	3	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction	Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
2230	6	SD19256	;	3	S	2273	6	SD31613	;	4	MS
2231	6	SD31475	;	3	S	2274	6	WD31922	;	4	MS
2232	6	VD34581	;	3	S	2275	6	U20152	;	4	MS
2233	6	VD32021	;	3	S	2276	6	U20390	;	4	MS
2234	6	VD31921	;	3	S	2277	6	T65316	;	4	MS
2235	6	VD31946	;	3	S	2278	6	W10759	;	4	MS
2236	6	WD31983	;	3	S	2279	6	V54110	;	4	MS
2237	6	WD31990	;	3	S	2280	6	N31101	;	4	S
2238	6	R50799	;	3	S	2281	6	25494S	;	4	S
2239	6	Q28751	;	3	S	2282	6	SD31473	;	4	S
2240	6	P60237	;	3	S	2283	6	SD31478	;	4	S
2241	6	Q21343	;	3	S	2284	6	UD31681	;	4	S
2242	6	U20101	;	3	S	2285	6	P60097	;	4	S
2243	6	U20414	;	3	S	2286	6	Q21366	;	4	S
2244	6	U20416	;	3	S	2287	6	U20352	;	4	S
2245	6	U20330	;	3	S	2288	6	U20371	;	4	S
2246	6	U20386	;	3	S	2289	6	T64112	;	4	S
2247	6	T64121	;	3	S	2290	6	N21175	;	4	S
2248	6	T64328	;	3	S	2291	6	W10852	;	4	S
2249	6	T64328	;	3	S	2292	6	S25544	;	4	S
2250	6	T64822	;	3	S	2293	6	P60038	;	5	MR
2251	6	P40195	;	3	S	2294	6	WD23966	;	5	MS
2252	6	P40269	;	3	S	2295	6	WD23981	;	5	MS
2253	6	Q51890	;	3	S	2296	6	S54015	;	5	MS
2254	6	R61025	;	3	S	2297	6	S63983	;	5	S
2255	6	Q52163	;	3	S	2298	6	S63987	;	5	S
2256	6	S60336	;	3	S	2299	6	Q21367	;	5	S
2257	6	S33288	;	3	S	2300	6	S54018	;	5	S
2258	6	W10753	;	3	S	2301	6	U20351	;	5	S
2259	6	U42720	;	3	S	2302	6	T64499	;	5	S
2260	6	WG19788	;	3	S	2303	6	S54007	;	6	S
2261	6	WG19822	;	3	S	2304	6	T64497	;	6	S
2262	6	W12017	;	3	S	2305	6	WD28313	;	7	S
2263	6	W12212	;	3	S	2306	6	T70171	;1	2	MS
2264	6	T36683	;	3	S	2307	6	VD31943	;1	2	MS
2265	6	V56549	;	3	S	2308	6	R50634	;1	2	MS
2266	6	R43383	;	3	S	2309	6	P60221	;1	2	MS
2267	6	U44755	;	3	S	2310	6	U20119	;1	2	MS
2268	6	S63991	;	4	MS	2311	6	U20313	;1	2	MS
2269	6	WK88717	;	4	MS	2312	6	T65282	;1	2	MS
2270	6	U20216	;	4	MS	2313	6	S40100	;1	2	MS
2271	6	25338S	;	4	MS	2314	6	S40101	;1	2	MS
2272	6	WD28306	;	4	MS	2315	6	R47652	;1	2	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction	Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
2316	6	P50080	;1	2	S	2359	6	WD28338	;1	3	MS
2317	6	VD12112	;1	2	S	2360	6	QD19921	;1	3	MS
2318	6	WD31980	;1	2	S	2361	6	UD11241	;1	3	MS
2319	6	WD31988	;1	2	S	2362	6	QD31840	;1	3	MS
2320	6	R50758	;1	2	S	2363	6	TD11156	;1	3	MS
2321	6	Q28668	;1	2	S	2364	6	VD19731	;1	3	MS
2322	6	T90190	;1	2	S	2365	6	TD11162	;1	3	MS
2323	6	Q21353	;1	2	S	2366	6	SD31451	;1	3	MS
2324	6	U20125	;1	2	S	2367	6	UD31713	;1	3	MS
2325	6	T65435	;1	2	S	2368	6	UD31732	;1	3	MS
2326	6	T64707	;1	2	S	2369	6	WD31914	;1	3	MS
2327	6	WG19789	;1	2	S	2370	6	WD31920	;1	3	MS
2328	6	WG19826	;1	2	S	2371	6	TD31354	;1	3	MS
2329	6	T36723	;1	2	S	2372	6	VD34201	;1	3	MS
2330	6	WK88714	;1	3	MS	2373	6	UD31684	;1	3	MS
2331	6	69916T	;1	3	MS	2374	6	VD31947	;1	3	MS
2332	6	R2062	;1	3	MS	2375	6	WD31978	;1	3	MS
2333	6	R2081	;1	3	MS	2376	6	WD31981	;1	3	MS
2334	6	UK77787	;1	3	MS	2377	6	WD31995	;1	3	MS
2335	6	UK77775	;1	3	MS	2378	6	WD32005	;1	3	MS
2336	6	WK88835	;1	3	MS	2379	6	N51304	;1	3	MS
2337	6	WK88879	;1	3	MS	2380	6	Q21227	;1	3	MS
2338	6	O54315	;1	3	MS	2381	6	Q28660	;1	3	MS
2339	6	S30892	;1	3	MS	2382	6	T60119	;1	3	MS
2340	6	U30315	;1	3	MS	2383	6	Q21184	;1	3	MS
2341	6	U30318	;1	3	MS	2384	6	U20060	;1	3	MS
2342	6	U30346	;1	3	MS	2385	6	Q28808	;1	3	MS
2343	6	U30352	;1	3	MS	2386	6	U20240	;1	3	MS
2344	6	T20318	;1	3	MS	2387	6	N51250	;1	3	MS
2345	6	U30311	;1	3	MS	2388	6	U20141	;1	3	MS
2346	6	42099Q	;1	3	MS	2389	6	S54222-2	;1	3	MS
2347	6	23152U	;1	3	MS	2390	6	S54254-1	;1	3	MS
2348	6	29637T	;1	3	MS	2391	6	T60478	;1	3	MS
2349	6	WD28424	;1	3	MS	2392	6	U20301	;1	3	MS
2350	6	WD28382	;1	3	MS	2393	6	U20419	;1	3	MS
2351	6	WD11169	;1	3	MS	2394	6	U20420	;1	3	MS
2352	6	WD11172	;1	3	MS	2395	6	U20322	;1	3	MS
2353	6	WD24411	;1	3	MS	2396	6	U20421	;1	3	MS
2354	6	WD24311	;1	3	MS	2397	6	U20329	;1	3	MS
2355	6	WD28471	;1	3	MS	2398	6	R35451	;1	3	MS
2356	6	WD28397	;1	3	MS	2399	6	U20372	;1	3	MS
2357	6	29178WD	;1	3	MS	2400	6	S54390	;1	3	MS
2358	6	WD28329	;1	3	MS	2401	6	T64267	;1	3	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
2402	6	T64330	;1	3	MS
2403	6	T65434	;1	3	MS
2404	6	Q26081	;1	3	MS
2405	6	P40154	;1	3	MS
2406	6	Q51646	;1	3	MS
2407	6	P40168	;1	3	MS
2408	6	N21152	;1	3	MS
2409	6	N21225	;1	3	MS
2410	6	N21228	;1	3	MS
2411	6	U44619	;1	3	MS
2412	6	N21196	;1	3	MS
2413	6	P40215	;1	3	MS
2414	6	P40246	;1	3	MS
2415	6	Q51941	;1	3	MS
2416	6	R61029	;1	3	MS
2417	6	R61747	;1	3	MS
2418	6	S60424	;1	3	MS
2419	6	S33253	;1	3	MS
2420	6	S33317	;1	3	MS
2421	6	W10780	;1	3	MS
2422	6	V54106	;1	3	MS
2423	6	V54122	;1	3	MS
2424	6	V56599	;1	3	MS
2425	6	W10829	;1	3	MS
2426	6	UK77759	;1	3	S
2427	6	U30323	;1	3	S
2428	6	TD20427	;1	3	S
2429	6	WD28422	;1	3	S
2430	6	WD28384	;1	3	S
2431	6	25142V	;1	3	S
2432	6	25412S	;1	3	S
2433	6	12082U	;1	3	S
2434	6	WD24236	;1	3	S
2435	6	WD24091	;1	3	S
2436	6	QD31783	;1	3	S
2437	6	VD19161	;1	3	S
2438	6	TD11166	;1	3	S
2439	6	VD33941	;1	3	S
2440	6	UD31690	;1	3	S
2441	6	UD31691	;1	3	S
2442	6	UD31694	;1	3	S
2443	6	VD31915	;1	3	S
2444	6	VD31919	;1	3	S
2445	6	VD31930	;1	3	S
2446	6	VD31940	;1	3	S
2447	6	VD31955	;1	3	S
2448	6	WD31969	;1	3	S
2449	6	WD31982	;1	3	S
2450	6	P60186	;1	3	S
2451	6	N51346	;1	3	S
2452	6	N51584	;1	3	S
2453	6	N51227	;1	3	S
2454	6	Q28657	;1	3	S
2455	6	Q28662	;1	3	S
2456	6	T60339	;1	3	S
2457	6	U20221	;1	3	S
2458	6	U20044	;1	3	S
2459	6	T60355	;1	3	S
2460	6	Q21173	;1	3	S
2461	6	Q21187	;1	3	S
2462	6	Q21273	;1	3	S
2463	6	U20228	;1	3	S
2464	6	Q21299	;1	3	S
2465	6	U20079	;1	3	S
2466	6	T90192	;1	3	S
2467	6	Q21330	;1	3	S
2468	6	U20084	;1	3	S
2469	6	V20244	;1	3	S
2470	6	T60229	;1	3	S
2471	6	U20121	;1	3	S
2472	6	U20122	;1	3	S
2473	6	U20136	;1	3	S
2474	6	U20151	;1	3	S
2475	6	U20160	;1	3	S
2476	6	T60464	;1	3	S
2477	6	S54225-2	;1	3	S
2478	6	T60490	;1	3	S
2479	6	U20292	;1	3	S
2480	6	U20297	;1	3	S
2481	6	U20302	;1	3	S
2482	6	U20415	;1	3	S
2483	6	R35391	;1	3	S
2484	6	U20350	;1	3	S
2485	6	S54097	;1	3	S
2486	6	S54120-1	;1	3	S
2487	6	U20356	;1	3	S

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction	Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
2488	6	S54132	;1	3	S	2531	6	WG17252	;1	4	MS
2489	6	U20401	;1	3	S	2532	6	U42449a	;1	4	MS
2490	6	U20403	;1	3	S	2533	6	I21473	;1	4	S
2491	6	U20410	;1	3	S	2534	6	29576S	;1	4	S
2492	6	T64335	;1	3	S	2535	6	20295T	;1	4	S
2493	6	T64338-1	;1	3	S	2536	6	QD19296	;1	4	S
2494	6	T64543	;1	3	S	2537	6	VD31651	;1	4	S
2495	6	T64193	;1	3	S	2538	6	WD31931	;1	4	S
2496	6	T64584	;1	3	S	2539	6	WD31947	;1	4	S
2497	6	T65481-2	;1	3	S	2540	6	UD31660	;1	4	S
2498	6	P60428	;1	3	S	2541	6	VD31914	;1	4	S
2499	6	P40161	;1	3	S	2542	6	WD31999	;1	4	S
2500	6	N21088	;1	3	S	2543	6	R50804	;1	4	S
2501	6	N21133	;1	3	S	2544	6	R50820	;1	4	S
2502	6	P40229	;1	3	S	2545	6	P60042	;1	4	S
2503	6	P40268	;1	3	S	2546	6	Q28703	;1	4	S
2504	6	R61111	;1	3	S	2547	6	O54237	;1	4	S
2505	6	U44628	;1	3	S	2548	6	P60228	;1	4	S
2506	6	R61427	;1	3	S	2549	6	V20248	;1	4	S
2507	6	S33273	;1	3	S	2550	6	U20379	;1	4	S
2508	6	S40097	;1	3	S	2551	6	Q21502	;1	4	S
2509	6	W11477	;1	3	S	2552	6	Q21507	;1	4	S
2510	6	W10774	;1	3	S	2553	6	N21153	;1	4	S
2511	6	WG19823	;1	3	S	2554	6	N21169	;1	4	S
2512	6	W12198	;1	3	S	2555	6	P40281	;1	4	S
2513	6	V54014	;1	3	S	2556	6	Q51856	;1	4	S
2514	6	V56578	;1	3	S	2557	6	Q51980	;1	4	S
2515	6	U44729	;1	3	S	2558	6	W10772	;1	4	S
2516	6	WG17237	;1	3	S	2559	6	WG19321	;1	4	S
2517	6	W10824	;1	3	S	2560	6	V56581	;1	4	S
2518	6	W10833	;1	3	S	2561	6	W10844	;1	4	S
2519	6	W10855	;1	3	S	2562	6	T30300	;1	4	S
2520	6	U42471a	;1	3	S	2563	6	20245T	;1	5	MS
2521	6	R48426b	;1	3	S	2564	6	U30356	;1	5	S
2522	6	U77816	;1	4	MS	2565	6	12067U	;1	5	S
2523	6	WD31910	;1	4	MS	2566	6	U20370	;1	5	S
2524	6	VD31959	;1	4	MS	2567	6	S54392	;1	5	S
2525	6	WD31970	;1	4	MS	2568	6	S40091	;1	5	S
2526	6	R50738	;1	4	MS	2569	6	P40287	;1	6	MS
2527	6	R35442	;1	4	MS	2570	6	Q40409a	;1	6	S
2528	6	U20378	;1	4	MS	2571	6	TD31402	;1	7	S
2529	6	P40239	;1	4	MS	2572	6	R50819	;1	7	S
2530	6	W10819	;1	4	MS	2573	6	U77809	;1+	4	MS

Appendix 1 (cont.)

Entry no.	Response group	Line	Seedling IT	Field rating	Field reaction
2574	6	U30324	;C	3	MS
2575	6	VD31902	;C	2	S
2576	6	T64574	;C	2	S
2577	6	WD28395	;C	3	MS
2578	6	VD31911	;C	3	S
2579	6	T90196	;C	4	S
2580	6	WD33416	;CN	2	MS
2581	6	WD32001	;CN	2	MS
2582	6	WD28391	;CN	2	S
2583	6	WD28354	;CN	2	S
2584	6	VD31912	;CN	2	S
2585	6	P40204	;CN	3	MS
2586	6	R61122	;CN	3	MS
2587	6	Q54424	;CN	3	MS
2588	6	U42847	;CN	3	MS
2589	6	U20337	;CN	3	S
2590	6	Q51971	;CN	3	S
2591	6	VD31938	;CN	4	MS
2592	6	Q51699	;CN	4	MS
2593	6	TD31661	;CN	4	S
2594	6	WD36421	;CN	4	S