GENETIC CHARACTERIZATION OF MAIZE FOR *STENOCARPELLA MAYDIS* EAR ROT RESISTANCE

BY

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A MINI-DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE MASTERS OF SCIENCE IN AGRICULTURE (CROP SCIENCE)

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DECLARATION

I declare that the mini-dissertation hereby submitted to the University of Limpopo, for degree of Master of Science in Agriculture (Crop Science) has not previously been submitted by me for a degree at this or any other university; that it is my work in design and in execution, and that all material contained has been duly acknowledged.

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Sincere thanks go to colleagues, relatives and friends who were with me in prayers and encouragements who gave me strength during the hardest time when my mother passed away. It would be impossible to name all those that played a supporting role, their efforts have been greatly appreciated.

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DEDICATION

To my late mom ‘Maliepollo Nunu Annie Mojabeng, my father Peete Edgar, my late grandfather Mosiuoa Mitchel-force Elias, my late grandmother ‘Manthatisi Corina and my daughter Meka Jabukile Deborah Moremoholo; your advices, love and support have encouraged me to reap these fruits. To my God “those who trust in God are like mount Zion, except the Lord build the house, they labour in vain that built it”. “They that sow in tears shall reap in joy”.

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ABSTRACT

Stenocarpella ear rot caused by *Stenocarpella maydis* (Berck) Sutton is the most important disease of maize in South Africa. It is a sporadic disease which makes it difficult for farmers to prepare for its occurrence and consequently of the control measure. The objectives of this study were to genetically characterise the resistance of *Stenocarpella maydis* ear rot and to identify agronomically suitable *Stenocarpella* ear rot resistant inbred lines with good combining ability for grain yield. The experimental design was a randomised complete block design with three replications. Studies were conducted at Bethlehem, Cedara and Potchefstroom. To facilitate the comparison, separate trials were established for inbred lines and top cross hybrids. Fifty-four inbred lines were compared against four inbred lines vs. E739, DO620Y, H111 and Mo17 that are well adapted and stable yielders possessing variable resistance to *Stenocarpella maydis* ear rot. Fifty-four top crosses were compared against one open pollinated variety (SAM 1066), which was used as a tester line as well as three commercial hybrids vs. PAN 6124BT, PAN 6026 and CRN 3505. At Potchefstroom there was an inoculation trial using both inbreds and top crosses. The inbred and top cross materials were obtained from 2004/05 breeding nursery under natural infestation of *Stenocarpella maydis* at Agricultural Research Council-Grain Crops Institute, Potchefstroom. Data collected were number of days to 50% silking, plant and ear height in centimetres, husk cover, ear position, stand count, total number of ears, number of diseased ears and lodging resistance,. Entries 43 and 4 were the most stable inbred lines with a beta close to 1, while entries 9 and 25 had the smallest deviation from regression. Among the tested inbred lines entry 47 was superior over other inbred lines for grain yield followed by entry 4. Entry 47 showed grain yield of 2.84 tons ha^{-1} at Bethlehem and 4.42 tons ha^{-1} at Potchefstroom. While entry 4 had a grain yield of 2.19 tons ha^{-1} at Bethlehem and 4.58 tons ha^{-1}at Potchefstroom. The two lines, however, are poor combiners for both grain yield and *Stenocarpella maydis* ear rot resistance. Using SAM 1066 as a tester the grain yield observed for top crosses at Bethlehem, Cedara and Potchefstroom were 5.94, 7,15 and 9.95 tons ha^{-1}, respectively. Entries 57 and 14 were the most stable top cross hybrids with a beta close to one, while entries 46 and 47 had the smallest deviation from regression. Entries 56 and 28 were the most superior top cross hybrids. Entry 56 showed grain yield of 5.58 tons ha^{-1} at

Bethlehem, at Cedara it showed the yield of 5.90 tons ha^{-1} and at Potchefstroom it was 9.95 tons ha^{-1} and for the average of three sites it was 7.14 tons ha^{-1}. Entry 28 showed grain yield of 5.80 tons ha^{-1} at Bethlehem, at Cedara it was 5.80 and at Pothefstroom it was 9.35 tons ha^{-1} and the combined average was 6.98 tons ha^{-1}. These values compared favourably with the commercial standards. The checks entries 58 and 57 had proved to be resistant over locations. The best combiners for *Stenocarpella maydis* resistance were entries 29 and 52. *Stenocarpella maydis* ear rot was found to be of polygenic resistance with additive genetic effects.

The inbred and top cross materials were obtained from 2004/05 breeding nursery under natural infestation of *Stenocarpella maydis* at Agricultural Research Council-Grain Crops Institute, Potchefstroom. Data collected were number of days to 50% silking, plant and ear height in centimetres, husk cover, ear position, stand count, total number of ears, number of diseased ears and lodging resistance,. Entries 43 and 4 were the most stable inbred lines with a beta close to 1, while entries 9 and 25 had the smallest deviation from regression. Among the tested inbred lines entry 47 was superior over other inbred lines for grain yield followed by entry 4. Entry 47 showed grain yield of 2.84 tons ha^{-1} at Bethlehem and 4.42 tons ha^{-1} at Potchefstroom. While entry 4 had a grain yield of 2.19 tons ha^{-1} at Bethlehem and 4.58 tons ha^{-1}at Potchefstroom. The two lines, however, are poor combiners for both grain yield and *Stenocarpella maydis* ear rot resistance. Using SAM 1066 as a tester the grain yield observed for top crosses at Bethlehem, Cedara and Potchefstroom were 5.94, 7,15 and 9.95 tons ha^{-1}, respectively. Entries 57 and 14 were the most stable top cross hybrids with a beta close to one, while entries 46 and 47 had the smallest deviation from regression. Entries 56 and 28 were the most superior top cross hybrids. Entry 56 showed grain yield of 5.58 tons ha^{-1} at Bethlehem, at Cedara it showed the yield of 5.90 tons ha^{-1} and at Potchefstroom it was 9.95 tons ha^{-1} and for the average of three sites it was 7.14 tons ha^{-1}. Entry 28 showed grain yield of 5.80 tons ha^{-1} at Bethlehem, at Cedara it was 5.80 and at Pothefstroom it was 9.35 tons ha^{-1} and the combined average was 6.98 tons ha^{-1}. These values compared favourably with the commercial standards. The checks entries 58 and 57 had proved to be resistant over locations. The best combiners for *Stenocarpella maydis* resistance were entries 29 and 52. *Stenocarpella maydis* ear rot was found to be of polygenic resistance with additive genetic effects.

CHAPTER 1

1.1 General introduction

Maize (*Zea mays* L.; 2n=2x=20) belongs to the family *Gramineae* (*Poaceae*). The centre of origin of maize is now presumed to be Mexico (Galinat, 1988). Genus *Tripsacum* is a close relative of *Zea* but differs from maize in many respects, including chromosome number (2n=2x=18) (Galinat, 1988). All species of *Tripsacum* can cross with *Zea*, but only with difficulty and crosses shows extreme sterility and it is mostly grown for food, animal feed, silage, vegetable oil, sugar syrups, and other miscellaneous uses. Maize is the third cereal crop produced and consumed after wheat and rice in the world (Poehlman and Sleper, 1995). Global production of maize reached 622 million metric tons in 2003-2004 (USDA-FAS, 2005). It was estimated that about 68% of the global maize area is in the developing countries, but the developing countries accounts for only 46% of the world's maize production (Pingali and Pandey, 2001). Maize has been cultivated since the earliest historic times from Peru to central North America.

Maize production in Africa in 2004 was estimated to be 41.6 million metric tons of which 27.4 million metric tons were produced in sub-Saharan Africa (FAOSTAT, 2005). Maize accounts for 30% of the calories consumed in southern Africa (Hassan *et al*., 2001). In Southern Africa, per capita annual consumption of maize averages more than 100kg in several countries (Lesotho, 149 kg; Malawi, 181 kg; South Africa, 195 kg; Swaziland, 138 kg; Zambia, 168 kg and Zimbabwe, 153 kg) (CIMMYT, 1999). In southern Africa white maize is the dominant staple food. Yellow-grained varieties are grown in some countries in southern Africa especially South Africa and Zimbabwe (Hassan *et al*., 2001). Maize in Africa is grown by small and medium-scale farmers who cultivate 10 ha or less (DeVries and Toenniessen, 2001) under extremely low-input systems where average maize yields are 1.3 t ha^{-1} (Bänziger and Diallo, 2004). Biotic factors limiting maize production in the region include pests, diseases and parasitic weeds. While the abiotic stresses limiting maize production in the region are drought and low soil fertility. Maize in sub-Saharan Africa is produced in a wide range of environments that can be grouped into lowland tropical zones (0-1,000 meters above sea level (masl)), wet subtropical zones (900-1500 masl), dry subtropical zones (900-1500 masl), and highland zones (>1800 masl), with varying amounts of rainfall (Hassan *et al*., 2001). In seasons when rainfall is high after silking, maize crops are often infested with diplodia ear rot.

Maize is the main grain crop grown in South Africa and it is produced on approximately 3.2 million hectares. It is produced in a basic triangle encompassing Belfast in the east towards Lesotho highlands in the south and Setlagoli in the west. It is also grown in a small area in Kwazulu-Natal and irrigation schemes on the banks of South Africa's major rivers, the Vaal and Orange in the far west. The average total maize crop per annum is about 7 million metric tons most of which is used internally and only small amounts are exported (Alberts, 2004). The soil and climatic conditions vary in extremes from shallow loamy to clay soils in the east to deep sandy soils with a restrictive layer at 1.2-2.0 meters and a fluctuating water table in northwest province, Free State province and sandy loam soils in the western part of Free state province. The rainfall per annum varies from 300mm in the far west to 650mm per annum in the east. Rainfall is extremely variable and erratic during the season and over years. High spring and summer temperatures, with low humidity, and prolonged periods without rain, leads to serious drought and heat stress. The average long-term yield per hectare in South Africa varies between 2.2-3.2 tons per hectare (Van den Berg, 2005).

In South Africa commercial farmers produce maize under conservation tillage and monoculture, which results in *Stenocarpella maydis* ear rot inoculum build up of diseases. A number of maize production constraints both biotic and abiotic are present in the region, and they are threatening maize production, food security and economic growth (Bänziger and Diallo, 2004). Maize suffers from several ear rot diseases including *Stenocarpella* ear rot, *Gibberella* ear rot, *Penicillium* ear rot, *Aspergillus* ear rot and Grey ear rot. These diseases rarely cause severe yield losses over wide geographical areas (Vincelli, 1979; Smith and White, 1988), varying greatly between years depending on pre-harvest environment. The fungal pathogen that causes *Stenocarpella maydis* ear rot is *Stenocarpella maydis* (Berck.) Sutton, which is, also called *Diplodia maydis* (Berck) Sacc. (Rheeder *et al.*, 1990; Flett, 1999). This fungus does not only cause ear rot but also causes stalk rot and seedling blight of maize. Maize is the only host for this pathogen. *Stenocarpella maydis* over winters on diseased stalk and ear tissues that have not been buried under the soil (Flett, 1990). The inheritance of this disease is said to be complex (Dorrance *et al.*, 1998; Rossouw *et al.*, 2002). Consequently, various types of inheritance have been reported. Under natural infection, resistance is said to be dominant, additively inherited or partially dominant while under artificial infections it shows quantitative inheritance (Vencelli, 1979). From studies done in South Africa (Rossouw *et al.*, 2002) it was concluded that there is a need for research on genetics of plant resistance to ear rot since there are some uncertainty about the levels of resistance present in most of the sources used in the previous studies. The objectives of this study were to genetically characterise the resistance of *Stenocarpella maydis* ear rot and to compare 58 inbred lines and 58 top cross hybrids of maize for grain yield and ear rot resistance with a good combining ability and stability of grain yield and *Stenocarpella maydis* ear rot in maize lines evaluated at three locations in South Africa. Selected lines will be used in breeding the crop for *Stenocarpella maydis* ear rot resistance.

CHAPTER 2

2. Literature review

2.1 Introduction

Maize (*Zea mays* L.), is a member of the tribe *Maydae*, which belongs to the family *Graminiae* (*Poaceae*) (Galinat, 1988). Cultivated maize is presumed to have been transformed from teosinte (*Zea mays* subspecies *mexicana* (Schrader) Iltis). Teosinte, however, remains a successful wild grass in Mexico and Guatemala (Galinat, 1988). It is one of the largest of the cereals and can reach heights of 200 cm and above. The plant is monoecious, possessing separately located male and female flowers. The male (staminate) flowers are borne in the tassel at the top of the stalk, and the female (pistillate) inflorescence is a cluster, called a cob, at a joint of the stalk. The maize silks hanging from the husk of each cob are the pollen receptors; each silk must receive pollen grain in order for its fruit (kernel) to develop. A fertilized cob (ear) contains eight or more rows of kernels. Typically, maize stalks have one to three cobs. In 1901, *Stenocarpella maydis* ear rot, which is caused by *Stenocarpella maydis*, was found in South Africa by Smith and Hedges (Van der Bijl, 1914). Van der Bijl (1914) found that *Stenocarpella maydis* infested kernels and reported high catalyse acidity, high percentage nitrogen, and high percentage organic substances than in healthy maize. Van der Bijl (1916) further concluded that *S. maydis* infected maize had no effect on cattle. Mithel (1918) reported a number of cases of paralysed cattle that grazed in lands with *S. maydis* infested cobs. Dickson (1956) claims that the distribution and extent of damage caused by the disease depends on climatic conditions.

2.2 World maize production

Maize is one of the world's important cereal crops. Countries with large areas devoted to maize include the United States, China, Brazil, the USSR, Mexico, Argentina, Romania, Yugoslavia, France, India, and South Africa (Poehlman and Sleper, 1995). Maize may be divided into several groups, each differing primarily in the properties of the starch accumulated by the seeds (Goodman and Brown, 1988). *Stenocarpella maydis* have been found in South Africa, USA, Argentina, Canada, Kenya, UK, China, Nigeria and Malawi. Some areas in the world show a restricted distribution (Figure 2.1). It has been found that South African, USA and Argentina isolates were the most toxic or pathogenic (Rabie *et al*., 1987).

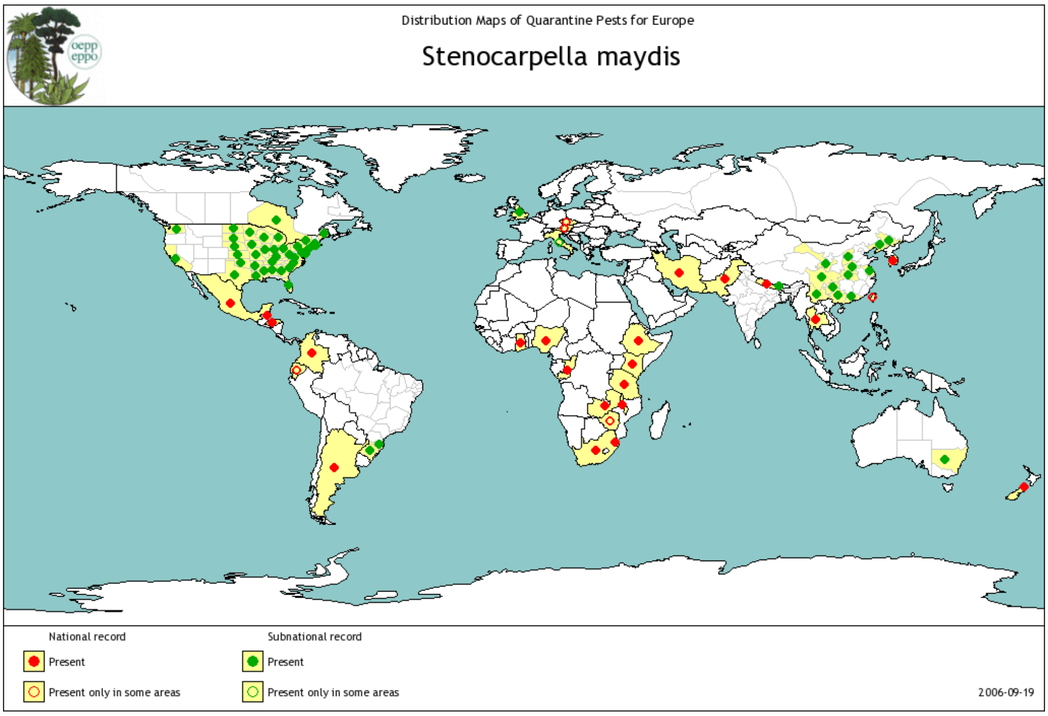

Figure 2.1 Distribution map of *Stenocarpella maydis* ear rot (Source: European and Mediterranean Plant Protection Organization, 2006).

2.3 Maize production in South Africa

The largest area of farmland in South Africa is planted with maize, followed by wheat and, to a less extent, sugar cane and sunflowers. Maize is the largest locally produced field crop and most important source of carbohydrates for human and animal consumption in South Africa. Average production per year is approximately 7 million tons (mt). Local consumption is about 7.4 mt. Maize meal is eaten as a staple food by majority of the South Africans. Maize is undoubtedly South Africa's most important field crop. Maize can be produced in areas where the rainfall exceeds 350 mm per year. Production is dependent on an even distribution of rain throughout the growing season. Dry land production mainly takes place in the Free State (34%), North West (32%), Mpumalanga (24%), Gauteng (7%) and Kwazulu-Natal Province (3%). In these areas, maize is planted from October to December. Due to variation in rainfall pattern, temperature and duration of the growing season, planting time varies from the eastern to the western production areas. Tillage practices vary from ploughing to no-till depending on soil type and rainfall. Maize grows best in deep, well-aerated, warm, loam soils rich in organic matter, and with a high nitrogen, phosphorus, and potassium content.

Optimum crop performance is achieved under moderately high summer temperatures with warm nights, and adequate rainfall that is evenly distributed during the growing season. Use of high yielding, disease resistant hybrids, nitrogen fertilizers, heavy plant populations, efficient mechanization, effective pest control and improved water management, have contributed to an annual increase of maize during each of the past 25 years (Hall *et al.,* 1992). The area planted per year varies between 3.8 and 4.8 million ha, which represents approximately 25% of the country's total arable land (Van den Berg, 2005). The average annual commercial production of maize during the past 10 years was 8.2 million tonnes (4.3 million t of white and 3.9 million t of yellow maize). Subsistent farmers produce an average of 500, 000 t of maize, mainly white maize, for household consumption each year. The local consumption requirements for maize are approximately 7.5 million t (4.4 million t white and 3.1 million t yellow). The average annual gross value of maize for the past five years is R4 808 million (Van den Berg, 2005).

2.4 Uses of maize

Unlike wheat and rice that are mainly consumed by human, maize is a multipurpose crop serving as food, feed, medicinal purposes or as a raw input to industry (Morris, 1998). Maize is an excellent raw material for the manufacture of starch that is easily recovered in high yield and purity. Maize oil is commercially processed from the germ for use as vegetable oil. Each of these materials is a component of many foods including bakery and dairy goods, beverages, confections, and meat products. Animal feeding is by far the largest use of maize worldwide with the majority of annual production fed to cattle, chickens, and swine. Maize is now used for boifuel production from its fermentable starch. Maize by-products are used for wet and dry milling industries, primarily maize gluten meal and feed, are fed directly or in formulated feeds. Virtually every part of the maize plant has economic value, including the grain, the leaves, the stalks, the silks, the husks and the tassel (Pingali, 2001).

2.5. Economic importance of *Stenocarpella* maydis ear rot

Rabie *et al.*, (1987) suggested that regular and widespread occurrence of *Stenocarpella maydis* in South African maize may be of economic importance in the poultry industry. Incorporation of *S. maydis* culture material of two different South African isolates at 5%, 2% and 1% dietary concentrations in broilers resulted in significantly poorer weight gains. These isolates, both capable of inducing diplodiosis in ruminants and both acutely toxic in ducklings, nevertheless differed significantly in their toxigenic effect in broilers. Feeding of 5% culture material to laying hens for 7 days resulted in a drastic (43%) drop in egg production. Even at 5% dietary level, egg production as well as egg weights of laying hens were significantly reduced (Rabie *et al*., 1987). Nwigwe (1974) reported that *S. maydis* has shown to cause between 5 to 37% loss in germination as well as being a serious pathogen of maturing plants. Furthermore, infected grain has been reported to cause mycotoxicosis when fed to cattle and sheep. *Stenocarpella maydis* ear rot becomes of economic importance only in localized areas of its occurrence.

Wolthers (1988) suggested that there is no evidence that this fungus produces toxin, it can significantly reduce grain quality by causing the kernels to turn grey or brown. The fungus creates small black reproductive structures, called pycnidia, on the ear and kernels that feel like sandpaper. The fungus can grow rapidly in areas of a bin and create “hot spots”. For this reason, it is important to stir and aerate stored grain. Minimizing mechanical and insect damage to kernels will help prevent the fungus from spreading to new kernels. After the bin is emptied, it is important to remove all remaining grain and plant debris that the fungus could survive on before it is filled again.

2.6 Types of maize

(1) Dent maize (*Z. mays indentata*): named because the seed has a depression, or dent, in the crown. It is the most widely grown type of maize in the U.S., used extensively for industrial use and livestock feed (Paiwal, 2000).

(2) Flint maize (*Z. mays indurate*) (Kent, 1984). Kernels are smooth and hard and contain little soft starch. Flint maize is more widely grown in Europe, Asia, Central

America, and South America than in the U.S. In temperate zones, flint maize often matures earlier, germinates better, and has better plant vigour than dent maize (Goodman and Brown, 1988).

(3) Popcorn (*Z. mays evarta*): an extreme form of flint contains only a small proportion of soft starch. It is grown primarily for human consumption as freshly popped maize and popcorn confections. The ability to pop seems to be conditioned by the unique quality of the endosperm that resists the steam pressure generated within the heated kernel until it reaches explosive force (Paiwal, 2000).

(4) Floury maize (*Z. mays amylacea*). Kernels are composed largely of soft starch and have little or no dent. Because of the softness of the kernels, the American Indians ground them for flour (Poelhman and Sleper, 1995).

(5) Sweet corn (*Z. mays saccharata*). Kernels have a translucent, horny appearance when immature and are wrinkled when dry. The immature ears are eaten fresh or are canned or frozen (Paiwal, 2000).

(6) Waxy maize (*Z. mays ceratina*): its kernels are waxy in appearance. Its starch differs chemically from common maize starch in that it lacks amylase. Waxy mutations conditioned by recessive allele wx are well characterized in American dents (Paiwal, 2000).

(7) Podcorn (*Z. mays tunicata*) is of interest in terms of the origin of maize, since it is thought to resemble varieties of primitive maize. In addition to the entire ear being enclosed by a husk, each kernel is enclosed in a pod or husk in podcorn (Paiwal, 2000).

2.7 Maize growth stages

An understanding of the developmental processes of a maize plant is important in evaluating its yield potential and growth stages that are most favourable for certain diseases (Ritchie *et al*., 1992). As the plant develops from a seed to a vegetative stage it grows and puts forth more and more leaves (Figure 2.1, Table 2.1). It then develops reproductive organs, which in maize, results in the emergence of a tassel and one or many ears.

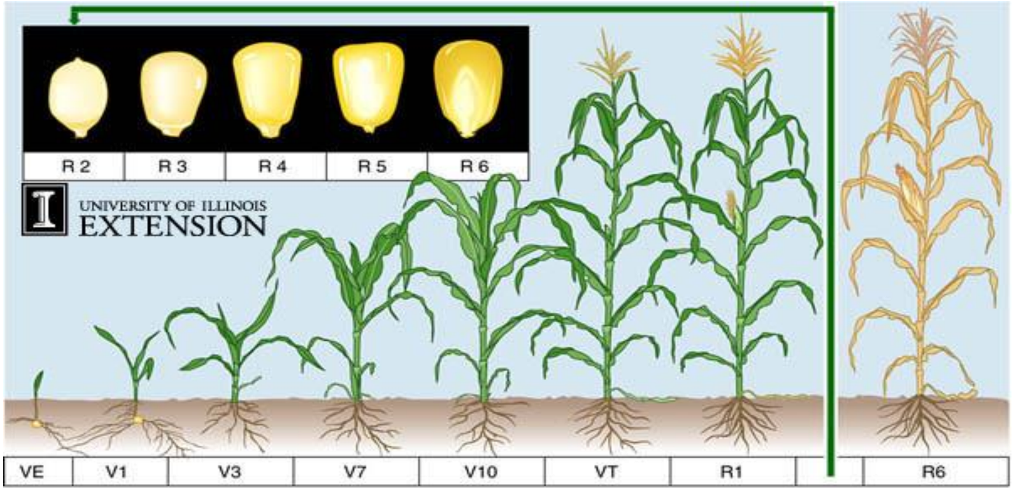

Figure 2.2 Developmental stages of maize (Source: University of Illinois Extension, 1992).

The importance of these various stages is evident when considering that plant requirements are different at different stages of its life cycle and disease initiation occurs at different growth stages. Therefore, management practices and stresses impact the plant's ability to yield to different degrees at different points in its life cycle. For the present study the most important developmental stages are silking (R1), blister (R2), milk (R3), dough (R4), dent (R5) and physiological maturity (R6) (Table 2.2). At silking most damage is done and the infection that comes later on only causes minor infection (skelem diplodia). The production of dry matter by maize is dependent on its ability to capture radiation energy from the sun through photosynthesis (Collinear *et al*., 1979). Therefore, the longer the duration of the plant's life cycle, the greater is its potential to photosynthesis. Tollenaar *et al.*, (1993) suggested that temperature and photoperiod are the two most important factors controlling development of plants. Maize is a short-day plant and thus flowers faster under shorter days. Heat Unit system is used to quantify hybrid relative maturity that suited for any region (Tollenaar *et al.*, 1979).

Table 2.1 Developmental stages of field maize based on the Leaf Collar Method (Ritchie *et al.*, 1992).

Vegetative Stages	Reproductive Stages
VE (emergence)	R1 (silking)
V1 (first leaf)	R2 (blister)
V2 (second leaf)	R3 (milk)
V3 (third leaf)	R4 (dough)
V(n) (nth leaf)	R5 (dent)
VT (tasseling)	R6 (physiological maturity)

Most maize cultivars produce from 16 to 20 leaves, which corresponds to relative maturity of cultivars. These are general values and can change depending on Cultivar, season, location and planting date (Vorst, 1990). The vegetative phase begins at planting and ends with the initiation of reproductive primordia (tassel initiation) (Figure 2.1). In maize, the end of the vegetative phase is marked by the initiation of the tassel primordia. However, leaves still emerge from the whorl even though the primordia is now reproductive (Ritchie *et al*., 1992).

The reproductive phase begins with tassel initiation and ends at physiological maturity (black layer). Ear shoots (potential ear) develop at the topmost axillary bud (i.e., topmost ear) is positioned 5 to 7 leaves below the topmost leaf (Vorst, 1990). The potential for a plant to produce more than one harvestable ear on the main stem (prolificacy) will increase with low plant density. Ear development proceeds as the last few leaves expand before tassel emergence (VT). Stress during this period is more inhibitory to ear development than tassel development (Vorst, 1990). Therefore, stress during this period can affect yield by reducing ovule number though pest and disease development. Tassel emergence (VT) is the point at which the last branch of the tassel is completely visible. The period between tassel emergence and silking can vary from a few days to a week. Silking (R1) begins when silks are visible outside the husks, this is the stage that is most susceptible to *Stenocarpella maydis* ear rot infestation. Generally 2-3 days are required for all silks on a single ear to be exposed. The two weeks prior to and after silking mark the period in the maize plant's life cycle in which it is the most sensitive to environmental stresses (Vorst, 1990;

Ritchie *et al*., 1992). Kernel abortion is common under stress conditions during this period. Reductions in kernel number due to abortion can seriously reduce yield.

Blister stage (R2) is characterized by a white kernel that resembles a blister in shape. The silks have completed their function and are beginning to dry the *S. maydis* infection coming at this stage will only be effective under high disease pressure. Milk (R3) stage is distinguishable when the kernel displays a yellow colour on the outside. Yield is now dependent on accumulation of dry matter in the kernel (kernel weight) (Vorst, 1990). Dough (R4) stage occurs when the accumulation of starch within the endosperm causes the milky inner fluid to thicken and produce a doughy consistency and maize grain has accumulated almost half of its mature dry weight. Dent stage (R5) begins when the top of the kernel dries and collapses forming a ridge around the horny endosperm. The plant is said to be at the R5 stage only when all the kernels on the cob are dented.

A hard white layer of starch is formed from the top of the kernel as the kernel dries down. The hard starch line will advance toward the base of the kernel (toward the cob) as the kernel matures. The line at which the hard starch line and the milky layer meet is referred to as the milk line. When the milk line is 50% between tip and base of the kernel (i.e., half milk line), kernels are at 40-45% moisture and have reached 95% of their potential final dry weight (Vorst, 1990). An early frost can reduce yield by reducing kernel weight. Delays in drying may also occur as the frost-damaged maize takes longer to dry down. Physiological maturity (R6) is reached when a black or brown abscission layer has formed at the base of the kernel. Black layer is found first on tip kernels and progresses to the kernels at the base of the cob. The kernels are now at their maximum growth and the hard starch layer has advanced to the base of the kernel. The average kernel moisture at black layer is 30-35%, however, this can vary with environmental conditions. Safe storage requires 13-15% moisture levels for shelled maize (Rabie *et al.*, 1987) otherwise there is a risk for further diplodia ear rot infestation after storage, this is activated by high moisture levels and heat in the storage bag/bin or silo.

There are several leaf staging methods used in maize. Leaf Tip Method where the number of visible leaf tips is counted in the leaf-tip method. Temperature is the most important factor controlling the rate at which the leaves appear from the whorl. The relationship between temperature of the growing point and rate of leaf-tip appearance is constant from maize planting to the appearance of the topmost leaf (Tollenaar *et al*., 1979), which is the major advantage of this method over the other leaf-staging methods. Another advantage of the leaf-tip method is that leaf tips can be counted starting immediately after plant emergence. Leaf Collar Method is one of the most common staging methods in maize (Table 2.1) (Ritchie *et al*., 1992). Leaf stages are referred to as V (for vegetative) stages. The first leaf is smaller and has a rounded tip. This leaf is counted as leaf 1 when staging by this method. A single plant is staged by counting the number of visible leaf collars (Table 2.1). If a plant has "n" number of visible leaf collars, then it is defined as being at leaf stage Vn (e.g. if a plant has 3 visible leaf collars, then it is at stage V3). A field is defined as being at a specific leaf stage when at least 50% of the plants are at the given stage or beyond.

Horizontal Leaf Method is used for crop insurance adjustments and it is a slightly different method. This method as described by Vorst (1990), also starts counting at the first leaf, but continues counting leaves to the uppermost leaf that is 40-50% exposed out of the whorl. This last leaf is called the "indicator" leaf. The tip of the indicator leaf is typically pointing downward. For this reason this method is sometimes known as the droopy leaf method. This method is harder to use as it depends on cultivar differences in leaf angle (Vorst, 1990). The ability to determine the percentage of the leaf exposed is dependent on an individual subjective view of the potential size of the developing leaf. Therefore, individuals may differ in opinion as to which leaf should be defined as the indicator leaf.

2.8 Ear rot diseases of maize

Maize is more often infected with various ear rot fungi. The most important are *Fusarium* ear rot (*Fusarium moniliforum*), *Gibberella* ear rot (*Fusarium graminearum*), *Stenocarpella* ear rot (*Stenocarpella maydis*), *Stenocarpella macrospora* (Diplodia macrospora) and *Aspergillus* ear rot (*Aspergillus flavus*) (Smith and White, 1988). These rots cause considerable damage in humid areas especially when rainfall is above normal during silking to harvest. The fungi produce potentially dangerous mycotoxins hazardous when consumed by humans or animals. The prevalence of rots is increased by insect and bird damage to ear and stalks and by lodging where ears touch the ground. Ears well covered by husks and maturing in a downward position usually has less rot than ears with open husks or maturing upright (Smith and White, 1988). Ear and kernel rots can reduce yield, quality, and feed value of the grain. Mycotoxin caused by S. *maydis* is diplodiosis. Diplodiosis is a disease of cattle caused by the yet to be isolated mycotoxin. Diplodiosis symptoms in cattle include nervous system defects, coordination loss, paralysis and finally death. Diplodiosis of sheep leads to abortions. Poultry are also particularly susceptible to Diplodia toxins resulting in poor broiler growth and reduced egg laying (Flett, 1997).

Stenocarpella maydis ear rot (*Stenocarpella maydis*) is also called *Diplodia* ear rot (maydis) is a soil borne and seed transmitted disease (Smith and White, 1988). *Stenocarpella maydis* ear rot is the same fungus that causes *Stenocarpella* stalk rot (Rheeder *et al.*, 1990; Flett, 1999). The symptoms are seedling blight, and on the stalk the lower nodes turn brown and spongy several weeks after silking. Sub-epidermal pycnidia may appear clustered round the nodes. On the ear the white fungal growth is found between seeds, pycnidia may be present on the seeds and cob (McGee, 1988). Husk of early-infected ears appear bleached or straw-coloured (Figure 2.3) (Flett *et al.*, 1996).

Figure 2.3: Husks of early-infested ear appears bleached or straw coloured.

If infection occurs within two weeks after silking, the entire ear turns greyish-brown,

Figure 2.4: Maize cob infected by *Stenocarpella* ear rot.

Figure 2.5: Cross-section of maize cob showing infection caused by *stenocarpella* ear rot.

shrunken and completely rotted (Figure 2.4). Lightweight ears usually stand upright with inner husks adhering tightly to one another because of mycelial growth between them. Black pycnidia may be scattered on husks, floral bracts and sides of kernels. Ears infected later in the growing season show no external symptoms, but when ears are broken and kernels removed, a white mould is found growing between the kernels whose tips are discoloured (Figure 2.5) (Muller, 1976; Flett *et al.*, 1996). Infection usually begins at the base, moving up from the shank (Figure 2.6). Some isolates of *S. maydis* induce vivipary (premature germination).

Figure 2.6: *Stenocarpella maydis* ear rot infection beginning at the base of the cob, moving up from the shank.

Stenocarpella maydis over winters as spores in pycnidia or mycelium on the stover or maize residue, cobs and on the maize kernels (Flett, 1990). Under warm, moist conditions, spores are extruded from pycnidia in long cirri and disseminated by rain, wind and probably insects. Infection of maize plants occurs primarily through the crown, mesocotyl and roots or occasionally at the nodes between crown and ear. The pathogen then grows into stalks. When plants are silking, spores may splash up to the ear leaf and then deposited by rainwater around the ear shank to initiate infection. These spores can germinate and penetrate the ear shank, growing up into the cob and outward into the kernels (Smith and White, 1988). The fungus does not invade the entire plant. Dry conditions early in the season and warm (28-30°c) coupled with a wet weather in two to three weeks after silking favour ear infection of *S. maydis* (CIMMYT, 2004). This disease is distributed in North and South America, Africa, Asia, Australia and Europe. When the incidence is high, it is of major economic importance as it can affect more than 50 percent of the field. A research conducted in South Africa showed that pycnidia and incidence of *Stenocarpella maydis* ear rot were consistently higher under conservation tillage systems (Flett, 1990). The incidence of affected ears in a field can range from 1 percent to 2 percent to as high as 75 percent to 80 percent. Fungal growth can continue even after physiological maturity, although its growth is probably somewhat slower in mature kernels.

Stenocarpella macrospora (Earle) Sutton over winters as viable pycnidia and mycelium on maize stover in the soil, or on the seed. Under warm, moist conditions, spores are extruted from pycnidia in long cirrhi and disseminated by wind and rain plus probably insects. The ear and grain rotting is favoured by above-normal rainfall from silking to harvest, ears are must susceptible during two weeks after silking. Invasion of the ear is usually by way of the shank. Genotypes with poor husk coverage or thin pericarps are often very susceptible. Like for diplodia maydis the symptoms begin at the base of the ears. Infected kernels are grey-brown, the covering leaves are pressed hardly against the ear. In between kernels the white mycelial are visible, the infected ear will later rot completely (Shurtleff, 1980).

Fusarium ear rot (*Fusarium moniliforme*) appears as a white-to-pink or salmon-coloured mould. This mould can begin on birds, deer or insect-damaged kernels. *Fusarium* ear rot may contain fumonisins that are mycotoxins that can be toxic to livestock (CIMMYT, 2004).

Gibberella ear rot (*Gibberella zeae*) symptoms are pink to reddish colored mould. This disease starts near the tip of the ear and progressing down toward the base of the ear. *Gibberella* can produce vomitoxin and zearalenone, which is toxic to many kinds of livestock (Agrios, 1988).

Aspergillus ear rot (*Aspergillus flavus*) produces black, powdery masses of spores that cover both kernels and cob. It produces mycotoxins known as aflatoxins that are harmful to birds and mammals (Agrios, 1988).

2.9 Physiological races of pathogens

Knowledge of identity of a pathogen is essential in order to develop strategies for the management of crop damage. It will also help in targeting resistance to diseases caused by specific pathogens (Day, 1974). The classification of races is accomplished by using races with strong resistance genes. Resistance in the host controls the epidemic. If it is resistant, it reduces the level reached by the population of the pathogen. In resistance breeding studies, it is wise to study the effect of resistance on the population dynamics and the genetic make up of the pathogen (Day, 1974).

It is generally reported that for disease to occur the genes of the pathogen must match those of the host, the more resistance genes in the host, the less likely the pathogen is to match them (Day, 1974). Monogenic resistance can be relatively easily matched, and it is more likely to be race-specific and overcome by new races of the pathogen. Resistance from many genes combination is durable, and it is likely to be horizontal. In general, the resistance given by many genes is safer than resistance given by few genes (Van Der Plank, 1968). When a variety is more resistant to some races of pathogen than others, the resistance is said to be vertical or race-specific. Race-specific resistance implies a differential interaction between varieties of the host and races of the pathogen. When the resistance is evenly spread against all races of the pathogen it is said to be horizontal or lateral. In horizontal resistance, there is no differential interaction and this is the most durable.

Interaction of genes governing resistance in the host with those governing pathogencity in the pathogen depends not only the genotype of the host resistance, but also upon the genotype of the virulence or aggressiveness of the race. In “Gene for gene hypothesis" in every gene for resistance in the host there is corresponding gene for pathogenecity in the pathogen (Flor, 1942). There are at least two alleles at a locus controlling resistance or susceptibility in the host and two alleles at a corresponding locus in the pathogen controlling virulence/avirulence. Out of the four possible interactions between these alleles only one-combination leads to the expression of resistance (Parlevliet, 1995).

2.10 Disease initiation and Development

The initiation of disease caused by biotic agents depends upon three main factors: the host, the environment and the pathogen (Figure 2.7). The severity of disease development is dependent on the degree of interaction of these factors. Plants have highly effective mechanisms for disease resistance that have contributed to survival under the selection pressure of evolution (Day, 1974). In plants, there are structural barriers to infection, preformed resistance factors and response factors. There are five principles of controlling maize diseases including exclusion, eradication, avoidance, protection and the use of resistant cultivars.

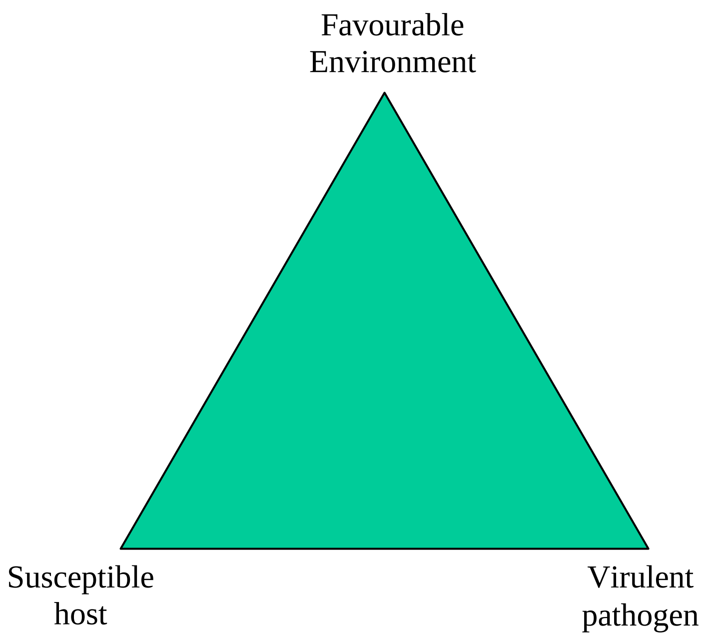

Figure 2.7. Disease triangle: disease only develops when three conditions are met: a pathogen infects a susceptible host under disease-favourable conditions (Day, 1994).

2.11 Control of plant diseases

Exclusion is an attempt to prevent the introduction of a pathogen through quarantines into an area in which that pathogen did not previously exist. Eradication is an attempt to eliminate or greatly reduce the pathogen after it has become established in a specific area. This can be achieved through crop rotation, sanitation and avoiding over-seasoning host of maize pathogens. Avoidance is a means of escaping infection or reducing the intensity of disease by growing maize in areas free of specific pathogens (Day, 1974). Protection is attained by chemical control measures that are targeted to reduce the intensity of disease development (Vincelli, 1979).

2.12 Breeding for disease resistance

Plants may be susceptible, tolerant, or resistant (Figure 2.8) to various pathogens. The term susceptible indicates that the plant readily becomes diseased if the environment, time and pathogen are favourable. The term tolerant implies that the plant may become diseased but little damage occurs. Resistant plants do not become diseased readily unless environmental conditions are extremely favourable to the pathogen (Heitefuss, 2003). Resistance is less affected by external factors or management decision than other disease control measures. Resistant cultivars offer the most feasible control of corn diseases and are the most widely used method of maize disease control that is environmentally safe. When new virulent pathogens emerge resistance breaks down and new resistant gene(s) will be needed and incorporated into commercially acceptable maize cultivars (Elliot, 1958).

Figure 2.8: Cobs from *Stenocarpella maydis* ear rot resistant (top) and susceptible (bottom) maize inbred lines.

Since disease resistance is physiological in nature and at least in part dependent on a metabolic response, any factor that affects the physiology of a plant, may also affect its resistance. Resistance can be oligogenic or polygenic. One or a few genes whose individual effects are readily detected determine oligogenic resistance, also known as major gene resistance. Oligogenic resistances are simple inherited and are easy to incorporate into existing varieties (Day, 1974). They are either dominant or recessive in their action. The dominant oligogenic resistances are more useful than recessive ones in hybrid maize, as only one of the inbred parents or one side of the pedigree requires the presence of the resistance to protect the resulting hybrid. Many genes of individuals having small effect determine polygenic resistance. It is usually affording resistance to a wide spectrum of pathogen races. Their incorporation into existing varieties is much more complex, but these resistances are considered to be more stable and enduring than oligogenic resistance.

Resistance, like other traits occurs in a qualitative or quantitative way. With the qualitative resistance different genotypes in a population occur as discernible phenotypes, it is usually controlled by major genes (Parlevliet, 1995). Quantitative resistance (QR) on the other hand is a resistance that varies in a continuous way between the various phenotypes of the host population, from almost only a slight reduction in the growth of the pathogen to quite strong reduction. This resistance is often indicated with other terms such as partial, residual and field resistance and it is usually controlled by minor genes (Parlevliet, 1995). Qualitative resistance is monogenic showing complete and major or oligogentic inheritance (Koehler, 1959). Parlov *et al.*, (2003) suggested that it is possible to partition at least three components of QR against pathogens that are not systemic; infection frequency, lesion size and sporulation rate per lesion. The latency period, which is the period between infection and first spore production, is associated with the lesion size and sporulation rate. The epidemic development of the first spores produced by a lesion is far more important than ones produced later. This also means that the case of polcyclic pathogens, the latency period is a highly important component. Thus, a short latency period is essential for the pathogen, while a long one is good for quantitative resistance.

In polycyclic pathogens the epidemic builds up each season. Thus, the higher the level of QR, the lower the rate of build up (Van der Plank, 1968). In order to estimate the progress of the disease severity there must be several trials in different environments and in several years. Van der Plank, (1968) suggested that measuring disease severity is the best method to assess quantitative resistance, but one has to realize that various factors may interfere with it. Degree of yield reduction is also used to measure resistance. This, however, does not measure resistance alone because it also includes the consequence of tolerance. At the same time, it is a very inaccurate way of measuring as yield is very sensitive to genotype (g) x environment (e) interactions, while the disease severity is much less sensitive to g x e interactions though being a quantitative trait. It is often thought that quantitative resistance will be sensitive to genotype x environment interactions not unless they are of complex traits (traits that are the accumulation result of a number of other traits and each of those traits contributing in a way that it react differently to different environments) hence resulting in strong g x e interactions. Quantitative resistance is not a complex trait; the QR genes only affect the trait, the reason why QR is not more sensitive to g x e interactions than qualitative resistance.

Options for managing *S. maydis* ear rot are limited. Fields should be scouted for this disease between flowering and harvest to help determine its occurrence, and to determine if there are differences in resistance among hybrids. Unfortunately, some high-yielding hybrids are susceptible, and the risks of potential yield loss from *S. maydis* must be considered relative to potential yield loss from lower-yielding but more resistant hybrids.

2.13 Inoculation techniques and evaluation of *Stenocarpella maydis* ear rot

The evaluation of maize germplasm for response to endemic diseases should be an integral part of all maize breeding programs, where selection for resistance to these diseases will lead to improved yield stability. Standard resistant and susceptible checks need to be included in all evaluations so that the level of infection can be compared with previous inoculations. Locations with high levels of natural infestations (hotspots) can be used effectively for selection of susceptible germplasm in a breeding program, but still natural infection will be variable from year to year due to the influence of climatic conditions and crop management practices. Therefore, the use of artificial inoculation methods can provide more uniformity in the evaluation process. There are several inoculation techniques for *Stenocarpella maydis* adopted by different researchers like the toothpick method and ground infected maize kernels applied in the whorl or on the silks (Nowell, 1990).

With the toothpick method, about 150 to 200 colonized toothpicks are prepared by firstly removing inhibitory compounds such as tannis and phenolic through pasteurisation for two to six minutes (Jeffers, 2002). Toothpicks are thorouly washed in fresh tap water, dried and placed in a glass jar with 45 ml of potato dextrose gel broth such that it will provide sufficient liquid to moisten the toothpicks for good mycelial growth with a slight excess liquid in the bottom of the jar. The jars of toothpicks are sterilized for 30 minutes immediately after the broth is added, and then allowed to cool and inoculated with the mycelium of *Stenocarpella maydis*. From about three weeks of incubation at 25 to 30ºC, the fungus has colonised the toothpicks, and are ready for use. These colonized toothpicks are inserted into the shank of the ear at 14-21 days after silking. Jeffers (2002) emphasised that it is important to hit the peduncle tissue for more consistent and uniform results. The author further suggested that it is the most efficient, rapid and easy to use means of inoculation since the fungus grows uniformly over the toothpicks resulting in a similar amount of disease pressure being delivered to each plant. Since *Stenocarpella maydis* ear rot normally enters the ear through the shank, this inoculation method provides the inoculum in the location where the fungus passes to arrive in the ear.

For the ground maize kernel method the inoculum is applied in the whorl or on the silks (Figure 2.9). The diseased kernels (150 g) and 100 ml of distilled water agar are autoclaved for 40 minutes on two consecutive days in a 375 ml plastic box, then inoculated with a 10 ml conidial suspension. The boxes are incubated at 25ºC, 12-hour photoperiod, for six to eight weeks and dried (Rheeder and Marasas, 1990; Klapproth, 1991; Flett, 1997). After three weeks when sample is dried it will be milled and three to five grams of ground *Stenocarpella maydis* infested ears inoculated in the whorl three weeks prior to tasseling. If the environment is dry, water should be added to the whorl after adding the ground tissue (Jeffers, 2002). Inoculation in the whorl with ground grain is very easy to apply and does not injure the plant (Rheeder and Marasas, 1990; Flett, 1997). There are various ways of evaluating ear rot reaction in maize including:

Figure 2.9 Inoculation of maize with *S. maydis* during mid-whorl stage.

1. Weighted average

In order to facilitate the evolution of the ears, a 60 x 33 x 14 cm box was constructed according to CIMMYT inoculation methods (Nowell, 1990). This box has four 15 cm compartments across the top and two 15 cm, and one 30 cm compartments across the bottom (Figure 2.10). This allows to empty the ears in the 30 x 60 cm compartment and then separate the ears based on the percent infection into six remaining compartments. Disease reactions of the genotypes are evaluated at harvest. For evaluation a weighted average based on the number of ears in each division is used whereby the weighted average = (((# ears at 2 rating * 0.1) + (# ears at 3 rating * 0.25) + (# ears at 4 rating * 0.5) + (# ears at 5 rating * 0.75) + (# ears at 6 rating * 1.0)) / total # ears) * 100.

Figure 2.10 Partitions for separating ears for different *Stenocarpella* ear rot levels of infestation.

2. Visual rating

For the visual rating the 1-6 scale was used where 1 = No infection on kernels or bottom of the ear, 2 = 1-10% of the kernels on the ear have visible infection, 3 = 11 - 25% of the kernels on the ear have visible infection, 4 = 26 - 50% of the kernels on the ear have visible infection, 5 = 51 - 75% of the kernels on the ear have visible infection and 6 = 76 - 100% of the kernels on the ear have visible infection.

3. Percent diseased grain

The other rating method is percent diseased grain that is estimated visually by separating out the diseased grain from the healthy, then calculating the percent diseased grain based on mass. In this method 250 grams of each plot is sampled to determine percent diseased grain (Nowell, 1990). This method is very time consuming but it was found to be the most appropriate for genetic studies (Enerson and Hunter, 1990).

2.14 Genotype x environment interaction on grain yield and *Stenocarpella maydis* ear rot resistance

Genotype X environment (GE) interaction is the differential performance of genotypes across environments (Hallauer *et al.*, 1988) and it is an important consideration for plant breeders. The effects that cultivars and environments exert on cultivar-environment interactions (G x E) are statistically non-additive, indicating that differences in yields among cultivars will depend on the environment (Eberhart and Russell, 1966), thus G x E interaction involves selecting cultivates with better stability across a wide range of environments. New cultivars and breeding lines are evaluated in field trials for yield potential, resistance to environmental stress, naturally occurring disease pathogens or insect pests and lodging resistance.

Genotypes with highest performance in preliminary trials are re-evaluated in advanced trials at different locations for genotype X environment interactions and stability. The comparative performance of crop cultivars differs when yield and disease resistance trials are conducted at particular locations (Crossa *et, al*., 1990). Each location provides a different environment in which genotypes are grown. Replication or blocking of an experiment at different locations serves to sample major genotype X environment interactions and assist the breeder in identifying cultivars with stable yield performance over a range of environments since cultivars developed with stable yields over a broad range of environments may not be highest yielding cultivar at a particular location or a cultivar developed with stable disease resistance over broad range of environments may not be resistant at a particular location (Poehlman and Sleper, 1995).

Eberhart and Russell (1966) proposed a statistical method, which interprets the variance of the regression deviations (σ_{di}^2) as a measure of cultivar stability and the linear regression coefficient (β_i) as a measure of the cultivar adaptability. This model is widely used because of its simplicity and efficiency. The cultivars are grouped according to the size of their regression coefficient, less than, equal to, or greater than one and according to the size of the variance of the regression deviations (equal to or different from zero) (Eberhart and Russell, 1966). Cultivars with regression coefficients greater than one would be more adapted to favourable growth conditions, those with regression coefficients less than one would be adapted to unfavourable environmental conditions, and those with regression coefficients equal to one would have an average adaptation to all environments. Thus, genotypes with variances in regression deviations equal to zero would have highly predictable behaviour, whereas with a regression deviation greater than zero would have low predictability because of the environmental effect.

Lin and Binns' (1988) model is a good alternative for the assessment of cultivar performance in the G x E interactions. Their method does not have limitations inherent to use of regression. It characterises the genotypes with a parameter (P_i) by associating stability and productivity, and defines a superior cultivar as one with a performance near the maximum in various environments (Lin and Binns, 1988). P_i is the superiority index of the *i*-th cultivar relative to the genotype with maximum performance in each environment and it is used to assess the superiority of the cultivar. This P_i quantifies the genetic deviation and the G x E interaction. The superior genotype would be that one with the lowest P_i value, that one which remained among the most productive in a given set of environments. The estimate of P_i could be partitioned into a portion attributed to genetic deviation, which is the sum of squares of the genotypes. The cultivars of greatest interest would be those with the lowest P_i values, most of which would be attributed to genetic deviation (Lin and Binns, 1988).

Stenocarpella maydis ear rot depends on environmental effects for good spore survival and viability otherwise the natural inoculum reduces within two seasons (Flett, 1990). In South Africa it is mainly distributed towards the eastern part and in the cooler regions with high rainfall from silking to harvest. Dry conditions earlier in the season followed by high rainfall are also an ideal environmental condition and if there is a suitable host there will be a disease infestation. Thus, it is very important to use several locations for screening breeding materials.

2.15 Combining ability and heterosis

When cultivars are improved for either yield or disease resistance, etc. inbred lines are crossed with different genotypes to produce a hybrid (Singh and Chaudhary, 1979). These inbred lines are homozygous parent lines that are first created by inbreeding through several generations of selfing in a natural or segregating population of a cross-pollinated species (Beil and Atkins, 1967 and Bernado, 2002). Where the inbred lines are developed from the hybrid progeny created by crossing two elite inbred lines the original heterozygous selfed plant is normally referred to as the S_O plant, and the progeny obtained from selfing this plant as the S_1 (first-generation selfed) progeny. The second-generation selfed progeny are called the S_2 and so on. Whereas if the heterozygous plant originates from a cross between homozygous inbred lines, the F_1, F_2, etc., designation would be used as in self-fertilized species (Poehlman and Sleper, 1995). The purpose of inbreeding is to reduce the offspring of a heterozygous plant into an array of dissimilar, homozygous, inbred lines. With successive generations of inbreeding, homozygosity and uniformity are increased within the progeny lines; during this process the variance within lines is reduced while the variance between lines is increased.

When breeding for complex characters like yield or disease resistance, which comprised of several components it is very difficult to choose good parents (Bernado, 2002). Therefore, breeders use the line x tester analysis to evaluate the general and specific combining ability of parents. At the same time this analytical tool is useful in estimating various types of gene effects (Singh and Chaudhary, 1979). The analysis provides an opportunity for discriminating large numbers of parents for their combining ability without making so many crosses. Prasad and Sastry (1987) and Manuel and Palanisamy (1989) used this technology to identify parents and crosses that could be exploited for future breeding programs.

Hussain and Aziz (1998) confessed that the top cross (inbred x open pollinated variety) method proved to be efficient in testing of inbred lines for combining ability because with its use, it was possible to identify more promising inbred lines by making fewer number of crosses than are required for making all possible single crosses. After the more promising inbred lines have been selected on the basis of good GCA, it is necessary to identify the particular combination that will reproduce the highest yield or be more resistant through SCA (Singh and Chaudhary, 1979; Dheya *et al.*, 1992 and Bolandi *et al.* 2000). The importance of line by tester hybridisation technique in maize breeding have been further signified by researchers like Mutwia *et al.* (1989), Arceo and Galan (1990), Ivakhnenko and Kolmov (1991) and Zagnitkok (1991).

An important difference between breeding self-pollinated and cross-pollinated crops is found in the way the breeder evaluates breeding materials (Manuel and Palanisamy, 1989). In a cross-pollinated crop, individual plants are heterozygous and field grown plants will largely be pollinated by pollen from other heterozygous plants growing in the vicinity and even if self- fertilized, the genotype of a heterozygous plant is not faithfully reproduced in its progeny. In order to get inbred lines with desirable combinations to cross in the breeding of hybrid cultivars it is essential to conduct a progeny test which would measure the result of combining the assortment of gametes from representative mother plants with gametes of identical genotype from the tester (Miller *et al.*, 1980 and Owolade, 2006).

A test cross evaluates the combining ability of the mother plants or strains with the common tester line (Hussain and Aziz, 1998). The choice of a tester is an important decision, the most efficient tester would be one that is homozygous recessive at all loci (Hussain and Aziz, 1998). When selecting testers for ear rot resistance, it is very important that yield potential is assessed as well (Nowell, 1990). A good tester would be an inbred line, open-pollinated cultivar which is highly heterogeneous, single cross or a double cross with a good additive resistance to ear rot and also be a good tester for yield (Hallauer *et* al., 1988).

The heterogeneous tester contributes less to line X tester interaction than does a narrow genetic base tester (Miller *et al.*, 1980 and Punia, 1986). A use of a double-double cross tester that included the eight most commonly used lines within a given maturity group would be a good tester for general combining ability. There are two pre-requisites for a good tester to evaluate inbred lines being the entries under test must be classified correctly and the tester must discriminate effectively among the materials under test. Hallauer *et al.* (1976) suggested that a tester should include simplicity in use, provide information that correctly classifies merit of lines and maximizes genetic gain.

Combining ability is the potential to produce a high proportion of desirable individuals (Welsh, 1993). There are two types of combining abilities of inbred lines i.e. general combining ability (GCA), which is the average or overall performance of a genetic strain in crosses. The GCA of an inbred line is evaluated by crossing it with open-pollinated cultivar or another inbred line and comparing the overall performance of the single-cross progenies. General combining ability evaluates the additive portion of the genetic effects by selecting the inbred whose single crosses have the highest average yield to have the greatest GCA.

Specific combining ability (SCA) is the performance of specific combinations of genetic strains in relation to the average performance of all combinations. Specific combining ability evaluates non-additive gene action and is utilized to identify the inbred X inbred cross combination with superior performance to create single crosses which are then evaluated in yield trials for SCA (Hallauer and Miranda Filho, 1988). For maize it was found that the GCA was relatively more important than SCA for unselected inbred lines, whereas SCA was important than GCA for previously selected lines (Nass *et al*., 2000). Growing the testcross progenies at multiple locations is essential to evaluate genotype X environment interactions and to identify inbred lines with stable progeny performance in a broad array of environments.

Heterosis is a phenomenon in which F_1 hybrids showing superiority over their parents in vigour, grain yield and yield components and disease resistance (Figure 2.11). Heterosis is expressed in the first generation only (Virman *et al.*, 2003). Heterosis varies according to the level of parental diversity and or presence of heterotic gene blocks in parental lines. Heterosis can be positive or negative. Both positive and negative heterosis can be useful depending on the trait in question, for an example, positive heterosis for yield and negative heterosis for disease intensity. It is assumed that the greatest heterosis is displayed by crosses from pure line inbreds experiencing the most inbreeding depression (Young and Virman, 1990 and Tsaftaris *et al.* 1999).

Figure 2.11 Photos showing F_1 hybrid plants (middle three rows left photo) and cobs (middle two rows of right photo) and two inbred lines at left and right.

Heterosis is expressed in three ways, depending on the reference used to compare the performance of a hybrid including (1) mid-parent heterosis (MPH) which is the increase or decrease in the performance of a hybrid in comparison with the mid-parent value; it is calculated as $MPH=F_1 -(P_1 + P_2)/ P_1 + P_2$, (2) heterobeltiosis which is the increase or decrease in the performance of a hybrid in comparison with the better parent of the cross combination, and it is calculated as $\% H_b = (F_1- BP) x 100 / BP$ where F_1 = performance of a specific cross, BP = performance of the better parent of the cross and (3) the standard heterosis which is the increase or decrease in the performance of a hybrid in comparison with the standard check variety of the region (Virman *et al.*, 2003) and it is calculated as $H = 100 x (F_1 – P_1 + P_2)/2$.

Standard heterosis (percentage heterosis) is generally expressed as the percent increase or decrease in the performance of a hybrid in comparison with the reference variety or a parameter. From practical viewpoint, standard heterosis is found to be the most important because the aim is to develop hybrids that are better than the existing high-yielding varieties grown commercially by farmers. Studies on the genetic basis of heterosis for polygenic traits in various crops have shown that heterosis is the result of a partial to complete dominance, overdominance and epistasis or a combination of all these (Comstock and Robinson, 1952).

Individual plants in a mixed population will vary in yield, height, disease resistance and other characteristics of quantitative nature. Where two populations differ in yield or disease resistance, the difference may be hereditary or in the environment in which they were grown or a combination of both. The extent to which the variability in yield and disease resistance of individual plants in the population is the result of genetic factors and it is transmitted to the progenies of the selected plants and how much the variability is due to the environmental effect in which they are grown. The degree to which the variability of a quantitative character is transmitted to the progeny is referred to as its heritability (Poehlman and Sleper, 1995). Heritability is the proportion of the observed variation in a progeny that is inherited. It is said to be high if the genetic variation in a progeny is large in relation to the environmental variation.

CHAPTER 3

3. COMPARISON OF MAIZE INBRED LINES AND TOP CROSS HYBRIDS FOR AGRONOMIC TRAITS, GRAIN YIELD AND *STENOCARPELLA MAYDIS* EAR ROT RESISTANCE

3.1 INTRODUCTION

Maize suffers from several ear rot diseases including *Stenocarpella maydis* ear rot, *Gibberella* ear rot, *Penicillium* ear rot, *Aspergillus* ear rot and Grey ear rot. These diseases rarely cause severe yield losses over wide geographical areas (Smith and White, 1988), varying greatly between years depending on pre-harvest environment. The fungal pathogen that causes S*tenocarpella maydis* ear rot is *Stenocarpella maydis* (Berck.) Sutton, it is also called *Diplodia maydis* (Berck) Sacc. (Rheeder *et al.;* 1990; Flett, 1999). This fungus not only causes ear rot but also causes stalk rot and seedling blight of maize. Maize is the only host for this pathogen. *Stenocarpella. maydis* over winters on diseased stalk and ear tissues that have not been buried (Flett, 1990).

The inheritance of resistance to *Stenocarpella maydis* is said to be complex with many types of inheritance mechanisms reported (Dorrance *et al.*, 1998; Rossouw *et al.*, 2002) which are conditioned by additive, dominance, modifier, epistasis, or recessive genes. Villena (1971) reported that the resistance to ear rots was additive, while Thompson *et al*., (1971) reported resistance to ear rots of maize as quantitatively inherited that was confirmed by Ullstrup (1977) and Enern and Hunter (1980). Under natural infection, resistance was dominant, additively inherited or partially dominant while artificial infections showed quantitative inheritance (Vencelli, 1979). Nelson (1988) reported that no resistance to cob rot was reported in literature. Thus it can reasonably be assumed that the heritability of genetic resistance to cob rot is low, and consequently that progress in breeding resistant cultivars is likely to be slow.

Stenocarpella maydis ear rot is considered to be a potential cause of yield loss in susceptible lines. The incidence of ear rot in affected fields generally ranges from 1% to 80% or more. In severe infestations grain quality is down graded that affect profit due to reduced test weight and a higher number of damaged or broken kernels (Rheeder *et al*., 1988). If *Stenocarpella maydis* ear rot infected maize is not dried below 15% moisture content the moulds can easily attack the damaged kernels and result in further spoilage. Therefore, the use of resistant cultivars, with stalk strength and tight husks and angled ears is the best strategy. Cultivars with poor husk coverage or thin pericarps are often very susceptible (Le Roux, 1988). Too much nitrogen and too low potassium levels leads to susceptibility. One should also not use too high plant population (Le Roux, 1988). Another key to management of this disease is crop rotation and residue removal because the fungus survives on infested debris (Flett, 1999).

Farmers and breeders want successful new maize hybrids that show high performance for yield and other essential agronomic traits. Their superiority should be stable over a wide range of environmental conditions. The basic cause of differences between genotypes in their yield stability and ear rot susceptibility is due to genotype by environment interaction (GEI) (Nowell, 1990). Multi-location trials play an important role in plant breeding and agronomic research to study GEI. Data from such trials will help 1) to estimate and predict yield accurately, 2) to determine yield stability, 3) to determine the pattern of response of genotypes across environments and 4) to provide reliable guidance for selecting the best genotypes (Crossa, 1990).

Development of *Stenocarpella maydis* resistant hybrids requires selection for certain traits during inbred line development (Beck *et al*., 1997; Betran *et al*., 1997). It is believed that improvements of inbred performance will play an increasingly important role in improving the performance of hybrids (Beck *et al*., 1997; Duvick, 1999). In contrast, some breeders are not convinced that parental performance has any direct relationship to hybrid performance, especially with regard to grain yield (Hallauer and Miranda, 1988; Lamkey and Edwards, 1999). However, specific combinations of inbred lines that are good general combiners will remain an essential requirement for production of superior new hybrids (Hallauer and Miranda, 1988; Duvick, 1999). However, performance and combining ability and relationship between hybrid and line in different environments is not well known. Many researchers have also shown that GCA and SCA can interact with environments (Sprague and Tatum, 1942; Matzinger *et al*., 1959; Beck *et al*., 1990; Han *et al*, 1991; Betran *et al*., 2003).

To develop resistant varieties detailed information is required among inbred lines and their hybrids on *Stenocarpella maydis* resistance under inoculation and natural infestation. Thus, this study aimed at genetically characterising the resistance of *Stenocarpella maydis* ear rot and to compare 58 inbred lines and 58 top cross hybrids of maize for important agronomic traits, grain yield and ear rot resistance at three locations in South Africa with good combining ability. Selected lines may be used in breeding maize for *Stenocarpella maydis* ear rot resistance.

3.2 MATERIALS AND METHODS

3.2.1 Study sites

The study was conducted during summer 2005/06 over three locations: Bethlehem, Cedara and Potchefstroom representing various categories of regional environmental variation in the maize triangle. Description of the study sites is shown in Table 3.1.

Table 3.1 Description of study sites

Location	Soil type	Latitude (South)	Longitude (East)	Altitude (masl)
Bethlehem	Sandy	28°.1626´	28°.2953´	1660
Cedara	Sandy	29°.5333´	30°.2833´	1079
Potchefstroom	Sandy	26°.7361´	27°.0757´	1347

Masl: meters above sea level

3.2.2 Plant materials

For this study 54 maize inbred lines and 54 top cross hybrids were used (Table 3.2). The inbred lines were at F_6 generation. Top cross hybrids were the result of crosses of the same inbred lines with a tester line (SAM 1066) at F_5. Both inbred lines and top crosses were selected from 2004/05 nursery under natural infestation of *S. maydis* at Agricultural Research Council-Grain Crop Institute (ARC-GCI). At Potchefstroom there were an inoculation and natural infestation trials, whereas at Bethlehem and Cedara the studies were carried out under natural infestation. Four checks were included viz E379, Do620Y, H111 and Mo17. Checks are inbred lines and relatively high yielders with average stability and have considerable variations in *Stenocarpella* *maydis* ear rot infection levels. The checks for top cross hybrids were one open pollinated variety SAM 1066 that was used as a tester and three commercial hybrids viz PAN 6124, PAN 6026 and CRN 3505.

Table 3.2. Description of 58 maize inbred lines and top cross hybrids used for the study.

Entry	Pedigree[a]	Entry	Pedigree[b]
1	B2 x A2P31 (J589) Ry 11-3-1-1-1-B	1	B2 x A2P31 (J589) Ry 11-3-1-1-1/SAM 1066
2	B2 x A2P31 (J589) Ry 11-3-1-1-2-B	2	B2 x A2P31 (J589) Ry 11-3-1-1-2/SAM 1066
3	B2 x A2P31 (J591) Ry 16-2-1-1-2-2-B	3	B2 x A2P31 (J591) Ry 16-2-1-1-2-2/SAM 1066
4	B2 x A2P31 (J592) Ry 19-2-1-1-1-2-B	4	B2 x A2P31 (J592) Ry 19-2-1-1-1-2/SAM 1066
5	B2 x A2P31 (J599) Ry 35-5-1-1-1-1-B	5	B2 x A2P31 (J599) Ry 35-5-1-1-1-1/SAM 1066
6	B2 x A2P31 (J601) Ry 38-3-1-1-2-B	6	B2 x A2P31 (J601) Ry 38-3-1-1-2/SAM 1066
7	B2 x B2P22 (J570) Ry 3-3-1-1-2-B	7	B2 x B2P22 (J570) Ry 3-3-1-1-2/SAM 1066
8	B2 x B2P22 (J571) Ry 5-1-1-1-2-B	8	B2 x B2P22 (J571) Ry 5-1-1-1-2/SAM 1066
9	B2 x B2P22 (J577) Ry 20-1-1-1-6-B	9	B2 x B2P22 (J577) Ry 20-1-1-1-6/SAM 1066
10	B2 x B2P22 (J577) Ry 20-3-1-1-3-B	10	B2 x B2P22 (J577) Ry 20-3-1-1-3/SAM 1066
11	B2 x B2P22 (J577) Ry 20-3-1-1-5-B	11	B2 x B2P22 (J577) Ry 20-3-1-1-5/SAM 1066
12	B2 x B2P22 (J577) Ry 20-3-1-1-7-B	12	B2 x B2P22 (J577) Ry 20-3-1-1-7/SAM 1066
13	B2 x B2P22 (J577) Ry 20-3-1-1-8-B	13	B2 x B2P22 (J577) Ry 20-3-1-1-8/SAM 1066
14	B2 x B2P22 (J577) Ry 20-4-1-1-2-B	14	B2 x B2P22 (J577) Ry 20-4-1-1-2/SAM 1066
15	B2 x B2P22 (J580) Ry 23-3-1-1-2-B	15	B2 x B2P22 (J580) Ry 23-3-1-1-2/SAM 1066
16	B37xDO620Y (J525) Ry 12-2-1-1-2-B	16	B37x DO620Y (J525) Ry 12-2-1-1-2/SAM 1066
17	B37xDO620Y (J526) Ry 14-1-1-1-1-B	17	B37xDO620Y (J526) Ry 14-1-1-1-1-B/SAM 1066
18	B37xDO620Y (J532) Ry 29-3-1-1-1-B	18	B37x DO620Y (J532) Ry 29-3-1-1-1/SAM 1066
19	B37xDO620Y (J532) Ry 29-5-1-1-3-B	19	B37x DO620Y (J532) Ry 29-5-1-1-3/SAM 1066
20	B37xDO620Y (J532) Ry 29-5-1-1-4-B	20	B37x DO620Y (J532) Ry 29-5-1-1-4/SAM 1066
21	B37xDO620Y (J532) Ry 29-5-1-1-5-B	21	B37x DO620Y (J532) Ry 29-5-1-1-5/SAM 1066
22	CB.M-B	22	CB.M/SAM 1066
23	CB.M-B	23	CB.M/SAM 1066
24	CB.M-B	24	CB.M/SAM 1066
25	CB®.I-B	25	CB®.I/SAM 1066
26	CB®.SNK-B	26	CB®.SNK/SAM 1066
27	CB®.SNK-B	27	CB®.SNK/SAM 1066

[a] :Inbred lines [b] :Top cross hybrids * : checks as comparative control

Table 3.2 continued

Entry	Pedigree[a]	Entry	Pedigree[b]
28	CB®.SNK-B	28	CB®.SNK/SAM 1066
29	E739 x B37 (J541) Ry 1-4-1-1-4-B	29	E739 x B37 (J541) Ry 1-4-1-1-4/SAM 1066
30	E739 x B37 (J544) Ry 8-3-1-1-3-B	30	E739 x B37 (J544) Ry 8-3-1-1-3/SAM 1066
31	E739 x B37J (551) Ry 27-1-1-1-2-B	31	E739 x B37 (J551) Ry 27-1-1-1-2/SAM 1066
32	E739 x B37 (J551) Ry 27-1-1-1-2-B	32	E739 x B37 (J551) Ry 27-1-1-1-2/SAM 1066
33	E739 x B37 (J551) Ry 27-1-1-1-3-B	33	CB®.SNK/SAM 1066
34	E739 x B37 (J551) Ry 27-1-1-1-5-B	34	E739 x B37 (J541) Ry 1-4-1-1-4/SAM 1066
35	E739 x B37 (J551) Ry 27-4-1-1-1-B	35	E739 x B37 (J544) Ry 8-3-1-1-3/SAM 1066
36	E739 x B37 (J551) Ry 27-5-1-1-1-1-B	36	E739 x B37 (J551) Ry 27-1-1-1-2/SAM 1066
37	E739 x B37 (J551) Ry 27-5-1-1-1-3-B	37	E739 x B37 (J551) Ry 27-1-1-1-2/SAM 1066
38	E739 x B37 (J551) Ry 27-5-1-1-2-1-B	38	E739 x B37 (J551) Ry 27-1-1-1-3/SAM 1066
39	E739 x B37 (J553) Ry 40-2-1-1-1-2-B	39	E739 x B37 (J551) Ry 27-1-1-1-5/SAM 1066
40	E739 x Do620Y (J507) Ry 8-1-1-1-1-B	40	E739 x B37 (J551) Ry 27-4-1-1-1/SAM 1066
41	E739 x Do620Y (J509) Ry 14-2-1-1-2-B	41	E739 x B37 (J551) Ry 27-5-1-1-1-1/SAM 1066
42	E739 x Do620Y (J509) Ry 14-2-1-1-3-B	42	E739 x B37 (J551) Ry 27-5-1-1-1-3/SAM 1066
43	E739 x Do620Y (J511) Ry 17-1-1-1-2-B	43	E739 x B37 (J551) Ry 27-5-1-1-2-1/SAM 1066
44	E739 x Do620Y (J512) Ry 24-2-1-1-1-3-B	44	E739 x Do620Y (J512) Ry 24-2-1-1-1-3-B/SAM 1066
45	E739 x Do620Y (J512) Ry 24-2-1-1-5-B	45	E739 x Do620Y (J512) Ry 24-2-1-1-5-B/SAM 1066
46	F.'M-B	46	F.'M-B/SAM 1066
47	Fx2.M-B	47	Fx2.M-B/SAM 1066
48	I.F.F.M-B	48	I.F.F.M-B/SAM 1066
49	I.M.M-B	49	I.M.M-B/SAM 1066
50	I.M.US (NC).CB(L)-B	50	I.M.US (NC).CB(L)-B/ SAM 1066
51	I.M-B	51	I.M-B/SAM 1066
52	I-B	52	I-B/SAM 1066
53	I-B	53	I-B/SAM 1066
54	M-B	54	M-B/ SAM 1066
55	E739*	55	SAM 1066*
56	D620Y*	56	PAN 6124*
57	H111*	57	PAN 6026*
58	MO17*	58	CRN 3505*

[a] :Inbred lines   [b] :Top cross hybrids   * : checks as comparative control

3.2.3 Experimental design and planting

The study was carried out using a randomised complete block design (Gomez and Gomez, 1984). Genotypes were assigned randomly in three replications. Plots consisted of two rows of 4.5 m long and 1 m apart making a plot size of 9 m^2. The trials were planted by hand with two seeds per hill and thinned after emergence to a uniform stand of 30 plants per plot.

3.2.4 Inoculation

The inoculum for artificial infestation of plants was prepared in accordance with techniques recommended by ARC-GCI using an isolate from Viljoenskroon. All plants were inoculated by applying 5 ml of ground-infested kernels in the whorls two weeks prior to tasseling. There was no need of irrigation to promote disease development after inoculation due to favourable climatic conditions during the growing season 648.4mm per annum. Irrigation was applied four times after planting. For fertilization 3:2:1 (25%) + Zn was broadcasted prior to planting at the rate of 300 kg ha^{-1}. At V6 LAN (28%) was banded at the rate of 300 kg ha^{-1}. In order to control stalk borer, kombat granule stalk borer bait was applied in the whorl. Pre-emergence and post-emergence herbicides plus manual weeding were used for weed control.

3.2.5 Measurements

3.2.5.1 Data on phenological traits, yield components and *Stenocarpella maydis* ear rot ratings

At all locations trials were manually harvested. Field weight (FW) which is the weight of the cob with grai; grain weight and percent moisture content were recorded. In order to get the shelling percentages grain weight (GW) was divided by field weight (FW) as (S = [GW/FW]). To obtain yield in tons per hectare the following formula was used Y = (100 – % moisture)/12% moisture*field weight *shelling % * 10/plot size (conversion factor).

The agronomic traits recorded were number of days to 50% silking (DS), plant height (PH) and ear height (EH) in centimetres (using five plants per plot sampled at random), husk cover (HC) rating (closed = 1 or open = 2), ear position (EP) rating (dropping =1 or upright = 2), number of ears harvested per plot (EN) (prolificacy = number of ears/stand count) and percentage of plants with stem lodging (SL) (number of plants with 50% stem lodging/stand count * 100). Data for number of diseased ears were scored using a weighted average (WA) and visually using scale (VR) of 1–6 with one showing *S. maydis* resistance reaction while six showing *S. maydis* susceptible reaction (Jeffers, 2002) (see pages 22 and 23).

3.2.5.2 Meteorological data

Rainfall and temperature (maximum and minimum) data were collected daily from the nearby meteorological station at Bethlehem, Cedara and Potchefstroom (Table3.2) in order to make possible associations of weather patterns on the occurrence of *Stenocarpella* ear rot..

Table 3.3 Maximum and minimum temperature (°C) and Rainfall (mm) records of Bethlehem (Beth), Cedara (Ceda) and Potchefstroom (Potch) from June 2005 to June 2007.

	Temperature (°C)										Temperature (°C)								
	Maximum			Minimum			Rainfall (mm)				Maximum			Minimum			Rainfall (mm)		
	Location			Location			Location				Location			Location			Location		
Month	Beth	Ceda	Potch	Beth	Ceda	Potch	Beth	Cedara	Potch	Month	Beth	Ceda	Potch	Beth	Ceda	Potch	Beth	Cedar	Potch
Jun ‘05	18.7	20.6	22.2	-0.3	4.6	3.0	0.0	11.2	0.0	Jun ‘06	17.4	19.2	19.9	-2.0	2.4	0.6	0.3	5.8	0.0
Jul ‘05	19.2	20.7	21.8	-2.1	3.4	0.6	0.3	0.4	0.0	Jul ‘06	18.7	22.1	21.8	-0.6	4.1	2.9	0.0	0.0	0.5
Aug ‘05	21.7	22.3	24.7	2.6	7.7	5.5	5.7	25.9	0.0	Aug 06	17.0	20.1	20.4	1.4	5.7	3.9	58.3	13.8	21.9
Sept 05	25.5	24.3	28.6	5.7	10.2	9.1	5.0	23.3	0.3	Sep 06	22.6	22.7	25.8	4.4	9.2	6.8	4.0	37.2	9.4
Oct ‘05	25.1	24.1	29.8	9.3	11.7	13.2	81.0	93.5	15.3	Oct ‘06	24.8	23.8	28.7	10.1	12.8	12.8	32.8	105.8	67.5
Nov ‘05	25.9	23.9	30.3	11.2	11.3	14.4	123.8	103.9	34.4	Nov 06	24.8	24.0	28.4	11.3	13.0	14.2	25.7	135.7	79.5
Dec ‘05	27.0	24.4	30.3	11.6	12.8	15.7	39.0	69.5	64.7	Dec 06	26.9	25.2	29.7	13.0	14.9	16.5	42.5	113.7	206.2
Jan ‘06	25.8	25.8	27.7	14.8	16.5	17.7	167.3	245.8	161.6	Jan ‘07	28.2	26.9	30.8	13.0	15.4	16.0	25.2	72.2	45.1
Feb ‘06	25.1	25.7	27.1	15.1	16.3	17.0	105.7	123.6	138.3	Feb ‘07	29.3	28.2	31.2	12.7	15.7	15.2	25.1	18.9	73.4
Mar ‘06	22.2	23.2	24.8	10.9	13.1	13.7	129.6	83.9	161.5	Mar ‘07	27.2	25.2	29.5	10.6	13.9	13.4	33.9	107.9	50.3
Apr ‘06	20.8	22.6	23.8	7.6	11.3	10.2	47.2	89.0	65.9	Apr ‘07	23.7	23.6	25.5	7.8	11.8	10.6	44.5	34.8	64.5
May ‘06	16.1	19.1	19.9	0.7	5.3	2.9	30.5	21.0	6.4	May 07	20.8	23.4	22.8	0.1	6.0	2.6	1.5	0.5	0.0
Jun ‘06	17.4	19.2	19.9	-2.0	2.4	0.6	0.3	5.8	0.0	Jun ‘07	16.5	19.8	19.4	-1.3	3.5	1.2	27.6	31.8	25.1

°C: Degree Celsius, Beth: Bethlehem, Ceda: Cedara, Potch: Potchefstroom, Jun: June, Jul: July, Aug: August, Sep: September, Oct: October, Nov: November, Dec: December, Jan: January, Feb: February, Mar: March and Apr: April

3.3 Data analysis

Data were subjected to analysis of variance per location using Agrobase 98™ software (Agronomix Software Inc). When found significant per location combined ANOVA was performed (Gomez and Gomez, 1984). Husk coverage, ear position, number of *S. maydis* infested ears and percent grain moisture was correlated to grain yield (Falconer and Mackay, 1996). Means were compared using Least significant difference (LSD) at p= 0.05 (significant level). Eberhart- Russell regression analysis (Eberhart and Russell, 1966) and Lin and Binns's superiority (Lin and Binns, 1988) were performed for obtaining the yield and *Stenocarpella maydis* ear rot infestation stability across three locations. The Eberhart- Russell model is defined as $Yij = m + biIj + dij + eij$, where Yij = observation of the *i-th* (i = 1, 2, ..., g) cultivar in the *j-th* (j = 1, 2, ...n) environment, m = general mean, bi = regression coefficient, Ij = environmental index obtained by the difference among the mean of each environment and the general mean ($S^2d_{ij} = 0$), d_{ij} = the regression deviation of the *i-th* cultivar in the *j-th* environment and eij = effect of the mean experimental error. The Lin and Binns' (1988) model is defined as $P_i = S\ (Xij - Mj)2\ /2n$ that was used to assess the superiority of a cultivar, where P_i = superiority index of the *i-th* cultivar, Xij = yield of the i-th cultivar in the *j-th* environment, Mj = maximum response obtained among all the cultivars in the *j-th* environment, and n = number of environments. This expression was further partitioned as Pi = [n ($Xi.$ - M)2 + S (Xij - Mj + M)2]/2n, where $Xi = S\ Xij/n$ and $M = S\ Mj/n$, Xi = mean yield of the *i-th* cultivar in the n environments and M = mean of the maximum response in the n environments.

Line x tester analysis for the grain yield and *Stenocarpella maydis* ear rot resistance was run in order estimate the combining ability (Grüyter, 1986 and Singh and Choudhary, 1985).

Model for estimation for general combining ability for the lines $g_i = \left(\frac{Xi...}{tr}\right) - \left(\frac{Xi...}{ltr}\right)$

was used where g_i = the estimation of GCA for the *i-th* line, x_i = the grand total value for the *i-th* line crossed with the tester, x the grand total value for all crosses, l = number of lines, t = number of testers and r = number of replications.

Model for estimation for general combining ability for the testers gi =. $\left(\frac{X.\,j.}{lr}\right) - \left(\frac{X...}{ltr}\right)$

g_i = the estimates of GCA for the i-th tester, *x.j.* = the grand total value for the *j-th* testers crossed with all lines, *x…* = the grand total values for all crosses, *l* = the number of lines, *t* = the number of testers and r = the number of replications.

Mid-parent value and percent heterosis for grain yield and *Stenocarpella maydis* ear rot were calculated (Falconer and Mackay, 1996). Mid-parent heterosis value was estimated as MPH=F_1 -(P_1 + P_2)/ P_1 + P_2, where F1 = the mean of the top cross hybrid performance, P1 = parent 1(inbred line) and P_2 = parent 2 (tester) means. Percent heterosis was calculated as H = 100 x (F_1 – P_1 + P_2)/2 where H = heterosis, F_1 = mean of F_1, P1 = parent 1(inbred line) and P_2 = parent 2 (tester) means.

3.4 RESULTS

3.4.1 Responses of 58 maize inbred lines and 58 top cross hybrids for agronomic traits evaluated under natural infestation at Bethlehem, Cedara and Potchefstroom

Days to 50% silking

Inbred lines showed significant difference in days to 50% silking at Bethlehem, Cedara and Potchefstroom (Appendices 8.1, 8.2 and 8.3). Entries 22 and 2 took more days to silking with 79 days at both localities. Entries 41, 3, 23, 42, 4, 43 and 25 were not significantly different to entries 22 and 2 at Bethlehem. Entry 26 took few days to reach 50% silking at Bethlehem this entry had 77 days to silking (Table 3.4) followed by entries 28, 9, 8, 39, 47 and 46. The grand mean for 58 inbred lines to reach 50% silking at Bethlehem was 78 days. Entries 22, 2 and 41 took longer days to silking with 79 days followed by entries 3, 23, 42, 4, 11, 25 and 43 at Cedara. Entries 26, 28, 9, 8, 39, 47 and 46 took few days to silking with 77 days at Cedara. The grand mean of the 58 maize inbred lines to reach 50% silking at Cedara was 78 days. At Potchefstroom, entries 3, 25, 41, 24, 23, 43 and 42 were not significantly different to entries 22 and 2. At Potchefstroom entry 46 took few days to reach silking with 77 days to silking followed by entries 28, 9, 29 and 47 showing no significance difference. The grand mean for 58 inbred lines for days to 50% silking at Potchefstroom was 78 days.

Similarly, top cross hybrids showed significant difference in days to 50% silking at Bethlehem, Cedara and Potchefstroom (Appendices 8.4, 8.5 and 8.6). Entries 33 and 43 took more days to silking (79 days) at Bethlehem followed by entries 24, 39, 41, 52, 16, 23, 48, 55, 51, 36 and 54. Entries 22, 12 and 38 took few days to reach 50% silking at Bethlehem followed by entries 50, 4, 58, 8, 17 and 2 (77 days). The grand mean for 58 inbred lines to reach 50% silking was 78 days. At Cedara entries 33 and 43 took more days to silking with 79 days at Cedara followed by entries 24, 39, 41, 57, 16, 23, 52, 55, 48, 36, 51 and 54 showing no significance difference. Entries 22, 12 and 38 took few days to 50% flowering at Cedara with 77 days to silking followed by entries 50, 8 and 58 with 77.33 days to 50% silking. The grand mean for days to 50% silking at Cedara was 78 days. Entries 16, 33 and 43 took more days to flowering with 79 days at Potchefstroom followed by entries 24, 3, 41, 21, 23, 30, 39, 55, 48, 52, 36, 51 and 54. Entries 22, 38 and 4 took few days to reach 50% silking followed by entries 50, 58, 12, 8, 1 and 15 (Table 3.5) at Potchefstroom. The grand mean was 78 days.

Plant height

At Bethlehem, Cedara and Potchefstroom lines and replications showed significant differences (Appendices 8.7, 8.8 and 8.9). At Bethlehem entry 40 was the shortest with the plant height of 102 cm followed by entries 41 and 29 with 107 cm. The tallest inbred line at Bethlehem was entry 30 with the height of 157 cm followed by entry 3 with 155 cm. At Cedara entry 40 was the shortest with the plant height of 102 cm followed by entries 29 and 41 with 105 cm and 107 cm, respectively. The tallest inbred line at Cedara was entry 30 with 157 cm followed by entry 3 with 155 cm. The shortest entry at Potchefstroom was entry 40 with 102 cm followed by entries 41 and 29 with plant height of 107 cm. At Potchefstroom entry 30 was the tallest followed by entry 27 with 142 cm (Table 3.4).

Top crosses had significant differences for this trait at Bethlehem, Cedara and Potchefstroom (Appendices 8.10, 8.11 and 8.12). Entry 28 was the shortest with the plant height of 175 cm followed by entry 55 with 180 cm at Bethlehem. The tallest top cross at Bethlehem was entry 17 with the height of 230 cm followed by entries 42, 52, 33, 26 and 53 cm (Table 3.5). At Cedara entry 55 was the shortest with 180 cm followed by entries 11 and 29 with 192 and 193 cm, respectively. The tallest entry at

Cedara was entry 17 with 230 cm followed by entries 42, 52, 33, 26 and 53 with 229 to 228 cm. Entry 28 was the shortest top cross at Potchefstroom with 175 cm followed by 55 cm with 180 cm. The tallest entry at Potchefstroom was entry 33 with 228 cm followed by entries 26 and 37 with 225 cm.

Ear height

Lines showed significant differences for ear height at Bethlehem, Cedara and Potchefstroom (Appendices 8.13, 8.14 and 8.15). Entry 33 had the shortest ear height with the height of 30 cm followed by entries 19, 45 and 40 with the ear height of 31 cm (Table 3.4). The tallest ear height at Bethlehem was found in entries 12, 36 and 42 with the ear height of 43 cm followed by entries 9, 4 and 47cm with the ear height of 42 and 41 cm, respectively. At Cedara entry 33 had the shortest ear height of 30 cm followed by entries 40, 41, and 45 with the ear height of 31 cm. The tallest entries were entry 12, 36 and 42 with the ear height of 43 cm. The grand mean for ear height at Cedara was 36 cm. At Potchefstroom entry 33 had the shortest ear height followed by entries 19, 45 and 40 with the height of 31 cm. The tallest entries at Potchefstroom were entries 12, 36 and 42 with the ear height of 43 cm.

Top cross hybrids showed differences for this trait both at Bethlehem, Cedara and Potchefstroom (Appendices 8.16, 8.17 and 8.18). Entries 29, 28 and 7 were the shortest in ear height at Bethlehem with 72 cm followed by entries 48 and 43 with the height of 73 and 74 cm, respectively. The tallest ear height that was found at Bethlehem was in entry 52 with the ear height of 105 cm followed by entries 26, 2 and 17 with the ear height ranging from 102 to 100 cm. At Cedara entries 29, 28 and 7 (Table 3.5) had the shortest ear height of 72 cm followed by entries 48 and 43 with the height of 73 and 74 cm, respectively. At Cedara entry 52 had the tallest ear height of 105 cm followed by entries 26, 2 and 17 with ear height ranging from 102 to 100 cm. Entries 29, 28 and 7 had the shortest ear height at Potchefstroom with the height of 72 cm followed by entries 48 and 43 with the ear height of 73 and 74 cm, respectively. The entry with the tallest ear height was 52 with the height of 105 cm followed by entry 26, with the ear height of 102 cm.

Husk cover

Inbred lines had significance differences to husk coverage at Bethlehem, Cedara and Potchefstroom (Appendices 8.16, 8.17 and 8.18). The inbred line with a well-closed husk cover was entry 43 at Bethlehem. Entries 8, 9 and 12 had open tips at Bethlehem. At Cedara and Potchefstroom entry 58 (Table 3.4) had a well-closed husk cover. Entries 44, 31, 24, 4, 11 and 51 had open tips at Cedara and Potchefstroom.

The top cross hybrids had significance differences to husk coverage at Bethlehem, Cedara and Potchefstroom (Appendices 8.19, 8.20 and 8.21). The top cross, which had a well-closed husk cover at Bethlehem, was entry 58 followed by entries 13, 12, 40, 33, 23, 52, 51, 43, 46 and 19 (Table 3.5). Entries with open/loose husks at Bethlehem were 30, 31, 3, 4, 5, 6, 36, 37 9 and 10. At Cedara entries 43, 13, 12, 40, 33, 23, 52, 51, 7 and 46 had a well closed husk while entries 30, 31, 3, 4, 5, 6, 36, 37, 9, 10 and 11 had a loose husk cover. At Potchefstroom entries 43, 13, 12, 40, 33, 23, 52, 51, 7 and 46 had a closed husk cover while entries 30, 31, 3, 4, 5, 6, 36, 37, 9 and 10.

Ear position

Inbred lines displayed significance differences with respect to ear position at Bethlehem, Cedara and Potchefstroom (Appendices 8.22, 8.23 and 8.24). The inbred lines with a good dropping ear at Bethlehem were entries 43, 42, 34, 26, 32, 46, 45 and 22 while the entries with erect/upright ears were entries 8, 9, 12 and 11. At Cedara entries 58, 42, 56, 55, 54, 53, 45, 22, 50 and 34 had a dropping ear while entries 44, 31, 24, 4, 11 and 51 (Table 3.4) had an upright ear. At Potchefstroom entries 58, 42, 56, 55, 54, 53, 45, 22, 50 and 34 while entries 44, 31, 24, 4, 11 and 51 had an upright ear.

The top cross hybrid had significance differences with respect to ear position at Bethlehem, Cedara and Potchefstroom (Appendices 6.25, 6.26 and 6.27). The top cross hybrids with a good dropping ear at Bethlehem, Cedara and Potchefstroom were entries 58, 57, 56, 26, 25, 53, 52, 51, 50 and 49, while entries 23, 9, 47, 4, 33 and 14 had an erect or upright ear (Table 3.5).

Stand count

Inbred lines were significantly different for stand count ($P<0.05$) at Bethlehem and Cedara. There was no significance difference for stand count at Potchefstroom (Appendices 8.31, 8.32 and 8.33). The highest stand count at Bethlehem was 15 plants per $5m^2$ plot while the lowest stand count was 5 plants per $5m^2$ plot (Table 3.4). The highest stand count at Cedara was 17 plants per $5m^2$ plot and the lowest stand count was one plant per $5m^2$ plot. At Potchefstroom the highest stand count was 30 plants per $10m^2$ plot while lowest was 18 plants per $10m^2$ plot.

The top cross hybrids were significantly different at Bethlehem, Cedara and Potchefstroom ($P<0.05$) (Appendices 8.34, 8.35 and 8.36). The highest stand count at Bethlehem was 16 plants per $5m^2$ plot and the lowest stand count was 13 plants per $5m^2$ plot. At Cedara the highest stand count was 30 plants per $10m^2$ plot and the lowest was 28 plants per $10m^2$ plot. At Potchefstroom the highest stand count was 29 plants per $10m^2$ plot and the lowest was 23 plants per $10m^2$ plot (Table 3.5).

Prolificacy

Inbred lines had significance differences with respect to prolificacy (stand count divided by number of harvested ears) i.e. numbers of ears per plant both at Bethlehem, Cedara and Potchefstroom (Appendices 8.28, 8.29 and 8.30). The most prolific inbred line at Bethlehem was entry 56 followed by entries 47, 57, 4 and 28 (Table 3.4), while entries 3, 6, 15, 21, 24 and 46 had single ears per plant. At Cedara entry 35 followed by entries 57 and 56 were prolific. Entries 1, 4, 5, 7, 9 and 13 had single ears per plant. The prolific entries at Potchefstroom were entries 13, 6, 22 and 26 while entries 12, 33, 44, 29 and 38 had single ears per plant.

The top cross hybrids had significance differences with respect to prolificacy at Bethlehem, Cedara and Potchefstroom (Appendices 8.31, 8.32 and 8.33). The most prolific top cross was entry at Bethlehem was entry 29 followed by entries 8, 28, 44, 4 and 49. Entries 56, 57 and 58 had a single cob per plant (Table 3.5) The entries which were prolific at Cedara were entries 8, 7, 3, 40, 27 and 29 while entries 56, 42, 54 and 11 had a single ear per plant. At Potchefstroom the most prolific entries were entries 28, 14, 46, 27, 39, 30, 54, 7, 45 and 16 while entries 18, 8, 20, 55, 29 and 21 had single ears per plant.

Stem lodging

There were significant differences between 58 maize inbred lines at Bethlehem, Cedara and Potchefstroom (Appendices 8.34, 8.35 and 8.36). At Bethlehem entry 5 was prone to stem lodging followed by entries 30, 35, 20, 44 and 12. At Bethlehem the most lodging resistant entry was entry 43. At Cedara entries 24 and 53 were very prone to stem lodging followed by entries 38 and 4. The most stem lodging resistant entry at Cedara was entry 8 followed by entries 42, 31, 40, 10, 18 and 45 (Table 3.4). At Potchefstroom entries 56 and 13 were very prone to stem lodging. The entries with stem lodging resistance at Potchefstroom were entries 18 and 31. The grand mean for Potchefstroom was 3.36.

Top crosses had significant differences at Bethlehem, Cedara and Potchefstroom (Appendices 8.37, 8.38 and 8.39). Entry 56 was prone to stem lodging followed by entries 13, 5, 55 and 50 at Bethlehem. The lodging resistant entry was 29. At Cedara entry 15 was the most prone to stem lodging followed by entries 14, 35 and 9. The most stem lodging resistant was entry 56. At Potchefstroom entry 37 was prone to stem lodging followed by entry 14 and 19. Entry 16 was the most stem lodging resistant entry at Potchefstroom followed by entries 22, 58, 12, 17 and 44 (Table 3.5).

Table 3.4 Mean responses of 58 maize inbred lines for days to 50% silking, plant height (cm), ear height (cm), husk cover, ear position, stand count, number of ears per plant and lodging resistance evaluated under natural infestation at Bethlehem, Cedara and Potchefstroom.

	Location and traits[a]																							
	Bethlehem								Cedara								Potchefstroom							
Entry	DS	PH	EH	HC	EP	SC	EN	SL	DS	PH	EH	HC	EP	SC	EN	SL	DS	PH	EH	HC	EP	SC	EN	SL
1	77	119	32.0	1.09	2.0	13	22	0.0	78	120	32.0	1.7	1.3	15	15	5.0	77	119	37.0	1.7	1.3	28	33	2.3
2	79	112	38.3	1.92	2.3	13	15	0.0	79	113	38.3	1.7	1.0	12	14	1.7	79	113	38.3	1.7	1.0	19	22	0.7
3	79	135	37.7	1.45	1.3	12	12	0.0	79	155	37.7	1.7	1.3	17	15	2.3	79	124	39.3	1.7	1.3	26	29	1.0
4	79	132	41.3	1.69	1.7	13	24	0.0	70	135	41.3	1.0	1.7	13	13	9.0	79	122	41.3	1.0	1.7	29	35	7.3
5	78	117	35.7	1.02	1.3	14	13	1.3	78	118	35.7	1.0	1.0	8	8	5.7	78	111	37.0	1.0	1.0	29	35	2.3
6	78	116	36.3	1.32	1.7	12	12	0.7	77	117	36.3	2.0	1.0	13	12	1.3	78	118	36.3	2.0	1.0	23	30	2.3
7	78	109	32.7	1.67	2.0	13	25	0.0	78	109	32.7	1.7	1.3	12	12	5.7	78	109	32.7	1.7	1.3	26	31	7.3
8	77	122	36.7	1.71	3.3	12	19	0.9	77	122	36.7	1.0	1.3	8	13	0.7	77	122	36.7	1.0	1.3	23	26	4.7
9	77	128	41.7	1.52	3.3	14	20	0.0	77	128	41.7	1.3	1.3	13	13	3.7	77	125	41.7	1.3	1.3	29	34	1.3
10	78	116	33.3	1.44	2.0	14	16	0.0	78	117	33.3	2.0	1.0	10	13	1.0	77	117	38.0	1.0	1.0	27	32	2.7
11	78	117	34.0	1.96	3.0	12	20	0.3	79	117	34.0	1.3	1.7	13	12	2.3	78	114	37.0	1.3	1.7	28	35	1.7
12	78	120	43.0	1.83	3.3	13	15	1.0	77	120	43.0	1.0	1.3	12	13	6.7	77	121	43.0	1.3	1.3	25	24	4.7
13	78	127	35.3	1.08	1.7	13	22	0.0	78	127	35.3	1.3	1.0	10	10	2.3	78	124	35.3	1.3	1.0	25	33	10.7
14	78	114	34.7	1.11	1.7	12	13	0.7	78	114	34.7	1.3	1.0	12	13	3.7	78	114	34.7	1.3	1.0	29	32	0.7
15	78	116	32.3	1.21	1.7	11	11	0.7	77	117	32.3	1.3	1.0	13	14	7.0	77	117	32.3	1.3	1.0	22	25	1.3
16	78	118	36.0	1.13	1.0	13	23	0.3	78	118	36.0	1.0	1.0	13	14	2.3	78	116	36.0	1.7	1.0	21	23	7.7
17	79	122	36.3	1.21	1.3	13	17	0.7	79	122	36.3	1.3	1.3	15	16	4.7	79	122	36.3	1.3	1.3	23	27	3.3
18	78	122	35.7	1.38	2.3	12	14	0.0	78	122	35.7	1.7	1.0	13	16	1.0	77	122	35.7	1.7	1.0	28	31	0.3
19	78	110	30.7	1.62	1.0	10	6	0.3	78	113	31.7	1.0	1.0	14	13	1.3	78	110	30.7	1.0	1.0	23	33	2.3
20	77	113	32.0	2.29	1.3	12	11	1.0	77	113	32.7	1.3	1.3	12	16	4.0	77	115	34.3	1.3	1.3	27	31	3.3
21	78	114	36.3	2.01	2.3	9	9	0.3	78	114	36.3	1.7	1.3	13	12	3.0	78	134	36.3	1.7	1.3	27	35	0.7
22	79	118	36.0	1.72	1.2	13	16	0.7	79	118	36.0	1.7	1.0	11	13	6.3	79	118	36.0	1.7	1.0	26	33	6.0
23	79	113	37.7	1.33	1.3	14	20	0.0	70	113	37.7	1.7	1.3	13	14	1.7	79	113	37.7	1.7	1.3	20	23	6.0
24	78	116	36.7	1.60	2.0	14	14	0.0	78	116	36.3	1.0	1.7	12	13	12.0	79	116	36.7	1.0	1.7	23	28	4.7
25	79	117	33.0	1.53	1.3	14	14	0.0	79	117	33.0	1.0	1.0	12	16	2.0	79	117	33.3	1.0	1.0	24	28	1.3
26	77	110	39.0	2.33	1.0	13	18	0.3	77	110	38.0	2.0	1.0	14	18	4.0	77	110	39.0	2.0	1.0	22	29	5.3
27	77	142	34.0	1.54	2.0	13	21	0.0	77	142	34.0	1.7	1.3	12	13	4.3	77	142	34.0	1.7	1.3	24	30	1.0
28	77	124	37.7	1.69	1.3	14	24	0.0	77	124	37.0	1.0	1.3	9	10	2.0	77	124	37.7	1.0	1.3	21	23	6.7
29	77	107	38.3	1.67	2.3	13	20	0.7	77	105	38.3	1.3	1.3	12	14	2.0	77	108	38.3	1. 3	1.3	23	25	2.0
30	78	137	38.0	1.20	1.0	13	14	1.0	78	157	38.0	2.0	1.0	13	16	2.3	78	157	38.0	2.0	1.0	27	33	4.3
31	78	124	32.3	1.50	1.0	13	10	0.7	78	124	31.0	1.3	1.7	16	16	1.0	78	124	32.3	1.3	1.7	25	28	0.3
32	77	119	33.7	1.10	1.0	13	18	0.3	78	119	33.7	1.0	1.3	17	14	1.7	78	119	33.7	1.0	1.3	30	33	0.7
33	77	109	30.0	1.80	1.7	15	21	0.7	77	109	30.0	1.3	1.0	12	13	6.3	77	109	30.0	1.3	1.0	27	27	5.3
34	77	116	39.0	1.80	1.0	13	15	0.3	77	116	39.0	1.3	1.0	14	14	1.7	77	116	39.0	1.3	1.0	25	27	1.0
35	78	118	33.0	1.90	1.7	12	8	1.0	78	118	33.0	1.3	1.0	1	17	6.0	78	118	33.0	1.3	1.0	24	27	1.7
36	79	120	42.7	1.80	1.3	13	18	0.0	79	120	42.7	1.7	1.0	15	16	2.3	79	120	42.7	1.7	1.0	29	33	1.0
37	77	113	38.3	1.60	1.3	12	15	0.0	77	113	38.3	1.3	1.3	14	17	4.3	77	113	38.3	1.3	1.3	29	32	2.0

Table 3.4 continued

	Location and traits[a]																							
	Bethlehem								Cedara								Potchefstroom							
Entry	**DS**	**PH**	**EH**	**HC**	**EP**	**SC**	**EN**	**LR**	**DS**	**PH**	**EH**	**HC**	**EP**	**SC**	**EN**	**LR**	**DS**	**PH**	**EH**	**HC**	**EP**	**SC**	**EN**	**LR**
38	78	123	36.3	1.9	1.3	14	20	0.0	78	123	36.3	1.7	1.0	13	15	9.0	78	121	36. 3	1.7	1.0	24	26	5.3
39	77	113	37.0	1.2	1.7	13	16	0.7	77	113	37.0	1.0	1.0	12	16	4.0	77	113	37.0	1.0	1.0	29	33	1.3
40	78	102	31.0	1.3	2.0	13	10	0.0	78	102	31.0	1.3	1.3	12	16	1.0	78	102	31.0	1.3	1.3	25	28	1.0
41	79	107	39.3	1.9	1.7	14	18	0.3	79	107	39.3	1.7	1.3	12	19	1.7	79	102	39.3	1.7	1.3	27	33	1.7
42	79	123	42.7	1.4	1.0	11	16	0.0	79	123	42.7	1.7	1.0	13	15	1.0	79	123	42.7	1.7	1. 0	27	29	16.7
43	79	120	35.3	0.6	1.0	14	21	0.0	79	120	35.3	1.7	1.3	13	20	7.0	79	107	35.3	1.7	1.3	20	22	0.7
44	78	125	32.3	1.0	1.7	13	23	1.0	78	125	32.3	1.0	1.7	12	13	2.7	78	125	32.3	1.0	1.7	18	18	4.7
45	78	111	31.0	1.0	1.0	15	25	0.0	77	111	31.0	1.0	1.0	11	13	1.0	78	108	31.0	1.0	1.0	27	29	1.3
46	77	117	37.7	1.5	1.0	14	13	0.3	77	117	37.7	2.0	1.0	14	16	4.3	77	117	37.7	2.0	1.0	24	28	3.7
47	77	115	41.0	1.8	1.7	14	29	0.0	77	115	41.0	1.7	1.3	12	12	4.0	77	115	41.0	1.0	1.3	25	29	1.3
48	78	124	38.3	1.5	1.7	13	18	0.0	78	124	38.3	1.0	1.3	11	13	2.0	78	124	38.3	1.3	1.3	22	25	6.7
49	78	112	35.0	1.6	1.7	14	20	0.0	78	112	35.0	1.3	1.3	13	17	2.3	78	112	35.0	2.0	1.3	24	27	6.0
50	78	124	37.3	1.3	1.0	14	24	0.0	78	124	37.3	2.0	1.0	15	18	5.0	78	124	37.3	1.3	1.0	28	30	5.3
51	78	126	35.0	1.3	2.0	15	18	0.3	78	126	35.0	1.3	1.7	13	19	1.7	78	126	35.0	1.0	1.7	20	24	1.3
52	78	112	33.3	1.0	2.0	14	17	0.0	78	112	33.3	1.0	1.3	12	20	4.3	78	112	33.3	1.3	1.3	29	33	3.7
53	77	121	33.0	1.6	1.3	13	16	0.0	77	121	33.0	1.3	1.0	15	19	11.7	77	121	33.0	1.3	1.0	24	25	6.3
54	78	120	36.7	0.8	2.7	15	23	0.0	78	120	36.7	1.3	1.0	14	21	2.7	78	120	36.7	1. 3	1.0	18	22	5.0
55	78	116	34.3	0.9	2.0	14	5	0.3	78	116	34.3	1.3	1.0	12	20	2.3	78	116	34.3	1.7	1.0	29	32	1.7
56	78	118	39.7	1.2	2.7	11	27	0.0	78	118	39.7	1.7	1.0	14	23	1.3	78	118	39.7	1.3	1.0	27	31	12.0
57	78	122	37.3	1.4	1.7	12	25	0.7	78	122	37.3	1.3	1.3	14	26	3.0	78	122	37.3	1.3	1.3	27	31	2.0
58	77	132	37.3	1.0	2.3	13	19	0.3	78	133	37.3	1.7	1.0	15	15	4.0	78	133	37.3	1.7	1.0	28	30	4.3
LSD	**1.26**	**20.8**	**7.13**	**0.6**	**1.5**	**2.2**	**8.1**	**0.8**	**1.25**	**21**	**6.91**	**0.6**	**0.54**	**3.9**	**4.7**	**5.72**	**1.21**	**17.9**	**7.28**	**0.6**	**0.5**	**8.0**	**9.058**	**5.40**
CV(%)	**1.19**	**128**	**14.60**	**33**	**66**	**13**	**34**	**206**	**1.19**	**13**	**14.15**	**33**	**33.2**	**22**	**23**	**116**	**1.15**	**11.2**	**14.79**	**33**	**33**	**23**	**23.11**	**119**
R^2(%)	**43.85**	**388**	**38.44**	**51**	**34**	**42**	**56**	**39**	**45.06**	**39**	**40.05**	**41**	**35.3**	**37**	**57**	**36.5**	**47.77**	**39.2**	**35.87**	**40**	**35**	**28**	**35.35**	**39.8**

[a] DF: days to 50% silking, PH: plant height (cm), EH: ear height (cm), HC: husk cover rating, EP: ear position rating, SC: stand count, SL: % stem lodging, and EN: number of harvested ears

Table 3.5 Mean responses of 58 maize top cross hybrids for days to 50% silking, plant height (cm), ear height (cm), husk cover, ear position, stand count, number of ears per plant and lodging resistance evaluated under natural infestation at Bethlehem, Cedara and Potchefstroom.

	Location and traits[a]																							
	Bethlehem								Cedara								Potchefstroom							
Entry	DS	PH	EH	HC	EP	SC	EN	SL	DS	PH	EH	HC	EP	SC	EN	SL	DS	PH	EH	HC	EP	SC	EN	SL
1	77.3	201	85	1.0	1.0	15	27	0.3	78	202	85	1.0	1.0	28	37	19	77.3	202	85	1.0	1.0	28	38	2.0
2	77.3	223	100	1.0	1.0	13	27	0.0	78	223	100	1.0	1.0	29	33	6	77.7	223	93	1.0	1.0	28	39	3.0
3	78.3	211	82	2.0	1.0	14	32	0.0	78	212	85	2.0	1.0	30	39	2	78.7	212	82	2.0	1.0	26	38	1.0
4	77.3	223	97	2.0	2.0	16	31	0.0	78	223	97	2.0	2.0	29	35	23	77.0	217	95	2.0	2.0	28	34	3.0
5	78.0	213	82	2.0	1.0	15	30	1.3	78	213	82	2.0	1.0	30	33	22	77.7	213	82	2.0	1.0	24	40	4.0
6	78.0	209	85	2.0	1.0	13	28	0.3	78	210	85	2.0	1.0	30	33	22	77.7	210	85	2.0	1.0	25	37	4.0
7	77.3	206	72	1.0	1.0	13	28	0.0	78	206	72	1.0	1.0	30	40	15	77.7	206	72	1.0	1.0	28	41	2.0
8	77.3	218	87	1.0	1.0	14	36	0.0	77	218	87	1.0	1.0	30	42	18	77.3	218	87	1.0	1.0	27	29	4.0
9	78.0	205	88	2.0	2.0	16	25	0.0	78	205	88	2.0	2.0	30	34	25	78.0	205	88	2.0	2.0	23	36	6.0
10	77.7	208	88	2.0	1.0	12	24	0.0	78	208	88	2.0	1.0	28	35	7	78.3	200	88	2.0	1.0	24	36	2.0
11	77.7	191	83	2.0	1.0	14	20	0.7	78	192	83	2.0	1.0	30	29	17	77.7	192	80	2.0	1.0	27	32	6.0
12	77.0	210	92	1.0	1.0	15	31	0.0	77	210	92	1.0	1.0	29	34	16	77.3	210	92	1.0	1.0	28	32	0.7
13	78.0	197	90	1.0	1.0	14	29	1.8	73	197	90	1.0	1.0	30	33	7	78.3	197	87	1.0	1.0	28	39	2.0
14	78.0	219	92	2.0	2.0	12	30	0.7	78	220	92	2.0	2.0	30	32	30	78.0	220	85	2.0	2.0	28	45	2.0
15	77.3	205	87	1.0	1.0	14	28	0.7	78	205	87	1.0	1.0	29	33	28	77.3	205	87	1.0	1.0	25	41	2.0
16	78.7	215	80	2.0	1.0	15	28	0.7	79	215	80	2.0	1.0	30	36	7	79.3	203	80	2.0	1.0	29	39	0.0
17	78.0	230	100	2.0	1.0	14	27	0.0	78	230	100	2.0	1.0	30	32	12	78.0	218	97	2.0	1.0	24	42	0.7
18	78.3	223	88	2.0	1.0	14	25	0.7	78	223	88	2.0	1.0	30	30	20	78.3	216	87	2.0	1.0	25	31	2.0
19	78.0	210	97	1.0	1.0	13	22	0.3	78	210	97	1.0	1.0	30	34	4	78.0	210	97	1.0	1.0	25	38	6.0
20	78.0	217	93	2.0	1.0	15	30	0.0	78	217	93	2.0	1.0	30	33	15	78.0	217	93	2.0	1.0	23	34	5.0
21	78.3	211	96	1.7	1.0	14	28	0.0	78	212	96	1.7	1.0	28	33	12	78.7	203	96	1.7	1.0	24	35	6.0
22	77.0	214	83	1.0	1.0	14	25	0.3	77	214	83	1.0	1.0	30	36	4	77.0	202	83	1.0	1.0	27	35	0.3
23	78.7	211	82	1.0	1.0	15	27	0.7	79	212	82	1.0	2.0	30	31	5	78.7	212	82	1.0	2.0	29	36	3.0
24	78.7	210	85	2.0	1.0	15	28	0.3	79	210	85	2.0	1.0	30	32	2	78.7	210	85	2.0	1.0	27	37	2.0
25	78.0	220	95	2.0	1.0	15	29	0.3	78	220	95	2.0	1.0	29	33	17	78.0	208	95	2.0	1.0	29	37	2.0
26	78.3	228	101	2.0	1.0	15	24	0.0	78	228	102	2.0	1.0	29	36	3	78.3	225	102	2.0	1.0	27	39	1.0
27	78.3	201	83	2.0	1.0	15	30	0.0	78	202	83	2.0	1.0	30	37	2	78.3	202	83	2.0	1.0	27	45	1.0
28	78.0	175	72	2.0	1.0	16	32	0.0	78	195	72	2.0	1.0	29	35	7	78.0	175	72	2.0	1.0	29	46	1.0
29	78.0	193	72	2.0	1.0	15	39	0.0	78	193	72	2.0	1.0	30	37	17	78.0	193	72	2.0	1.0	23	35	2.0
30	78.3	211	87	2.0	1.0	15	27	0.3	78	212	87	2.0	1.0	30	32	23	78.7	205	87	2.0	1.0	28	43	5.0
31	77.7	199	88	2.0	1.0	14	20	0.0	78	199	88	2.0	1.0	30	35	8	77.7	199	88	2.0	1.0	27	38	2.0

Table 3.5 continued

	Location and traits[a]																							
	Bethlehem								Cedara								Potchefstroom							
Entry	**DS**	**PH**	**EH**	**HC**	**EP**	**SC**	**EN**	**SL**	**DS**	**PH**	**EH**	**HC**	**EP**	**SC**	**EN**	**SL**	**DS**	**PH**	**EH**	**HC**	**EP**	**SC**	**EN**	**SL**
32	77.7	224	95	2.0	1.0	14	29	0.0	78	224	95	2.0	1.0	30	34	6	77.7	210	95	2.0	1.0	26	34	1.0
33	79.0	228	88	1.0	1.0	15	28	0.3	79	228	88	1.0	2.0	30	34	3	79.0	228	88	1.0	1.0	27	36	3.0
34	77.7	220	87	2.0	2.0	14	29	0.0	78	220	87	2.0	1.0	30	32	11	77.7	220	87	2.0	1.0	25	42	4.0
35	78.3	196	97	2.0	1.0	14	25	0.0	78	197	97	2.0	1.0	30	33	26	78.3	197	97	2.0	1.0	27	37	3.0
36	78.7	214	84	2.0	1.0	13	22	0.0	79	214	84	2.0	1.0	30	33	4	78.7	214	84	2.0	1.0	28	34	6.0
37	77.7	225	95	2.0	1.0	15	30	0.0	78	225	95	2.0	1.0	30	33	2	77.7	225	95	2.0	1.0	27	35	7.0
38	77.0	194	75	2.0	1.0	14	25	0.0	77	204	75	2.0	1.0	30	32	16	77.0	182	75	2.0	1.0	27	36	3.0
39	78.7	203	88	2.0	1.0	14	28	0.0	79	213	88	2.0	1.0	30	32	8	78.7	200	88	2.0	1.0	29	43	5.0
40	78.0	218	82	1.0	1.0	14	32	0.3	78	218	82	1.0	1.0	30	38	9	78.0	218	82	1.0	1.0	26	41	3.0
41	78.7	203	82	2.0	1.0	13	22	0.0	79	204	82	2.0	1.0	30	30	5	78.7	204	82	2.0	1.0	28	34	2.0
42	77.7	228	87	2.0	1.0	15	29	0.7	78	228	87	2.0	1.0	27	31	3	77.7	219	87	2.0	1.0	26	37	4.0
43	79.0	199	74	1.0	1.0	14	28	0.0	79	199	74	1.0	1.0	30	31	22	79.0	199	74	1.0	1.0	28	38	2.0
44	78.0	208	85	1.0	1.0	15	33	0.0	78	208	85	1.0	1.0	30	36	17	78.0	202	85	1.0	1.0	26	39	0.7
45	78.0	213	92	1.0	1.0	15	26	0.7	78	213	92	1.0	1.0	30	31	17	78.0	199	92	1.0	1.0	27	42	2.0
46	78.0	223	82	1.0	1.0	14	29	0.7	78	223	82	1.0	1.0	30	35	5	78.0	212	82	1.0	1.0	27	46	4.0
47	78.3	204	78	2.0	2.0	13	23	0.0	73	204	78	2.0	2.0	30	34	11	78.3	194	78	2.0	2.0	25	38	3.0
48	78.9	207	73	2.0	1.0	15	30	0.0	79	207	73	2.0	1.0	30	35	2	78.7	207	73	2.0	1.0	26	41	4.0
49	78.3	198	92	1.3	1.0	15	32	0.7	78	198	92	1.3	1.0	29	32	3	78.3	198	92	1.3	1.0	24	42	3.0
50	77.3	214	87	2.0	1.0	15	26	1.0	77	214	87	2.0	1.0	29	37	2	77.3	207	87	2.0	1.0	28	37	2.0
51	78.7	203	77	1.0	1.0	14	22	0.3	79	203	77	1.0	1.0	30	33	3	78.7	203	77	1.0	1.0	24	40	3.0
52	78.7	228	105	1.0	1.0	15	26	0.0	79	228	105	1.0	1.0	30	33	12	78.7	222	105	1.0	1.0	25	35	4.0
53	78.3	228	90	2.0	1.0	15	25	0.0	78	228	90	2.0	1.0	30	35	9	78.3	207	90	2.0	1.0	25	38	3.0
54	78.7	218	85	2.0	1.7	14	24	0.0	79	218	85	2.0	1.7	29	30	5	78.7	202	85	2.0	1.7	29	40	2.0
55	78.7	180	85	1.3	1.3	14	24	1.0	79	180	85	1.3	1.3	30	34	10	78.7	180	85	1.3	1.3	24	33	3.0
56	78.0	195	82	2.0	1.0	14	11	4.0	78	213	82	1.7	1.0	29	29	1	78.0	182	82	1.7	1.0	26	36	2.0
57	78.0	213	80	2.0	1.0	13	14	0.0	79	228	82	2.0	1.0	30	33	7	78.0	193	80	2.0	1.0	25	40	4.0
58	77.3	206	82	1.0	1.0	15	16	0.3	77	207	82	1.3	1.0	30	33	3	77.3	195	82	1.3	1.0	28	390	0.7
LSD	**1.24**	**28.1**	**20.7**	**0.2**	**0.2**	**2.2**	**6.8**	**1.2**	**1.2**	**26.6**	**20.4**	**0.2**	**0.1**	**0.8**	**2.7**	**4.6**	**1.2**	**21**	**19.8**	**0.2**	**0.1**	**4.1**	**8.12**	**4.37**
CV (%)	**1.18**	**9.85**	**17.7**	**8**	**10**	**11**	**19**	**273**	**1.1**	**9.28**	**17.4**	**10**	**9.6**	**1.9**	**6**	**31**	**1.2**	**7.4**	**17.0**	**10**	**10**	**11**	**15.4**	**111**
R^2 (%)	**32.3**	**0.33**	**27.9**	**95**	**93**	**31**	**59**	**42**	**31**	**31.4**	**27.7**	**92**	**93**	**63**	**72**	**89**	**35**	**46**	**27.66**	**92**	**93**	**33**	**36.5**	**28.6**

[a] DS: days to 50% silking, PH: plant height (cm), EH: ear height (cm), HC: husk cover rating, EP: ear aspect rating, SC: stand count, SL: % stem lodging, and EN: number of harvested ears

3.4.2 Correlation of morphological characteristics with grain yield and *Stenocarpella maydis* ear rot resistance

The correlation coefficients for pair-wise comparison of the degree of relatedness between morphological characters with grain yield and *Stenocarpella maydis* ear rot among 58 inbred lines are shown in Table 3.6. Results showed plant height had a negative non-significant correlation to grain yield from the combined average of Bethlehem and Potchefstroom. Days to 50% silking and ear height showed a positive non-significant correlation to grain yield. Stem lodging showed a positive non-significant correlation to grain yield. Stand count and ear number showed a positive highly significant correlation to grain yield. At Bethlehem, Cedara and Potchefstroom ear rot reaction showed negative non-significant correlations to days to 50% silking, plant height, stem lodging and stand count, but had a positive non-significant correlation to ear height, ear number and grain yield.

Among the top cross hybrids tested at Bethlehem, Cedara and Potchefstroom results from a combined data showed a negative non significant correlations among days to 50% silking with plant height, ear height, stem lodging and grain yield (Table 3.7). Stand count showed a positive non-significant correlation whereas with EP and GY while it had positive significant correlation with EN. Number of ears per plant showed a positive significant correlations to grain yield. Ear rot reactions showed negative non-significant correlations to plant height, ear height, stem lodging, and stand count. Days to 50% silking, ear number and grain yield had a positive non-significant correlation to ear rot infestation.

Table 3.6 Correlation coefficients for pair-wise comparison of 58 inbred lines for the degree of relatedness of morphological characters to the grain yield and *Stenocarpella maydis* ear rot resistance evaluated under natural infestation

	DS	PH	EH	SL	SC	EN	GY	ER	HC
PH	0.02^{ns}								
EH	0.04^{ns}	0.20^{ns}							
SL	-0.05^{ns}	0.01^{ns}	-0.04^{ns}						
SC	-0.02^{ns}	-0.03^{ns}	0.04^{ns}	0.41*					
EN	-0.04^{ns}	-0.01^{ns}	0.10*	0.27^{ns}	0.81**				
GY	0.08^{ns}	-0.05^{ns}	0.06^{ns}	0.38^{ns}	0.64**	0.53**			
ER	-0.09^{ns}	-0.00^{ns}	0.01^{ns}	-0.04^{ns}	-0.00^{ns}	0.08^{ns}	0.05^{ns}		
HC	0.11^{ns}	0.09^{ns}	0.15^{ns}	0.03^{ns}	0.05	0.11^{ns}	0.07^{ns}	-0.03^{ns}	
EP	0.07^{ns}	-0.00^{ns}	-0.06^{ns}	0.03^{ns}	0.13*	0.07^{ns}	0.16^{ns}	-0.06^{ns}	-0.14^{ns}

DS: days to 50% silking; PH: plant height; EH: ear height; SL: stem lodging; SC: stand count at harvest; EN: number of harvested ears; GY: grain yield; ER: ear rot infestation; HC: husk cover and EP: ear position

^{Ns}: non significant * : significant at P=0.05 ** : highly significant at P=0.01

Table 3.7 Correlation coefficients for pair-wise comparison of 58 top cross hybrids for the degree of relatedness of morphological characters to the grain yield and *Stenocarpella maydis* ear rot resistance evaluated under natural infestation

	DS	PH	EH	SL	SC	EN	GY	ER	HC
PH	-0.05^{ns}								
EH	-0.12^{ns}	0.53*							
SL	-0.02 ^{ns}	0.02 ^{ns}	0.02 ^{ns}						
SC	0.03 ^{ns}	-0.04 ^{ns}	-0.02 ^{ns}	0.52**					
EN	0.00 ^{ns}	-0.05 ^{ns}	-0.05 ^{ns}	0.15 ^{ns}	0.57**				
GY	-0.01 ^{ns}	-0.03 ^{ns}	-0.13 ^{ns}	-0.09 ^{ns}	0.43 ^{ns}	0.66**			
ER	0.02 ^{ns}	-0.03 ^{ns}	-0.04 ^{ns}	-0.21 ^{ns}	-0.14 ^{ns}	0.06 ^{ns}	0.12 ^{ns}		
HC	0.06 ^{ns}	0.03 ^{ns}	0.00 ^{ns}	0.00 ^{ns}	-0.01 ^{ns}	-0.05 ^{ns}	-0.04 ^{ns}	-0.01 ^{ns}	
EP	0.10 ^{ns}	0.09 ^{ns}	0.05 ^{ns}	0.07 ^{ns}	0.01 ^{ns}	-0.02 ^{ns}	0.02 ^{ns}	0.01 ^{ns}	0.05 ^{ns}

DS: days to 50% silking; PH: plant height; EH: ear height; SL: stem lodging; SC: stand count at harvest; EN: number of harvested ears; GY: grain yield; ER: ear rot infestation; HC: husk cover and EP: ear position

^{ns} : non significant * :significant at P=0.05 ** : highly significant at P=0.01

3.4.3 Mean grain yield responses among 58 maize inbred lines evaluated under natural infestation at Bethlehem and Potchefstroom

Significant differences between genotypes ($P<0.05$) were observed at Bethlehem for grain yield (Appendix 8.40). These indicated significant variability between genotypes. At Bethlehem entry 47 was superior over the other inbred lines with grain yield of 2.84 tons ha^{-1} (Table 3.8) followed by entries 43, 57, 4, 11, 55, 12, 2, 38, and 35 showing 2.55, 2.39, 2.19, 2.18, 2.08, 1,99, 1.92, 1.92 and 1.87 tons ha^{-1}, respectively. The r^2 value was 61.07% showing that the yield variation was explained by the difference between inbred lines by about 60%.

At Potchefstroom there was also a significance difference ($P< 0.05$) between inbred lines on grain yield (Appendix 8.41). Entry 4 over-yielded all entries with grain yield of 4.58 tons ha^{-1} followed by entries 15, 47, 1, 56, 2, 21, 20, 16 and 52 (Table 3.8) showing 4.56, 4.42, 4.39, 4.15, 4.15, 4.00, 3.99 and 3.93 tons ha^{-1}, respectively.

Cedara is a hot spot site for various pathogens; therefore, inbred lines were highly infested by other diseases including rust, grey leaf spot and Gibberella that confounded the present study. Thus, results on grain yield from this location were excluded for inbred lines.

Table 3.8 Mean grain yield (tons ha^{-1}) response and ranks of 58 maize inbred lines tested under natural infestation at Bethlehem and Potchefstroom during 2005/06.

	Location					Location			
	Bethlehem		Potchefstroom			Bethlehem		Potchefstroom	
Entry	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank	Entry	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank
1	1.03	54	4.39	4	30	1.17	45	3.33	25
2	1.92	8	4.15	6	31	1.45	28	3.80	14
3	1.11	49	3.62	20	32	1.11	48	2.91	44
4	2.19	4	4.58	1	33	1.79	11	2.63	51
5	0.86	57	2.92	43	34	1.43	29	2.60	52
6	1.32	36	3.80	13	35	1.87	10	2.09	55
7	1.39	31	2.76	48	36	1.08	53	3.24	31
8	1.43	30	2.66	50	37	1.59	22	3.78	15
9	1.32	37	2.98	40	38	1.92	9	2.52	53
10	1.14	46	2.97	42	39	1.18	44	3.71	17
11	2.18	5	3.27	20	40	1.28	40	2.74	49
12	1.99	7	2.79	47	41	1.78	12	2.91	45
13	1.08	52	3.37	23	42	1.35	33	3.34	24
14	1.11	50	3.86	12	43	2.55	2	3.00	39
15	1.23	41	4.56	2	44	1.08	51	3.71	18
16	1.13	47	3.99	9	45	0.98	56	2.50	54
17	1.21	43	1.86	57	46	1.23	42	3.31	26
18	1.38	32	3.68	19	47	2.84	1	4.42	3
19	1.62	18	3.28	29	48	1.54	26	2.97	41
20	1.60	19	4.00	8	49	1.57	23	3.30	28
21	1.68	16	4.15	7	50	1.30	38	3.30	27
22	1.72	14	3.12	32	51	1.30	40	3.07	36
23	1.33	35	3.73	16	52	1.01	55	3.93	10
24	1.60	21	3.14	34	53	1.60	20	3.89	11
25	1.53	27	3.46	22	54	0.83	58	3.05	37
26	1.66	17	3.01	38	55	2.08	6	3.49	21
27	1.54	25	1.64	58	56	1.56	24	4.34	5
28	1.69	15	3.18	33	57	2.39	3	2.89	46
29	1.75	13	1.91	56	58	1.34	34	3.10	35
					LSD	**0.5634**		**0.9080**	
					C.V. (%)	**27.76**		**20.39**	
					R^2 (%)	**61.07**		**59.53**	

GY= Grain yield, t ha^{-1} =tons per hectare, LSD=Least significance difference, CV%= percent coefficient of variation and R%^{2}= percent R squared

3.4.4 *Stenocarpella maydis* ear rot reaction of 58 maize inbred lines and 58 top cross hybrids evaluated under natural infestation at Bethlehem, Cedara and Potchefstroom

Results of analysis of variance on the rating of *Stenocarpella maydis* ear rot reactions on inbred lines showed significant differences among entries. At Bethlehem there was a highly significance difference (P< 0.05) among entries (Appendix 8.46). Entries 43, 42, 34, 26, 32, 46, 45, 22, 50, and 16 were the most resistant lines showing resistant reaction types as compared to checks (Table 3.9). At this location entries 8, 9, 12, 11, 54, 56, 29, 2, and 18 were the most ten susceptible lines. Cedara is a hot spot area for maize diseases. At this location tested inbred lines were highly infested by other diseases like rust, grey leaf spot and *Gibberella* other than *Stenocarpella maydis* ear rot. Entries 58, 57, 56, 40, 54, 53, 52, 51, 21 and 20 were the most resistant lines (Table 3.9). Entries 24, 23, 2, 36, 55, 4, 1 and 15 were the most susceptible lines. At Potchefstroom entries had significant differences at (P< 0.05) for *Stenocarpella maydis* ear rot reaction (Appendix 8.48). Entries 48, 57, 49, 52, 18, 52, 32, 45 and, 2 were found to be most resistant (Table 3.9). While entries 50, 47, 42, 5, 3, 6, 10, 12, 19, 20, 25, 29, 34 and 37 were the most susceptible inbred lines.

Table 3.9 *Stenocarpella maydis* ear rot responses of 58 maize inbred lines to natural *Stenocarpella* ear rot infection at Bethlehem, Cedara and Potchefstroom during 2005/06

	Location							Location					
	Beth		Cedara		Potch			Beth		Cedara		Potch	
Entry	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**	**Entry**	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**
1	2.00	3	1.67	2	1.33	2	30	1.00	2	1.00	2	1.33	2
2	2.33	3	2.33	3	1.00	2	31	1.00	2	1.00	2	1.33	2
3	1.33	2	1.33	2	2.00	3	32	1.00	2	1.33	2	1.00	2
4	1.67	2	2.00	3	1.67	2	33	1.67	2	1.00	2	1.67	2
5	1.33	2	1.00	2	2.33	3	34	1.00	2	1.00	2	2.00	3
6	1.67	2	1.00	2	2.00	3	35	1.67	2	1.33	2	1.67	2
7	2.00	3	1.33	2	1.67	2	36	1.33	2	2.33	3	1.67	2
8	3.33	3	1.00	2	1.33	2	37	1.33	2	1.00	2	2.00	3
9	3.33	3	1.00	2	1.67	2	38	1.33	2	1.00	2	1.67	2
10	2.00	3	1.00	2	2.00	3	39	1.67	2	1.00	2	1.67	2
11	3.00	3	1.00	2	1.33	2	40	2.00	3	1.00	2	1.33	2
12	3.33	3	1.00	2	2.00	3	41	1.67	2	1.33	2	1.67	2
13	1.67	2	1.33	2	1.67	2	42	1.00	2	1.00	2	2.33	3
14	1.67	2	1.00	2	2.67	3	43	1.00	2	1.33	2	1.67	2
15	1.67	2	1.67	2	1.67	2	44	1.67	2	1.33	2	2.33	3
16	1.00	2	1.00	2	1.33	2	45	1.00	2	1.00	2	1.00	2
17	1.33	2	1.33	2	1.67	2	46	1.00	2	1.00	2	1.33	2
18	2.33	3	1.00	2	1.00	2	47	1.67	2	1.00	2	2.33	3
19	1.00	2	1.00	2	2.00	3	48	1.67	2	1.00	2	1.00	2
20	1.33	2	1.00	2	2.00	3	49	1.67	2	1.33	2	1.00	2
21	2.33	3	1.00	2	3.00	3	50	1.00	2	1.33	2	2.33	3
22	1.00	2	1.00	2	1.67	2	51	2.00	3	1.00	2	1.67	2
23	1.33	2	2.67	3	1.33	2	52	2.00	3	1.00	2	1.00	2
24	2.00	3	3.00	3	1.67	2	53	1.33	2	1.00	2	1.33	2
25	1.33	2	1.33	2	2.00	3	54	2.67	3	1.00	2	1.67	2
26	1.00	2	1.33	2	1.67	2	55	2.00	3	2.33	3	1.67	2
27	2.00	3	1.00	2	2.00	3	56	2.67	3	1.00	2	1.33	2
28	1.33	2	1.33	2	1.33	2	57	1.67	2	1.00	2	1.00	2
29	2.33	3	1.33	2	2.00	3	58	2.33	3	1.00	2	1.33	2
							LSD	**1.5148**		**0.7717**		**1.0890**	
							C.V. %	**65.54**		**45.29**		**48.59**	
							R^2 (%)	**33.96**		**49.52**		**40.20**	

WA = weighted average, VR = visual rating, LSD = Least Significance difference, C.V.% = percent coefficient of variation, and R^2% = percent R squared

3.4.5 Mean grain yield (tons ha^{-1}) response of 58 maize top cross hybrids evaluated under natural infestation at Bethlehem, Cedara and Potchefstroom

There was a significant difference ($P< 0.05$) between top cross hybrids at Bethlehem for grain yield (Appendix 8.43). Entries 8, 28, 49, 4, 56, 12, 9, 34, 42 and 21 showed yields of 5.94, 5.80, 5.80, 5.65, 5.58, 5.50, 5.48, 5.42, 5.40 and 37 tons ha^{-1}, respectively (Table 3.10). Top cross hybrids showed significance difference ($P< 0.05$) at Cedara (Appendix 8.44). Entries 58, 24, 3, 23, 57, 26, 16, 27, 56 and 28 had heights grain yields (Table 3.10) showing 7.15, 6.61, 6.26, 6.23, 6.11, 6.06, 5.94, 5.91, 5.90 and 5.80 tons ha^{-1}, respectively. At Potchefstroom the top cross hybrids showed significance difference ($P< 0.05$) (Appendix 8.45). Entries 56, 28, 14, 30, 27, 23, 38, 49, 58 and 3 had the heights grain yields of 9.95, 9.35, 9.33, 9.21, 9.11, 8.83, 8.69, 8.67, 8.67 and 8.63 tons ha^{-1}, respectively (Table 3.10).

Table 3.10 Mean grain yield (tons ha^{-1}) response and ranks of 58 maize top cross hybrids tested under natural infestation at Bethlehem, Cedara and Potchefstroom during 2005/06.

	Location							Location					
	Bethlehem		Cedara		Pothefstroom			Bethlehem		Cedara		Potchfestroom	
Entry	**GY t ha^{-1}**	**Rank**	**GY t ha^{-1}**	**Rank**	**GY t ha^{-1}**	**Rank**	**Entry**	**GY t ha^{-1}**	**Rank**	**GY t ha^{-1}**	**Rank**	**GY t ha^{-1}**	**Rank**
1	4.38	37	5.23	34	7.95	24	30	3.95	51	4.69	54	9.21	4
2	4.70	24	5.51	21	7.82	33	31	3.35	58	5.06	40	7.84	31
3	4.68	25	6.27	3	8.63	10	32	4.62	27	4.92	47	6.69	58
4	5.65	4	5.50	22	7.02	52	33	4.57	31	5.06	39	8.17	18
5	4.08	46	5.05	41	6.69	58	34	5.42	8	4.87	49	7.59	37
6	4.39	35	4.44	55	7.81	34	35	4.60	28	5.39	24	8.34	12
7	4.85	20	5.00	43	7.51	39	36	3.61	53	4.87	48	7.87	28
8	5.94	1	5.27	30	7.32	42	37	4.38	36	4.74	53	7.20	48
9	5.48	7	5.27	31	7.25	43	38	3.99	50	5.26	32	8.69	7
10	4.32	39	5.58	16	6.90	54	39	4.90	19	5.30	29	8.02	22
11	4.03	48	1.80	58	7.16	50	40	4.08	45	4.83	51	7.82	32
12	5.50	6	5.66	15	7.17	49	41	3.41	55	4.83	50	7.79	35
13	5.08	13	4.74	52	8.33	13	42	5.40	9	4.96	45	7.95	25
14	3.50	54	5.67	14	9.33	3	43	4.92	18	5.21	35	7.89	26
15	3.75	52	5.69	13	7.72	36	44	5.11	12	5.07	38	6.98	53
16	4.84	21	5.94	7	7.21	46	45	4.59	29	5.57	17	8.02	21
17	4.29	41	2.18	57	8.00	23	46	4.95	16	5.52	19	8.17	17
18	4.57	30	5.09	37	7.42	40	47	4.62	26	5.50	23	8.11	19
19	3.39	56	4.99	44	8.39	11	48	4.32	38	5.26	33	7.55	38
20	5.21	11	5.02	42	7.20	47	49	5.80	3	5.51	20	8.67	8
21	5.37	10	5.33	27	7.41	41	50	4.01	49	5.30	28	7.23	44
22	4.06	47	4.93	46	7.22	45	51	4.17	42	5.71	12	8.26	14
23	4.49	34	6.23	4	8.83	6	52	4.75	23	5.16	36	8.25	15
24	4.31	40	6.61	2	6.75	56	53	4.52	33	5.79	11	7.04	51
25	4.79	22	5.55	18	7.87	30	54	4.09	44	4.06	56	7.88	27
26	4.55	32	6.06	6	7.87	29	55	4.17	43	5.35	25	6.81	55
27	5.02	15	5.91	8	9.11	5	56	5.58	5	5.90	9	9.95	1
28	5.80	2	5.80	10	9.35	2	57	3.36	57	6.11	5	8.21	16
29	4.94	17	5.34	26	8.10	20	58	5.03	14	7.15	1	8.67	9
							LSD	1.0028		0.5038		1.3696	
							C.V. (%)	16.13		7.08		12.86	
							R^2 (%)	55.91		87.95		47.53	

GY= Grain yield, t ha^{-1} =tons per hectare, LSD=Least significance difference, CV%= percent coefficient of variation and $R\%^2$= percent R squared

3.4.6 *Stenocarpella maydis* ear rot reaction of 58 maize top cross hybrids evaluated under natural infestation at Bethlehem, Cedara and Potchefstroom

The top cross hybrids were significantly different (P< 0.05) (Appendix 8.49) at Bethlehem. Entries 57, 58, 56, 20, 21, 31, 42, 35, 36 and 5 were the most resistant top crosses while entries 24, 53, 15, 45, 26, 3, 41, 23, 49 and 55 were the most susceptible top cross hybrids (Table 3.11). At Cedara there was a significance difference between top crosses (P< 0.05) (Appendix 8.50). Entries 57, 58, 2, 4, 5, 25, 31, 42, 35 and 47 were the most resistant top cross hybrids, entry 17 was the most susceptible top cross (Table 3.11). There was a significance difference (P< 0.05) (Appendix 8.51) amongst the top cross hybrids at Potchefstroom. Entries 58, 3, 33, 39, 40, 30, 28, 39 and 14 were the most resistant top cross while entries 47, 51, 26, 27, 36, 5, 23, 29 and 32 were the most susceptible top cross hybrids (Table 3.12) all the across three locations (Bethlehem, Cedara and Potchefstroom).

Table 3.11 ***Stenocarpella maydis*** **ear rot responses of 58 maize top cross hybrids to natural** ***Stenocarpella*** **ear rot infection at Bethlehem, Cedara and Potchefstroom during 2005/06**

	Average severity and rating							Average severity and rating					
	Bethlehem		Cedara		Potchefstroom			Bethlehem		Cedara		Potchefstroom	
Entry	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**	**Entry**	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**
1	1.00	2	1.00	2	2.33	3	30	2.00	3	1.00	2	1.00	2
2	1.00	2	1.00	2	1.67	2	31	1.00	2	1.00	2	2.33	3
3	2.33	3	1.00	2	1.00	2	32	1.00	2	1.00	2	2.67	4
4	1.67	2	1.00	2	1.33	2	33	1.33	2	1.00	2	1.67	2
5	1.00	2	1.00	2	2.67	3	34	1.33	2	1.00	2	1.33	2
6	1.67	2	1.00	2	1.00	2	35	1.00	2	1.00	2	2.33	3
7	1.67	2	1.00	2	2.33	3	36	1.00	2	1.00	2	3.00	3
8	1.00	3	1.00	2	1.00	2	37	1.67	2	1.00	2	1.00	2
9	1.00	2	1.00	2	1.00	3	38	1.67	2	1.00	2	2.00	3
10	1.67	2	1.00	2	1.33	2	39	1.33	2	1.00	2	1.00	2
11	1.33	2	1.00	2	1.00	3	40	1.00	2	1.00	2	1.00	2
12	1.33	2	1.00	2	1.33	2	41	2.33	3	1.00	2	1.67	2
13	1.33	2	1.00	2	1.33	2	42	1.00	2	1.00	2	1.67	2
14	1.67	2	1.00	2	1.00	2	43	2.00	3	1.00	2	2.00	3
15	2.67	3	1.00	2	1.67	2	44	2.00	3	1.00	2	1.00	2
16	1.67	2	1.00	2	1.00	2	45	2.67	3	1.00	2	1.67	2
17	1.33	2	2.33	3	1.00	2	46	1.67	2	1.00	2	1.67	2
18	1.33	2	1.00	2	1.00	2	47	1.00	2	1.00	2	3.33	4
19	1.00	2	1.00	2	1.67	2	48	1.67	2	1.00	2	1.33	2
20	1.00	2	1.00	2	1.33	2	49	2.33	3	1.00	2	2.33	3
21	1.00	2	1.00	2	1.67	2	50	1.33	2	1.00	2	1.67	2
22	2.00	3	1.00	2	1.33	2	51	1.33	2	1.00	2	3.33	4
23	2.33	3	1.00	2	2.67	3	52	1.33	2	1.00	2	1.67	2
24	3.00	3	1.00	2	1.67	2	53	3.00	3	1.00	2	1.67	2
25	1.00	2	1.00	2	2.00	3	54	1.67	2	1.00	2	1.67	2
26	2.67	3	1.00	2	3.33	3	55	2.33	3	1.00	2	2.33	3
27	2.33	3	1.00	2	3.33	3	56	1.00	2	1.67	2	1.67	2
28	1.67	2	1.00	2	1.00	2	57	1.00	2	1.00	2	1.33	2
29	1.67	2	1.00	2	2.67	3	58	1.00	2	1.00	2	1.00	2
							LSD	**1.2094**		**0.2279**		**1.6140**	
							C.V. %	**56.11**		**16.27**		**67.78**	
							R^2%	**38.56**		**67.02**		**34.11**	

WA = weighted average, VR = visual rating, LSD = Least Significance difference, C.V.% = percent coefficient of variation, and R^2% = percent R squared

Table 3.12 ***Stenocarpella maydis*** **ear rot incidence among 58 inbred lines and 58 top cross hybrids tested under natural infestation at Bethlehem, Cedara and Potchefstroom.**

Entry	Inbred lines Disease rating		Top cross hybrids Disease rating		Entry	Inbred lines Disease rating		Top cross hybrids Disease rating	
	WA	VR	WA	VR		WA	VR	WA	VR
1	2.33	3	1.44	2	30	1.67	2	1.33	2
2	2.00	3	1.22	2	31	1.17	2	1.44	2
3	1.33	2	1.44	2	32	1.17	2	1.56	2
4	1.67	2	1.33	2	33	1.50	2	1.33	2
5	1.17	2	1.56	2	34	1.00	2	1.22	2
6	2.33	3	1.22	2	35	1.33	2	1.44	2
7	2.00	3	1.67	3	36	1.17	2	1.67	3
8	2.17	3	1.33	2	37	1.33	2	1.22	2
9	2.67	3	1.33	2	38	1.67	2	1.56	2
10	3.00	3	1.33	2	39	1.50	2	1.11	2
11	2.33	3	1.44	2	40	1.67	2	1.00	2
12	2.33	3	1.22	2	41	1.00	3	1.67	2
13	1.50	3	1.22	2	42	1.50	2	1.22	2
14	2.17	3	1.22	2	43	1.00	2	1.67	3
15	1.67	2	1.78	3	44	1.67	2	1.33	2
16	1.50	2	1.22	2	45	1.50	2	1.78	3
17	1.17	2	1.56	2	46	1.50	2	1.44	2
18	2.00	3	1.11	2	47	1.50	2	1.78	3
19	1.17	2	1.22	2	48	1.50	2	1.33	2
20	1.50	2	1.11	2	49	1.83	2	1.89	3
21	1.83	2	1.22	2	50	1.33	2	1.33	2
22	1.00	2	1.22	2	51	1.67	2	1.89	3
23	1.50	2	2.00	3	52	1.83	2	1.33	2
24	1.67	2	1.89	2	53	1.67	2	1.89	3
25	1.50	2	1.33	2	54	2.17	3	1.44	2
26	1.17	2	2.33	3	55	1.67	2	1.89	3
27	1.67	2	2.22	3	56	2.00	3	1.44	2
28	2.00	3	1.22	2	57	1.50	2	1.11	2
29	1.67	2	1.78	3	58	1.83	2	1.00	2
					LSD	**0.1941**		**0.6729**	
					C.V %	**65.65**		**59.21**	
					R^2%	**0.3204**		**43.54**	

WA: weighted average, VR: visual rating, LSD: Least Significance difference, C.V.%: percent coefficient of variation, and R^2%: percent R squared

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3.4.7 Mean grain yield (tons ha^{-1}) response of 58 maize inbred lines and 58 top cross hybrids with inoculation by *Stenocarpella maydis* ear rot pathogen at Potchefstroom

In Potchefstroom two inoculation levels/methods (non-inoculation and inoculation) were compared and there was a highly significance difference (P< 0.05) amongst the levels on grain yield (Appendices 8.60). For the inbred lines entry 4 out yielded all other entries with 4.55 t ha^{-1} followed by entries 51, 48, 7, 42, 23, 18, 37, 53 and 57 with 4.40, 4.13, 3.82, 3.80, 3.75, 3.73, 3.60 and 3.46 tons ha^{-1}, respectively (Tables 3.13[a]). For the top cross hybrids there entries were significantly different (P< 0.05) (Appendix 8.64). Entry 17 was the first with 7.76 tons ha^{-1} followed by entries 16, 39, 33, 35, 49, 32 and 57 showing 7.22, 6.94, 6.91, 6.85, 6.82. 6.79, 6.76 and 6.71 tons ha^{-1} (Tables 3.13[a], 3.13[b] and 3.13[c]). When two inoculation levels compared on the inbred lines: entries, inoculation levels and blocks in inoculation showed a highly significance difference (P< 0.05) (Appendix 8.61). Further, there was no interaction effect between entries and inoculation methods. When the two inoculation levels were compared using top crosses entries and blocks within inoculation methods were highly significant (P< 0.05) (Appendix 8.66), while inoculation method was not significantly different and there was no interaction effect between inoculation methods and entries.

Table 3.13[a] Mean grain yield (tons ha^{-1}) responses and ranks among 58 inbred lines and 58 top cross hybrids of maize when tested with inoculation by *Stenocarpella maydis* ear rot pathogen at Potchefstroom.

	Inbred lines		Top cross hybrids			Inbred lines		Top cross hybrids	
Entry	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank	Entry	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank
1	2.67	47	5.16	35	30	2.79	42	4.48	47
2	3.02	31	4.05	54	31	2.67	48	4.07	53
3	3.26	20	4.30	51	32	2.76	44	6.72	9
4	4.55	1	5.15	36	33	3.18	23	6.91	4
5	2.48	53	5.35	31	34	1.61	58	5.12	37
6	3.40	15	5.10	38	35	2.38	55	6.85	5
7	3.98	4	3.42	57	36	3.00	32	5.67	29
8	2.69	16	3.36	58	37	3.73	8	5.80	24
9	3.45	12	4.88	41	38	3.30	18	6.68	11
10	3.11	25	3.83	55	39	2.83	40	6.94	3
11	2.69	45	3.63	56	40	3.05	30	4.10	52
12	3.00	33	5.02	39	41	3.46	11	4.45	48
13	3.95	36	6.55	17	42	3.82	5	4.53	45
14	2.93	37	6.63	15	43	2.98	34	6.57	17
15	2.33	56	5.18	34	44	2.44	54	4.75	44
16	3.09	28	7.22	2	45	2.56	50	5.68	28
17	3.30	19	7.76	1	46	2.95	35	4.91	40
18	3.75	7	6.63	13	47	2.54	51	6.19	20
19	3.45	13	5.87	23	48	4.13	3	6.63	14
20	3.11	27	6.65	12	49	3.06	29	6.79	7
21	2.51	52	5.80	25	50	2.01	57	5.75	26
22	2.60	49	6.04	21	51	4.40	2	4.37	50
23	3.80	6	4.50	46	52	2.82	41	6.76	8
24	3.35	16	6.51	18	53	3.60	9	5.69	27
25	3.42	13	4.83	42	54	3.19	22	6.82	6
26	2.87	38	4.78	43	55	3.20	21	5.25	33
27	3.11	26	6.26	19	56	3.34	17	5.33	32
28	2.79	42	5.58	30	57	3.46	10	6.71	10
29	3.17	24	5.90	22	58	2.85	39	4.42	49
					LSD	**1.1038**		**2.7152**	
					C.V %	**26.49**		**36.24**	
					R^2 %	**41.95**		**32.74**	

GY t ha^{-1}: grain yield tons per hectare, LSD: Least Significance Difference, C.V.%: percent Coefficient of Variation and R^2%: percent R squared

Table 3.13[b] Mean grain yield (tons ha^{-1}) responses and ranks among 58 inbred lines of maize when tested without and with inoculation by *Stenocarpella maydis* ear rot pathogen at Potchefstroom.

	Without inoculation		With inoculation			Without inoculation		With inoculation	
Entry	**GY t ha^{-1}**	**Rank**	**GY t ha^{-1}**	**Rank**	**Entry**	**GY t ha^{-1}**	**Rank**	**GY t ha^{-1}**	**Rank**
1	4.39	4	2.67	47	30	3.33	25	2.79	42
2	4.15	6	3.02	31	31	3.80	14	2.67	48
3	3.62	20	3.26	20	32	2.91	44	2.76	44
4	4.58	1	4.55	1	33	2.63	51	3.18	23
5	2.92	43	2.48	53	34	2.60	52	1.61	58
6	3.80	13	3.40	15	35	2.09	55	2.38	55
7	2.76	48	3.98	4	36	3.24	31	3.00	32
8	2.66	50	2.69	16	37	3.78	15	3.73	8
9	2.98	40	3.45	12	38	2.52	53	3.30	18
10	2.97	42	3.11	25	39	3.71	17	2.83	40
11	3.27	20	2.69	45	40	2.74	49	3.05	30
12	2.79	47	3.00	33	41	2.91	45	3.46	11
13	3.37	23	3.95	36	42	3.34	24	3.82	5
14	3.86	12	2.93	37	43	3.00	39	2.98	34
15	4.56	2	2.33	56	44	3.71	18	2.44	54
16	3.99	9	3.09	28	45	2.50	54	2.56	50
17	1.86	57	3.30	19	46	3.31	26	2.95	35
18	3.68	19	3.75	7	47	4.42	3	2.54	51
19	3.28	29	3.45	13	48	2.97	41	4.13	3
20	4.00	8	3.11	27	49	3.30	28	3.06	29
21	4.15	7	2.51	52	50	3.30	27	2.01	57
22	3.12	32	2.60	49	51	3.07	36	4.40	2
23	3.73	16	3.80	6	52	3.93	10	2.82	41
24	3.14	34	3.35	16	53	3.89	11	3.60	9
25	3.46	22	3.42	13	54	3.05	37	3.19	22
26	3.01	38	2.87	38	55	3.49	21	3.20	21
27	1.64	58	3.11	26	56	4.34	5	3.34	17
28	3.18	33	2.79	42	57	2.89	46	3.46	10
29	1.91	56	3.17	24	58	3.10	35	2.85	39
					LSD	**0.9080**		**1.1038**	
					C.V %	**20.39**		**26.49**	
					R^2 %	**59.53**		**41.95**	

Table 3.13[c] Mean grain yield (tons ha^{-1}) responses and ranks among 58 top cross hybrids of maize when tested without and with inoculation by *Stenocarpella maydis* ear rot pathogen at Potchefstroom.

	Without inoculation		With inoculation			Without inoculation		With inoculation	
Entry	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank	Entry	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank
1	7.95	24	2.67	47	30	9.21	4	4.48	47
2	7.82	33	3.02	31	31	7.84	31	4.07	53
3	8.63	10	3.26	20	32	6.69	58	6.72	9
4	7.02	52	4.55	1	33	8.17	18	6.91	4
5	6.69	58	2.48	53	34	7.59	37	5.12	37
6	7.81	34	3.40	15	35	8.34	12	6.85	5
7	7.51	39	3.98	4	36	7.87	28	5.67	29
8	7.32	42	2.69	16	37	7.20	48	5.80	24
9	7.25	43	3.45	12	38	8.69	7	6.68	11
10	6.90	54	3.11	25	39	8.02	22	6.94	3
11	7.16	50	2.69	45	40	7.82	32	4.10	52
12	7.17	49	3.00	33	41	7.79	35	4.45	48
13	8.33	13	3.95	36	42	7.95	25	4.53	45
14	9.33	3	2.93	37	43	7.89	26	6.57	17
15	7.72	36	2.33	56	44	6.98	53	4.75	44
16	7.21	46	3.09	28	45	8.02	21	5.68	28
17	8.00	23	3.30	19	46	8.17	17	4.91	40
18	7.42	40	3.75	7	47	8.11	19	6.19	20
19	8.39	11	3.45	13	48	7.55	38	6.63	14
20	7.20	47	3.11	27	49	8.67	8	6.79	7
21	7.41	41	2.51	52	50	7.23	44	5.75	26
22	7.22	45	2.60	49	51	8.26	14	4.37	50
23	8.83	6	3.80	6	52	8.25	15	6.76	8
24	6.75	56	3.35	16	53	7.04	51	5.69	27
25	7.87	30	3.42	13	54	7.88	27	6.82	6
26	7.87	29	2.87	38	55	6.81	55	5.25	33
27	9.11	5	3.11	26	56	9.95	1	5.33	32
28	9.35	2	2.79	42	57	8.21	16	6.71	10
29	8.10	20	3.17	24	58	8.67	9	4.42	49
					LSD	**1.3696**		**2.7152**	
					C.V %	**12.86**		**36.24**	
					R^2 %	**47.53**		**32.74**	

3.4.8 *Stenocarpella* ear rot response of 58 maize inbred lines and 58 top cross hybrids with inoculation by *Stenocarpella maydis* ear rot pathogen at Potchefstroom

When inoculation methods were compared on inbred lines for ear rot resistance there was a highly significance difference ($P< 0.05$) between entries and there was no interaction effect between entries and inoculation methods (Appendix 8.63), but there was a significance difference between inoculation levels/methods. When analysis of variance was conducted for the top cross hybrids there was no significance difference between entries and there was no interaction effect between entries and inoculation methods (Appendix 8.67), but there was a significance difference between inoculation methods (Table 3.14[a], 3.14[b] and 3.14[c]).

Table 3.14[a] Mean response among 58 maize inbred lines for ear rot reaction with inoculation by *Stenocarpella maydis* ear rot pathogen at Potchefstroom.

	Inbred lines		Top cross hybrids			Inbred lines		Top cross hybrids	
	Disease rating		Disease rating			Disease rating		Disease rating	
Entry	**WA**	**VR**	**WA**	**VR**	**Entry**	**WA**	**VR**	**WA**	**VR**
1	2.67	3	2.33	3	30	2.33	3	1.00	2
2	1.67	2	1.67	2	31	1.33	2	2.33	3
3	1.00	2	1.00	2	32	1.33	2	2.67	3
4	1.67	2	1.33	2	33	1.33	2	1.67	2
5	1.00	2	2.67	3	34	1.00	2	1.33	2
6	3.00	3	1.00	2	35	1.00	2	2.33	3
7	2.00	3	2.33	3	36	1.00	2	3.00	3
8	1.00	2	1.00	2	37	1.33	2	1.00	2
9	2.00	3	1.00	3	38	2.00	3	2.00	2
10	4.00	4	1.33	2	39	1.33	2	1.00	2
11	1.67	2	2.00	3	40	1.33	2	1.00	2
12	1.33	2	1.33	2	41	2.33	3	1.67	2
13	1.33	2	1.33	2	42	2.00	3	1.67	2
14	2.67	3	1.00	2	43	1.00	2	2.00	3
15	1.67	2	1.67	2	44	1.67	2	1.00	2
16	2.00	3	1.00	2	45	2.00	3	1.67	2
17	1.00	2	1.00	2	46	2.00	3	1.67	2
18	1.67	2	1.00	2	47	1.33	2	3.33	3
19	1.33	2	1.67	2	48	1.33	2	1.33	2
20	1.67	2	1.33	2	49	2.00	3	2.33	3
21	1.33	2	1.67	2	50	1.67	2	1.67	2
22	1.00	2	1.33	2	51	1.33	2	3.33	3
23	1.67	2	2.67	3	52	1.67	2	1.67	2
24	1.33	2	1.67	2	53	2.00	3	1.67	2
25	1.67	2	2.00	3	54	1.67	2	1.67	2
26	1.33	2	3.33	3	55	1.33	2	2.33	3
27	1.33	2	3.33	3	56	1.33	2	1.67	2
28	2.67	3	1.00	2	57	1.33	2	1.33	2
29	1.00	2	2.67	3	58	1.33	2	1.00	2
					LSD	**1.4525**		**1.6140**	
					C.V%	**65.72**		**67.78**	
					R%	**29.64**		**34.11**	

WA: weighted average, VR: visual rating, LSD: Least Significance difference, C.V.%: percent coefficient of variation, and R^2%: percent R squared

Table 3.14[b] Mean response among 58 maize inbred lines for ear rot reaction without and with inoculation by *Stenocarpella maydis* ear rot pathogen at Potchefstroom.

	Without inoculation		With inoculation			Without inoculation		With inoculation	
	Disease rating		Disease rating			Disease rating		Disease rating	
Entry	WA	VR	WA	VR	Entry	WA	VR	WA	VR
1	1.33	2	2.67	3	30	1.33	2	2.33	3
2	1.00	2	1.67	2	31	1.33	2	1.33	2
3	2.00	3	1.00	2	32	1.00	2	1.33	2
4	1.67	2	1.67	2	33	1.67	2	1.33	2
5	2.33	3	1.00	2	34	2.00	3	1.00	2
6	2.00	3	3.00	3	35	1.67	2	1.00	2
7	1.67	2	2.00	3	36	1.67	2	1.00	2
8	1.33	2	1.00	2	37	2.00	3	1.33	2
9	1.67	2	2.00	3	38	1.67	2	2.00	3
10	2.00	3	4.00	4	39	1.67	2	1.33	2
11	1.33	2	1.67	2	40	1.33	2	1.33	2
12	2.00	3	1.33	2	41	1.67	2	2.33	3
13	1.67	2	1.33	2	42	2.33	3	2.00	3
14	2.67	3	2.67	3	43	1.67	2	1.00	2
15	1.67	2	1.67	2	44	2.33	3	1.67	2
16	1.33	2	2.00	3	45	1.00	2	2.00	3
17	1.67	2	1.00	2	46	1.33	2	2.00	3
18	1.00	2	1.67	2	47	2.33	3	1.33	2
19	2.00	3	1.33	2	48	1.00	2	1.33	2
20	2.00	3	1.67	2	49	1.00	2	2.00	3
21	3.00	3	1.33	2	50	2.33	3	1.67	2
22	1.67	2	1.00	2	51	1.67	2	1.33	2
23	1.33	2	1.67	2	52	1.00	2	1.67	2
24	1.67	2	1.33	2	53	1.33	2	2.00	3
25	2.00	3	1.67	2	54	1.67	2	1.67	2
26	1.67	2	1.33	2	55	1.67	2	1.33	2
27	2.00	3	1.33	2	56	1.33	2	1.33	2
28	1.33	2	2.67	3	57	1.00	2	1.33	2
29	2.00	3	1.00	2	58	1.33	2	1.33	2
					LSD	**1.0890**			
					C.V %	**48.59**			
					R^2 %	**40.20**			

Table 3.14[c] Mean response among 58 maize top cross hybrids for ear rot reaction without and with inoculation by *Stenocarpella maydis* ear rot pathogen at Potchefstroom.

	Without inoculation		With inoculation			Without inoculation		With inoculation	
	Disease rating		Disease rating			Disease rating		Disease rating	
Entry	WA	VR	WA	VR	Entry	WA	VR	WA	VR
1	2.33	3	3.00	3	30	1.00	2	2.00	2
2	1.67	2	2.00	3	31	2.33	3	2.33	3
3	1.00	2	3.67	3	32	2.67	4	3.33	3
4	1.33	2	3.00	3	33	1.67	2	2.00	3
5	2.67	3	1.67	2	34	1.33	2	2.00	3
6	1.00	2	1.67	2	35	2.33	3	1.67	2
7	2.33	3	1.67	2	36	3.00	3	2.00	3
8	1.00	2	2.00	3	37	1.00	2	3.00	3
9	1.00	3	2.00	3	38	2.00	3	2.33	3
10	1.33	2	2.33	3	39	1.00	2	3.00	3
11	1.00	3	2.67	3	40	1.00	2	2.33	3
12	1.33	2	2.33	3	41	1.67	2	2.00	3
13	1.33	2	1.67	2	42	1.67	2	2.00	3
14	1.00	2	2.67	2	43	2.00	3	3.33	3
15	1.67	2	2.00	3	44	1.00	2	2.00	3
16	1.00	2	2.33	3	45	1.67	2	2.00	3
17	1.00	2	2.00	3	46	1.67	2	2.33	3
18	1.00	2	1.67	2	47	3.33	4	3.00	3
19	1.67	2	2.67	3	48	1.33	2	2.00	3
20	1.33	2	2.67	3	49	2.33	3	1.33	2
21	1.67	2	2.67	3	50	1.67	2	2.33	3
22	1.33	2	3.33	3	51	3.33	4	3.00	3
23	2.67	3	2.67	3	52	1.67	2	2.33	3
24	1.67	2	2.33	3	53	1.67	2	1.67	2
25	2.00	3	3.33	3	54	1.67	2	2.33	3
26	3.33	3	2.33	3	55	2.33	3	2.33	3
27	3.33	3	2.67	3	56	1.67	2	3.00	3
28	1.00	2	2.67	3	57	1.33	2	1.33	2
29	2.67	3	2.33	3	58	1.00	2	1.67	2
					LSD	**1.6140**		**1.6140**	
					C.V %	**67.78**		**67.78**	
					R^2 %	**34.11**		**34.11**	

3.4.9 Grain yield and *Stenocarpella maydis* stability analysis and cultivar superiority of 58 maize inbred lines and 58 top cross hybrids over two years at Bethlehem, Cedara and Potchefstroom under natural infestation

During the study the Eberhart-Russell regression analysis (Eberhart and Russell, 1966) and Lin and Binns' superiority parameter (Lin and Binns, 1988) were carried out to establish the yield stability of entries in the three environments. The parameter of Eberhart and Russell (1966) is based on the regression of each genotypic yield on the environmental index (the mean yield at each environment). According to Eberhart and Russell (1966), a stable cultivar has a regression coefficient close to unity (bi=1), minimum deviation from regression ($\Sigma s^2 di=0$) and high mean yield. Lin and Binns' (1988) superiority parameter (P_i) is the squared difference between cultivar's yield and the maximum yield within each environment, averaged over all environments. Genotypes with broader adaptation have lower values of this superiority parameter, because they yield closer to the maximum within each environment, relative to genotypes with poor adaptation to the target environments.

Consequently for grain yield entries 43, 2, 15, 16, 47, 2, 56 and 14 showed to be stable inbred lines. While entries 9, 25, 51, 49, 42, 45, 28, 32, 20 and 15 had a less deviation from the regression line (Table 15). Entries 47, 4, 2, 21, 53, 56, 37, 11, 2, 20 and 15 showed to be superior inbred lines with the lowest P_i value. For the grain yield of top hybrids entries 57, 14, 19, 31, 23, 15, 58, 38, 41, 51, 3, 30 and 36 were found to be the most stable entries. While entries 46, 47, 39, 29, 1, 45, 25, 2, 43 and 22 had the least deviation from the regression line (Table 3.16) Entries 56, 28, 58, 27, 3, 23, 49, 46, 35, 29 and 47 were found the most superior top cross hybrids with the lowest P_i value. The superior inbred lines for *Stenocarpella maydis* ear rot were entries 10, 1, 6, 9, 14, 11, 41, 54, 7 and 28. While superior top cross hybrids for *Stenocarpella maydis* ear rot were entries 26, 27, 23, 49, 55, 29, 51, 7, 15 and 24 (Table 3.17).

Table 3.15 Estimates of stability parameters and cultivar superiority proposed by Eberhart and Russell (1966) and Lin and Binns (1988) for grain yield (t ha^{-1}) of 58 maize inbred lines evaluated in two environments over two years under natural infestation

	Eberhart and Russell (1966)				Lin and Binns (1988)			Eberhart and Russell (1966)				Lin and Binns (1988)	
Entry	β_i	Rank	σ	Rank	P_i value	Rank	Entry	β_i	Rank	σ	Rank	P_i value	Rank
1	1.3817	4	0.4946	50	0.7448	23	30	1.1269	17	-0.0651	14	1.1153	45
2	1.2862	8	0.1213	41	0.4859	8	31	1.1664	15	-0.0315	22	0.6450	14
3	0.9819	28	0.0567	35	0.7580	25	32	0.9340	33	-0.0853	8	1.1996	49
4	1.5313	2	-0.0197	23	0.2862	2	33	0.7417	50	0.2129	47	1.0810	42
5	0.9100	36	-0.0423	18	1.3494	53	34	0.6745	55	0.0734	36	1.2267	52
6	1.1825	12	0.0128	27	0.7122	18	35	0.6463	56	0.08271	37	1.6091	54
7	0.7268	51	-0.0402	19	1.0882	43	36	0.9800	29	0.0395	34	0.9893	40
8	0.7087	53	0.0261	29	1.1722	47	37	1.0729	22	-0.0430	17	0.4725	6
9	0.8235	47	-0.0997	1	0.9643	37	38	0.7129	52	0.3998	49	1.1126	44
10	0.8650	42	-0.0719	13	1.2021	50	39	1.1902	11	0.0308	31	0.8635	34
11	0.9002	37	0.0337	32	0.4748	7	40	0.8552	43	-0.0787	11	1.2255	51
12	0.8255	46	0.2055	46	0.8765	35	41	0.7664	49	0.0270	30	0.7974	29
13	1.1599	16	-0.0402	20	1.1388	46	42	1.0195	25	-0.0878	5	0.8499	32
14	1.2313	10	0.1552	43	0.8206	31	43	1.5340	1	0.5745	54	0.9854	39
15	1.4122	3	0.5203	51	0.5763	10	44	1.1108	19	0.3815	48	0.7656	26
16	1.3204	6	0.1595	44	0.8528	33	45	0.8539	44	-0.0861	6	1.6774	55
17	0.7894	48	0.5667	53	2.4743	58	46	0.8361	45	-0.0534	15	0.7761	27
18	1.0918	21	-0.0038	26	0.6342	12	47	1.3153	7	0.1167	40	0.0363	1
19	0.9656	30	-0.0795	10	0.7545	24	48	0.8714	40	-0.0779	12	0.8822	36
20	0.9366	32	0.1798	45	0.4965	9	49	0.9119	35	-0.0909	4	0.6479	15
21	1.0386	24	0.0233	28	0.3152	3	50	0.9454	31	-0.0399	21	0.8081	30
22	0.8681	41	-0.0828	9	0.6420	13	51	0.9247	34	-0.0916	3	0.9683	38
23	1.1683	14	-0.0158	24	0.7401	21	52	1.1240	18	0.6728	56	0.7290	19
24	0.8909	38	0.0927	39	0.7322	20	53	1.0072	27	0.0871	38	0.3682	4
25	1.0117	26	-0.0949	2	0.6702	17	54	1.0949	20	-0.0094	25	1.1769	48
26	0.5455	58	0.0389	33	0.7401	22	55	1.3646	5	0.1261	42	0.5840	11
27	0.6138	57	0.9963	58	2.3471	57	56	1.2416	9	0.6591	55	0.3693	5
28	0.8796	39	-0.0855	7	0.6641	16	57	1.1744	13	0.5491	52	0.7880	28
29	0.6812	54	0.881	57	1.8962	56	58	1.0688	23	-0.0487	16	1.0175	41
							G mean	2.429					
							C.V. %	22.64					

Table 3.16 Estimates of the stability parameters and cultivar superiority proposed by Eberhart and Russell (1966) and Lin and Binns (1988) for grain yield (t ha^{-1}) of 58 maize top cross hybrids evaluated in three environments over two years under natural infestation

	Eberhart and Russell (1966)				Lin and Binns (1988)			Eberhart and Russell (1966)				Lin and Binns (1988)	
Entry	β_i	Rank	σ	Rank	P_i value	Rank	Entry	β_i	Rank	σ	Rank	P_i value	Rank
1	1.0351	19	-0.1926	5	1.7009	27	30	1.1121	12	0.9869	54	1.7719	29
2	1.0094	29	-0.1856	8	1.4676	18	31	1.1564	4	0.1147	36	2.5933	49
3	1.1175	11	-0.0417	23	0.6875	5	32	0.9111	45	0.1300	39	2.9070	55
4	0.8360	54	0.5796	53	1.9121	34	33	1.0072	30	-0.1495	17	1.5778	24
5	0.9983	32	0.0278	29	3.0640	56	34	0.8436	53	0.1127	35	1.8480	32
6	0.6565	58	-0.0634	20	2.3925	46	35	1.0390	18	-0.1590	14	1.2530	9
7	0.9287	43	-0.1295	18	1.9761	35	36	1.1065	13	-0.0107	26	2.2002	41
8	0.7927	56	0.5231	52	1.7469	28	37	0.9554	41	-0.1685	12	2.6463	50
9	0.8516	51	0.2541	46	1.8495	33	38	1.1289	8	0.2206	45	1.4972	19
10	1.0196	25	0.2113	44	2.4108	47	39	0.9730	36	-0.1982	3	1.3799	16
11	0.7504	57	2.1130	57	6.6941	58	40	1.0346	20	-0.1557	16	2.2329	42
12	0.8221	55	0.3011	48	1.7922	31	41	1.1262	9	0.0361	30	2.7521	53
13	0.9173	44	0.0717	31	1.5341	23	42	0.8728	48	0.0148	28	1.5251	22
14	1.2080	2	1.2286	56	1.5206	21	43	0.9573	40	-0.1839	9	1.5147	20
15	1.1498	6	0.1051	34	1.9899	36	44	0.8709	49	0.2036	42	2.3195	45
16	0.9388	42	0.1656	41	1.7823	30	45	1.0396	17	-0.1895	6	1.3439	13
17	0.8456	52	2.3522	58	4.9436	57	46	0.9937	33	-0.2093	1	1.1372	8
18	0.9704	38	-0.1670	13	2.1007	39	47	1.0337	21	-0.1987	2	1.3103	11
19	1.1730	3	0.3959	50	2.2808	44	48	1.0253	23	-0.1798	11	1.9975	37
20	0.8653	50	0.1256	37	2.1147	40	49	0.9018	46	-0.1557	16	0.7265	7
21	0.8809	47	0.1006	33	1.6870	26	50	1.0538	15	-0.0750	19	2.4322	48
22	1.0161	28	-0.1821	10	2.6602	51	51	1.1203	10	-0.0368	25	1.3507	14
23	1.1514	5	0.0717	32	0.7073	6	52	0.9934	34	-0.1572	15	1.3859	17
24	1.0464	16	1.1758	55	2.2409	43	53	1.0166	27	0.2642	47	2.0651	38
25	1.0033	31	-0.1871	7	1.3779	15	54	0.9707	37	0.1489	40	2.8862	54
26	1.0229	24	-0.0496	22	1.3175	12	55	1.0168	26	0.1256	38	2.7078	52
27	1.0651	14	-0.0553	21	0.5206	4	56	1.0307	22	0.3450	49	0.2848	1
28	0.9613	39	0.0063	27	0.3715	2	57	1.2565	1	0.4872	51	1.6663	25
29	0.9751	35	-0.1975	4	1.2892	10	58	1.1410	7			0.3734	3
							G mean	6.844					
							C.V. %	11.61					

Table 3.17 Cultivar superiority proposed by Lin and Binns (1988) for *Stenocarpella maydis* ear rot reaction of 58 maize inbred lines and 58 top cross hybrids evaluated in three environments over two years under natural infestation

	Inbred lines		Top cross hybrids			Inbred lines		Top cross hybrids	
Entry	P_i value	Rank	P_i value	Rank	Entry	P_i value	Rank	P_i value	Rank
1	0.7883	2	0.9632	17	30	2.0545	24	1.3663	39
2	1.6072	11	1.4208	42	31	2.9608	49	1.1282	26
3	2.6267	44	1.2745	36	32	3.1395	53	1.0341	21
4	2.0461	21	1.1922	28	33	2.4711	39	1.2189	31
5	3.0945	51	1.0341	20	34	3.4286	55	1.4263	47
6	0.9389	3	1.4304	48	35	2.9389	48	1.0272	19
7	1.4422	9	0.6922	8	36	3.2500	54	0.9796	18
8	2.2500	32	1.3022	37	37	2.7822	47	1.4945	52
9	1.0000	4	1.1554	27	38	2.0000	2	0.8845	15
10	0.4422	1	1.1922	29	39	2.4711	40	1.6645	56
11	1.3845	6	1.0545	24	40	2.2245	29	1.8663	57
12	1.7822	14	1.4263	45	41	1.3861	7	0.8289	14
13	2.4711	38	1.4263	46	42	2.1786	26	1.4208	44
14	1.1311	6	1.4945	49	43	3.6072	57	0.7563	12
15	2.0461	22	0.7082	9	44	2.0461	23	1.3663	40
16	2.1786	25	1.4945	50	45	2.3572	35	0.7722	13
17	3.0161	50	1.3696	41	46	2.3572	36	1.0489	22
18	1.6072	12	1.6004	54	47	2.4711	41	0.9615	16
19	2.7483	46	1.4208	43	48	2.4711	42	1.2563	35
20	2.3575	37	1.5272	53	49	1.6889	13	0.5363	4
21	2.0322	19	1.3567	38	50	2.7145	45	1.2189	32
22	3.6072	56	1.0822	25	51	2.2245	30	0.6746	7
23	2.3572	33	0.4422	3	52	1.7995	15	1.2189	33
24	2.2245	27	0.7541	10	53	1.8445	16	0.7541	11
25	2.3572	34	1.2563	34	54	1.4253	8	1.0489	23
26	3.1395	52	0.3130	1	55	2.2245	31	0.5363	5
27	2.2245	28	0.3696	2	56	1.8911	17	1.1985	30
28	1.4422	10	1.4945	51	57	2.4711	43	1.6282	55
29	5.5000	58	0.6622	6	58	2.0322	20	1.8663	58

3.4.10 Line x tester analysis for grain yield and *Stenocarpella maydis* ear rot resistance of 58 inbred lines and 58 top cross hybrids evaluated under natural infestation at Bethlehem, Cedara and Potchefstroom

At Bethlehem the general combining ability (GCA) was found to be attributed by the effects of varieties. Entries 9, 29, 50, 5, 10, 35, 43, 22 and 21 respectively were the best combiners for grain yield (Table 3.18) with the grand mean of 4.587 tons ha^{-1}. While entries 32, 20, 15, 42, 37, 31, 12, 16, 23 and 41 respectively were having a poor combining ability for grain yield. At Cedara variety effects attributed the general combining ability. Entries 25, 4, 24, 16, 17, 23, 28, 29, 52 and 54 proved to have a good combining ability (Table 3.18) with the grand mean of 5.191 tons ha^{-1}. On the other hand entries 12, 18, 7, 55, 31, 41, 42, 37, 33 and 14 were found to be poor combiners.

At Potchefstroom entries 26, 52, 39, 9, 38 29, 36, 10, 48, and 44 had a good combining ability (Table 3.18) with the grand mean of 7.853 tons ha^{-1}. Entries 22, 4, 7, 15, 6, 16, 28, 37, 47, and 33 were found to be poor combiners. At Potchefstroom entries 26, 52, 39, 9, 38 29, 36, 10, 48, and 44 had a good combining ability (Table 3.18). On the other hand entries 22, 4, 7, 15, 6, 16, 28, 37, 47, and 33 were found to be poor combiners.

At Bethlehem the general combining ability (GCA) was found to be attributed by the effects of entries. Entries 25, 54, 27, 46, 16, 1, 4, 24, 28 and 42 were the best combiners for *S.maydis* ear rot resistance (Table 3.18). While entries 2, 3, 6, 21, 22, 26, 32, 33 and 10 had poor combining ability for *S.maydis* ear rot resistance. At Cedara the grain yield general combining ability (GCA) was found to be attributed by the effects of varieties. Entry 18 was found to be the best combiner for *S.maydis* ear rot (Table 3.18) resistance. At Potchefstroom the grain yield general combining ability (GCA) was found to be attributed by the effects of entries. Entries 9, 41, 48, 8, 11, 12, 16, 17, 35 and 36 were the best combiners for *S.maydis* ear rot (Table 3.19). While entries 6, 7, 20, 21, 33, 37, 44, 50 and 52 had poor combining ability to *S.maydis* ear rot resistance.

For the inoculated trial at Potchefstroom entries 17, 16, 39, 33, 20, 32, 35, 38, 49 and 54 had a good combining ability (Table.3.19). On the other hand entries 8, 7, 11, 10, 2, 31, 40, 51, 31 and. 23 were poor combiners. In non-inoculated trial entries 26, 52, 39, 9, 38 29, 36, 10, 48, and 44 were good combiners. On the other hand entries 22, 4, 7, 15, 6, 16, 28, 37, 47 and 33 were found to be poor combiners. For the inoculated trial entries 17, 16, 39, 54, 35, 49, 52, 32, 38 and 20 were best combiners. On the other hand entries 8, 7, 11, 10, 2,3, 31, 40, 41, and 42 were found to be poor combiners.

The results for non-inoculated trial on *stenocarpella maydis* ear rot were as follows the general combining ability (GCA) was found to be attributed by the effects of entries. Entries 9, 41, 48, 8, 11, 12, 16, 17, 35 and 36 were the best combiners for *S.maydis* ear rot resistance (Table 3.19). While entries 6, 7, 20, 21, 33, 37, 44, 50 and 52, were poor combining for *S.maydis* ear rot resistance. For the inoculated trial, entries 26, 27, 51, 36, 47, 5, 23, 29, 32 and 7 were found to be good combiners for *stenocarpella maydis* ear rot resistance. On the other hand entries 3, 6, 14, 16, 17, 18, 28, 39, 40 and 44 were found to be poor combiners.

Table 3.18 Combining ability estimates for grain yield (tons ha^{-1}) and *Stenocarpella maydis* ear rot reaction of 55 inbred lines evaluated in 2005/06 under natural infestation at Bethlehem, Cedara and Potchefstroom

Entry	General Combining Ability						Entry	General Combining Ability					
	Bethlehem		Cedara		Potchefstroom			Bethlehem		Cedara		Potchefstroom	
	GY[a]	ER[a]	GY[a]	ER[a]	GY[a]	ER[a]		GY[a]	ER[a]	GY[a]	ER[a]	GY[a]	ER[a]
1	-0.42	0.71	0.16	-0.02	-0.38	-0.07	29	1.22	0.04	0.61	-0.02	1.18	0.26
2	-0.21	-0.62	0.03	-0.02	-0.57	-0.07	30	0.36	0.04	0.14	-0.02	-0.23	0.59
3	0.11	-0.62	0.32	-0.02	-1.05	-0.07	31	-0.64	0.38	-0.50	-0.02	-0.21	-0.07
4	0.10	0.71	1.08	-0.02	-1.51	-0.41	32	-1.24	-0.62	-0.13	-0.02	0.71	-0.41
5	1.07	0.04	0.31	-0.02	0.17	-0.41	33	0.03	-0.62	-0.27	-0.02	-0.53	-0.74
6	-0.51	-0.62	-0.14	-0.02	-0.75	-0.74	34	-0.02	0.29	-0.13	-0.02	0.18	-0.41
7	-0.20	0.04	-0.75	-0.02	-1.34	-0.74	35	0.83	-0.29	-0.32	-0.02	0.73	0.93
8	0.26	0.04	-0.19	-0.02	-0.24	1.26	36	0.01	0.62	0.20	-0.02	0.85	0.93
9	1.36	0.38	0.08	-0.02	0.94	1.59	37	-0.98	0.62	-0.32	-0.02	-0.63	-0.74
10	0.90	-0.62	0.08	-0.02	0.78	-0.41	38	-0.21	0.04	0.45	-0.02	0.66	-0.41
11	-0.27	0.04	0.39	-0.02	-0.35	1.26	39	0.59	0.04	0.07	-0.02	1.40	0.93
12	-0.56	-0.29	-3.39	-0.02	0.33	0.93	40	0.32	-0.29	0.11	-0.02	-0.41	-0.41
13	0.92	-0.29	0.47	-0.02	-1.26	-0.07	41	-0.50	-0.62	-0.36	-0.02	0.10	1.59
14	0.49	0.29	-0.45	-0.02	-0.18	-0.07	42	-1.18	0.71	-0.36	-0.02	0.42	-0.41
15	-1.09	0.04	0.48	-0.02	-1.03	0.26	43	0.81	-0.62	-0.23	-0.02	0.38	-0.74
16	-0.84	1.04	0.50	-0.02	-0.82	0.93	44	0.33	0.38	0.02	-0.02	0.53	-0.74
17	0.25	0.04	0.75	-0.02	-0.39	0.93	45	0.53	0.38	-0.12	-0.02	0.15	-0.74
18	-0.30	-0.29	-3.01	1.31	-0.35	0.59	46	0.00	1.04	0.38	-0.02	0.10	-0.07
19	-0.02	-0.29	-0.10	-0.02	0.16	-0.41	47	0.36	0.04	0.33	-0.02	-0.54	-0.41
20	-1.20	-0.62	-0.20	-0.02	0.23	-0.74	48	0.04	-0.62	0.31	-0.02	0.57	1.26
21	0.62	-0.62	-0.17	-0.02	-0.04	-0.74	49	-0.26	0.04	0.07	-0.02	0.42	-0.41
22	0.78	-0.62	0.14	-0.02	-1.55	-0.74	50	1.21	0.71	0.32	-0.02	0.18	-0.74
23	-0.52	0.38	-0.26	-0.02	-0.49	0.26	51	-0.57	-0.29	0.11	-0.02	0.06	0.93
24	-0.10	0.71	1.04	-0.02	0.45	-0.41	52	-0.41	-0.29	0.52	-0.02	1.47	-0.74
25	0.28	1.38	1.42	-0.02	-0.40	-0.41	53	0.17	-0.29	-0.03	-0.02	0.37	-0.74
26	0.20	-0.62	0.36	-0.02	1.48	-0.07	54	-0.07	1.38	0.60	-0.02	0.22	-0.74
27	-0.04	1.04	0.87	-0.02	-0.18	-0.07	55	-0.49	0.04	-1.14	-0.02	0.90	-0.74
28	0.43	0.71	0.72	-0.02	-0.68	0.59							
							Mean	**4.59**	**1.62**	**5.19**	**1.02**	**7.85**	**1.74**
							C.V. %	**16.47**	**56.48**	**7.27**	**15.20**	**13.67**	**64.24**
							R^2%	**0.54**	**0.37**	**0.87**	**0.67**	**0.41**	**0.39**

GY: grain yield, ER: ear rot, C.V%. percent coefficient of variation, R^2%: percent R-squared

Table 3.19 Combining ability estimates for grain yield (tons ha^{-1}) and *Stenocarpella maydis* ear rot reaction of 55 inbred lines evaluated in 2005/06 without and with inoculation with *Stenocarpella maydis* ear rot pathogen at Potchefstroom

Entry	Without inoculation		With inoculation			Without inoculation		With inoculation	
	GY[a]	ER[a]	GY[a]	ER[a]	Entry	GY[a]	ER[a]	GY[a]	ER[a]
1	-0.38	-0.07	-0.38	0.55	29	1.18	0.26	0.37	0.88
2	-0.57	-0.07	-1.49	-0.12	30	-0.23	0.59	-1.05	-0.78
3	-1.05	-0.07	-1.23	-0.78	31	-0.21	-0.07	-1.47	0.55
4	-1.51	-0.41	-0.38	-0.45	32	0.71	-0.41	1.19	0.88
5	0.17	-0.41	-0.18	0.88	33	-0.53	-0.74	1.37	-0.12
6	-0.75	-0.74	-0.43	-0.78	34	0.18	-0.41	-0.42	-0.45
7	-1.34	-0.74	-2.12	0.55	35	0.73	0.93	1.32	0.55
8	-0.24	1.26	-2.18	-0.78	36	0.85	0.93	0.13	1.22
9	0.94	1.59	-0.65	0.22	37	-0.63	-0.74	0.27	-0.78
10	0.78	-0.41	-1.70	-0.45	38	0.66	-0.41	1.15	0.22
11	-0.35	1.26	-1.90	0.22	39	1.40	0.93	1.40	-0.78
12	0.33	0.93	-0.51	-0.45	40	-0.41	-0.41	-1.43	-0.78
13	-1.26	-0.07	1.01	-0.45	41	0.10	1.59	-1.09	-0.12
14	-0.18	-0.07	1.09	-0.78	42	0.42	-0.41	-1.01	-0.12
15	-1.03	0.26	-0.36	-0.12	43	0.38	-0.74	1.04	0.22
16	-0.82	0.93	1.68	-0.78	44	0.53	-0.74	-0.78	-0.78
17	-0.39	0.93	2.22	-0.78	45	0.15	-0.74	0.15	-0.12
18	-0.35	0.59	1.10	-0.78	46	0.10	-0.07	-0.62	-0.12
19	0.16	-0.41	0.33	-0.12	47	-0.54	-0.41	0.66	1.55
20	0.23	-0.74	1.12	-0.45	48	0.57	1.26	1.09	-0.45
21	-0.04	-0.74	0.26	-0.12	49	0.42	-0.41	1.26	0.55
22	-1.55	-0.74	0.51	-0.45	50	0.18	-0.74	0.21	-0.12
23	-0.49	0.26	-1.04	0.88	51	0.06	0.93	-1.16	1.55
24	0.45	-0.41	0.98	-0.12	52	1.47	-0.74	1.22	-0.12
25	-0.40	-0.41	-0.70	0.22	53	0.37	-0.74	0.16	-0.12
26	1.48	-0.07	-0.76	1.55	54	0.22	-0.74	1.29	-0.12
27	-0.18	-0.07	0.72	1.55	55	0.90	-0.74	-0.29	0.55
28	-0.68	0.59	0.05	-0.78					
					Mean	**7.85**	**1.74**	**5.54**	**1.78**
					C.V. %	**13.67**	**64.24**	**35.79**	**68.36**
					R^2%	**0.41**	**0.39**	**0.34**	**0.34**

GY: grain yield, ER: ear rot, C.V%.: percent coefficient of variation, R^2%: percent R-squared

3.4.11 Mid-parent values and percent heterosis for grain yield and *Stenocarpella maydis* ear rot resistance of 54 maize inbred lines and 54 top cross hybrids evaluated under natural infestation

For the grain yield at Bethlehem entries 12, 47, 43, 4, 11, 2, 38, 33 and 41, had a high mid-parent value ranging from 3.80 to 2.98. The heterosis ranged between 314 and 43.5%. Entries 8, 49, 28, 9, 7, 42, 34, 44, 4, and 13 had the heights heterosis percentage ranging from 314 to 245.5% (Table 3.20). At Potchefstroom entries 15, 47, 1, 2, 21, 20, 16, 52, 53 and 14 had the highest mid-parent value for yield ranging between 5.69 to 5.34 with heterosis ranging between 488.5 and 169%. Entries 27, 28, 30, 38, 14, 35, 29, 17, 49 and 23 had the highest heterosis for yield with the range of 488.5 to 356% (Table 3.21).

For *Stenocarpella maydis* resistance at Bethlehem entries 16, 22, 26, 30, 31, 32, 34, 42, 43, 45 and 50 had a mid-parent value of 1.67. Heterosis ranged between ¯183 to 100 %, entries 8, 9, 12, 11, 2, 21, 1, 40, 18 and 35 had the lowest negative heterosis. At Cedara all most entries had a low mid-parent value except entries 5, 6, 8, 9, 10, 11, 12, 14, 16, 18, 19, 20, 21, 22, 27, 30, 31, 33, 34, 37, 38, 39, 40, 42, 45, 46, 47, 48, 51, 52, 53 and 54 that had a mid-parent value of 1.00. Entries 24, 23, 2, 36, 4, 1, 15, 3, 7 and 13 had the lowest negative heterosis ranging between ¯100 to ¯16.5%. At Potchefstroom entries 18, 8, 16, 28, 30, 40 and 48 had a mid-parent value that ranged from 1.00 to 1.67, respectively. Entries 14, 44, 3, 6, 37, 9, 17, 39, 21 and 10 had the lowest negative heterosis ranging from ¯150 to ¯99.5%.

Table 3.20 Mid-parent value and percent heterosis of 54 maize inbred lines and 54 top cross hybrids for grain yield (tons ha^{-1}) evaluated at Bethlehem under natural infestation.

Entry	Mid-parent value	Rank	Heterosis %	Rank	Entry	Mid-parent value	Rank	Heterosis %	Rank
1	2.60	50	178.0	25	28	2.93	14	287.0	3
2	3.05	6	165.5	28	29	2.96	11	198.0	21
3	2.64	44	204.0	19	30	2.67	41	128.0	43
4	3.18	4	247.0	9	31	2.81	25	54.0	52
5	2.52	53	156.5	36	32	2.64	46	198.0	22
6	2.75	31	164.5	29	33	2.98	9	159.0	33
7	2.78	28	270.0	5	34	2.80	27	262.0	7
8	2.80	26	314.0	1	35	3.02	8	158.0	35
9	2.75	32	273.5	4	36	2.63	48	98.5	48
10	2.66	42	166.5	27	37	2.88	20	150.0	38
11	3.18	5	85.5	51	38	3.05	7	94.5	49
12	3.80	1	242.0	12	39	2.68	40	222.5	15
13	2.63	47	245.5	10	40	2.73	36	135.5	42
14	2.64	45	86.0	50	41	2.98	10	43.5	54
15	2.70	37	105.0	47	42	2.76	30	264.0	6
16	2.65	43	219.0	16	43	3.36	3	156.0	37
17	2.69	39	160.0	32	44	2.63	49	248.5	8
18	2.78	29	179.5	24	45	2.58	52	201.5	20
19	2.90	16	49.5	53	46	2.70	38	225.0	14
20	2.89	17	232.5	13	47	3.51	2	111.5	46
21	2.93	13	244.5	11	48	2.86	23	146.5	39
22	2.95	12	111.5	45	49	2.87	21	293.0	2
23	2.75	33	174.0	26	50	2.74	34	127.5	44
24	2.89	18	142.5	41	51	2.74	35	143.5	40
25	2.85	24	194.0	23	52	2.59	51	216.0	51
26	2.92	15	163.5	30	53	2.89	19	163.5	31
27	2.86	22	216.5	17	54	2.50	54	159.0	34

Table 3.21 Mid-parent value and percent heterosis of 54 maize inbred lines and 54 top cross hybrids for grain yield (tons ha^{-1}) evaluated at Potchefstroom under natural infestation.

Entry	Mid-parent value	Rank	Heterosis %	Rank	Entry	Mid-parent value	Rank	Heterosis %	Rank
1	5.60	3	235.0	36	28	5.00	30	435.5	2
2	5.48	4	234.0	37	29	4.43	51	374.0	7
3	5.22	18	341.5	12	30	5.07	23	414.0	3
4	5.07	22	132.5	54	31	5.31	12	253.5	32
5	4.87	39	182.5	48	32	4.86	40	183.0	47
6	5.31	11	250.5	33	33	4.72	46	345.0	11
7	4.79	43	272.5	29	34	4.71	47	288.5	23
8	4.74	45	258.5	31	35	4.45	50	389.0	6
9	4.09	54	232.5	38	36	5.03	29	284.5	26
10	4.89	37	201.0	44	37	5.30	13	190.5	46
11	5.04	28	212.0	42	38	4.67	48	402.5	4
12	4.80	42	237.0	35	39	5.26	15	276.0	27
13	5.09	20	324.0	16	40	4.78	44	304.5	18
14	5.34	10	399.5	5	41	4.86	41	293.0	22
15	5.69	1	203.5	43	42	5.08	21	287.5	25
16	5.40	7	181.0	49	43	4.91	36	298.5	19
17	4.34	52	366.5	8	44	5.26	16	172.0	52
18	5.25	17	217.5	40	45	4.66	49	336.5	13
19	5.05	27	334.5	14	46	5.06	24	311.0	17
20	5.41	6	179.5	50	47	5.62	2	249.5	34
21	5.48	5	193.0	45	48	4.89	38	266.0	30
22	4.97	32	225.5	39	49	5.06	25	361.5	9
23	5.27	14	356.0	10	50	5.06	26	217.5	41
24	4.98	31	177.5	51	51	4.94	33	332.0	15
25	5.14	19	273.5	28	52	5.37	8	288.0	24
26	4.91	35	296.0	20	53	5.35	9	169.0	53
27	4.23	53	488.5	1	54	4.93	34	295.0	21

Table 3.22 Mid-parent value and heterosis of 54 maize inbred lines and 54 top cross hybrids for *Stenocarpella maydis* ear rot reaction evaluated at Bethlehem evaluated under natural infestation

Entry	Mid-parent value	Visual rating	Heterosis %	Rank	Entry	Mid-parent value	Visual rating	Heterosis %	Rank
1	2.17	3	-116.5	7	28	1.83	2	-16.0	36
2	2.33	3	-133.0	5	29	2.33	3	-66.0	26
3	1.83	2	50.0	48	30	1.67	2	33.5	46
4	2.00	3	-33.0	32	31	1.67	2	-66.5	23
5	1.83	2	-83.0	14	32	1.67	2	-66.5	24
6	2.00	3	-33.0	33	33	2.00	3	-67.0	20
7	2.17	3	-49.5	28	34	1.67	2	-33.5	30
8	2.83	3	-183.0	1	35	2.00	3	-100.0	10
9	2.83	3	-183.0	2	36	1.83	2	-83.0	17
10	2.18	3	-49.5	29	37	1.83	2	-16.0	37
11	2.67	3	-133.5	4	38	1.83	2	-16.0	38
12	2.83	3	-150.0	3	39	2.00	3	-67.0	21
13	2.00	3	-67.0	19	40	2.17	3	-116.5	8
14	2.00	3	-33.0	34	41	2.00	3	33.0	43
15	2.00	3	67.0	50	42	1.67	2	-66.5	25
16	1.67	2	0.5	40	43	1.67	2	33.5	47
17	1.83	2	-50.0	27	44	2.00	3	0.00	39
18	2.33	3	-100.0	9	45	1.67	2	100.5	53
19	1.67	2	-66.5	22	46	1.67	2	0.5	41
20	1.83	2	-83.0	15	47	2.00	3	-100.0	11
21	2.33	3	-133.0	6	48	2.00	3	-33.0	35
22	1.67	2	33.5	45	49	2.00	3	33.0	44
23	1.83	2	50.0	49	50	1.67	2	-33.5	31
24	2.17	3	83.5	51	51	2.17	3	-83.5	12
25	1.83	2	-83.0	15	52	2.17	3	-83.5	13
26	1.67	2	100.5	52	53	1.83	2	117.0	54
27	2.17	3	16.5	42	54	2.50	3	-83.0	18

Table 3.23 Mid-parent value and percent heterosis of 54 maize inbred lines and 54 top cross hybrids for *Stenocarpella maydis* ear rot reaction at Cedara evaluated under natural infestation

Entry	Mid-parent value	Visual rating	Heterosis %	Rank	Entry	Mid-parent value	Visual rating	Heterosis %	Rank
1	1.34	2	-33.5	6	28	1.17	2	-16.5	13
2	1.67	2	-66.5	3	29	1.17	2	-16.5	14
3	1.17	2	-16.5	8	30	1.00	2	100.0	49
4	1.50	2	-50.0	5	31	1.00	2	0.0	32
5	1.00	2	0.0	17	32	1.17	2	-16.5	15
6	1.00	2	.00	18	33	1.00	2	33.0	37
7	1.17	2	-16.5	9	34	1.00	2	33.0	38
8	1.00	2	0.0	19	35	1.17	2	-16.5	16
9	1.00	2	0.0	20	36	1.67	2	-66.5	4
10	1.00	2	0.0	21	37	1.00	2	67.0	42
11	1.00	2	0.0	22	38	1.00	2	67.0	43
12	1.00	2	0.0	23	39	1.00	2	33.0	39
13	1.17	2	-16.5	10	40	1.00	2	0.0	33
14	1.00	2	0.0	24	41	1.17	2	116.5	51
15	1.34	2	-33.5	7	42	1.00	2	0.0	34
16	1.00	2	.00	25	43	1.17	2	83.5	47
17	1.17	2	116.5	50	44	1.17	2	83.5	48
18	1.00	2	0.0	26	45	1.00	2	167.0	53
19	1.00	2	0.0	27	46	1.00	2	67.0	44
20	1.00	2	0.0	28	47	1.00	2	0.0	35
21	100	2	0.0	29	48	1.00	2	67.0	45
22	1.00	2	0.0	30	49	1.17	2	116.5	52
23	1.84	2	-83.5	2	50	1.17	2	16.5	36
24	2.00	3	-100	1	51	1.00	2	33.0	40
25	1.17	2	-16.5	11	52	1.00	2	33.0	41
26	1.17	2	-16.5	12	53	1.00	2	200.0	54
27	1.00	2	0.0	31	54	1.00	2	67.0	46

Table 3.24 Mid-parent value and percent heterosis of 54 maize inbred lines and 54 top crosses for *Stenocarpella maydis* ear rot reaction at Potchefstroom evaluated under natural infestation

Entry	Mid-parent value	Rank	Heterosis %	Rank	Entry	Mid-parent value	Rank	Heterosis %	Rank
1	1.83	21	50.0	44	28	1.17	50	-83.0	17
2	1.34	43	0.5	38	29	2.34	7	50.5	46
3	1.50	35	-116.5	3	30	1.17	51	-83.0	18
4	1.50	36	-67.0	20	31	1.83	22	50.0	45
5	2.50	3	34.0	43	32	1.84	18	100.5	51
6	1.50	37	-116.5	4	33	1.67	25	-33.0	30
7	2.00	9	33.0	41	34	1.67	32	-83.5	13
8	1.17	48	-83.0	14	35	2.00	12	33.0	42
9	1.84	15	-100.0	6	36	2.34	8	100.0	49
10	1.67	28	-83.5	10	37	1.50	40	-116.5	5
11	1.67	29	-83.0	15	38	1.84	19	0.0	36
12	1.67	30	-83.5	11	39	1.34	45	-100.0	8
13	1.50	38	-67.0	21	40	1.17	52	-83.0	19
14	1.84	16	-150.0	1	41	1.67	26	-33.0	31
15	1.67	23	-33.0	28	42	2.00	13	-66.0	24
16	1.17	49	-83.0	16	43	1.84	20	0.0	37
17	1.34	44	-100.0	7	44	1.67	33	-133.0	2
18	1.00	54	-66.5	23	45	1.34	46	0.5	39
19	1.84	17	-49.5	26	46	1.50	41	-16.0	34
20	1.67	31	-83.5	12	47	2.83	47	100.0	50
21	2.34	6	-99.5	9	48	1.17	53	-33.5	27
22	1.50	29	-67.0	22	49	1.67	34	66.5	47
23	2.00	10	84.0	48	50	2.00	14	-66.0	25
24	1.67	24	-33.0	29	51	2.50	5	133.0	54
25	2.00	11	-16.5	33	52	1.34	47	0.5	40
26	2.50	4	133.0	53	53	1.50	42	-16.0	35
27	2.67	4	116.5	52	54	1.67	27	-33.0	32

CHAPTER 4

4.1 Discussion

The present study showed that there were considerable variations between entries for agronomic traits, yield and *stenocarpella maydis* ear rot resistance among tested inbred lines and top cross hybrids.

Effective infection to ear rot takes place within the first three weeks after silking (Koehler, 1959). After three weeks ears become more resistant to the pathogen as they approach maturity. In this study the rainy season coincided with the silking period but there was less infestation. Inbred lines had a positive non-significant correlation to grain yield and top cross hybrids showed a negative non-significant correlation to 50% days to silking which could have been due to high temperature (Table 3.2) especially at Potchefstroom. This was also confirmed by Flett (1997). It is notable that black layer formation coincides with this period. Daynard (1972) suggested that inbred lines and hybrids differ in date of black layer formation despite some having the same mid-silk date.

Plant height was another agronomic trait measured under this study, but it was negatively and non-significantly correlated to both grain yield and *Stenocarpella maydis* ear rot for inbred lines and top cross hybrids. *Stenocarpella maydis* infection takes place at the ear height. Thus, it is suspected that the lower the ear height the more susceptible to ear rot infestation but Ferreira (1992) indicated that differences in ear height cannot always explain the range of resistance to susceptibility. Ear height in some lines/hybrids may interact with the environment. Inbred lines, however, are shorter than hybrids (Table 3.4 and 3.5), resulting in ears not being carried high above the inoculum source. If the disease triangle is not met even plants with lower ears will not have *Stenocarpella maydis* ear rot infestation. This was confirmed during this study by non-significant correlation between ear height and *Stenocarpella maydis* ear rot for both inbred lines and top cross hybrids. These lower ears maybe more exposed to *Stenocarpella maydis* spores than ears carried higher above the soil.

When breeding for ear rot resistance, it is important to realise that resistance to the three main causal fungi, namely *Stenocarpella maydis. Stenocarpella. macrospora* and *Fusarium graminearum* are generally inherited independently of each other (Koehler, 1959). However, Mesterhazy (1982) and Mesterhazy and Kovacs (1986) suggested that at times there might be specific instances when there is a correlation between, resistance to more than one fungus. Mulvick (2000) suggested that the specific reasons for the severe epidemics of *S. maydis* ear rot are not clear, but this ear rot has been a problem in isolated geographical areas. *S. maydis* infestation is not uniform even in the same field. This is probably due to differences in *S. maydis* stalk rot in previous years, planting date and cultivar susceptibility, although Thompson *et al*., (1971) and Ooka and Kommendahl (1977) had argued that there is no correlation between stalk rot and ear rot resistance and that not all morphological characteristics have a direct effect to *Stenocarpella maydis* ear rot infestation. In this study the inbred lines were positively significantly correlated to grain yield but negatively non-significantly correlated to *Stenocarpella maydis* ear rot. For the top cross hybrids there was a negative non-significant correlation between stem lodging and grain yield and ear rot.

Ferreira (1992) suggested that there is a tendency for susceptible inbred lines/hybrids to have fewer ears per plant. During this study, entries 47 and 4 were prolific and had lower infestation rate. It was also found that there was no correlation between *Stenocarpella maydis* ear rot and number of ears per plant (prolificacy) in both inbred lines and top cross hybrids.

Material known to be most susceptible to ear rot in the field has a delayed ear declination and less effective closing of the hilar orifice after fertilization of the kernel. This study confirmed that upright and open tip inbred lines and top cross hybrids were the most susceptible to *Stenocarpella maydis* ear rot infestation. Ferreira (1992) pointed out that an effective closing layer is the indication of chemical changes in the maturation process, which afford a less favourable nutrient medium for *Stenocarpella maydis* fungal growth within the plant, and it can act as a barrier to fungus advance. The above statement confirms the findings of this study whereby there was non-significant correlation between husk cover and ear rot infestation. Rainfall during the milk stage may wash spores down among the husks behind the ear into the leaf whorl where suitable microclimate for the pathogen exists. Although the ear itself is most susceptible in the milk stage, it normally has the best husk protection at that time; therefore, ears with well-covered husks have less ear rot. As the ear matures, the husks gradually become looser, making it easier for spores to get to the ear or between the husks. These later infections may result in partial rotting of the ear, most frequently seen at the base. Rainwater drains away more easily from declined ears and late declination or erect ears are associated with a higher percentage of *Stenocarpella maydis* ear rot. This was confirmed by Ferreira (1992) that ears that remain in an upright position with loose, open husks would provide ideal conditions for germination of *Stenocarpella maydis* spores landing in the space between husks and the ear. For this study it was found that there was no correlation between *Stenocarpella* ear rot infestation and ear position that was contradicting Ferreira (1992). During this study entries 11, 23 and 51 had loose husk cover and a high ear rot infestation, which supports Ferreira (1992).

This was also found during this study since there were a negative non-significant correlation for days to silking, plant height and ear height. Husk cover and ear position were non-significantly correlated to the grain yield and *Stenocarpella maydis* ear rot. These was further reported by Rossouw *et al.* (2002) that upright ears might be a result of *Stenocarpella maydis* ear rot infection rather than to predispose ears to the disease.

There is evidence that *Stenocarpella maydis* ear rot resistance fluctuates from location to location in a given season and there is unlikely total resistance to *Stenocarpella maydis* ear rot in varieties that is why in this study there was a low *Stenocarpella maydis* ear rot infestation and there was a non-significant correlation between *Stenocarpella maydis* ear rot and other traits. This is contributed by its polygenic inheritance as suggested by Rossouw *et al.*, (2002). Thus, this study confirms that *Stenocarpella maydis* ear rot is of polygenic inheritance as different infestation ratings were observed from the three locations. Maize is most vulnerable to *Stenocarpella maydis* ear rot pathogen when stressed during the period at and immediately after silking. Dry spell prior to flowering followed by cool wet weather became a favourable weather condition for *Stenocarpella maydis* ear rot infestation conceding with flowering and silking stages which are said to be the most effective growth stages for the host to infest the maize plant under natural infestation as observed at Bethlehem and Cedara (Table 3.3). Although there was rainfall at Potchefstroom during this growth stages, there was not much differences between non-inoculated and inoculated trial due to high temperatures (Table 3.3) which are not suitable for *Stenocarpella maydis* ear rot infestation (Flett and Van Rensburg personal communication) but if it was dry and hot soon after silking even resistant lines were going to be affected by the *Stenocarpella maydis* ear rot pathogen.

Stability analysis provides a general summary of the response patterns of genotypes to the environmental change. Eberhart and Russell (1966) suggested that a joint regression analysis provides a means of testing whether the genotypes have characteristic linear response to change in environments. For the grain yield response, inbred lines 2, 5, 8, 34, 37, 38 and 46 were stable as they had the smallest deviation from the regression line from all entries over locations. Entry 4 is the most resistant and stable and it ranked 1st across all locations even compared to the resistant checks. However, there is no complete resistance for *Stenocarpella maydis* ear rot, which was reported by Rossouw *et al*. (2002). The high yielding resistant materials with good *Stenocarpella maydis* resistance were found to be from entries with closed husks and dropping ears as suggested by Rheeder *et al*, (1990) and Keller *et al.*, (2001) that the plant aspect and moisture percentage at harvest plays a significant role in *Stenocarpella maydis* ear rot resistance. For the top cross hybrids entries 46, 29, 1, 2, 22, 25 and 58 were the most stable entries over locations with smallest deviation from the regression line. Grain yield of top crosses were at par with the trial average and there was a progressive improvement in resistance in top crosses with *Stenocarpella maydis* ear rot disease severities decidedly in the resistance range.

Viveck *et al.*, (2001) suggested that not only grain yield is required for a good hybrid or cultivar, but also attributes like good stability, common disease resistance, prolificacy and ear rot resistance. During this study yellow kernel lines were chosen because it was suggested by Rheeder *et al.*, (1988) that yellow maize had higher levels of *Stenocarpella maydis* ear rot than white varieties. Yellow corn-belt components are susceptible to the ear rot, especially B73 type (Gevers *et al*., 1990 and Troyer, 1996). Gevers *et al*. (1990) showed that foreign (corn-belt) germplasm is usually much more susceptible to ear rots than locally adapted germplasm. During this study materials with a combination of Do620Y, E739 and B37 (belt corn type) showed some promising resistance and good combining ability. This was observed by Van Rensburg and Ferreira (1997) that E739, Do620Y and B37 have got some useful levels of resistance to *Stenocarpella maydis* ear rot. Hooker (1956), Wiser *et al.* (1960), Boling and Gregan (1965), Thompson (1971), Villena (1971) and Scott (1992) further found that resistance to ear rots in maize is quantitatively inherited and ear rot resistance is most probably conditioned by many genes in a more complex quantitative genetic background. This was further confirmed by Sivasankar *et al*., (1976); Ooka and Kommendahl, (1977); Ullstrup (1977); Enerson and Hunter (1980); and Warren, (1982). It was further suggested that heritability of ear rot resistance has many types of inheritance mechanisms including additive resistance, dominance, modifier genes, epistasis and recessive resistance (Kempthrone, 1957; Dorrance, 1998 and Rossouw *et al.*, 2002).

A genotype's wide adaptation is the response of a productivity trait at a level not lower than the mean of all genotypes (environmental index) in every location within a target region in every year. Plant breeders are more interested in hybrids that are not affected much by environment-to-environment variations. On the other hand, many investigators proved that the environmental variation could be classified into predictable and unpredictable variations. Mostly permanent features cause the predictable ones, while the unpredictable variations are caused by year-to-year fluctuations in weather, insect infestation and disease infection (Eberhart and Russell, 1966). When stability analysis was performed for grain of inbred lines entries 43, 4, 15, 1, 55, 16, 47, 2, 56 and 14 showed to have a high mean yield b=1 (Eberhart and Russell, 1966). The overall mean grain yield of the entries ranged from 3.63 to 1.54 tons ha-1. Eberhart and Russell (1966) stated that the basic cause of the differences among genotypes in their yield stability is the wide occurrence of genotype x environment (G x E) interaction. Entries 9, 25, 51, 49, 42, 45, 28, 32, 22 and 19 showed a small deviation from regression (Table 3.15) and hence were fairly stable in performance across environments. When such significant interactions are observed they encourage maize breeders to develop high yielding and more uniform hybrids under varied environmental conditions. High yield potentiality and average stability are due to most attributes involved in determining the wide adaptation of a new variety or hybrids would be considered the most stable hybrids with respect to grain yield, since the regression coefficient values of the average of these crosses on the environmental index are approximately equal one, and their deviations from linearity are small.

The entry with a smaller value of *Pi*, has maximum yield and is the better (Lin and Binns, 1988). A cultivar that has a constant response to environments may be very stable, but if it is consistently lower yielding, it is not useful to the producer. Adaptability parameter (P_i) compares the yields of test cultivars with the greatest-yielding cultivar within each location in the experiment, rather than with the mean yield of all cultivars. Smaller values of P_i reflect greater adaptability of an entry across environments. When cultivar superiority analysis was performed entries 47, 4, 21, 53, 56, 37, 11, 2, 20 and 15 had the lowest P_i value indicating that they were the most superior entries with high yields (Tables 3.15 and 5.1).

The following top cross hybrids 57, 14, 19, 31, 23, 15, 58, 38, 41 and 51 showed to be stable with the mean yield closer to one. Entries with the smallest deviation from the regression were entries 46, 47, 39, 29, 1, 45, 25, 2, 43 and 22 (Table 3.16). On the other hand entries 56, 28, 58, 27, 3, 23, 49, 46, 35, 29 and 47 showed to be the most superior entries with low P_i values and high grain yields (Table 5.2). Estimation of cultivar superiority was only performed for *Stenocarpella maydis* ear rot for, whereby entries 10, 1, 6, 9, 14, 11, 54, 41, 7 and 28 (Table 3.17) were the most superior inbred lines. Whereas entries 26, 27, 23, 53, 55, 29, 51, 7, 15 and 24 showed to be the most superior entries (Table 3.17) for *Stenocarpella maydis* ear rot resistance.

As the South African climate is so variable, it is very unlikely that natural epidemics will be at consistent enough or have sufficiently high enough infection levels to ensure good selection pressure and to make accurate assessments of ear rot resistance of lines and hybrids over or within locations and seasons, therefore it is important that artificial epidemics be created to ensure adequate and uniform selection pressure (Nowell, 1990). It is not adequate to rely on natural inoculation to provide satisfactory level of infection in order to select resistant material (Berry and Maller, 1990). It is important that artificial epidemics be created to ensure adequate and uniform selection pressure. The other way to improve conditions for infection and disease development is through the use of irrigation and to build up the inoculum levels through monoculture and no-till. For this study Viljoenskroon isolate was used as it has been found to be the highest of *S. maydis* ear rot since 1986.

Variance components of combining ability (GCA or SCA) on *Stenocarpella maydis* ear rot of less than 1 were found to be an indication of non-additive genes that play a major role in the inheritance of *Stenocarpella maydis* ear rot resistance (Rabie *et al.*, 1999). Negative values for GCA indicate a contribution towards resistance to *Stenocarpella maydis* ear rot. From the combining ability studies of this study, it was found that inheritance of *Stenocarpella maydis* is of additive gene effect. This was confirmed by Rossouw *et al.* (2002) that *Stenocarpella maydis* ear rot has variable inheritance. Although entries 47 and 4 were found to be high yielders they are poor combiners for both grain yield and *Stenocarpella maydis* ear rot resistance.

4.2 Conclusion

Breeding for ear rot resistance is a medium to long-term solution. This strategy helps to improve the ear rot susceptible materials in a breeding program as this will result in limited risk of commercial crops being down graded due to ear rot infection. South African climate is so variable; it is very unlikely that natural epidemics will be at consistent enough to promote infection levels and ensure good selection pressure and to make accurate assessment of ear rot resistance of lines and hybrids over or within locations and seasons. Nowell, (1990) confirmed that there is a considerable unexplained variation in ear rot response between genotype, season and inoculum levels if the data is not considered over more than two locations. At all levels the best early generation lines are not only used in population recombination but in narrow base synthetic formation and advanced through the inbreeding process and top cross evaluations. It is important to characterize the lines for disease reaction and for general and specific combining ability (Short *et al,* 1990). It is also equally important to select genotypes, which shows a great stability of resistance over sites and inoculum levels. In this study genotype by environment effects were pronounced, indicating the necessity to conduct resistance evaluations in a variety of locations.

When planning the planting date for *S. maydis* ear rot one should make sure that flowering and grain filling coincides with that part of the season most likely to be conducive to ear rot infection. When selecting tester for *S. maydis* ear rot resistance it is also important that yield potential is assed as well (Nowell, 1990). A good tester would be an inbred, single cross or a double cross with a good additive resistance to ear rot and also be a good tester for yield (Nowell, 1989). Since there is still uncertainties in the inheritance or genes that confer resistance in *Stenocarpella maydis* ear rot it is better to conduct further studies using both conventional and molecular breeding. This will even help to breed resistant lines faster as the *Stenocarpella maydis* ear rot heritability is low. The maize breeders, biotechnologies pathologists and entomologists have a major role to play in the ultimate solution to the *Stenocarpella maydis* ear rot.

CHAPTER 5

Summary of the study

The present findings show that there is a considerable variations among both inbred lines and top crosses of maize for important agronomic traits, yield and *Stenocarpella maydis* ear rot resistance.

The study showed that there is a need to explore other ventures for studying *Stenocarpella maydis* ear rot extensively using artificial infestation at different locations and different dates of planting. The morphological traits have to be learned more in order to phenotype the lines with resistance and correlate it with molecular analysis. During visual scoring of lines other measurements like number of infested kernels and test weight have to be taken into consideration.

The grain yield results for the inbred lines at Bethlehem ranged from 2.84 to 0.83 tons ha^{-1}, while top cross hybrids had yields of 5.94 to 3.35 tons ha^{-1} (Tables 5.1 and 5.2), the mid-parent value ranged between 3.51 and 2.52 with the heterosis of 314 to 43.5% (Table 3.20). At Potchefstroom the grain yield for inbred lines ranged from 4.58 to 1.64 tons ha^{-1} and top cross hybrid grain yield ranged from 9.95 to 6.69 tons ha^{-1} (Tables 5.1 and 5.2), the mid-parent value ranged between 5.70 and 4.23 and heterosis was between 488.5 to 169% (Table 5.1). At Cedara the top cross hybrids had grain yield of 7.15 to 1.80 tons ha^{-1} (Table 5.2). These results show that there is considerable diversity between inbred lines and top crosses and that additive effects are playing a major role on inheritance of yield.

The *Stenocarpella maydis* ear rot resistance of inbred lines indicated that at Bethlehem severity varied from 3.33 to 1 (Table 5.3) with the mid-parent value of 2.83 to 1.67 and heterosis of -183 to 100.5%. At Cedara ear rot severity varied from 2 to 1 with mid-parent value of 2 to 1 and heterosis of -100 to 200%. At Potchefstroom ear rot severity varied from 2.67 to 1 with the mid-parent value of 52.47 to 33.47 and heterosis of -150 to 116.5% (Table 5.4). For the top cross hybrids at Bethlehem the ear rot severity ranged from 2.67 to 1, while at Cedara it varied from 2.33 to 1. At Potchefstroom the observed ear rot severity ranged from 3.33 to 1. These findings were under natural infestation showing that there are promising lines as the heterosis for the ear rot resistance shows promising ranges, which is a good indicator of disease resistance. When grain yield and ear rot of inbred lines were correlated to inoculation methods, grain yield was negatively non-significant to inoculation techniques and ear rot were correlated positively and non-significantly to inoculation methods (Table 5.5). When grain yield and *Stenocarpella maydis* ear rot of top cross were correlated to inoculation methods, grain yield and ear rot were negatively and non-significantly correlated to inoculation methods (Table 5.6). On this study it shows that there is no difference between the two inoculation methods (inoculated and non-inoculated). This might be due to unsuitable weather or the inoculation method was not very effective. This proposes for a further study to investigate the other inoculation methods and the effective date of planting that coincide with rainfall and low temperatures two weeks after silking. Quantitative resistance is not a complex trait; the QR genes only affect the trait QR, which is the reason why QR is not more sensitive to g x e (inoculation) interactions.

Table 5.1 Grain yield (tons ha^{-1}) of 58 maize inbred lines evaluated at Bethlehem and Potchefstroom under natural infestation

	Bethlehem		Potchefstroom					Bethlehem		Potchefstroom			
	Average		Average		Average			Average		Average		Average	
Entry	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank	Combined t ha^{-1}	Rank	Entry	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank	Combined GY t ha^{-1}	Rank
47	2.84	1	4.42	3	3.63	1	24	1.60	21	3.14	34	2.37	30
4	2.19	4	4.58	1	3.39	2	3	1.11	49	3.62	20	2.37	31
2	1.92	8	4.15	6	3.04	3	41	1.78	12	2.91	45	2.35	32
56	1.56	24	4.34	5	2.95	4	42	1.35	33	3.34	24	2.35	33
21	1.68	16	4.15	7	2.92	5	26	1.66	17	3.01	38	2.34	34
15	1.23	41	4.56	2	2.90	6	50	1.30	38	3.30	27	2.30	35
20	1.60	19	4.00	8	2.80	7	46	1.23	42	3.31	26	2.27	36
55	2.08	6	3.49	21	2.79	8	48	1.54	26	2.97	41	2.26	37
43	2.55	2	3.00	39	2.78	9	30	1.17	45	3.33	25	2.25	38
53	1.60	20	3.89	11	2.75	10	13	1.08	52	3.37	23	2.23	39
11	2.18	5	3.27	20	2.73	11	38	1.92	9	2.52	53	2.22	40
1	1.03	54	4.39	4	2.71	12	58	1.34	34	3.10	35	2.22	41
37	1.59	22	3.78	15	2.69	13	33	1.79	11	2.63	51	2.21	42
57	2.39	3	2.89	46	2.64	14	51	1.30	40	3.07	36	2.19	43
31	1.45	28	3.80	14	2.63	15	36	1.08	53	3.24	31	2.16	44
6	1.32	36	3.80	13	2.56	16	9	1.32	37	2.98	40	2.15	45
16	1.13	47	3.99	9	2.56	17	7	1.39	31	2.76	48	2.08	46
18	1.38	32	3.68	19	2.53	18	10	1.14	46	2.97	42	2.06	47
23	1.33	35	3.73	16	2.53	19	8	1.43	30	2.66	50	2.05	48
25	1.53	27	3.46	22	2.50	20	34	1.43	29	2.60	52	2.02	49
14	1.11	50	3.86	12	2.49	21	32	1.11	48	2.91	44	2.01	50
52	1.01	55	3.93	10	2.47	22	40	1.28	40	2.74	49	2.01	51
19	1.62	18	3.28	29	2.45	23	35	1.87	10	2.09	55	1.98	52
39	1.18	44	3.71	17	2.45	24	54	0.83	58	3.05	37	1.94	53
28	1.69	15	3.18	33	2.44	25	5	0.86	57	2.92	43	1.89	54
49	1.57	23	3.30	28	2.44	26	29	1.75	13	1.91	56	1.83	55
22	1.72	14	3.12	32	2.42	27	45	0.98	56	2.50	54	1.74	56
44	1.08	51	3.71	18	2.40	28	27	1.54	25	1.64	58	1.59	57
12	1.99	7	2.79	47	2.39	29	17	1.21	43	1.86	57	1.54	58
							Average	1.50		3.29		2.39	

GY: Grain yield, t ha^{-1}

Table 5.2 Grain yield (tons ha^{-1}) of 58 maize top cross hybrids evaluated at Bethlehem, Cedara and Potchefstroom under natural infestation

	Bethlehem		Cedara		Potchefstroom					Bethlehem		Cedara		Potchefstroom			
	Average		Average		Average		Average			Average		Average		Average		Ave	
Entry	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank	Combined GY t ha^{-1}	Rank	Entry	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank	GY t ha^{-1}	Rank	Combined GY t ha^{-1}	Rank
56	5.58	5	5.90	9	9.95	1	7.14	1	34	5.42	8	4.87	49	7.59	37	5.96	30
28	5.80	2	5.80	10	9.35	2	6.98	2	30	3.95	51	4.69	54	9.21	4	5.95	31
58	5.03	14	7.15	1	8.67	9	6.95	3	33	4.57	31	5.06	39	8.17	18	5.93	32
27	5.02	15	5.91	8	9.11	5	6.68	4	57	3.36	57	6.11	5	8.21	16	5.89	33
49	5.80	3	5.51	20	8.67	8	6.66	5	24	4.31	40	6.61	2	6.75	56	5.89	34
3	4.68	25	6.27	3	8.63	10	6.53	6	1	4.38	37	5.23	34	7.95	24	5.85	35
23	4.49	34	6.23	4	8.83	6	6.52	7	20	5.21	11	5.02	42	7.20	47	5.81	36
46	4.95	16	5.52	19	8.17	17	6.21	8	7	4.85	20	5.00	43	7.51	39	5.79	37
8	5.94	1	5.27	30	7.32	42	6.18	9	53	4.52	33	5.79	11	7.04	51	5.78	38
14	3.50	54	5.67	14	9.33	3	6.17	10	15	3.75	52	5.69	13	7.72	36	5.72	39
26	4.55	32	6.06	6	7.87	29	6.16	11	44	5.11	12	5.07	38	6.98	53	5.72	40
29	4.94	17	5.34	26	8.10	20	6.13	12	48	4.32	38	5.26	33	7.55	38	5.71	41
12	5.50	6	5.66	15	7.17	49	6.11	13	18	4.57	30	5.09	37	7.42	40	5.69	42
35	4.60	28	5.39	24	8.34	12	6.11	14	10	4.32	39	5.58	16	6.90	54	5.60	43
42	5.40	9	4.96	45	7.95	25	6.10	15	19	3.39	56	4.99	44	8.39	11	5.59	44
47	4.62	26	5.50	23	8.11	19	6.08	16	40	4.08	45	4.83	51	7.82	32	5.58	45
39	4.90	19	5.30	29	8.02	22	6.07	17	6	4.39	35	4.44	55	7.81	34	5.55	46
25	4.79	22	5.55	18	7.87	30	6.07	18	50	4.01	49	5.30	28	7.23	44	5.51	47
45	4.59	29	5.57	17	8.02	21	6.06	19	36	3.61	53	4.87	48	7.87	28	5.45	48
4	5.65	4	5.50	22	7.02	52	6.06	20	55	4.17	43	5.35	25	6.81	55	5.44	49
52	4.75	23	5.16	36	8.25	15	6.05	21	37	4.38	36	4.74	53	7.20	48	5.44	50
13	5.08	13	4.74	52	8.33	13	6.05	22	31	3.35	58	5.06	40	7.84	31	5.42	51
51	4.17	42	5.71	12	8.26	14	6.05	23	32	4.62	27	4.92	47	6.69	58	5.41	52
21	5.37	10	5.33	27	7.41	41	6.04	24	22	4.06	47	4.93	46	7.22	45	5.40	53
2	4.70	24	5.51	21	7.82	33	6.01	25	41	3.41	55	4.83	50	7.79	35	5.34	54
43	4.92	18	5.21	35	7.89	26	6.01	26	54	4.09	44	4.06	56	7.88	27	5.34	55
9	5.48	7	5.27	31	7.25	43	6.00	27	5	4.08	46	5.05	41	6.69	58	5.27	56
16	4.84	21	5.94	7	7.21	46	6.00	28	17	4.29	41	2.18	57	8.00	23	4.82	57
38	3.99	50	5.26	32	8.69	7	5.98	29	11	4.03	48	1.80	58	7.16	50	4.33	58
									Ave loc	4.59		5.25		7.87		5.90	

GY: grain yield, t ha^{-1}: tons per ha

Table 5.3 Rating of 58 maize inbred lines on *Stenocarpella maydis* ear rot infestation evaluated at Bethlehem, Cedara and Potchefstroom under natural infestation

	Stenocarpella maydis infestation									*Stenocarpella maydis* infestation							
	Bethlehem		Cedara		Potchefstroom		Combined infestation			Bethlehem		Cedara		Potchefstroom		Combined infestation	
Entry	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**	**Entry**	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**
1	2.00	3	1.67	2	1.33	2	2.00	2	30	1.00	2	1.00	2	1.33	2	1.47	2
2	2.33	3	2.33	3	1.00	2	2.33	2	31	1.00	2	1.00	2	1.33	2	1.47	2
3	1.33	2	1.33	2	2.00	3	1.73	2	32	1.00	2	1.33	2	1.00	2	1.47	2
4	1.67	2	2.00	3	1.67	2	2.07	2	33	1.67	2	1.00	2	1.67	2	1.67	2
5	1.33	2	1.00	2	2.33	3	1.73	2	34	1.00	2	1.00	2	2.00	3	1.60	2
6	1.67	2	1.00	2	2.00	3	1.73	2	35	1.67	2	1.33	2	1.67	2	1.73	2
7	2.00	3	1.33	2	1.67	2	2.00	2	36	1.33	2	2.33	3	1.67	2	2.07	2
8	3.33	3	1.00	2	1.33	2	2.13	2	37	1.33	2	1.00	2	2.00	3	1.67	2
9	3.33	3	1.00	2	1.67	2	2.20	3	38	1.33	2	1.00	2	1.67	2	1.60	2
10	2.00	3	1.00	2	2.00	3	2.00	2	39	1.67	2	1.00	2	1.67	2	1.67	2
11	3.00	3	1.00	2	1.33	2	2.07	2	40	2.00	3	1.00	2	1.33	2	1.87	2
12	3.33	3	1.00	2	2.00	3	2.27	2	41	1.67	2	1.33	2	1.67	2	1.73	2
13	1.67	2	1.33	2	1.67	2	1.73	2	42	1.00	2	1.00	2	2.33	3	1.67	2
14	1.67	2	1.00	2	2.67	3	1.87	2	43	1.00	2	1.33	2	1.67	2	1.60	2
15	1.67	2	1.67	2	1.67	2	1.80	2	44	1.67	2	1.33	2	2.33	3	1.87	2
16	1.00	2	1.00	2	1.33	2	1.47	2	45	1.00	2	1.00	2	1.00	2	1.40	2
17	1.33	2	1.33	2	1.67	2	1.67	2	46	1.00	2	1.00	2	1.33	2	1.47	2
18	2.33	3	1.00	2	1.00	2	1.87	2	47	1.67	2	1.00	2	2.33	3	1.80	2
19	1.00	2	1.00	2	2.00	3	1.60	2	48	1.67	2	1.00	2	1.00	2	1.53	2
20	1.33	2	1.00	2	2.00	3	1.67	2	49	1.67	2	1.33	2	1.00	2	1.60	2
21	2.33	3	1.00	2	3.00	3	2.27	3	50	1.00	2	1.33	2	2.33	3	1.73	2
22	1.00	2	1.00	2	1.67	2	1.53	2	51	2.00	3	1.00	2	1.67	2	1.93	2
23	1.33	2	2.67	3	1.33	2	2.07	2	52	2.00	3	1.00	2	1.00	2	1.80	2
24	2.00	3	3.00	3	1.67	2	2.53	2	53	1.33	2	1.00	2	1.33	2	1.53	2
25	1.33	2	1.33	2	2.00	3	1.73	2	54	2.67	3	1.00	2	1.67	2	2.07	2
26	1.00	2	1.33	2	1.67	2	1.60	2	55	2.00	3	2.33	3	1.67	2	2.40	3
27	2.00	3	1.00	2	2.00	3	2.00	2	56	2.67	3	1.00	2	1.33	2	2.00	2
28	1.33	2	1.33	2	1.33	2	1.60	2	57	1.67	2	1.00	2	1.00	2	1.53	2
29	2.33	3	1.33	2	2.00	3	2.13	2	58	2.33	3	1.00	2	1.33	2	1.93	2
									Ave	1.71		1.26		1.66			

WA: weighted average, VR: visual rating, Ave: average

Table 5.4 Rating of 58 maize top cross hybrids on *Stenocarpella maydis* ear rot infestation evaluated at Bethlehem, Cedara and Potchefstroom under natural infestation

	***Stenocarpella maydis* infestation**									***Stenocarpella maydis* infestation**							
	Bethlehem		**Cedara**		**Potchefstroom**		**Combined infestation**			**Bethlehem**		**Cedara**		**Potchefstroom**		**Combined infestation**	
Entry	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**	**Entry**	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**	**WA**	**VR**
1	1.00	2	1.00	2	2.00	3	1.33	2	30	2.00	3	1.00	2	1.00	2	1.83	2
2	1.00	2	1.00	2	1.67	2	1.61	2	31	1.00	2	1.00	2	2.33	3	1.89	2
3	2.33	3	1.00	2	1.00	2	1.89	2	32	1.00	2	1.00	2	2.67	4	2.11	3
4	1.67	2	1.00	2	1.33	2	1.67	2	33	1.33	2	1.00	2	1.67	2	1.67	2
5	1.00	2	1.00	2	2.67	3	1.95	3	34	1.33	2	1.00	2	1.33	2	1.61	2
6	1.67	2	1.00	2	1.00	2	1.61	2	35	1.00	2	1.00	2	2.33	3	1.89	2
7	1.67	2	1.00	2	2.33	3	2.00	3	36	1.00	2	1.00	2	3.00	3	2.00	3
8	1.00	3	1.00	2	1.00	2	1.67	2	37	1.67	2	1.00	2	1.00	2	1.61	2
9	1.00	2	1.00	2	1.00	3	1.67	2	38	1.67	2	1.00	2	2.00	3	1.95	2
10	1.67	2	1.00	2	1.33	2	1.67	2	39	1.33	2	1.00	2	1.00	2	1.56	2
11	1.33	2	1.00	2	1.00	3	1.72	2	40	1.00	2	1.00	2	1.00	2	1.50	2
12	1.33	2	1.00	2	1.33	2	1.61	2	41	2.33	3	1.00	2	1.67	2	2.00	3
13	1.33	2	1.00	2	1.33	2	1.61	2	42	1.00	2	1.00	2	1.67	2	1.61	2
14	1.67	2	1.00	2	1.00	2	1.61	2	43	2.00	3	1.00	2	2.00	3	2.17	3
15	2.67	3	1.00	2	1.67	2	2.06	3	44	2.00	3	1.00	2	1.00	2	1.83	2
16	1.67	2	1.00	2	1.00	2	1.61	2	45	2.67	3	1.00	2	1.67	2	2.06	2
17	1.33	2	2.33	3	1.00	2	1.94	2	46	1.67	2	1.00	2	1.67	2	1.72	2
18	1.33	2	1.00	2	1.00	2	1.56	2	47	1.00	2	1.00	2	3.33	4	2.22	3
19	1.00	2	1.00	2	1.67	2	1.61	2	48	1.67	2	1.00	2	1.33	2	1.67	2
20	1.00	2	1.00	2	1.33	2	1.56	2	49	2.33	3	1.00	2	2.33	3	2.28	3
21	1.00	2	1.00	2	1.67	2	1.61	2	50	1.33	2	1.00	2	1.67	2	1.67	2
22	2.00	3	1.00	2	1.33	2	1.89	2	51	1.33	2	1.00	2	3.33	4	2.28	3
23	2.33	3	1.00	2	2.67	3	2.33	3	52	1.33	2	1.00	2	1.67	2	1.67	2
24	3.00	3	1.00	2	1.67	2	2.11	3	53	3.00	3	1.00	2	1.67	2	2.11	3
25	1.00	2	1.00	2	2.00	3	1.83	2	54	1.67	2	1.00	2	1.67	2	1.72	2
26	2.67	3	1.00	2	3.33	3	2.50	3	55	2.33	3	1.00	2	2.33	3	2.28	3
27	2.33	3	1.00	2	3.33	3	2.44	3	56	1.00	2	1.67	2	1.67	2	1.72	2
28	1.67	2	1.00	2	1.00	2	1.61	2	57	1.00	2	1.00	2	1.33	2	1.56	2
29	1.67	2	1.00	2	2.67	3	2.06	3	58	1.00	2	1.00	2	1.00	2	1.50	2
									Ave.	1.58		1.04		1.71			

WA: weighted average, VR: Visual rating, Ave: average

Table 5.5 Pair-wise correlation for inbred lines on grain yield tons ha^{-1} and *Stenocarpella maydis* ear rot infestation when not inoculated and inoculated with *Stenocarpella maydis* ear rot pathogen

	Grain yield	**Ear rot (Uninoculated)**
Ear rot (Uninoculated)	0.03^{ns}	
Inoculated	-0.01^{ns}	0.23^{ns}

^{ns}= non significant, * = significant

Table 5.6 Pair-wise correlation for top cross on grain yield tons ha^{-1} and *Stenocarpella maydis* ear rot infestation when not inoculated and inoculated with *Stenocarpella maydis* ear rot pathogen

	Grain yield	**Ear rot (Uninoculated)**
Ear rot (Uninoculated)	0.27^{ns}	
Inoculated	-0.60*	-0.31^{ns}

^{ns} = non significant, * = significant

Table 5.7 Cultivar performance of 58 inbred lines at two locations in two years

Entry	Loc 1 Y1	Loc 1 Y2	Loc 2 Y1	Loc2 Y2	Comb ave.	Rank
47	2.84	4.34	4.42	3.35	3.74	1
56	1.56	3.06	4.34	3.27	3.06	2
52	1.01	2.51	3.93	2.86	2.58	3
53	1.6	3.1	3.89	2.8	2.85	4
44	1.08	2.58	3.71	2.64	2.50	5
15	1.23	2.73	4.56	2.49	2.75	6
55	2.08	3.58	3.49	2.42	2.89	7
21	1.68	3.18	4.15	2.38	2.85	8
37	1.59	3.09	3.78	2.38	2.71	9
1	1.03	2.55	4.39	2.32	2.57	10
18	1.38	2.88	3.68	2.28	2.56	11
46	1.23	2.73	3.31	2.24	2.38	12
49	1.57	3.07	3.3	2.23	2.54	13
50	1.3	2.81	3.3	2.23	2.41	14
3	1.11	2.61	3.62	2.21	2.39	15
11	2.18	3.68	3.27	2.2	2.83	16
4	2.19	3.69	4.58	2.17	3.16	17
36	1.08	2.58	3.24	2.17	2.27	18
22	1.72	3.22	3.12	2.14	2.55	19
14	1.11	2.61	3.86	2.13	2.43	20
28	1.69	3.19	3.18	2.11	2.54	21
6	1.32	2.82	3.8	2.07	2.50	22
24	1.6	3.1	3.14	2.07	2.48	23
31	1.45	2.95	3.8	2.06	2.57	24
25	1.53	3.03	3.46	2.05	2.52	25
58	1.34	2.84	3.1	2.03	2.33	26
51	1.3	2.8	3.07	2	2.29	27
23	1.33	2.83	3.73	1.99	2.47	28
39	1.18	2.68	3.71	1.98	2.39	29

Table 5.7 continues

Entry	Loc 1 Y1	Loc 1 Y2	Loc 2 Y1	Loc2 Y2	Comb ave.	Rank
54	0.83	2.66	3.05	1.98	2.13	30
26	1.66	3.16	3.01	1.94	2.44	31
42	1.35	2.85	3.34	1.94	2.37	32
20	1.6	3.1	4	1.93	2.66	33
43	2.55	4.05	3	1.93	2.88	34
16	1.13	2.63	3.99	1.92	2.42	35
9	1.32	2.82	2.98	1.91	2.26	36
48	1.54	3.04	2.97	1.9	2.36	37
19	1.62	3.12	3.28	1.88	2.48	38
5	0.86	2.36	2.92	1.85	2.00	39
32	1.11	2.61	2.91	1.84	2.12	40
41	1.78	3.28	2.91	1.84	2.45	41
57	2.39	4.11	2.89	1.82	2.80	42
2	1.92	3.42	4.15	1.75	2.81	43
12	1.99	3.49	2.79	1.72	2.50	44
7	1.39	2.93	2.76	1.69	2.19	45
40	1.28	2.78	2.74	1.67	2.12	46
13	1.08	2.58	3.37	1.63	2.17	47
8	1.43	2.93	2.66	1.59	2.15	48
30	1.17	2.67	3.33	1.59	2.19	49
10	1.14	2.64	2.97	1.57	2.08	50
33	1.79	3.29	2.63	1.56	2.32	51
34	1.43	2.93	2.6	1.53	2.12	52
38	1.92	3.42	2.52	1.45	2.33	53
45	0.98	2.48	2.5	1.43	1.85	54
35	1.87	3.37	2.09	1.02	2.09	55
29	1.75	3.29	1.91	0.84	1.95	56
27	1.54	3.04	1.64	0.57	1.70	57
17	1.21	2.71	1.86	0.45	1.56	58
Average	1.50	3.01	3.29	1.97		

Table 5.8 Cultivar performance of 58 maize top cross hybrids at three locations in two years

Entry	L1Y1	L1Y2	L2Y1	L2Y2	L3Y1	L3Y2	Com Ave	Rank
56	5.58	7.43	5.9	10.76	9.95	8.90	8.09	1
58	5.03	7.21	7.15	12.01	8.67	7.62	7.95	2
28	5.8	7.65	5.8	10.66	9.35	8.30	7.93	3
27	5.02	6.87	5.91	10.77	9.11	8.06	7.62	4
49	5.8	7.65	5.51	10.37	8.67	7.62	7.60	5
3	4.68	6.53	6.27	11.13	8.63	7.58	7.47	6
23	4.49	6.34	6.23	11.09	8.83	7.78	7.46	7
26	4.55	6.4	6.06	10.59	7.87	8.06	7.26	8
46	4.95	6.8	5.52	10.38	8.17	7.12	7.16	9
8	5.94	7.79	5.27	10.13	7.32	6.27	7.12	10
29	4.94	6.79	5.34	10.2	8.1	7.05	7.07	11
14	3.5	5.35	5.67	10.2	9.33	8.28	7.06	12
35	4.6	6.45	5.39	10.25	8.34	7.29	7.05	13
42	5.4	7.25	4.96	9.82	7.95	6.90	7.05	14
47	4.62	6.47	5.5	10.36	8.11	7.06	7.02	15
39	4.9	6.75	5.3	10.16	8.02	6.97	7.02	16
25	4.79	6.64	5.55	10.41	7.87	6.82	7.01	17
45	4.59	6.44	5.57	10.43	8.02	6.97	7.00	18
52	4.75	6.6	5.16	10.02	8.25	7.20	7.00	19
13	5.08	6.93	4.74	9.6	8.33	7.28	6.99	20
51	4.17	6.02	5.71	10.57	8.26	7.21	6.99	21
4	5.65	7.5	5.5	10.36	7.02	5.82	6.97	22
12	5.5	7.35	5.66	10.19	7.17	5.95	6.97	23
21	5.37	7.22	5.33	10.09	7.41	6.36	6.96	24
2	4.7	6.55	5.51	10.37	7.82	6.77	6.95	25
43	4.92	6.77	5.21	10.07	7.89	6.84	6.95	26
9	5.48	7.33	5.27	10.13	7.25	6.20	6.94	27
38	3.99	5.84	5.26	10.12	8.69	7.64	6.92	28
34	5.42	7.27	4.87	9.73	7.59	6.54	6.90	29

Table 5.8 continues

Entry	L1Y1	L1Y2	L2Y1	L2Y2	L3Y1	L3Y2	Com Ave	Rank
30	3.95	5.8	4.69	9.55	9.21	8.16	6.89	30
57	3.36	5.54	6.11	10.97	8.21	7.16	6.89	31
16	4.84	6.69	5.94	10.46	7.21	6.16	6.88	32
33	4.57	6.42	5.06	9.92	8.17	7.12	6.88	33
1	4.38	6.23	5.23	10.09	7.95	6.90	6.80	34
24	4.31	6.16	6.61	11.14	6.75	5.64	6.77	35
20	5.21	7.06	5.02	9.88	7.2	6.15	6.75	36
7	4.85	6.7	5	9.86	7.51	6.46	6.73	37
53	4.52	6.37	5.79	10.65	7.04	5.86	6.71	38
15	3.75	5.6	5.69	10.55	7.72	6.67	6.66	39
48	4.32	6.17	5.26	10.12	7.55	6.50	6.65	40
44	5.11	6.96	5.07	9.93	6.98	5.77	6.64	41
18	4.57	6.42	5.09	9.95	7.42	6.37	6.64	42
19	3.39	5.24	4.99	9.85	8.39	7.34	6.53	43
10	4.32	6.17	5.58	10.44	6.9	5.73	6.52	44
40	4.08	5.93	4.83	9.69	7.82	6.77	6.52	45
6	4.39	6.24	4.44	9.3	7.81	6.76	6.49	46
50	4.01	5.86	5.3	10.16	7.23	6.18	6.46	47
36	3.61	5.46	4.87	9.73	7.87	6.82	6.39	48
37	4.38	6.27	4.74	9.6	7.2	6.15	6.39	49
55	4.17	6.02	5.35	10.21	6.81	5.69	6.37	50
31	3.35	5.2	5.06	9.92	7.84	6.79	6.36	51
22	4.06	5.91	4.93	9.79	7.22	6.17	6.35	52
32	4.62	6.47	4.92	9.78	6.69	5.55	6.34	53
41	3.41	5.26	4.83	9.96	7.79	6.74	6.33	54
54	4.09	5.94	4.06	8.92	7.88	6.83	6.29	55
5	4.08	5.93	5.05	9.91	6.69	5.60	6.21	56
17	4.29	6.14	2.18	7.38	8	6.95	5.82	57
11	4.03	5.88	1.8	6.66	7.16	5.91	5.24	58
Ave	4.59	6.45	5.25	10.09	7.87	6.82	6.84	

CHAPTER 6

6 Recommendations and Future research

Entries 29, 47, 52 and 57 are considered as promising resistant inbred lines. But they still need to be genetically characterized with the aid of molecular (DNA) markers to exploit their genetic potential.

Discrimination based on general combining effects indicates entries 29 and 52 as potentially useful inbred lines for the synthesis of new *Stenocarpella maydis* ear rot conversions. An outstanding entry with a good general combining ability was entry 29, which was appearing amongst the top ten best combiners in all locations.

When making selections for *Stenocarpella maydis* ear rot it is better to make selections over several seasons and locations as *Stenocarpella maydis* ear rot varies from year to year and from location to location. Resistance for *Stenocarpella maydis* ear rot is characterized as polygenic with additive gene effects. This need to be further researched through molecular markers with effective inoculation techniques.

Variation of *Stenocarpella maydis* ear rot infestation is influenced by genetic and environmental effects, thus, resulting in variable and unstable cultural characteristics among *Stenocarpella maydis* isolates. As a result further analysis is needed to determine the genetic groups of *Stenocarpella maydis* population and whether it is uniform and behaves similarly because we need avirulant isolate for artificial infestations. Development of superior inbreds in relation to *Stenocarpella maydis* ear rot resistance with superior hybrid combination will result in superior hybrids.

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8. APPENDICES

Appendix 8.1 Analysis of variance for days to 50% silking of 58 inbred lines evaluated at Bethlehem under natural infestation

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2				
ENTRY	57	77.040	1.352	1.56*	0.0225
ERROR	114	98.667	0.865		
TOTAL	173	175.707			
Grand mean		R^2		C.V	
77.914		43.85%		1.19%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.2 Analysis of variance for days to 50% silking of 58 inbred lines at Cedara under natural infestation

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2				
ENTRY	57	79.839	1401	1.64**	0.0130
ERROR	114	97.333	0.854		
TOTAL	173	177.172			
Grand mean		R^2		C.V	
77.731		45.06%		1.19%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.3 Analysis of variance for days to 50% silking of 58 inbred lines at Potchefstroom under natural infestation

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.080	0.040	0.05[ns]	0.9510
ENTRY	57	83.385	1.463	1.83**	0.0033
ERROR	114	91.253	0.800		
TOTAL	173	174.718			
Grand mean		R^2		C.V	
77.960		47.77%		1.15%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.4 Analysis of variance for days to 50% silking of 58 top cross hybrids at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.034	0.017	0.02[ns]	0.9797
ENTRY	57	45.793	0.803	0.95*	0.57
ERROR	114	95.966	0.842		
TOTAL	173	141.793			
Grand mean		R²		C.V	
78.034		32.32%		1.18%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.5 Analysis of variance for days to 50% silking of 58 top cross hybrids at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	1.046	0.523	0.67*	0.5161
ENTRY	57	40.672	0.714	0.91**	0.6529
ERROR	114	89.621	0.786		
TOTAL	173	131.339			
Grand mean		R²		C.V	
78.098		31.76%		1.14	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.6 Analysis of variance for days to 50% silking of 58 top cross hybrids at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.218	0.109	0.13[ns]	0.8783
ENTRY	57	50.874	0.893	1.06**	0.3863
ERROR	114	95.782	0.840		
TOTAL	173	146.874			
Grand mean		R²		C.V	
78.080		34.79%		1.17%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.7 Analysis of variance for plant height in centimeters from 58 inbred lines at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	673.839	336.920	1.43**	0.2436
ENTRY	57	16344.69	286.749	1.22**	0.1875
ERROR	114	26864.83	235.656		
TOTAL	173	43883.36			
Grand mean		R^2		C.V	
119.471		38.78%		12.85%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.8 Analysis of variance for plant height in centimeters from 58 inbred lines at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	716.276	358.138	1.53**	0.2203
ENTRY	57	16552.368	290.392	1.24**	0.1632
ERROR	114	26632.391	233.617		
TOTAL	173	43901.034			
Grand mean		R^2		C.V	
119.552		39.34%		12.78	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.9 Analysis of variance for plant height in centimeters from 58 inbred lines at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	974.391	487.195	2.77**	0.0669
ENTRY	57	11939.20	209.460	1.19**	0.2144
ERROR	114	20052.94	209.460		
TOTAL	173	32966.59			
Grand mean		R^2		C.V	
118.425		39.17%		11.20%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.10 Analysis of variance for plant height in centimeters from 58 top cross hybrids at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	8.046	4.023	0.01[ns]	0.9907
ENTRY	57	24553.86	430.770	1.00**	0.4891
ERROR	114	49088.62	430.602		
TOTAL	173	73650.53			
Grand mean		R^2		C.V	
210.575		33.35%		9.85	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.11 Analysis of variance for plant height in centimeters from 58 top cross hybrids at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	13.138	6.569	0.02[ns]	0.9831
ENTRY	57	20100.86	352.647	0.92**	0.6378
ERROR	114	43876.20	384.879		
TOTAL	173	63990.19			
Grand mean		R^2		C.V	
211.362		31.43%		9.28%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.12 Analysis of variance for plant height in centimeters from 58 top cross hybrids at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	443.724	221.862	0.94**	0.3943
ENTRY	57	22735.13	398.862	1.96**	0.0093
ERROR	114	26958.94	236.482		
TOTAL	173	50137.79			
Grand mean		R^2		C.V	
205.966		46.23%		7.47%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.13 Analysis of variance for ear height in centimeters from 58 inbred lines at Bethlehem

Source of variation	**Degree of freedom**	**Sum of squares**	**Mean square**	**F-value[a]**	**Pr>F**
BLOCK	2	262.391	131.195	4.73**	0.0106
ENTRY	57	1712.70	30.047	1.08**	0.3544
ERROR	114	3162.94	27.745		
TOTAL	173	5138.029			
Grand mean		R^2		C.V	
36.075		38.44%		14.60%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.14 Analysis of variance for ear height in centimeters from 58 inbred lines at Cedara

Source of variation	**Degree of freedom**	**Sum of squares**	**Mean square**	**F-value[a]**	**Pr>F**
BLOCK	2	298.805	149.402	5.74**	0.0042
ENTRY	57	1682.966	29.526	1.13	0.2813
ERROR	114	2965.862	26.016		
TOTAL	173	4947.632			
Grand mean		R^2		C.V	
36.046		40.05 %		14.15%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.15 Analysis of variance for ear height in centimeters from 58 inbred lines at Potchefstroom

Source of variation	**Degree of freedom**	**Sum of squares**	**Mean square**	**F-value[a]**	**Pr>F**
BLOCK	2	241.046	120.523	4.16**	0.0180
ENTRY	57	1606.092	28.177	0.97**	0.5376
ERROR	114	3302.287	28.967		
TOTAL	173	5149.425			
Grand mean		R^2		C.V	
36.391		35.87%		14.79	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.16 Analysis of variance for ear height in centimeters from 58 top cross hybrids at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	26.724	13.362	0.06[ns]	0.9443
ENTRY	57	10048.78	176.294	0.76[ns]	0.8789
ERROR	114	26583.94	233.192		
TOTAL	173	36659.45			
Grand mean		R^2		C.V	
86.483		27.48%		17.66%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.17 Analysis of variance for ear height in centimeters from 58 top cross hybrids at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	18.103	9.052	0.04[ns]	0.9610
ENTRY	57	9928.006	174.176	0.77[ns]	0.8682
ERROR	114	25942.563	227.566		
TOTAL	173	35888.67			
Grand mean		R^2		C.V	
86.569		27.71%		17.43%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.18 Analysis of variance for ear height in centimeters from 58 top cross hybrids at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	65.517	32.759	0.15[ns]	0.8582
ENTRY	57	9263.868	162.524	0.76[ns]	0.8750
ERROR	114	24395.149	213.993		
TOTAL	173	33724.534			
Grand mean		R^2		C.V	
86.052		27.66%		17.00%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.19 Analysis of variance for husk cover from 58 inbred lines at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	3.480	1.740	7.94**	0.0006
ENTRY	57	22.308	0.391	1.79**	0.0045
ERROR	114	24.965	0.219		
TOTAL	173	50.753			
Grand mean		R²		C.V	
1.451		50.81%		32.26%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.20 Analysis of variance for husk cover from 58 inbred lines at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.046	0.023	0.10[ns]	0.9016
ENTRY	57	17.195	0.302	1.302**	0.0834
ERROR	114	25.287	0.222		
TOTAL	173	42.529			
Grand mean		R²		C.V	
1.425		40.54%		33.04%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.21 Analysis of variance for husk cover from 58 inbred lines at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.046	0.023	0.10[ns]	0.9016
ENTRY	57	17.195	0.302	1.36**	0.0834
ERROR	114	25.287	0.222		
TOTAL	173	42.529			
Grand mean		R²		C.V	
1.425		40.54%		33.04%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.22 Analysis of variance for husk cover from 58 top cross hybrids at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.046	0.023	1.34**	0.2656
ENTRY	57	37.908	0.665	38.80**	0.0000
ERROR	114	1.954	0.017		
TOTAL	173	39.908			
Grand mean		R²		C.V	
1.644		0.9510%		7.97%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.23 Analysis of variance for husk cover from 58 top cross hybrids at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.046	0.023	0.80**	0.4531
ENTRY	57	36.575	0.642	22.25**	0.000
ERROR	114	3.287	0.029		
TOTAL	173	39.908			
Grand mean		R²		C.V	
1.644		91.76%		10.33%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.24 Analysis of variance for husk cover from 58 top cross hybrids at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.046	0.023	0.80**	0.4531
ENTRY	57	36.575	0.642	22.25**	0.000
ERROR	114	3.287	0.029		
TOTAL	173	39.908			
Grand mean		R²		C.V	
1.644		91.76%		10.33	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.25 Analysis of variance for ear position from 58 maize inbred lines at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	6.655	3.328	2.66**	0.0744
ENTRY	57	66.718	1.170	0.94**	0.6042
ERROR	114	142.678	1.252		
TOTAL	173	216.052			
Grand mean		R^2		C.V	
1.707		33.96%		65.54%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.26 Analysis of variance for ear position from 58 maize inbred lines at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	1.253	0.626	3.95**	0.0220
ENTRY	57	8.626	0.151	0.95**	0.5705
ERROR	114	18.080	0.159		
TOTAL	173	27.960			
Grand mean		R^2		C.V	
1.201		35.33%		33.16%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.27 Analysis of variance for ear position from 58 maize inbred lines at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	1.253	0.626	3.95**	0.0220
ENTRY	57	1.253	0.151	0.95**	0.5705
ERROR	114	18.080	0.159		
TOTAL	173	27.960			
Grand mean		R^2		C.V	
1.201		35.33%		33.16%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.28 Analysis of variance for ear position from 58 maize top cross hybrids at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2				
ENTRY	57	17.132	0.301	25.70**	0.0000
ERROR	114	1.333	0.012		
TOTAL	173	18.466			
Grand mean		R²		C.V	
1.121		92.78%		9.65%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.29 Analysis of variance for ear position from 58 maize top cross hybrids at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2				
ENTRY	57	17.132	0.301	25.70**	0.0000
ERROR	114	1.333	0.012		
TOTAL	173	18.466			
Grand mean		R²		C.V	
1.121		92.78%		9.65%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.30 Analysis of variance for ear position from 58 maize top cross hybrids at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2				
ENTRY	57	17.132	0.301	25.70**	0.0000
ERROR	114	1.333	0.012		
TOTAL	173	18.466			
Grand mean		R²		C.V	
1.121		92.78%		9.65%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.31 Analysis of variance for stand count from 58 maize inbred lines at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	5.046	2.523	0.93**	0.3979
ENTRY	57	219.310	3.848	1.42**	0.0588
ERROR	114	309.621	2.716		
TOTAL	173	533.977			
Grand mean		R²		C.V	
12.989		42.02%		12.69	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.32 Analysis of variance for stand count from 58 maize inbred lines at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	8.287	4.144	0.51[ns]	0.5999
ENTRY	57	534.828	9.383	1.16**	0.2470
ERROR	114	920.379	8.074		
TOTAL	173	1463.494			
Grand mean		R²		C.V	
12.839		37.11%		22.13%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.33 Analysis of variance for stand count from 58 maize inbred lines at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.448	0.224	0.01[ns]	0.9936
ENTRY	57	1588.741	27.873	0.80[ns]	0.8295
ERROR	114	3991.552	35.014		
TOTAL	173	5580.741			
Grand mean		R²		C.V	
25.190		28.48%		23.49%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.34 Analysis of variance for stand count from 58 maize top cross hybrids at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	4.149	2.075	0.79**	0.4577
ENTRY	57	133.707	2.346	0.89**	0.6838
ERROR	114	300.517	2.636		
TOTAL	173	438.374			
Grand mean		R^2		C.V	
14.247		31.45%		11.40%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.35 Analysis of variance for stand count from 58 maize top cross hybrids at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	2.943	1.471	4.53**	0.0128
ENTRY	57	58.856	1.033	3.18**	0.0000
ERROR	114	37.057	0.325		
TOTAL	173	98.856			
Grand mean		R^2		C.V	
29.695		62.51%		1.92%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.36 Analysis of variance for stand count from 58 maize top cross hybrids at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.080	0.040	0.00[ns]	0.9956
ENTRY	57	512.552	8.992	0.99**	0.5124
ERROR	114	1038.586	9.110		
TOTAL	173	1551.218			
Grand mean		R^2		C.V	
26.460		33.05%		11.41%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.37 Analysis of variance for lodging resistance from 58 maize inbred lines at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	3.862	1.931	5.31**	0.0062
ENTRY	57	22.718	0.399	1.10**	0.3357
ERROR	114	41.471	0.364		
TOTAL	173	68.052			
Grand mean		R^2		C.V	
0.293		39.06%		205.8%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.38 Analysis of variance for lodging resistance from 58 maize inbred lines at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	20.770	10.385	0.58**	0.5601
ENTRY	57	1145.793	20.102	1.13**	0.2906
ERROR	114	2031.897	17.824		
TOTAL	173	3198.460			
Grand mean		R^2		C.V	
3.632		36.47%		116.2	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.39 Analysis of variance for lodging resistance from 58 maize inbred lines at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	20.793	10.397	0.65*	0.5221
ENTRY	57	1178.190	20.670	1.30**	0.1191
ERROR	114	1813.207	15.905		
TOTAL	173	3012.190			
Grand mean		R^2		C.V	
3.362		0.3980		118.6	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.40 Analysis of variance for lodging resistance from 58 maize top cross hybrids at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	4.563	2.283	2.74**	0.0685
ENTRY	57	65.333	1.146	1.38**	0.0744
ERROR	114	94.770	0.831		
TOTAL	173	164.667			
Grand mean		R^2		C.V	
0.333		42.45%		273.5%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.41 Analysis of variance for lodging resistance from 58 maize top cross hybrids at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	5.563	2.782	0.24[ns]	0.7831
ENTRY	57	10682.029	187.404	16.50**	0.0000
ERROR	114	1294.437	11.355		
TOTAL	173	11982.029			
Grand mean		R^2		C.V	
10.925		89.20%		30.84%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.42 Analysis of variance for lodging resistance from 58 maize top cross hybrids at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	14.632	7.316	0.70**	0.4987
ENTRY	57	462.029	8.106	0.78[ns]	0.8559
ERROR	114	1191.368	10.451		
TOTAL	173	1668.029			
Grand mean		R^2		C.V	
2.925		28.58%		110.5%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.43 Analysis of variance for number of ears per plant from 58 maize inbred lines at Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	321.966	160.983	4.55**	0.0125
ENTRY	57	4772.874	83.735	2.37**	0.0000
ERROR	114	4031.368	35.363		
TOTAL	173	9126.207			
Grand mean		R^2		C.V	
17.414		55.83%		34.15%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.44 Analysis of variance for number of ears per plant from 58 maize inbred lines at Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	9.966	4.983	0.41^{ns}	0.6649
ENTRY	57	1833.471	32.166	2.64**	0.0000
ERROR	114	1386.701	12.164		
TOTAL	173	3230.138			
Grand mean		R^2		C.V	
15.103		57.07%		23.09%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.45 Analysis of variance for number of ears per plant from 58 maize inbred lines at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	241.046	120.523	4.16**	0.0180
ENTRY	57	1606.092	28.177	0.97**	0.5376
ERROR	114	3302.287	28.967		
TOTAL	173	5149.425			
Grand mean		R^2		C.V	
36.391		35.87%		14.79%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.46 Analysis of variance for number of ears per plant from 58 maize top cross hybrids Bethlehem

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	215.598	107.799	4.28**	0.0162
ENTRY	57	3994.782	70.084	2.78**	0.0000
ERROR	114	2873.736	25.208		
TOTAL	173	7084.115			
Grand mean		R^2		C.V	
26.851		59.43%		18.70%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.47 Analysis of variance for number of ears per plant from 58 maize top cross hybrids Cedara

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	54.724	27.362	6.66**	0.0018
ENTRY	57	1139.494	19.991	4.86**	0.0000
ERROR	114	468.609	4.111		
TOTAL	173	1662.828			
Grand mean		R^2		C.V	
33.828		71.82%		5.99	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.48 Analysis of variance for number of ears per plant from 58 maize top cross hybrids Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	25.253	12.626	0.35^{ns}	0.7047
ENTRY	57	2331.448	40.903	1.14**	0.2779
ERROR	114	4099.414	35.960		
TOTAL	173	6456.115			
Grand mean		R^2		C.V	
37.851		36.50%		15.84%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.49 ANOVA for grain yield among 58 maize inbred lines evaluated at Bethlehem in 2005/06 under natural infestation.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	1.811	0.906	5.23**	0.0067
ENTRY	57	29.115	0.511	2.95**	0.0000
ERROR	114	19.739	0.173		
TOTAL	173	50.705			
Grand mean		R^2		C.V	
1.499		61.07%		27.76%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.50 ANOVA for grain yield among 58 maize inbred lines evaluated at Potchefstroom in 2005/06 under natural infestation.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	1.051	0.526	1.17**	0.3145
ENTRY	57	74.366	1.305	2.90**	0.0000
ERROR	114	51.266	0.450		
TOTAL	173	126.684			
Grand mean		R^2		C.V	
3.289		59.53%		20.39%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.51 ANOVA for grain yield among 58 maize top crosses evaluated at Bethlehem in 2005/06 under natural infestation.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	5.967	2.984	5.44**	0.0055
ENTRY	57	73.345	1.287	2.35**	0.0001
ERROR	114	62.534	0.549		
TOTAL	173	141.846			
Grand mean		R^2		C.V	
4.590		55.91%		16.13%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.52 ANOVA for grain yield among 58 maize top crosses evaluated at Cedara in 2005/06 under natural infestation.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	1.814	0.907	6.55**	0.0020
ENTRY	57	113.346	1.989	14.37**	0.0000
ERROR	114	15.780	0.138		
TOTAL	173	130.939			
Grand mean		R^2		C.V	
5.253		87.95%		7.08%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.53 ANOVA for grain yield among 58 maize top crosses evaluated at Potchefstroom in 2005/06 under natural infestation.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	16.341	8.170	7.99**	0.0006
ENTRY	57	89.302	1.567	1.53**	0.0277
ERROR	114	116.630	1.023		
TOTAL	173	222.273			
Grand mean		R^2		C.V	
7.866		47.53%		12.86%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.54 ANOVA for *Stenocarpella maydis* ear rot reaction of 58 inbred lines at Bethlehem under natural infestation.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	6.655	3.328	2.66**	0.0744
ENTRY	57	66.718	1.170	0.94**	0.6042
ERROR	114	142.678	1.252		
TOTAL	173	216.052			
Grand mean		R^2		C.V	
1.707		33.96%		65.54%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.55 ANOVA for *Stenocarpella maydis* ear rot reaction of 58 inbred lines at Cedara under natural infestation.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.966	0.483	1.49**	02306
ENTRY	57	35.362	0.620	1.91**	0.0018
ERROR	114	37.034	0.325		
TOTAL	173	73.362			
Grand mean		R^2		C.V	
1.259		49.52%		45.29%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.56 ANOVA for *Stenocarpella maydis* ear rot reaction of 58 inbred lines in Potchefstroom under natural infestation.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.149	0.075	0.06[ns]	0.9372
ENTRY	57	55.126	0.967	0.84**	0.7649
ERROR	114	131.184	1.151		
TOTAL	173	186.460			
Grand mean		R^2		C.V	
1.632		29.64%		65.72%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.57 ANOVA for *Stenocarpella maydis* ear rot reaction of 58 top crosses evaluated at Bethlehem under natural infestation.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	1.046	0.523	0.66**	0.5211
ENTRY	57	56.029	0.983	1.23**	0.1731
ERROR	114	90.954	0.798		
TOTAL	173	148.029			
Grand mean		R^2		C.V	
1.592		38.56%		56.11%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.58 ANOVA for *Stenocarpella maydis* ear rot reaction of 58 top crosses evaluated at Cedara under natural infestation.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.103	0.052	1.83**	0.1658
ENTRY	57	6.460	0.113	4.00**	0.0000
ERROR	114	3.230	0.028		
TOTAL	173	9.793			
Grand mean		R^2		C.V	
1.034		67.02%		16.27%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.59 ANOVA for *Stenocarpella maydis* ear rot reaction of 58 top crosses evaluated at Potchefstroom under natural infestation.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	3.345	1.672	1.18**	0.3119
ENTRY	57	80.529	1.413	0.99**	0.4998
ERROR	114	161.989	1.421		
TOTAL	173	245.862			
Grand mean		R^2		C.V	
1.759		34.11%		67.78%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.60 ANOVA for grain yield among 58 inbred lines evaluated at Potchefstroom under artificial infestation in 2005/06.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	0.368	0.184	0.28^{ns}	0.7585
ENTRY	57	54.387	0.954	1.44**	0.0521
ERROR	114	75.764	0.665		
TOTAL	173	130.520			
Grand mean		R^2		C.V	
3.077		41.95%		26.49%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.61 Split-plot ANOVA for grain yield for comparison of two inoculation methods of 58 inbred lines evaluated at Potchefstroom.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
ENTRY	57	69.336	1.216	2.29**	0.0000
INOCULATION	1	2.803	2.803	5.29**	0.0224
INOC x ENTRY	57	78.030	1.369	2.58**	0.0000
BLOCK (INOC)	4	4.526	1.132	2.13**	0.0774
ERROR	228	120.857	0.530		
TOTAL	347	275.552			
Grand mean		R^2		C.V	
3.199		56.14%		22.76%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.62 ANOVA for *Stenocarpella maydis* ear rot reaction of 58 inoculated inbred lines evaluated at Potchefstroom.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	14.931	7.466	11.54**	0.0000
ENTRY	57	34.644	0.608	0.94**	0.5963
ERROR	114	73.736	0.647		
TOTAL	173	123.310			
Grand mean		R^2		C.V	
1.655		40.20%		48.59%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.63 Split plot ANOVA for comparison of two inoculation methods of 58 inbred lines for *Stenocarpella maydis* ear rot reaction evaluated at Potchefstroom.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
ENTRY	57	46.141	0.809	0.56^{ns}	0.9947
INOCULATION	1	44.899	44.899	31.08**	0.0000
INOC x ENTRY	57	57.934	1.016	0.70^{ns}	0.9422
BLOCK (INOC)	4	2.644	0.809	0.56^{ns}	0.9947
ERROR	228	329.356	1.445		
TOTAL	347	480.974			
Grand mean		R^2		C.V	
1.991		31.52%		60.35%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.64 ANOVA for grain yield among 58 top crosses evaluated at Potchefstroom under artificial infestation in 2005/06.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	24.651	12.326	3.07**	0.0505
ENTRY	57	198.505	3.483	0.87**	0.7238
ERROR	114	458.405	4.021		
TOTAL	173	681.561			
Grand mean		R^2		C.V	
5.533		32.74%		36.24%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.65 ANOVA for *Stenocarpella maydis* ear rot reaction of 58 inoculated top crosses evaluated at Potchefstroom.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
BLOCK	2	3.345	1.672	1.18**	0.3119
ENTRY	57	80.529	1.413	0.99**	0.4998
ERROR	114	161.989	1.421		
TOTAL	173	245.862			
Grand mean		R^2		C.V	
1.759		34.11%		67.78%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.66 ANOVA for comparison of two *Stenocarpella maydis* ear rot inoculation methods of 58 inbred line for reaction

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
ENTRY	57	73.402	1.288	0.81[ns]	0.8251
INOCULATION	1	29.897	29.897	18.83**	0.0000
INOC x ENTRY	57	57.770	1.014	0.64[ns]	0.9773
BLOCK (INOC)	4	5.966	1.491	0.94	0.4420
ERROR	228	362.034	1.588		
TOTAL	347	529.069			
Grand mean		R^2		C.V	
2.052		31.57%		61.32%	

[a] ns = non significant, *significant at *p<0.05*

Appendix 8.67 ANOVA for *Stenocarpella maydis* ear rot reaction of 58 inoculated top crosses evaluated at Potchefstroom

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value[a]	Pr>F
ENTRY	57	135.337	2.374	3.31**	0.0000
INOCULATION	1	659.677	659.677	920.01**	0.0000
INOC x ENTRY	57	106.778	1.873	2.61**	0.0000
BLOCK (INOC)	4	17.018	4.255	5.93**	0.0001
ERROR	228	163.483	0.717		
TOTAL	347	1082.294			
Grand mean		R^2		C.V	
6.489		84.89%		13.05%	

[a] ns = non significant, *significant at *p<0.05*