EVALUATION OF GROUNDNUT (ARACHIS HYPOGAEA L.) GERMPLASM FOR RESISTANCE TO LEAF DISEASES AND RELATED CYTOPLASMIC FACTORS, TESTA COLOUR AND CUP LEAF

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EVALUATION OF GROUNDNUT (*ARACHIS HYPOGAEA* L.) GERMPLASM FOR RESISTANCE TO LEAF DISEASES AND RELATED CYTOPLASMIC FACTORS, TESTA COLOUR AND CUP LEAF

by

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ABBREVIATIONS AND ACRONYMS

ARC-GCI	Agricultural Research Council - Grain Crops Institute
AFLP	amplified fragment length polymorphism
ANOVA	analysis of variance
AU-PNUT	an overall pest management programme developed by Alabama Agricultural Experiment Station at Auburn
AUDPC	areas under disease programme curve
$Tmax_A$	average daily maximum temperature
RHn_A	average daily minimum relative humidity
$Tmin_A$	average daily minimum temperature
CVA	canonical variate analysis
cm	centimetre(s)
cm^2	centimetres squared
χ^2	chi-square
CpDNA	chloroplast DNA
CV	coefficient of variation
C	control
r	correlation factor
cv	cultivar
°C	degrees Celsius
DNA	deoxyribonucleic acid
ELS	early leaf spot
F	fumigated
GCV	genetic coefficient of variation
PI	germplasm breeding line
g	gram(s)
ha	hectare
h	hour(s)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
kg	kilogram(s)
LNR-IVG	Landbou Navorsingsraad – Instituut vir Graangewasse
LLS	late leaf spot
LP	latent period
Y	lesion density
LD	lesion diameter
LSD	lowest significant difference
MSP	maximum percentage sporulation lesions
μ	micro
μm	micrometer(s)
mg	milligram(s)
ml	millilitre(s)
mm	millimetre(s)
mm^2	millimetres squared
ng	no germination
na	not applicable

O/L	oleic to linoleic acid ratio
PPECB	Perishable Products Export Control Board, Silverton, South Africa
Po	peroxidase
PGPR	plant growth-promoting rhizobacteria
PCR	polymerase chain reaction
Ppo	polyphenol oxidase
PC	Potchefstroom crosses made in breeding programme
Potch	Potchefstroom
RR	rust resistant
-K	single plant selections
SA	South Africa
SADC	Southern African Development Community
SAGIS	South Africa Grain Information Service
LAI	specific leaf area x fraction leaf x biomass
sp	species
SP	sporulation score
SEM	standard error of means
SSA	Sub-Saharan Africa
ssp	subspecies
T	temperature
t	ton(s)
USA	United Stated of America
UBS	unsound, blemished and soiled
vari	variegated
var.	variety
WB	web blotch
W	wetness duration

CHAPTER 1

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important legume crop for sub-Saharan Africa (SSA). In South Africa (SA) subsistence as well as commercial farmers produce the crop. Estimates indicate that between 50 000 and 150 000t groundnuts are produced per annum in SA mostly by commercial farmers. Groundnuts are generally produced for human consumption for both the local and export markets, where relatively high prices are obtained. Groundnuts are an excellent source of plant protein and contain 45-50% oil, 27-33% protein as well as essential minerals and vitamins. They play an important role in the dietary requirements of resource poor women and children and haulms are used as livestock feed. Groundnut oil is composed of mixed glycerides and contains a high proportion of unsaturated fatty acids, in particular, oleic (50-65%) and linoleic (18-30%)(Young, 1996). Groundnut lines with a high oleic acid trait (O/L ratio) have been identified. Gorbet (2003) stated that the new market-type groundnut developed by the Florida Experimental Station, SunOleic®/high oleic, will last from three to 15 times longer than regular groundnuts before going rancid (oxidation). When regular groundnuts are cooked in the high oleic groundnut oil the product will have a longer shelf life. Groundnut oil (low in saturated fat and cholesterol and high in monounsaturated fat), when included in a diet, will lower the triglyceride levels. Groundnuts are also important in the confectionary trade and the stable oil is preferred by the deep-frying industries, since it has a smoke point of 229.4°C compared to the 193.5°C of extra virgin olive oil (Deane, 2004). The oil is also used to make margarines and mayonnaise (Hui, 1996; Sanders *et al.,* 2003). In 2003 the PPECB laboratory (Perishable Products Export Control Board, Silverton, SA) did an analysis on the fatty acids of selected groundnut samples. Lines with high O/L ratios, for example, PC299-K5 (PC = crosses made in the breeding programme at Potchefstroom and K represents single plant selections) with an O/L ratio of 77.44:4.58, have been identified (Analysis by PPECB, 2003).

In the past, the objective of the breeding programme at the Agricultural Research Council - Grain Crops Institute (ARC-GCI) was to develop high yielding groundnut lines with outstanding grain quality based on the export market standard. A range of cultivars has been released since 1974. Sellie was released in 1974 after a long period of domination by Natal-Common, which was a selection of a local landrace. Sellie was popular and for a period of 10 years the only cultivar (cv) available in SA. The one-cultivar situation made the crop extremely vulnerable as a result of a total lack of genetic variability. Sellie is susceptible to the fungal disease that causes black pod rot (*Chalara elegans* Nag Raj and Kendrick). This led to series of black pod rot epidemics during the 1980's. Resistant cultivars such as Harts, Kwarts and Akwa were developed and later demonstrated the importance of the breeding project in the recovery of the groundnut industry, especially for the Vaalharts irrigation area in the Northern Cape province (Van der Merwe and Vermeulen, 1977; Van der Merwe *et al*., 1988). Harts however, has a red testa that is unacceptable to the export market. Farmers plant Kwarts and Akwa but they are susceptible to foliar diseases (regular fungicide applications are needed) and do not have a high O/L ratio (the O/L ratio of Kwarts is 39.31:35.47 and of Akwa 40.73:37.21)(Analysis by PPECB, 2003).

In SA, agricultural production is under pressure with high input costs and relatively low commodity prices for farmers. Resistance breeding is an important component of integrated management strategies. SA is well known for high quality groundnuts. The breeding programme focuses on seed quality, as this is essential for the development of high yielding cultivars. During 2003/04 and 2004/05 totals of 20 400 and 21 100t groundnut kernels, of the 52 027 and 107 717t produced respectively, were exported, 8 478 and 5 768t choice grade kernels to Japan alone. Exports totalled 39 and 20% of the total production of groundnuts, of which 42 and 27% respectively to Japan. (South African Peanut Company, 2005; SAGIS, 2006).

Fungal foliar diseases such as early leaf spot (ELS) caused by *Cercospora arachidicola* Hori, late leaf spot (LLS) caused by *Cercosporidium personatum* (Berk. and Curt.), web blotch (WB) caused by *Phoma arachidicola* Marasas, Pauer and Boerema and rust caused by *Puccinia arachidis* Spegazinni are very important diseases on groundnut in South Africa. These diseases cause quality and yield losses (Pretorius, 2005). Other important fungal diseases are black pod rot (black hull), caused by *Chalara elegans* and *Sclerotinia* blight caused by *Sclerotinia minor* Jagger. Virus diseases, such as the tomato spotted wilt virus, groundnut rosette disease and the groundnut mottle virus also infect groundnut (Van Wyk and Cilliers, 2000).

ELS is one of the most important foliar diseases of groundnuts in SA and can cause considerable yield losses, particularly when the infection appears early in the season. Abundant moisture and high minimum (18-23°C) and maximum (31-35°C) temperatures are ideal conditions for an epidemic (Venkataraman and Kazi, 1979). Fungicides are effective for the control of ELS, but the most cost effective control measure will be resistant lines. On average, the yield increase of ELS-resistant compared to susceptible cultivars in Malawi under high disease pressure was 50% (Subrahmanyam and Chiyembekeza, 1995). Unfortunately, resistant cultivars lack the required seed quality characteristics.

In SA, LLS is similarly important. If not controlled by fungicides, the disease causes severe defoliation of plants and adversely affects yields. Resistant cultivars are available but need to be evaluated for resistance to the other foliar diseases as well. Jacobi *et al.* (1995) and Kokalis-Burelle *et al*. (1997) reported, respectively, that LLS infection is optimal at 20°C and a high relative humidity lasting more than 12 hours per day and that rust infection will be the highest at 20-25°C with a relative humidity ≥87%. LLS and rust often occur simultaneously on the same leaf.

In SA, WB often occurs as part of a complex with other foliar diseases, but it may be the most visible disease towards the end of the growing season. Premature defoliation can occur in severe cases and petioles and stems may also become infected. Reports indicated that wet (relative humidity above 85%), cool (below 29°C) weather, with little evaporation triggered WB outbursts in New Mexico, USA and SA and that WB was more severe on irrigated crops than on rain fed groundnut crops in the USA (Smith and Crosby, 1973; Subrahmanyam *et al.,* 1994; Blamey *et al.,* 1997). The disease is generally controlled by the application of suitable fungicides. Although control by means of fungicides is effective, the use of resistant or tolerant foliar disease cultivars will reduce the input costs of groundnut production considerably. At present, a single fungicide application can cost the farmer more than R90 per ha. Depending on the climate, three to five sprays per season may be required (Phipps, 2004).

Songklanakarin (2003) reported yield losses of as high as 50% from rust all over the world. Establishment of the disease early in the growing season reduced pod fill and necessitated early harvesting. In addition, haulm yields were drastically reduced (Kokalis-Burelle *et al*., 1997). High humidity and high maximum temperatures of 20-25°C and high relative humidity (≥87%) favour the pathogen. The disease is generally controlled with the application of suitable fungicides (Pauer and Baard, 1982a).

The aims of this study were to evaluate ARC-GCI germplasm for resistance or tolerance to the important foliar diseases such as ELS, LLS, WB and rust. A further aim was to ascertain if cytoplasmic factors influence the pattern of inheritance of resistance or tolerance to ELS, LLS and WB, testa colour and mutations such as the one responsible for cup leaf phenotypes.

CHAPTER 2

A REVIEW OF FOLIAR DISEASES ON GROUNDNUT AND RELATED CYTOPLASMIC FACTORS, TESTA COLOUR AND CUP LEAF

INTRODUCTION

Groundnut is a member of the genus *Arachis* in the subtribe Stylosanthinae of tribe Aeschynomeneae of the family Leguminosae. The only species in the genus of significant economic importance is *A. hypogaea* L., an annual herb that forms underground fruits. There are two subspecies of *A. hypogaea,* distinguished primarily on branching pattern and distribution of vegetative and reproductive axes. Subspecies *hypogaea* has two varieties (*hypogaea* and *hirsuta*), whereas ssp *fastigiata* has four (*fastigiata, vulgaris, peruviana and aequatoriana*). The botanical name is derived from the Greek word *arachis* meaning 'legume' and *hypogaea* meaning 'below ground', referring to the formation of pods in the soil (Pattee and Stalker, 1995).

The cultivated groundnut, (*Arachis hypogaea L.*) (2n = 40), described in 1753 by Linnaeus, is an allotetraploid species native to South America and is thought to be of monophyletic origin, harbouring relatively little genetic diversity (Pattee and Young, 1982). Polyploidy creates severe genetic bottlenecks, contributing to the genetic vulnerability of leading crops (Company *et al.,* 1982). Groundnut is cultivated in many countries throughout the world. All other species of the genus *Arachis* are wild, perennial and most are used for grazing (Simpson *et al.,* 2001).

A. hypogaea ssp. *hypogaea,* for instance the Virginia and the Peru types, have a low-growth habit (runner type) with a growth period of four to five months or more and seeds exhibiting marked dormancy. *A. hypogaea* ssp. *fastigiata*, for example the Valentia and Spanish types, has an upright-growth habit (bunch type) with a growth period of three to four months and seeds without dormancy. These types produce seeds that are larger and lower in oil content than those of the upright types. Seeds of the running type are generally used for direct consumption and confectionary purposes, where as those of the Valentia and Spanish types are generally grown for oil extraction (De Waele and Swanevelder, 2001).

Herselman (2003) published the first report where M*lu*I/*Mse*I primer combinations were used in the amplified fragment length polymorphism (AFLP) technique to detect polymorphisms between closely related cultivated groundnut genotypes. The 21 genotypes that were tested were divided into two main groups corresponding to the two subspecies of *A. hypogaea* namely *fastigiata* and *hypogaea*.

Groundnuts are susceptible to various fungal, viral and bacterial pathogens that can cause considerable losses. Control, either by chemical means or by selective breeding for disease resistance, is therefore necessary. Young *et al.* (1980) did trials where fungicides were used for the control of leaf diseases and stated that pod and haulm yields can be increased (at Dundee in Kwazulu-Natal), by using fungicides, but that climatic conditions in the groundnut producing areas in SA are very variable and in some areas, such as Cedara, it was not economical to spray. Swanevelder and Blamey (1981) studied the influence of foliar diseases on kernel mass and found that fungicides for the control of these diseases, increased the kernel mass up to 89%, depending on the locality, season and harvest dates.

Some wild species do have resistance to some of the diseases, but interspecific hybridisation between *Arachis hypogaea* and the wild species is very difficult to achieve. Crosses between different wild species are of particular importance because they might reveal which diploid species are progenitors of the tetraploid *A. hypogaea.* Raman and Kesavan (1962) and Gibbons and Turley (1967) produced the first interspecific hybrid with fertile F_1 progenies, between wild species (Pattee and Young, 1982).

Hybrids between the tetraploid cultigen and diploid species of section *Arachis* produced functionally sterile triploids. Natural or artificially induced hexaploidy usually restored fertility (Pattee and Young, 1982).

2.1 FOLIAR DISEASES

A. EARLY LEAF SPOT

Morphology

Early leaf spot (ELS) is caused by the fungus *Cercospora arachidicola* Hori. The perfect state (asci and septated ascospores) of the early leaf spot pathogen (*Mycosphaerella arachidicola*), described by Jenkins (1938), is rarely observed, but the imperfect state (*C. arachidicola*), also described by Jenkins (1938), is commonly present on lesions.

During the imperfect state the dark brown stromata produce brownish, septated conidiophores, which are generally restricted to the upper leaf surface. The conidiophores produce colourless, curved, septated conidia (35-110 by 3-6µ). Dry weather influence septation (Jenkins, 1938; Gibbons, 1966).

Disease cycle and dissemination

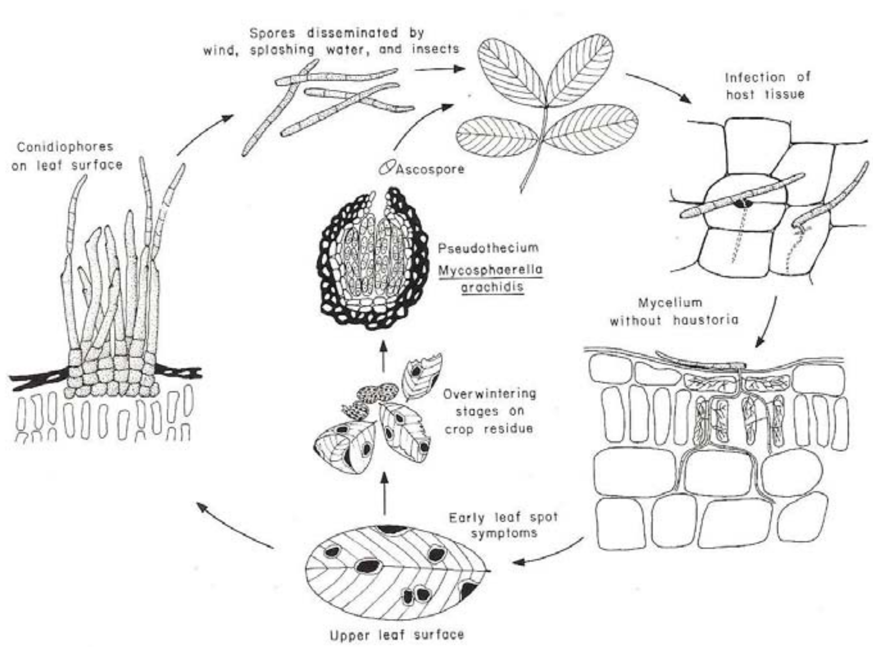

Figure 2.1 Disease cycle for early leaf spot caused by *Cercospora arachidicola* (Porter *et al.*, 1990).

Conidiophores from the imperfect state on groundnut leaves produce conidia, which are dispensed by wind, splashing rain, mechanical dissemination and insects and can germinate within 10 to 14 days to repeat the imperfect state (Porter *et al*., 1990; Subrahmanyam *et al.,* 1992). Conidia germinate, forming germ tubes, which enter open stomata and penetrate directly through the lateral faces of epidermal cells. The mycelium is initially intercellular but becomes intracellular on the death of host cells (Figure 2.1)(Gibbons, 1966; Porter *et al*., 1990). Stomata produce viable conidia after storage for 12 months at 20 to 30°C and 75 to 81% relative humidity (Alabi, 1986).

Climate, micro-environments and method of irrigation (overhead or flood), has been reported to affect disease severity. Optimum temperatures of 25-31°C, high minimum (18-23°C) and maximum (31-35°C) temperatures and high humidity, as well as a late rainy season favour sporulation (Venkataraman and Kazi, 1979; Subrahmanyam *et al.,* 1992). Wu *et al.* (1999) studied the combined effects of temperature (T) and wetness duration (W), (relative humidity ≥95%) and lesion density (Y) under controlled conditions. Disease severity was measured by either lesion density (number per leaf) or lesion size (diameter). In the regression model, the Weibull function characterised the monotonic increase of Y with respect to W, while the hyperbolic function characterised the unimodel response of Y with respect to T. Cultivars varied in their response to W at a given T. At 22.8°C, one lesion per leaf was expected following 26, 30and 36h of wetness. If T was increased to 28°C, one lesion was expected per leaf following 36, 44 and 54h of wetness.

Asci and ascospores are formed by the pathogen in the perfect stage (*Mycosphaerella arachidicola*) during over-wintering on crop residue or volunteer groundnut plants and together with mycelial fragments can also be potential sources of initial inoculum in the spring (Hemmingway, 1957).

Survival

It was suggested that the pathogen perpetuates from season to season on volunteer groundnut plants and infected plant debris, building up an inoculum reservoir for the following season (Subrahmanyam *et al.,* 1992). Later work by Rao *et al.* (1993a) indicated that the conidia, ascospores and mycelium could only survive for between 30-60 days on groundnut debris that was submerged under the soil surface. However, survival increased up to 12 months if the debris was stored indoors.

Symptoms

Lesions are roughly circular, dark brown on the upper leaflet surface, somewhat lighter on the adaxial surface and surrounded by a chlorotic (yellow) halo. They may coalesce in cases of severe attack, leading to defoliation. Lesions can also develop on stems, petioles and pegs (Woodroof, 1933; Jenkins, 1938; Van Wyk and Cilliers, 2000).

Symptoms can be confused with injuries caused by soil-applied chemicals, especially insecticides. However, in the latter case lesions are scattered along the margins of leaves of groundnut seedlings, whereas ELS symptoms are more prevalent on the mature leaves (Hagan, 1998).

Economic importance

Large variations in the severity of losses between localities and seasons occur and yield reductions of 20 to 100% have been reported in SA and other parts of the world (Venkataraman and Kazi, 1979; Subrahmanyam *et al.,* 1992). Both yield and grade can be affected by ELS and in particular by the reduced photosynthesis resulting from premature defoliation after severe infection. Peg rotting occurs when the pegs are weakened by ELS and/or by the reduced ability of diseased plants to maintain healthy pegs (Alcorn *et al.,* 1976; Cole, 1981; 1982; De Torres and Subero, 1992).

The choice of fungicides for the control of ELS is important as some are more economical, requiring fewer applications which can reduce equipment, fuel and labour costs as well as fungicide expenditures (Johnson and Beute, 1986). According to Swanevelder (1980), harvest dates could be postponed where leaf diseases were controlled, resulting in a higher kernel yield, but yield potential must always be taken into consideration before control of leaf diseases, depending on the locality and climatic factors, is recommended.

Disease management

The recommended control of ELS that will be discussed includes the use of multiple fungicide applications, planting of resistant and tolerant cultivars and farming practices such as crop rotation, manipulation of planting dates, careful handling of pods during harvesting and shelling, as well as biological control.

Fungicides

In SA, two seed coating agents are registered for use on groundnuts, namely mancozeb and thiram. The efficiency of the seed agents is directly dependent on the method of application. During dry application the seed testas do not detach easily, but during wet application the wetted testa stretches and can easily be detached from the cotyledons. If the seed is planted directly after wet applications, damage to the testas will be minimal. Complete coating of the seed is essential (Swanevelder, 1998).

The effects of various rates of chlorothalonil applications in combination with partial resistance to ELS were tested in field experiments conducted in North Carolina in 1982 to 1984. The two cultivars tested were NC5 and Florigiant. Areas under disease programme curves (AUDPCs) declined linearly with increasing fungicide rate on both cultivars. Infection and defoliation rates were reduced by both host resistance and increasing the dosages of chlorothalonil. Net return to ELS management on Florigiant was optimised at two and a half litre of chlorothalonil per ha. Yields and economic returns, however, continued to increase with increasing dosage of fungicides on NC5. The greatest benefit from the partial resistance to ELS exhibited by NC5 appeared to be in terms of increasing yield and gross economical value rather than in the reduction of recommended fungicidal dosage (Johnson and Beute, 1986; Shokes and Gorbet, 1990a).

Tebuconazole and chlorothalonil have also been used in spray programmes (Grichar *et al.*, 1998). Treatments included applications of the selected fungicides at a 14-, 21-, 28-day schedule and an unsprayed control. For the 14- and 21-day schedules, chlorothalonil was applied at the first and last spray with at least four sprays of tebuconazole in between. For the 28-day schedule, tebuconazole alone was applied four times. Less ELS infection was present in the 14-day schedule plots than at the 21- and 28-day schedule plots. Only the 14-day schedule plot resulted in significantly higher yield (43%).

Cole (1981) reported that mancozeb+chlorothalonil+vinclozolin or chlorothalonil (each treatment applied for one season) restricted ELS infection, improved kernel yields, reduced the percentage of pods left in the ground after harvest and resulted in fewer rotten pods. Mancozeb+benomyl was more effective than chlorothalonil with or without vinclozolin, which was added for control of *Botrytis cinerea* Pers. ex Fries. Where ELS was controlled, web blotch increased rapidly.

Under conditions of adequate and well-distributed rainfall, or in areas where the crop is grown under supplementary irrigation, there is generally a substantial increase in pod yield due to fungicidal control of ELS. However, under conditions of low rainfall and/or erratic rainfall distribution, fungicidal control of ELS has been found to be ineffective. A study conducted in Malawi by Subrahmanyam and Hildebrand (1997) illustrated this phenomenon. During the 1990/91 season, when rainfall was favourable, the pod yield increase, after fungicide application, varied from 33 to 207%, depending on the cultivar. However, during the 1991/92 season, when dry conditions prevailed, ELS was not affected by fungicide applications.

Although the disease control obtained by correctly applied fungicides is generally excellent, the cost of several fungicide applications required in a normal year is substantial and there are times when growers are unable to make timely applications, as in the aftermath of Hurricane Floyd in 1999 in North Carolina, when a serious outbreak of ELS could not be controlled in time. The groundnut crops in Edgecombe country were severely affected (Isleib *et al.*, 1999).

In the USA, weather based advisory programmes (now computerised) have been used to assist farmers in determining the optimal time for fungicide application and have resulted in significant increases in the net return of groundnut crops (Smith *et al.,* 1974; Horne *et al.* 2005; Johnson *et al.,* 1986a; Johnson and Beute, 1986; Knudsen *et al.,* 1988). However, the risk of development of tolerance to the chemical classes of the fungicides namely azole (benzimidazole and flusilazole), substituted benzene, dicarbozimide and dithiocarbamate inorganic zinc exists. Rao *et al.* (1993b) reported that *C. arachidicola* had developed tolerance to benomyl (benzimidazole) in France.

Breeding for resistance

Although fungicidal control is effective, it is not economically feasible for subsistence farmers due to their limited financial and other resources. It also adds to input costs of commercial farmers. Partial or field resistance has been shown to allow longer intervals between chemical applications, thereby saving the grower the cost of one or more applications per season (Green and Wynne, 1986; Weeks *et al.,* 2000). Green and Wynne (1986) evaluated 10 genotypes for components of partial resistance to ELS in the field and in two detached leaf tests in the greenhouse. In the field study necrotic area per $10cm^2$ leaf area was moderately correlated (r = 0.58) with lesion number per $10cm^2$ leaf area and highly correlated (r = 0.71 to 0.76) with a) total lesion number, b) the predicted number of days after planting by which a standard lesion count was reached and c) defoliation. In the greenhouse only the correlation between a) necrotic area $10mm^2$ per $10cm^2$ leaf area and b) sporulation per leaf was highly significant (r = 0.71 and 0.83 respectively). Necrotic area ($10mm^2$) per $10cm^2$ leaf area measured in the field was significantly correlated with that measured in the greenhouse (r = 0.66). Sporulation per leaf measured in the greenhouse was significantly correlated (r = 0.66) with lesion increase in the field. It may therefore be possible to evaluate and select for components of partial resistance in the greenhouse in order to develop lines with field resistance.

Tuggle *et al.* (1999) collected 43 isolates of *C. arachidicola* in groundnut fields in Florida, Georgia, Northern Carolina and Texas and suggested that the success of efforts to identify resistance to ELS can be affected by the aggressiveness of the pathogen isolate. Variation ($P \leq 0.05$) among the isolates was observed for the parameters of incubation period, the reciprocal of the latent period (an estimation of sporulation rate) and the number of lesions per leaflet. The more aggressive isolates came from Texas and had a shorter latent period and a greater number of lesions per leaflet. These isolates differed in aggressiveness and virulence on different groundnut genotypes. The results suggested that there were different pathotypes among the 43 isolates. Success of efforts to identify resistance to ELS can thus be affected by the aggressiveness of the pathogen. Additionally, the resistance of the breeding lines tested is likely to be effective against a wide array of isolates of *C. arachidicola.* Host plant resistance to ELS is an important component of disease management programmes. The durability of the resistance will only be assured after multiple trials over several years (Tuggle *et al.*, 1999).

During 1990-1991, Subrahmanyam *et al.* (1995) screened 1508 South American germplasm lines, 743 advanced generations and 4177 early generation breeding lines, as well as 126 interspecific hybrids for resistance to ELS. Only 80 germplasm lines, 46 breeding lines and four interspecific hybrids showed an acceptable level of resistance.

Rao *et al.* (1993b) inoculated four genotypes from Zimbabwe, Peru (A. *hypogaea* and A. *fastigiata*) and Burkina Faso with eight *C. arachidicola* isolates (collected in Malawi, Nigeria, ICRISAT, Suriname, China, Madagascar, Botswana and Brazil). The genotypes exhibited a differential reaction to all eight isolates for infection frequency (number of lesions per unit leaf area), lesion size and the presence of chlorosis. It is therefore important that the different pathotypes present in a production area be taken into account in resistance breeding programmes. Cases have been reported where lines selected for resistance to the ELS pathotypes in one locality have proved susceptible to the pathotypes in another (Chandra *et al*., 1995).

Sindhan and Jaglan (1988) reported that resistance to ELS is associated with certain elements and compounds within the groundnut plant. Nitrogen levels were lower and the phosphorous and potassium levels of resistant genotypes were significantly higher than those of susceptible genotypes. After infection, nitrogen and phosphorous levels decreased and the potassium level increased in both susceptible and resistant genotypes. Resistant genotypes contained higher levels of total phenols, ortho-dihydroxy-phenols and non-reducing sugars than the susceptible genotypes. The levels of sugars and reducing sugars, however, were lower. Ascorbic acid accumulates around the infected areas in the leaves of resistant lines and may reduce growth of the pathogen within the necrotic region (Karunakaran and Raj, 1980).

Farming practices

Significant control of ELS has been achieved by crop rotation with bahiagrass (Brenneman *et al*., 1995), cotton, grain sorghum and corn. Deep ploughing of crop residue suppresses the spore forming ability of the pathogen (Weeks *et al.,* 2000; Brenneman and Culbreath, 2005). These authors also reported that ELS epidemics were suppressed in reduced tillage (strip-till) plots as compared to conventional tillage plots. Monfort *et al.* (2004) reported that the number of fungicide applications of chlorothalonil could be reduced from seven to four without compromising control of ELS when reduced tillage was used. This could represent potential savings in production costs based on the current price of chlorothalonil and the labour involved. The effect was enhanced when moderately resistant cultivars were used (Brenneman and Culbreath, 2005).

Baysinger *et al.* (1999) reported that certain post emergence herbicides inhibited conidial germination, whereas others enhanced conidial germination. The herbicide 2,4-DB enhanced conidial germination at concentrations of one, 100 and 1000mg per litre. Lactofen, however, reduced conidial germination by 42% at a concentration of 100mg per litre and inhibited germination entirely at concentrations of 5000mg per litre and higher. It is also essential to use pesticides and nematicides only when needed (Brenneman and Culbreath, 2005).

Biological control

Kokalis-Burelle *et al.* (1992) reported positive results after treatment of leaves with chitin and the bacteria *Bacillus cereus.* Knudsen *et al.* (1987) obtained more effective control using *Pseudomonas cepacia. Verticillium lecanii* has been reported as a parasite on several groundnut pathogens in India, including C. *arachidicola* (Subrahmanyam *et al.,* 1990). The hyperparasitic fungus *Dicyma pulvanata* (Berk. And M.A. Curtis) feeds on leaf spot fungi but this fungus has not been tested yet for the control of ELS in field trials (Brenneman and Culbreath, 2005).

Association between ELS and web blotch (WB)

It appears that *C. arachidicola* produces, or, more likely, stimulates the production of a toxin by the plant, possibly a phyto-alexin, that inhabits the growth of WB (Cole, 1981). The two fungi have been reported to spread independently on groundnuts when leaf area was not limiting, but where *C. arachidicola* colonized leaves at an early stage, colonies generally expanded at the expense of *P. arachidicola*. The incidence of *P. arachidicola* on the cultivar Jacana increased dramatically from 5.5-44.2% where *C. arachidicola* was controlled by mancozeb+chlorothalonil+vinclozolin (1976-1977) or chlorothalonil only (1977-1978) (Cole, 1981; Kokalis-Burelle *et al.,* 1997).

Association between ELS and late leaf spot (LLS)

Anderson *et al.* (1986) investigated the possibility of combining resistance to ELS and LLS in the same genetic background. He suggested that resistance to both diseases is quantitative (due to more that one gene), which made selection for dual resistance difficult. Selection in the F_3 generation based on defoliation caused by ELS and LLS infection and sporulation of *C. arachidicola* and *C. personatum* was performed for resistance to ELS and LLS in North Carolina and Georgia, respectively, within populations of PI 314817/[TG3/EC 76446(292)] and PI 314817/ICGS 4. Selections were evaluated for resistance by visual rating of infection and defoliation in the F_4 generation at the same locality the following year. Anderson *et al.* (1986) calculated the maximum likelihood estimates of broad-sense heritability for resistance traits on F_2-derived lines. Environmental variance was estimated as the mean square for the replicate x F_2 family interaction. Broad-sense heritability estimates ranged from low to high (0.12-0.88) for components of resistance to each leaf spot disease. Non-additive gene effects added to the total genetic variance. Narrow-sense heritability estimates from parent-offspring regression (0.18-0.74) and realised heritability (0.60-1.41) were significant for LLS and

ELS resistances in the PI 314817/[TG3/EC 76446(292)] population. A significant decrease in ELS lesion numbers, infection and defoliation ratings caused by ELS, were found on lines selected for LLS resistance. Indications were that selecting for resistance to LLS could also improve ELS resistance. Further research by Anderson *et al.* (1991) also suggested that moderate to high correlations (0.41-0.86) exist between ELS and LLS disease components (lesion size and latent period) indicating possible genetic linkage of host-plant physiology that conferred resistance to both diseases in one population.

B. LATE LEAF SPOT

Morphology

Late leaf spot (LLS) is caused by the fungus *Cercosporidium personatum* (Berk. and Curt.). The LLS pathogen is seen primarily in its imperfect state, known as *C. personatum.* The perfect state (*Mycosphaerella berkeleyii* W.A. Jenkins) is classified under the asogeneous fungi and both asci and spermatogonia occur on debris where the fungus over-winters (Pattee and Young, 1982). Jenkins (1938) described the imperfect state as follows: conidiophores (10-100 x 3-6.5µm) are mostly hypophyllous, arising in more or less distinctly concentric reddish-brown tufts, generally with hyaline tips. Conidia (20-70 x 4-9µm) are generally cylindrical, pale brown, with somewhat attenuated tips and one or more septates.

Disease cycle and dissemination

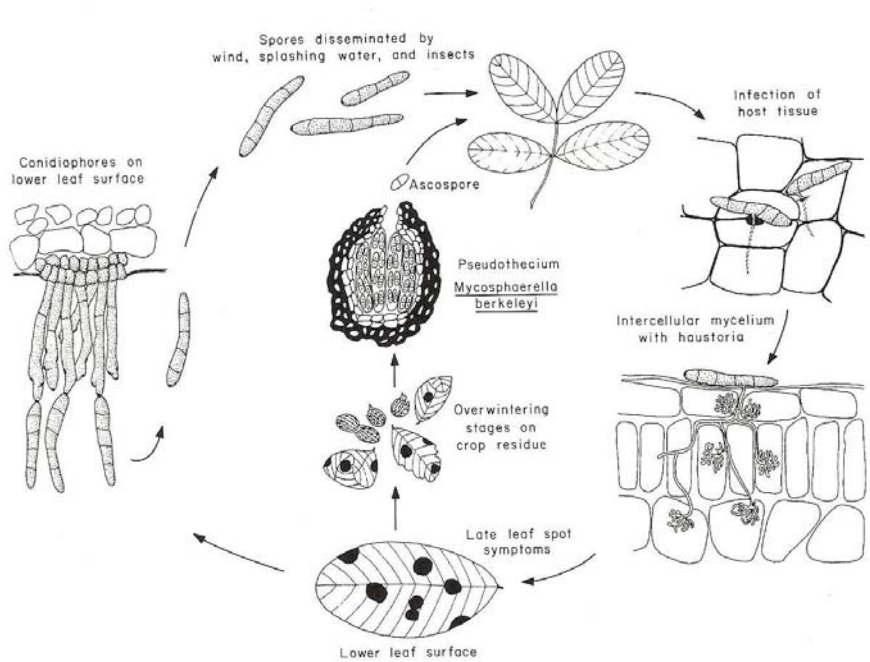

Figure 2.2 Disease cycle for late leaf spot caused by *Cercosporidium personatum* (Berk. and Curt.) (Porter *et al*., 1990).

High relative humidity and an increase in atmospheric temperatures in spring cause an increase in fungal activity. The optimum range for growth and sporulation for *C. personatum* is 25-30°C. Light is a requisite for sporulation. Germination is optimal when temperatures are slightly lower than those favourable for *C. arachidicola* (Pattee and Young, 1982).

Conidia, produced by conidiophores, on groundnut residue in the soil and off-season groundnut plants, serve as the principal source of initial inoculum. Intercellular haustoria are produced at temperatures from 25-31°C and lesions develop within 10-14 days. The lesion forming cycle (Figure 2.2) starts all over again and the conidia are dispersed by insects, farm implements (Pattee and Young, 1982), splashing water (from overhead irrigation or rain) and wind (Smith and Crosby, 1973; Horne *et al.,* 1976; Hagan, 1998; Subrahmanyam, *et al*., 1992). In spring ascospores (Jenkins, 1938), chlamydospores and mycelial fragments (Hemmingway, 1957) are also potential sources of initial inoculum produced on crop residue that over-wintered in the soil (Pattee and Young, 1982; Porter *et al*., 1990).

Survival

The pathogen perpetuates from season to season only on volunteer groundnut plants and infected plant debris, building up an inoculum reservoir for the following season (Subrahmanyam *et al.,* 1992).

Symptoms

According to Woodroof (1933) and Jenkins (1938) the lesions are very similar in size and form to those of ELS. These lesions are, however, darker brown and without a definite chlorotic halo. On the adaxial side of the leaflets, lesions are almost black, in contrast to the lighter coloured lesions of ELS. LLS generally occur later in the season and is often seen as a complex with other leaf spots.

Pattee and Young (1982) reported that *C. personatum* produced cellulolytic and pectolytic enzymes that altered the starch, sugar and amino acid content of leaf tissue, resulting in reduced leaf efficiency and premature abscission. Cercosporin, a biologically active red phytotoxin, was also isolated from *C. personatum.* Mohapatra (1982) also reported that infected leaves contained higher quantities of reducing sugars than healthy ones.

In a study conducted by Pattee and Young (1982), severe leaf spot damage reduced the leaf area index by 80%, the carbon dioxide uptake by 85%and the canopy carbon exchange rate by 93%. Photosynthesis of diseased canopies was reduced not only by defoliation but also by inefficient fixation of carbon dioxide by diseased attached leaves. Horne *et al.* (1976) reported that the LLS fungus produced haustoria that penetrate individual plant cells and that leaves infected with the fungus showed a marked increase in respiration.

Economic importance

In SA, LLS can cause extensive defoliation and substantial yield losses. The intensity of the disease varies from year to year depending on the rainfall and the irrigation methods used. It is enhanced in groundnut monocultures and especially if plant residues are left in the field (Swanevelder, 1998).

Yield losses appear to be brought about more by loss of mature pods due to breaking of pegs during harvest than by reduction of the number of pods formed. Culbreath *et al*. (1991) reported that the cv Southern Runner continued to produce new foliage as leaves infected by LLS were lost and also maintained more healthy leaves during leaf spot epidemics than the susceptible cv Florunner. Ghuge *et al*. (1980) found that reduced disease development resulted in an increase in the dry matter content of the plant, a higher number of mature pods, heavier nuts (as expressed in 100-kernel weight) and enhanced pod yield.

The planting of resistant cultivars will reduce the use of fungicides, maintenance of equipment will be less costly, less fuel will be needed to run the tractors and less labour will be needed to apply the fungicides. Thus farmers will benefit economically from planting resistant cultivars (Johnson and Beute, 1986).

Disease management programmes

Recommended control of LLS includes multiple fungicide applications, planting of resistant and tolerant cultivars and farming practices with crop rotation, deep ploughing of groundnut debris and clean equipment (Pattee and Stalker, 1995).

Fungicides

Pauer *et al.* (1983) evaluated commercial fungicides for the control of LLS in SA at the Vaalharts Agricultural Experimental Station (near Jan Kempdorp). In this study, benomyl, chlorothalonil, fentin hydroxide, mancozeb, a benomyl/mancozeb-combination and tiophanate methyl were the most effective in controlling LLS. Hagan *et al.* (2005)

reported that tebuconazole and tebuconazole+chlorothalonil both have protective and curative activity against leaf spot fungi while chlorothalonil fungicides are only protective.

Field trials were conducted in 1991 and 1992 in Benin and Niger in West Africa to evaluate the cost effectiveness of fungicide application timings and frequencies on four cultivars and nine breeding lines. When fungicides were applied at 40, 55, 70 and 85 days respectively after planting, yield increases of between 1.5 to almost 3t per ha were obtained for two of the lines (Waliyar *et al.,* 2000). Mixtures and alternate applications of chlorothalonil and benomyl were effective for management of the leaf spot diseases, but effective control was not achieved using benomyl only. Backman and Crawford (1984) reported that, for example on the cv Florunner, yield potential of approximately 4 400kg per ha was reduced by an average of 57kg per ha for each percent of defoliation. Groundnuts could tolerate low levels of infection, but all levels of defoliation resulted in some yield loss. Gorbet *et al.* (1982) tested a number of genotypes with pod yield potentials exceeding 3 000kg per ha even when LLS was not controlled with a fungicide. Some entries gave yields exceeding 4 000kg per ha with a moderate fungicide application programme. Southern Runner still gave high yields even when the fungicide applications were halved. In Florida, Gorbet *et al.* (1990) tested 14 breeding lines for reaction to different fungicide application programmes. All the genotypes gave higher yields on the 14-day sprayed plots than on the unsprayed plots. However, those with higher resistance to LLS required less fungicidal treatments.

Culbreath *et al.* (2002) reported that recent registration of sterol biosynthesis inhibitor and strobilurin fungicides for control of ELS and LLS had renewed interest in the potential for loss of disease control due to fungicide resistance. Field experiments were conducted at the University of Georgia Coastal Plain Experimental Station at Tifton in 1995 and 1996 to determine the effects of alternate applications, mixtures and alternating block applications of chlorothalonil and benomyl compared with full-season applications of two rates of chlorothalonil and two rates of benomyl alone on late leaf spot of groundnut and on the proportion of the pathogen population resistant to benomyl (benzimidazole) following the various regimes. Neither tank mixes nor alternating sprays prevented an increase in the relative frequency of benomyl-resistant isolates compared with other treatments in which benomyl was used.

Hagan (1998) reported hat LLS can be controlled by a flusilazool/carbendazim (systemic) compound. The fluzilazool (a silicontriazool) molecule rapidly penetrates the lipid layer on the leaf surface, becoming effective within three hours after application. This is particularly important in wet weather, when groundnuts are at risk from LLS. Crosby and Smith (1968) have employed weather based advisory programmes, utilizing the relationship between temperature, relative humidity and leaf spot development to predict when fungicides should be applied. Good results were obtained.

Bailey and Matyac (1985) developed an electronic weather station capable of measuring temperature and relative humidity that could calculate the fungicide spray advisory. The user would only need to press one or two keys to get the spray advisory information. Spray advisories are intended to add to, not replace, good management. The AU-PNUTS advisory, developed by Jacobi *et al.* (1995), uses the number of days with precipitation greater than 2.5 and National Weather Service precipitation possibilities to predict periods favourable for the development of LLS. The number of fungicide applications can be reduced and disease control and yield can be achieved similar to that of groundnuts where more fungicide applications were made to control ELS (Bailey and Spencer, 1982; Hagan, 1998).

Breeding for resistance

Resistance to LLS could be associated with low partitioning, late maturity and undesirable pod and seed characteristics (Nigam and Dwivedi, 2000).

Hemingway (1957) found a relationship between riboflavin content of the seed and LLS resistance and reported that thick dark green palisade layers and small stomata were associated with disease resistance. According to Cook (1981), cultivars resistant to LLS had fewer lesions on mature leaves. A necrotic defence reaction appeared to be operative on resistant cultivars in response to infection by the pathogen (Pattee and Young, 1982).

Pixley *et al.* (1990) compared LLS epidemic rates and leaf area dynamics on the susceptible cv Florunner and three other partially resistant lines. Percent necrotic area in three leaf canopy layers (estimated by using a modified Horsfall-Barratt diagram), defoliation of the main stem (determined by counting missing leaflets) and leaf area index were recorded at seven to 10 day intervals. The leaf area index (LAI) was calculated as:

LAI = specific leaf area x fraction leaf x biomass

This technique assumes that specific leaf area and the ratio of leaf weight to total aboveground plant weight (fraction leaf) are similar for neighboring plants of the same age and genotype. The specific leaf area is the ratio of leaf area to leaf mass. Leaf spot induced defoliation of Florunner progressed more rapidly than on the other three partially resistant lines. Maintenance of higher LAI by the partially resistant lines was associated with sustained leaf production until maturity.

Chiteka *et al.* (1988) evaluated 116 genotypes in Florida for resistance to LLS. Identical experiments were conducted in the field and greenhouse. The rank of genotypes in the field was significantly correlated with the rank in the greenhouse for latent period (r = 0.57), lesion diameter (r = 0.46) and sporulation (r = 0.59). Selection of genotypes with low sporulation levels could be expected to identify genotypes with desirable levels of other resistance components.

Luo *et al.* (2005) identified genes for resistance to LLS using micro array and real-time polymerase chain reaction (PCR). They detected 56 genes in several functional categories. Seventeen of the 20 most effective genes were selected for validation and they proposed to develop characterised gene probes for marker-assisted selection in breeding programmes.

A high level of resistance to LLS was identified in groundnut lines derived from interspecific crosses with *A. durenensis*. These homozygous lines were used as parents to incorporate resistance into high yielding breeding lines and to produce a segregating population for molecular marker studies (Anderson *et al.,* 2000).

Shokes and Gorbet (1990b) compared three LLS resistant to partly resistant breeding lines and one plant introduction (PI) to susceptible cv Florunner in a five year disease management programme. They used three treatment levels namely maximum, minimum and no disease control. Pod yields, grades and disease resistance were evaluated. The mean yield loss over the five years in the no disease control programme was 60.3% for Florunner, 20.4% for the PI line and 17.0-24.6% for the three resistant to the partly resistant breeding lines. Seed weight was the lowest with the no disease management programme and greatest with the maximal management programme. Seed weight of the susceptible cultivar gave the largest response to LLS control. Hagan (1998) reported that plant appearance scores generally resulted in the best separation of all genotypes particularly under the no disease control programme.

Farming practices

Crop rotation prevents build-up of pathogens in the soil. Breeding line selection of resistant cultivars, removal or deep ploughing of groundnut residue, elimination of volunteer groundnut plants following the harvest, disinfection of equipment, a calendar spray programme, replacement of worn nozzles and correct calibration with the boom set at the proper height to ensure spray penetration through the groundnut canopy are all methods recommended for the control of LLS. In fields sprayed by air some overlap between spray swaths as well as avoidance of irrigation during cool weather also help to keep LLS infection at a minimum. Irrigation should not continue during cool weather (Horne *et al.*, 1976; Shokes *et al.,* 1991; Subrahmanyam *et al.,* 1994; Kokalis-Burelle *et al.,* 1997; Swanevelder, 1998; Hagan, 1998; Kucharek, 2000; Phipps, 2000).

Biological control

Results indicated that LLS (and other leaf spots) resistance in groundnut was not systemically inducible by using strains (19 strains were tested) of plant growth-promoting rhizobacteria (PGPR) and chemical elicitors, as has been reported for reduced incidence of several diseases on other crops including cereals, rice, potato, tomato, miscellaneous vegetables, pome fruit, mango, citrus, grape, banana, peppers and tobacco. However, in one of two experimental tests, foliar sprays with DL-β-amino-n-butyric acid (an elicitor of localised acquired resistance) resulted in less LLS infection (Zhang *et al.,* 2001).

Association between LLS and rust

The connection between the genes that play a role in the combined inheritance of resistance to LLS and rust is still unclear. Subrahmanyam *et al.* (1992) did a survey in the major groundnut growing areas of Niger and Burkina Faso. They found that rust and LLS caused yield loss of up to 50% when rainfall was high. These diseases also have an adverse influence on seed quality and grade characteristics. Nigam and Dwivedi (2000) identified a total of 195 accessions with resistance to rust and/or LLS in groundnut. Pensuk *et al.* (2003) evaluated seven groundnut cultivars for their resistance to LLS and rust. Pod yield, seed yield, shelling percentage, pod number per plant and pod length were also measured. Some cultivars were resistant to LLS but susceptible to rust and visa versa. These cultivars can be used in breeding programmes as sources of LLS and rust resistance.

C. WEB BLOTCH

Morphology

Web blotch (WB) is caused by the fungus *Phoma arachidicola* (Chock.) Taber, Petit and Philly. According to Subrahmanyam *et al.* (1994) Woronichin (1924) reported *Ascochyta arachidis* on dead groundnut leaves in Russia and Khokhryakov (1934) described a similar foliar pathogen on groundnut (*Mycosphaerella arachidicola* Jenk. non Chochrjakov). The nomenclature of the anamorph is confusing as the fungus was previously assigned to the genus *Ascochyta* and the teleomorph included the genera *Mycosphaerella*. *Didymella arachidicola* (Choch.) Taber, Pettit and Philley, is the most commonly used holomorph classification (Kokalis-Burelle *et al.,* 1997).

WB is also known as *Phoma* leaf spot, *Ascochyta* leaf spot, net blotch and muddy spot. WB occurs all over the world and has been found in Australia, Zimbabwe, Brazil, Russia, Argentina, South Africa, USA (Georgia, Oklahoma, Texas)(Phipps, 1985) and Zambia (Subrahmanyam *et al.,* 1994).

Phipps (1985) isolated hyaline, smooth-walled conidia and micro-conidia, which are pigmented chlamydospores, the survival structures of the fungus. Dark brown pycnidia produce pycnidiospores and dark-coloured pseudothecia were also observed in cultures (Marasas *et al.*, 1974; Mikunthan, 1997). The hyphae are brownish and septate. Cylindrical asci form eight ascospores (6.5-7.5µm) with one septum, becoming dark with maturity (Kokalis-Burelle *et al.,* 1997).

Disease cycle and dissemination

WB is most severe during cool conditions with high relative humidity. Picnidiospores and ascospores serve as the main source of inoculum in the field. Under experimental conditions chlamydospores are also capable of initiating the disease. Lesions first appear on the upper surface of the lower leaflets. Pycnidia, conidia, micro-conidia (clusters chlamydospores) and pseudothecia develop on fallen groundnut leaves and provide inoculum that can be carried by wind and rain to infect subsequent groundnut crops (Phipps, 1985; Subrahmanyam *et al.,* 1994; Kokalis-Burelle *et al.,* 1997). The germinated spores form small infection pegs and the germ tubes penetrate the cuticle directly. Networks of individual hyphae ramify between the cuticle and the epidermis and kill adjacent cells, resulting in the web-like symptoms (Marasas *et al.,* 1974; Kokalis-Burelle *et al.,* 1997).

During October 1993, the first outbreak of WB was reported in normally dry zone areas in Sri Lanka, following heavy rains (average relative humidity 79-85%and average temperature of 15-20°C) (Mikunthan, 1997). Reports indicated that wet (relative humidity above 85%), cool (below 29°C) weather, with little evaporation triggered WB outbursts in New Mexico, USA and SA and that WB was more severe on irrigated crops than on rain-fed groundnut crops in the USA (Subrahmanyam *et al.,* 1994; Blamey *et al.,* 1997). Hurricanes with high winds and rain carry the airborne spores into the groundnut producing areas. Hurricane David may have introduced WB into Virginia in 1979

(Phipps, 1985). The lower the temperature, the larger the conidia grow. Pycnidia are immersed in the necrotic leaf spots (Kokalis-Burelle *et al.,* 1997).

Survival

Although *P. arachidicola* survives in infected crop residue or on volunteer groundnut plants and the groundnut plant is the only known natural host, experimental infections have been produced on six other legumes, such as soybean, sweet clover, alfalfa and hairy vetch. Sweet clover and hairy vetch were the most susceptible of the 22 legumes inoculated (Porter *et al*., 1990; Subrahmanyam *et al.,* 1994).

Symptoms

Lesions first appear on the upper surface of the lower leaflets. Although lesions may vary considerably in form and size, a webbed pattern is formed. The lesions may expand to form large greyish-brown blotches with diffused margins, as hyphae can also penetrate sub-epidermal tissue. Lesions may also occur on petioles and stems. Premature leaf shedding may result from severe infection (Kokalis-Burelle *et al.,* 1997; Van Wyk and Cilliers, 2000).

Economic importance

For a realistic economic evaluation of disease control, reasonable accurate estimates of input costs and product prices must be available. Fixed costs were considered as those operation costs (e.g. ploughing, disc harrowing, etc.) and cost of seed, herbicide, etc. not directly related to treatment yield differences. Variable costs were considered as those costs upon which differences were directly dependant (i.e. fungicide and spraying costs) plus those costs that varied according to the yield (e.g. harvesting and transport costs)(Young *et al.,* 1980).

Defoliation usually results in yield losses (Alcorn *et al.,* 1976). WB became a severe problem in SA during 1967, 1970/71and 1973/74 at Vaalharts and in Natal coinciding with very wet seasons experienced during those years (Marasas *et al*., 1974; Swanevelder, 1998). In Zimbabwe and New Mexico, approximately 10% and 50% yield losses respectively can be directly attributed to WB. The disease can also have a serious impact on the quality of Valencia groundnuts marketed in shell form (Kokalis-Burelle *et al.,* 1997). Valencia and Spanish type cultivars in Texas were more severely affected than Virginia types (Lee *et al*., 2005).

Disease management

Recommended control of WB includes multiple fungicide applications, planting of resistant and tolerant cultivars and farming practices with crop rotation, groundnut residue removal and manipulation of planting dates.

Fungicides

Experiments conducted at Vaalharts in SA showed that WB can be controlled by fungicides containing the following active ingredients: iprodione, mancozeb, propineb and especially chlorothalonil and procymidone. Under irrigation it was recommended that first applications should be made during early to mid-February and continued at fortnightly intervals thereafter. Under dry-land conditions, fungicide applications were only economically viable during seasons with unusually high rainfall (Pauer and Baard, 1982a). Cole (1981), working in Zimbabwe, reported that a mancozeb/benomyl mixture was generally more effective than chlorothalonil and Alcorn *et al.* (1976) reported benomyl to be ineffective for the control of WB.

In the USA, weather based advisory programmes have been used and computerised in order to assist farmers in determining the optimal time for fungicide applications (Smith *et al.,* 1974; Horne *et al.* 1976; Young *et al*., 1980; Johnson *et al.,* 1986a; 1986b). Knudsen *et al.* (1988) reported that their model accurately predicted periods of rapid disease increase during 1984. According to the advisory system, six fungicide sprays were recommended. For all treatments, the maximum disease predicted by the model was close to the maximum level of infection observed in the field. Phipps (2004) reported that the history of disease incidents, crop rotation, soil type and fertility and climatic changes in temperature and humidity will determine the need for fungicide and risk for yield losses in each field.

Breeding for resistance

Subrahmanyam *et al.* (1994) showed that the line PI 274190 exhibited the highest degree of resistance to WB in Zimbabwe, but there were reservations as to its use as a parent because of its prostrate growth habit, low-yield potential and purple testa. However, from the limited number of crosses made with this genotype, it was possible to select high yielding genotypes with a spreading-bunch growth habit, tan coloured testas and good resistance to WB. Some selections used in breeding programmes showed an unusual reaction to the pathogen, namely a net-like blotch on the leaflets. Microscopic examination revealed that the fungus was confined to the area below the epidermis. This could be an expression of hypersensitivity. These genotypes did not defoliate rapidly and produced high pod yields. Genotypes are regarded as resistant to WB and incorporated in breeding programmes when there is an extended incubation period, reduced infection frequency and small lesions (Subrahmanyam *et al.,* 1994; Kokalis-Burelle *et al.,* 1997).

In China, 437 groundnut genotypes were evaluated for resistance to LLS and WB during 1999 and 2000. Only two lines with high resistance to WB and four lines with high resistance to LLS were identified (Shanlin *et al.,* 2000).

Farming practices

Crop rotation prevents the build up of pathogens in the soil. During 1979-1984 fields in the USA (Virginia) were planted on a three-year rotation with groundnut and maize and no apparent yield losses were reported (Phipps, 1985). The eradication of volunteer groundnut plants, the selection of resistant cultivars and deep ploughing or removal of residue, are all methods used to control WB. Younger plants are more susceptible to WB infection than older plants, therefore conducive conditions can often be avoided while the plants are young by manipulation of planting dates. (Horne *et al*., 1976; Shokes *et al.,* 1991; Subrahmanyam *et al.,* 1994; Kokalis-Burelle *et al.,* 1997; Swanevelder, 1998; Kucharek, 2000).

Optimum maturity of pods and kernels where the oil content of the kernel is high and moisture levels are low (indicated by black or brown mesocarp) is important as this ensures good quality and yield. Rainfall, night temperatures and diseases influence maturity. To prevent serious damage to the leaves when WB is noticed and as a result, poorly filled pods, the groundnuts are harvested before optimum maturity has been reached. This practice can result in serious yield losses (Yancy, 2001).

No commercially effective biological control measures are available (Phipps, 2000).

Association between WB and ELS

Cole (1981) reported an interaction between *C. arachidicola* and *P. arachidicola*. *C. arachidicola* produces, or, more probably, stimulates the production of a toxin by the plant, possibly a phytoalexin, that inhibits the growth of *P. arachidicola.* The two fungi spread independently on groundnuts when leaf area was not limiting, but where ELS colonized leaves at an early stage it generally increases at the expense of WB. Not all fungicides effective against ELS, LLS and rust will control WB. Kokalis-Burelle *et al.* (1997) confirmed this result.

D. RUST

Morphology

Rust on groundnuts is caused by the fungus *Puccinia arachidis* Spegazinni. Spegazzini (1884) published the groundnut rust pathogen as a new species, *Puccinia arachidis*. Lagerheim recognised it as a new species and published it as *Uredo arachidis* Lagerheim in 1894 (Hennen *et al*., 1987). The names *U. arachidis* and *P. arachidis* refer to the same organism and *P. arachidis* Spegazzini is therefore currently accepted. However, new evidence indicated that the groundnut rust should probably not be classified under the genus *Puccinia*. DNA analysis may shed more light on this, as spermogonial and aecial characteristics cannot be used as these phases of the life cycle have not been reported (Hennen *et al*., 1987; Kokalis-Burelle *et al.,* 1997).

The uredinial stage is the predominant and the most commonly observed. Uredinial orange pustules (uredinia) are hypophyllous, but can develop on petioles and stems. They are scattered, round, or oblong, covered by a thin net-like peridium and are blister-like when immature. The pustules rupture to expose masses of reddish brown urediospores 1-2μm thick with two to four germpores. Teliospores may be intermixed with urediniospores. Telia are chiefly hypophyllous, 0.2-0.3mm in diameter, scattered and brown. A ruptured epidermis is prominent. Teliospores are oblong, predominantly two-celled and thin walled. Teliospores germinate at maturity without a dormancy requirement. Spermagonia, metabasidia, basidiospores and ascospores have not been reported (Hennen *et al*., 1987; Kokalis-Burelle *et al.,* 1997).

Disease cycle and dissemination

Orange coloured pustules on the lower leaflet surface of volunteer groundnut plants rupture to release masses of reddish-brown urediniospores. Urediniospores are the main, if not only, means of dissemination of this pathogen. The incubation period of the spore on the new host plant is seven to 20 days. There are a few records of the occurrence of teliospores in South America, but none from other countries (Savary, 1986; Hagan, 1998).

Temperatures of 20-25°C and high relative humidity (>87%) have been reported optimal for rust development. Under these conditions, infection efficiency, infectious period and sporulation intensity were maximal, whereas the latency period was shortest. Temperature fluctuations trigger the development of groundnut rust epidemics. Intensification in groundnut cultivation would enhance rust epidemics due to more hosts that rust spores can infect and accumulate on (Savary, 1986; Subrahmanyam *et al*., 1992).

Long distance dissemination of the pathogen may be by airborne urediniospores, blown in from the subtropical areas by tropical storms and hurricanes, movement of infected crop debris, pods or seed, the surfaces of which are contaminated with viable urediniospores. The pathogen is spread within fields by wind, rain splash and insects. An increasing number of spores were observed to fall from the canopy to the soil with increasing amounts of rain, suggesting that heavy rain would lessen the number of spores available to infection as spores are washed off the plant leaves (Hammons, 1977; Savary, 1986; Nagarajan and Singh, 1990; Kokalis-Burelle *et al.,* 1997; Hagan, 1998).

Survival

It is thought that *P. arachidis* originated in South America, where the groundnut was domesticated. Volunteer groundnut plants can enable the pathogen to over-winter (Brenneman and Culbreath, 2005). There is no record that *P. arachidis* occurs on any other genus or that any alternate host is involved in its life cycle (Subrahmanyam *et al*, 1989; Kokalis-Burelle *et al.,* 1997; Hagan, 1998). Urediniospores are short lived in infected crop debris, but may survive on volunteer groundnut plants (Hagan, 1998).

Symptoms

Chlorotic lesions develop on the upper leaflet surfaces. Brownish pustules may also appear later on the upper leaflet surface. In cases of heavy infestation leaflets become desiccated. However, the leaf stems still remain attached to the plant. Pustules may also form on shells of developing pods (Spegazzini, 1884; Kokalis-Burelle *et al.,* 1997; Van Wyk and Cilliers, 2000).

Rust symptoms are easily mistaken for spider mite damage and vice versa (Hagan, 1998; Weeks *et al.,* 2000).

Economic importance

In the People's Republic of China, a 49% reduction in pod yield and a 19% reduction in the 100-kernel weight were reported for 1997. Optimum maturity of pods and kernels, when the oil content of the kernel is high and moisture levels are low (indicated by black or brown mesocarp) is important. Establishment of the disease early in the growing season results in reduced pod fill as the plant, which represents the nutrient factory, is weakened and may necessitate early harvesting. In addition, there may be a serious reduction in kernel and hay yields (Kokalis-Burelle *et al.,* 1997; Yancy, 2001, Songklanakarin, 2003).

Disease management

Recommended control of rust includes multiple fungicide applications, planting of resistant and tolerant cultivars and farming practices with crop rotation, manipulation of planting dates and careful handling of pods during harvesting and shelling.

Fungicides

A mixture of benomyl and mancozeb, as well as foliar sprays of chlorothalonil, has been reported to effectively control rust (Pattee and Young, 1982). Chlorothalonil and tebuconazole are effective against both rust and LLS. Fungicide treatment for control of rust should therefore also be effective against LLS and vice versa (Kokalis-Burelle *et al.,* 1997; Hagan, 1998).

Fungicides applied according to a recommended calendar or weather based spray schedule such as AU-PNUT, will generally control rust effectively (Hagan, 1998). It is recommended that, in vulnerable areas, suitable fungicides should be applied as soon as the first rust pustule is noticed (Pensuk *et al.,* 2003; Songklanakarin, 2003). The scouting method used by Weeks *et al.* (2000) (described under ELS) enables early detection.

Breeding for resistance

Although fungicide application is effective in controlling the disease, its high cost is considered uneconomical in many developing countries. The use of resistant cultivars offers a more feasible alternative (Subrahmanyam *et al*, 1992; Songklanakarin, 2003).

Subrahmanyam *et al*. (1989) reported that rust resistance available in the cultivated groundnut is the ‘slow-rusting’ type, where resistant genotypes have an increased incubation period, decreased infection frequency and reduced pustule size, spore production and spore viability. Grouping of the foliar-disease-resistant genotypes based on botanical type indicated that about 87% of them belonged to var. *fastigiata*, 13% to var. *hypogaea*, but none to var. *vulgaris.* The *fastigiata* types are distinct from the normal valencia groundnut types in having typically ribbed, constricted and prominently beaked pods. They also have comparatively long maturation periods. The majority of rust resistant groundnuts are primitive valencia types. Mehan *et al.* (1996) conducted trials for each of the three growth habits, namely erect bunch [Spanish (var. *vulgaris*) and Valencia (var. *fastigiata*)], spreading bunch [Virginia bunch (var. *hypogaea*)) and runners [Virginia runner (var. *hypogaea*)]. They identified 38 genotypes with resistance to rust, representing all three different growth habit groups of groundnut. These genotypes were incorporated in further breeding programmes.

Velazhahan and Vidhyasekaran (1994) studied alterations in the phenolic content and the activities of peroxidase (Po) and polyphenol oxidase (Ppo) in both resistant and susceptible groundnut leaves in response to infection by *P. arachidis*. Total phenol and ortho-dihydroxy phenol contents of resistant breeding lines were higher throughout the growing period when compared to susceptible breeding lines. Activity levels were higher in non-infected resistant breeding lines than in non-infected susceptible breeding lines, but increased in both susceptible and resistant breeding lines after infection.

Kokalis-Burelle *et al.* (1997) reported high levels of resistance and/or immunity to rust among wild *Arachis* species. Two or three duplicate recessive genes govern rust resistance in cultivated groundnut. On the contrary, in diploid *Arachis* spp, rust resistance appears to be, according to the author, partially dominant. In crosses involving both cultivated and interspecific derivatives, rust resistance was controlled by both additive and non-additive gene action. Subrahmanyam *et al*. (1985) reported that the wild *Arachis* species may have genes for resistance to rust different from those in *A. hypogaea*, thus providing the possibility of combining the rust resistance of wild and cultivated species to provide more effective and stable resistance in the cultivated groundnut. Even if some of the same genes are involved, they may be linked to different desirable traits or may produce more effective allelic combinations. It was concluded that rust resistance in diploid wild species is of a partially dominant nature, unlike in *A. hypogaea* where it is, according to the author, recessive. The transfer of rust resistance from wild species should be straightforward because of the dominant nature of the genes (Subrahmanyam *et al*., 1985). Most of the rust-resistant germplasm lines are primitive landraces and have undesirable pod and seed characters (Kokalis-Burelle *et al.,* 1997). Reddy *et al*. (1987) reported that two or three duplicate recessive genes are involved in conferring resistance to rust. Very little is known regarding the relationship between the gene centres of the cultivated groundnut and sources of the resistance to diseases. Resistance genes possibly arose as mutations and were subjected to natural/human selection as the resistant types had advantages over the susceptible ones (Subrahmanyam *et al*., 1989). Cytogenetic research has been successful in incorporating some of these resistance genes into the cultivated groundnut (Kokalis-Burelle *et al.,* 1997).

Rust resistance in most genotypes is stable over a wide range of geographical localities except in a few, indicating possible variation in the pathogen. An array of resistant lines has also been generated at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), from selections within segregating natural hybrids from the USA and from many crosses made between germplasm accessions and agronomically superior but susceptible parents (Reddy *et al*., 1987).

Farming practices

Crop rotation prevents the building up of pathogens in the soil. Planting of resistant cultivars, removal or deep ploughing of groundnut residue, elimination of volunteer groundnut plants following the harvest, a calendar spray programmes, replacement of worn nozzles, recalibration and washing of spray equipment with the boom set at the proper height to ensure spray penetration through the groundnut canopy are all methods used to control the damage that can be done by rust and in fields sprayed by air some overlap between spray swaths is necessary (Horne *et al*., 1976; Shokes *et al.,* 1991; Subrahmanyam *et al.,* 1994; Kokalis-Burelle *et al.,* 1997; Swanevelder, 1998; Hagan, 1998; Kucharek, 2000).

Leaf age and plant development stage influence rust development. Groundnut should not follow groundnut, as pods break off and stay behind in the soil with plant residues. Fungi may over-winter on these materials and provide inoculum in the following spring. Damage can be avoided by planting early when inoculum levels are low. Existing plantquarantine procedures should suffice to prevent spread of the pathogen from field to field on pods, seed and equipment externally contaminated with rust spores, to areas where the disease is absent (Hagarajan and Singh, 1990; Kokalis-Burelle *et al.,* 1997).

Biological control

Several mycoparasites of the rust pathogen have been reported and mycophagous insects may feed on urediniospores. However, no serious attempts have been made to use any of these organisms in biological control of groundnut rust at field levels (Kokalis-Burelle *et al.,* 1997).

Association between rust and LLS

Together, rust and LLS can cause yield losses of 50-70%. The incidence and severity of each disease however, varies with season, location and cultivar (Mehan *et al.,* 1996). Pande and Rao (2001), Pensuk *et al.* (2003) and Sonklanakarin (2003) evaluated groundnut cultivars for resistance to LLS and rust. Pod yield, seed yield, shelling percentage, pod number per plant and pod length were also measured. Some breeding lines were resistant to rust and susceptible to LLS and vice versa. These breeding lines are recommended as sources of LLS and rust resistance. Although the connection between the genes that play a role in the combined inheritance of resistance to LLS and rust is still unclear, Subrahmanyam *et al.* (1992) conducted a survey in the major groundnut growing areas of Niger and Burkina Faso. They found that rust and LLS caused serious damage when rainfall was high. These diseases also have an adverse influence on seed quality and grade characteristics.

2.2 POSSIBLE CYTOPLASMIC FACTORS AFFECTING INHERITANCE OF RESISTANCE TO FOLIAR DISEASES, TESTA COLOUR AND THE CUP LEAF GENOTYPE

INTRODUCTION

The phenomenon of cytoplasmic inheritance occurs because mitochondria and chloroplasts have their own extra-nuclear genes and can reproduce independently. These genomes are maternally inherited. Where maternal inheritance is involved all progeny resemble the female parent. Cytoplasmic effects complicate qualitative inheritance studies. There are cooperative gene expression systems between the organelle and the nucleus (Jinks, 1976; McClean, 1997). The incidence and inheritance of a chloroplast DNA (CpDNA) was studied in crosses among cultivated carrot (*Daucus carota* spp. *sativus*) using the mutation marker, BP10U. CpDNA inheritance was strictly maternal (McClean, 1997; Vivek *et al.,* 1999). In groundnut traits such as number of leaves, cotyledonary lateral branches, leaf width (Parker *et al*., 1970) and pod constriction (Coffelt and Hammons, 1974), have been described as being influenced by cytoplasmic factors. Husted (1934) was the first to suspect a cytoplasmic influence on growth habit. Reciprocal cross differences were reported for, for example, biochemical characters (Gupta, 1990) and foliar disease resistance (Kornegay *et al.,* 1980; Coffelt and Porter, 1982).

Cytoplasmic factors related to foliar diseases in groundnuts

Kornegay *et al.* (1980) observed differences in resistance to leaf spot diseases among the F_2 generation, but not between F_2 reciprocal crosses. In contrast Coffelt and Porter (1982, 1986) compared nine advanced derivatives of the reciprocal cross Chico x Florigiant for reaction to ELS. The derivatives exhibited a wide variation in resistance to ELS and some exhibited higher levels of resistance to ELS than either of the parents. The authors proposed that resistance to ELS was due to a predominant additive gene action. The derivatives selected from reciprocal crosses differed in their degree of susceptibility and that this was indicative that cytoplasmic factors are involved in the inheritance of ELS resistance. They also conducted research on the inheritance of resistance to *Schlerotinia* and reported that when Chico (resistant to *Schlerotinia*) was used as the female parent, the offspring exhibited higher resistance than when Florigiant (susceptible to *Schlerotinia*) was used as female parent. It is therefore possible that cytoplasmic factors may be involved in resistance to *Schlerotinia* (Porter *et al.*, 1992). Pattee and Young (1982) reported that Sharief (1972) inferred that two or more nuclear genes may determine resistance to leaf spots, whereas Sharief *et al.* (1978) and Kornegay *et al.* (1980) proposed that quantitative inheritance may be involved.

Chiteka *et al.* (1996) determined the combining ability for four components of rate reducing ELS resistance. The components were latent period (LP), defined as days from inoculation to sporulation of the first lesion, lesion diameter (LD), sporulation score (SP) with a one to five scale, where one = little or no sporulation and five = more than 50% of lesion covered with stromata with heavy sporulation and maximum percentage sporulation lesions (MSP) at 30 days after inoculation. Additive genetic effects were more important than non-additive genetic effects in the control of partial resistance for LP, LD, SP and MSP. The author concluded that a cytoplasmic factor might be involved in the inheritance of resistance to ELS.

Testa colour

According to Pattee and Young (1982) van der Stok reported on testa colour in 1910. Testa colour is generally categorised as tan, red, variegated, purple, white, yellow or wine, although environmental factors and maturity can influence the intensity of each colour (Pattee and Young, 1982; Cilliers *et al.*, 2001). Between tan and red, variations of pink (dark pink, pink and rose), can occur. This is the result of the presence of different genes with different expressions. Interactions between genes have led to reports of several phenotypes, genotypes and F_2 phenotypic ratios. In incomplete dominance the heterozygote exhibits a phenotype that is intermediate between the two homozygous forms. Co-dominance as well as epistasis could also be involved here (Jones and Karp, 1990).

Duplicate genes (F1f1F2f2/ D1d1D2d2) control the expression of testa colour (pink, rose, russet or tan). According to Pattee and Young (1982) the latter are equivalent to the R1r1R2r2 genes as proposed by Patel *et al.* (1936). In another study it was stated that R was partially dominant to r in some crosses. The white testa is controlled by the double recessive d1d1d2d2 epistatic to the F loci. One dominant allele at either F locus plus 1 dominant allele at either D locus controls tan testa colour. The pigment phlobophene produces the pink or rose testa colour. Another rose pigment produced by gene R, does not dissolve in ethanol. Phlobophene alters the performance of some of the other controlling genes or converts its product to other pigments (Pattee and Young, 1982).

The inheritance of red testa colour is complex. No literature could be found so far identifying cytoplasmic factors involved in the government of testa colour in groundnut. Red is usually dominant to pink or rose, with the red factor interacting with the F loci to produce red testa. The F_2 and F_3 progenies of crosses between two pink or rose testa-coloured lines produced some red testas. Epistasis, where the red colour was inhibited, was suspected in one of the lines (Guaycuru). In one cross, monogenic inheritance caused rose to be dominant to red. Variegated testa was reported as dominant, partially dominant, recessive and digenic. Similar results were observed for inheritance of the red portion of the testa of a variegated seed coat. A single factor T controls rose testa colour and not, as was previously suggested, two factors (F1F2). Incomplete dominance of red testa was reported in crosses of nine tan-coloured lines with the red testa coloured line, Makulu Red. It is evident from these studies that at least two loci (R1r1R2r2) are involved in controlling testa colour (Pattee and Young, 1982).

Cup leaf phenotype

The mutant cup leaf was one of a number of mutations induced by treating dormant groundnut seeds with X-rays. A complex of morphological features ascribed to pleiotropy characterise the phenotype of cup leaf plants. Diagnostic features were involute leaflets disposed in the form of a cup and succulent, easily broken stems. Inheritance of the cup leaf genotype as a mendelian recessive was affirmed in naturally self- and artificially cross-pollinated progenies. Homozygotes reproduced the mutant type and heterozygotes segregated 3:1 phenotypic and 1:2:1 genotypic ratios. The backcross ratio was 1:1 (Pattee and Young, 1982). No literature could be found so far identifying cytoplasmic factors involved in the government of mutations resulting in different phenotypes in groundnut.

CONCLUSIONS

ELS, LLS, WB and rust cause defoliation, which in turn cause yield losses. Control measures have been discussed, but fungicides, the equipment needed for spraying, workers to spray and deep turning of the debris, are expensive. It will be economically viable to develop groundnut genotypes with adequate levels of multiple resistances to ELS, LLS, WB and rust. The cultivation of resistant breeding lines and crop rotations should be highly beneficial in reducing disease severity and its impact on yield and quality of the kernels (Subrahmanyam *et al.,* 1994).

With the development of yield loss models, simulation experiments will be useful in optimising fungicide or bio-control strategies for long-term financial benefit to growers. At present, cytoplasmic factors do not seem to be important in the inheritance of resistance or tolerance to foliar diseases, but little attention has been paid to the nature and extent of cytoplasm/maternal influence. An extensive survey is necessary, as well as a detailed genetic analysis of such important traits as male sterility resistance to different foliar diseases, for genetic improvement programmes in groundnut (Murthy and Reddy, 1993).

Research is needed to understand the association between the genes (nuclear or cytoplasmic) responsible for resistance to ELS, LLS, WB and rust. Pathotypes must be identified. Genetic markers for resistance genes must be researched as this will assist in the testing of potential resistant lines and in shortening the time factor to breed cultivars with potential ELS, LLS, WB and rust resistance.

CHAPTER 3

POSSIBLE CYTOPLASMIC INHERITANCE OF RESISTANCE TO IMPORTANT LEAF DISEASES, TESTA COLOUR AND CUP LEAF

INTRODUCTION

Mitochondria and chloroplasts (in plants) have their own extra-nuclear genes. When cytoplasmic factors are involved the progeny will resemble the female parent for the trait that is cytoplasmically inherited. There are cooperative gene expression systems between the organelle and the nucleus (Jinks, 1976; Hartl, 1994; McClean, 1997).

One or two genes determine high oleic acid percentage. Some traits are determined by many nuclear genes (multigenic). Other traits, like leaf colour, number of leaves, cotyledonary branches, leaf width, pod constriction, seed calcium concentrations, fruit length, weight, oil content and the protein percentage of seeds were produced by the interaction of nuclear and cytoplasmic factors. In cases where cytoplasmic factors exert control over a trait such as male sterility in plants, they are extremely useful. Geneticists can alter more characteristics by manipulation of nuclear genes than plasmogenes (McClean, 1997; Pattee and Young, 1982).

The genes in the nucleus and the genes of the organelles in the cytoplasm of a plant cell, like chloroplasts and mitochondria, show similar patterns of gene expression, so it is sometimes difficult to determine which is responsible for a particular cytoplasmic inheritance phenomenon. For example: three unlinked nuclear loci and one cytoplasmic factor interact with complementary duplicate action to condition pod constriction (Pattee and Young, 1982).

Where cytoplasmic inheritance of resistance to diseases is involved, the genes in the chloroplasts and mitochondria can produce enzymes that can attack the pathogen, help the host to produce physical barriers or produce phyto-alexins that are toxic to the pathogen (Anderson, 1989).

Where there are differences between reciprocal crosses, subsequent failure to segregate according to Mendelian expectations could point to possible cytoplasmic inheritance factors being involved. In *Saccharomyces cereviseae*, the respiratory deficient mutant, *petite*, was cytoplasmically inherited by its failure to segregate according to Mendelian expectations following a cross to the normal strain (Jinks, 1976).

The aim of this study was to ascertain if cytoplasmic factors influence the inheritance of resistance/tolerance to important foliar diseases such as early leaf spot (ELS), late leaf spot (LLS), web blotch (WB), testa colour and mutations such as the one responsible for cup leaf phenotypes.

MATERIALS AND METHODS

Treatments for production of hybrids in the greenhouse

Study of the inheritance of resistance to important foliar diseases

Twelve reciprocal crosses were made for the study of the inheritance of resistance to important foliar diseases. Cultivar (cv) Billy and cv TMV1 show tolerance to infection by LLS and WB; cv Akwa and cv Kwarts are susceptible to LLS, WB and rust; cv Jasper has possible cytoplasmic inheritance of resistance to LLS and WB and the breeding line PC280 (PC = crosses made in the breeding programme at Potchefstroom), shows tolerance to infection by LLS and WB.

Study of the inheritance of testa colour

The seven combinations for the study of the inheritance of testa colour were cv Harts and TMV1 with red testas; Akwa, PC280 and cv Sellie with tan testas and Billy with variegated (var) testas (red with white stripes).

Study of the inheritance of the cup leaf mutation

The two combinations for the study of the inheritance of the cup leaf mutation were the lines, Cup leaf and PC113.

Treatments in the greenhouse

Twenty-five litre pots were filled with sterilised light sandy soil with a pH of 5.3. Fertilizer (4:3:4 33%) was applied at the recommended dosage. The soil was watered the day before planting so as to reach the correct planting temperature of 18°C. In March 2002 three seeds, covered with a fungicide dressing (thiram powder), to prevent soil borne diseases and Rhizobium spores, were planted 5cm deep per pot. The day temperature was 25-30°C and the night temperature was 15-18°C. Irrigation with a hose took place every second or third day to prevent moisture stress. Thrips and red spider mite were controlled with chlorophenapyr (2ml on five litres of water) and mercaptothion (12ml on five litres of water) alternately. Mercaptothion (12ml on five litres of water) was also used to control aphids and bifenthrim (pyretroid) was used to control whitefly and leaf miner (4ml on five litres of water).

To compensate for different growth periods, breeding lines used as males were planted in duplicate, one week before and one at the same time the females were planted. This ensured that pollen was available when the female flower buds started appearing.

Method for crosses

Groundnut plants flower from 40 up to 63 days. Anthers were removed between 15h00 and 18h00. The flower bud on the maternal parent was emasculated the previous evening by first removing the lower lip of the calyx and then the wing and keel petals to expose the anthers and stigma. The anthers were removed carefully so as not to damage the stigma. A short piece of string was tied around the hypanthium of the flower. Watering and nutrient applications were done in the evening after the emasculations had been made. A small wire dome (60cm high and with a diameter of 36cm) covered with a big plastic bag, was placed over the emasculated flower to prevent the stigma drying out and losing its stickiness.

The pollinations were done between 7h00 and10h00 the following morning by removing a healthy, fully open flower from the male parent, squeezing pollen onto a forceps and transferring the pollen to the stigma of the emasculated flower. When changing from one pollen source to another, the forceps and fingers of the operator were dipped in an alcohol solution to reduce the possibility of pollen contamination. The small dome covered with the plastic bag was then placed over the pollinated flowers to prevent the pollen and stigma from drying out.

After seven days, unpollinated flowers, as well as all other flowers that had not been emasculated, were removed.

If fertilisation was successful, the aerial peg was usually visible seven to 10 days after pollination. Fitting a thin wire with a loop around the peg marked the developing pegs, with withered flowers and strings still attached. The lateral vegetative growth and fruiting branches were kept pruned back. The plant matured the hybrid pegs and seeds without the development of other pods. At the end of the growth season the pods with the wire still attached, were harvested, dried for two weeks and shelled (Nigam *et al.,* 1990).

Planting the F_1 seed for the study of testa colour and cup leaf phenotypes in the greenhouse (self-pollination)

Seedbeds in the greenhouse were filled with sterilised sandy soil with a pH of 5.4. Fertilizer (4:3:4 33%) was added at the recommended dosage. The soil was watered the day before planting so as to reach the correct planting temperature of 18°C. The F_1 generation seeds were covered with thiram powder to control soil borne diseases and Rhizobium spores for good nitrogen production and planted 5cm deep, 7cm apart in the row and 50cm between rows. The day temperature was 25-30°C and the night temperature was 15-18°C. Irrigation with a hose took place every second or third day to prevent moisture stress. Thrips and red spider mite were controlled with chlorophenapyr (2ml on five litres of water) and mercaptothion (12ml on five litres of water) alternately. Mercaptothion (12ml on five litres of water) was also used to control aphids and bifenthrim (pyretroid) was used to control whitefly and leaf miner (4ml on five litres of water).

Planting the F_1 seed for the study of foliar diseases in brick blocks (self-pollination)

The F_1 generation seeds were planted in square brick blocks (6m x 6m) filled with sandy/loamy soil with a pH of 5.5, together with their parental genotypes, at Potchefstroom (localities: Appendix 2). The seeds were planted by hand at a depth of 5cm in single rows (the seeds were limited), 10cm inter rows and 50cm between rows. The blocks were flood irrigated to prevent moisture stress. Lasso was sprayed at the prescribed concentration to manage weeds and further weed control was done by hand hoeing. Insects were no problem and no chemicals were used to prevent foliage diseases. All the plants of the F_1 generation were rated for LLS and WB by using the International Modified 9-Point Scale (Appendix 1: Table 1b) (Subrahmanyam *et al.,* 1995) and the adapted constructed Modified 9-Point Scale for rating the WB infection (Appendix 1: Table 1c). One equals no infection and nine equals 100% infection. For all scales, a rating of three or lower was regarded as an indication of resistance and shaded in grey.

Genetic analysis

The chi-squared test (χ^2) was used to test the goodness of fit to different genetic ratios (Jones and Karp, 1990).

The formula for calculating chi-squared is:

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

Σ = sum of; O = observed values; E = expected values.

RESULTS AND DISCUSSION

Foliar diseases

F_1 generation

No differences in resistance as was shown by the reciprocal parents, to foliar diseases were observed on the F_1 generation. Disease ratings for foliar diseases are shown in Table 3.1.

F_2 generation

The disease ratings on the F_2 progenies are presented in Table 3.1.

Table 3.1 Disease ratings on F_2 segregating material of the crosses between entries

Crosses	♀	♂	LLS	Mean	WB	Mean
	4 ratings		1 2 3 4		1 2 3 4	
	Billy(C)		1 1 1 2	1.25	1 1 1 2	1.25
1	Billy	Akwa	1 2 4 8	3.75	1 2 4 8	3.75
2	Akwa	Billy	1 3 7 8	4.75	1 2 3 7	3.25
	Akwa (C)		2 3 4 5	3.5	1 2 3 5	2.75
	Jasper (C)		1 2 3 5	2.75	1 2 4 5	3.0
3	Jasper	Akwa	1 2 2 5	2.5	1 2 3 5	2.75
4	Akwa	Jasper	1 2 3 5	2.75	1 2 3 5	2.75
	Kwarts (C)		1 2 4 4	2.75	1 2 3 4	2.5
5	Jasper	Kwarts	1 3 3 6	3.25	1 3 3 5	3.0
6	Kwarts	Jasper	1 2 3 6	3.0	1 2 3 5	2.75
	PC280 (C)		1 1 2 3	1.75	1 1 2 3	1.75
7	Kwarts	PC280	1 2 4 6	3.25	1 3 4 5	3.25
8	PC280	Kwarts	1 2 4 5	3.0	1 2 4 5	3.0
9	Jasper	PC280	1 3 7 7	4.5	1 2 3 7	3.25
10	PC280	Jasper	1 2 4 7	3.5	1 2 5 7	3.75
	TMV1(C)		1 1 2 2	1.5	1 1 2 3	1.75
11	TMV1	PC280	1 1 2 3	1.75	1 1 2 3	1.75
12	PC280	TMV1	1 1 2 3	1.75	1 1 2 3	1.75

C control

resistance shaded in grey

The results showed that although Billy has the resistance gene(s) to LLS and WB the offspring of the reciprocal crosses between Billy and Akwa did not differ significantly in their reaction to the diseases suggesting the absence of maternal effects. If genes in the chloroplasts or mitochondria influenced resistance to foliar diseases, it would have been expected of the offspring of Billy and Akwa to be resistant or tolerant to LLS and WB. This was not the case. If these chromosomes have effects, it will be in addition to the effects of the genes on the chromosomes in the nucleus. The reciprocal crosses of TMV1 and PC280 showed no more resistance to LLS and WB than their parents also suggesting the absence of maternal effects.

Testa colour

F_1 generation

The seeds from the crosses where planted, harvested and the results noted.

F_2 generation

The F_1 seeds where planted, harvested and categorised (Table 3.2).

Table 3.2 Observations on testa colour of offspring of the crosses between entries

♀	♂	F_1	Populations of F_2 plants	F_2 seeds red:tan	Expected ratio	χ^2	P	df
Harts	Sellie	red	61	1700:600	3:1	1.4492	20-30%	1
Sellie	Harts	red	10	243:66	3:1	2.1845	20-30%	1
PC280	TMV1	red	20	399:152	3:1	1.9509	50-70%	1
TMV1	PC280	red	31	763:259	3:1	0.0639	80-90%	1
				vari: pink+dark pink:tan				
Billy	Akwa	vari	18	459:135:54	1:(1:1):1	0.2222	95-98%	3
Akwa	Billy	vari	15	325:130:26	1:(1:1):1	1.0685	70-80%	3
PC280	Billy	vari	45	910:560:112	1:(1:1):1	34.9709	none	3

vari variegated

Some patterns of inheritance in chloroplasts are known. Normal chloroplasts are light-responsive and revert to smaller forms without chloroplasts, called proplastids in the absence of light. Genetically defective chloroplasts often fail to respond to light, causing the presence of spots or stripes that lack chlorophyll on the leaf surfaces or other areas of the plant. In the simplest cases, there is clearly defined cytoplasmic inheritance. Thus, for example, a flower from a white region of a four-o'-clock plant will produce white progeny no matter what pollen it is fertilised with and a flower from a green area will always produce a green plant, irrespective of the pollen. Variegated plants with areas of white and green typically arise from heteroplasmic ovules. There are some plants in which the chloroplasts are paternally inherited (from the pollen-producing parent) and some cases the inheritance is biparental. Genes in the nucleolus determine the phenotype of the chloroplasts (Jinks, 1976; Jones and Karp, 1990).

The testas of the F_1 seeds as a result of successful reciprocal crosses between Harts and Sellie and PC280 and TMV1 were all red. Nuclear genes were suspected to be responsible for testa colour. The F_2 progenies all gave χ^2 values that supported the expected ratio of 3:1 (df = 1) and it can be concluded that a single dominant gene is responsible for the red testa colour in the crosses mentioned above.

The offspring of Billy (variegated: red with white stripes) x Akwa (tan) gave two tan :two pink :three dark pink :three slightly variegated :five more variegated: eight variegated testas. The offspring of the reciprocal cross gave two tan: five pink: five dark pink: five slightly variegated: 10 more variegated: 10 variegated. By grouping the tan, pink and dark pink testas together and the variegated testas together, the chi square test (at three df as there actually were four groups) showed that incomplete dominance of genes controlled the variegated testa colour.

The χ^2 value of 34.9709 for the cross PC280 x Billy was highly significant and rejected the hypothesis of a 1:2:1 ratio. It is possible that the variation is due to chance. PC280 is one of the breeding lines developed at Potchefstroom and has already been evaluated in the Elite trials (the F_7 generations are included in the Elite trials) for yield and quality. The combination of genes responsible for the tan testa colour of specifically PC280 is not known.

The cup leaf phenotype

F_1 generation

The seed resulting from the crosses were planted and the resulting plants were categorised for their phenotypes and counted Table 3.3).

F_2 generation

The F_1 pods were harvested, shelled, planted and the phenotypes counted (Table 3.3).

Table 3.3 Phenotypes of the F_1 and F_2 generations for the cup leaf crosses

♀	♂	F_1 phenotypes	F_2 phenotypes Cup:normal	Expected ratio	χ^2	P	df
PC113	Cup	cup	16:9	3:1	1.6133	20-30%	1
Cup	PC113	cup	38:13	3:1	0.0065	90-95%	1

The F_1 offspring of the reciprocal crosses between Pc113 and Cup gave the cup leaf phenotype. Nuclear gene involvement was suspected. The χ^2 values of 1.6133 and 0.0065 for the respective reciprocal crosses in the F_2 supported the expected ratio of 3:1.It can thus be concluded that cytoplasmic factors do not govern the cup leaf phenotype and that a single dominant gene is responsible for the cup leaf phenotype. The results showed that PC113 x Cup leaf is an example of a monohybrid cross.

CONCLUSIONS

None of the results suggested that cytoplasmic factors have specific effects on the inheritance of resistance or tolerance to LLS and WB, testa colour and the cup leaf phenotypes in groundnut. It is however, always possible for genes, in the nucleus or the organelles in the cytoplasma, to have additive influences.

CHAPTER 4

EVALUATION OF GROUNDNUT GERMPLASM FOR RESISTANCE TO EARLY LEAF SPOT, LATE LEAF SPOT, WEB BLOTCH AND RUST DURING 2003/04 IN SOUTHERN AFRICA

INTRODUCTION

The groundnut-breeding programme at the Agricultural Research Council of the Grain Crops Institute (ARC-GCI) at Potchefstroom is the only one in South Africa and dates back more than 100 years (Herselman, 2003). The vast majority of groundnut cultivars currently produced in SA, including Harts, Akwa, Kwarts, Anel, Rambo and Sellie, have been developed by this institute. It is important that the germplasm collection should be expanded to enable the programme to produce new cultivars capable of increasing and improving groundnut production, not only for South Africa but also for other Southern African Development Community (SADC) countries. This has also been a tendency in foreign breeding programmes (Anderson *et al.,* 1986; Green and Wynne, 1986; Subrahmanyam *et al.,* 1994; Luo *et al*., 2005). In 1940 J.P.F. Sellschop 'rediscovered' Natal Common, a Spanish type groundnut brought in by Portuguese traders, among the indigenous people of South Africa and released it as a cultivar in 1942 (Van der Merwe, 1981). During a world study tour Sellschop collected various exotic groundnut breeding lines, including Namark, a landrace from Kenya. The cultivar (cv) Sellie (resulting from a cross between Natal Common and Namark) was registrated in 1974 (Herselman, 2003). Sellie was selected primarily for the irrigation area at Vaalharts and gave a kernel yield of 2916.2kg per ha, 29% higher than that of the cultivars planted at that time (Van der Merwe and Vermeulen, 1977). For 18 years Sellie was the only commercial cultivar available in South Africa. During that time black pod rot (caused by the fungus *Chalara elegans* Nag Raj and Kendrick), to which Sellie was susceptible, assumed epidemic proportions under irrigation in South Africa. Consequently, the cv Harts, which is still resistant to black pod rot, was developed by the ARC-GCI in Potchefstroom from a cross between the cultivars Guat and Atete (Van der Merwe and Swanevelder, 1988).

Genetic diversity and relationships between cultivated Southern African genotypes such as Harts, Akwa and Kwarts (cultivars developed from a cross between Harts and Sellie), Anel and Sellie, were detected by using the amplified fragment length polymorphism (AFLP) technique although low levels of genetic diversity exists among these genotypes (Herselman, 2003).

The South African ARC-GCI germplasm collection now totals 960 entries (since June 2003, 81 new additions were made) and contains released cultivars and lines from international (such as USA, ICRISAT-India and ICRISAT-Malawi) and local breeding programmes, as well as old and new local and African continent landraces with different favourable characteristics such as resistance to diseases and pests, quality, a high oleic acid and low linoleic acid content (O/L ratio), high oil percentages, yield and adaptation. Wide genetic variation as to traits such as yield, pod- and kernel phenotypes, number of seeds per pod and testa colour, can also be found in the germplasm bank (Cilliers and Swanevelder, 2003). Hassan and Beute (1977) evaluated germplasm lines for resistance to ELS and used lines with resistance successful in their breeding programme.

In SA, farmers prefer the short/medium growth season cultivars (±150 days from planting to harvesting) as they do not have the costly equipment to plant and harvest the larger and longer kernel types that require a long growth season (±180 days). Climatic conditions in SA do not favour the long growth season cultivars although they are generally high yielding. During harvesting short/medium growth season cultivars are stacked with less difficulty than the long growth season cultivars, which are also inclined to lose more pods in the soil and hamper the farmer in the preparation of fields for winter crops (Swanevelder, 1998).

The aim of the ARC-GCI breeding programme is to develop short/medium growth season cultivars with improved resistance to diseases and nematodes, while at the same time improving other attributes such as yield, seed size, testa colour, dormancy and high oleic acid percentage for improved shelf life.

Wild groundnut species such as *Arachis duranensis* Krap.et Greg. *nom. nud* and *A. cardenasii* Krap.et Greg. *nom. nud*. (Pattee and Young, 1982) have been used in crosses at Potchefstroom (PC) and the progeny will be evaluated for resistance to foliar diseases in field trials. Wild species often have genes responsible for resistance or tolerance to foliar diseases, insects and drought but some have additional chromosomes and during crosses with commercial cultivars, sterile triploids are produced. Wild species generally have a low yield potential and are difficult to harvest. The kernels are small and the testa colour fluctuates between black, red and white which is usually unacceptable for the market.

The aim of this study was to evaluate the germplasm of the ARC-GCI for resistance or tolerance to four foliar diseases, early leaf spot (ELS), late leaf spot (LLS), web blotch (WB) and rust under a variety of local conditions of natural disease pressure. Lines tested included selected progeny of crosses between local cultivars (for example Harts) and wild species, as well as the newly acquired germplasm mentioned above.

MATERIALS AND METHODS

Localities

The various trials were planted at one, two, or three of the following five localities namely Potchefstroom, Vaalharts, Brits, Cedara and Burgershall. These were representative of the different climatic areas where groundnuts are grown in South Africa and for climatic conditions conducive to the development of fungal diseases. The data represent latitude, longitude, altitude, pH, soil types and other climatical criteria that can influence the severity of infection and were recorded between October 2003 and May 2005 at the five localities and is shown in Appendix 2.

Germplasm entries

One hundred and thirty eight ARC-GCI germplasm entries were used. These consisted of 58 from ICRISAT-Malawi, 13 from Mayaguaz, Puerto Rico, three from the USA and 64 “Potchefstroom Cross” (PC) lines from the ARC-GCI breeding programme.

Short/medium growth season lines (±150 days) are of the bunch type and long growth season lines (±180 days) are of the runner or semi-runner type. Where growth season length was known, entries were separated into short/medium and long growth season trials for ease of harvesting.

Trial layout for 2003/04

Four groups of trials were planted during the 2003/04 season, namely 4.1: Unreplicated trials using promising material at three localities (Vaalharts, Cedara and Burgershall), representing different climatic zones. 4.2: Replicated trials at Brits using Elite and advanced ICRISAT lines. 4.3: A nematode evaluation micro plot trial and 4.4: ICRISAT lines with limited available seed, in brick beds at Potchefstroom. The former was planted to evaluate nematode resistance (results not reported here) but were also evaluated for resistance to fungal foliar diseases.

4.1 Unreplicated trials at three localities (Vaalharts, Cedara and Burgershall)

Fifty-nine promising entries, chosen for their potential resistance (according to the Groundnut Germplasm Catalogue of the ARC-GCI at Potchefstroom) (Cilliers *et al*., 2001) to ELS, LLS, WB, rust, groundnut pod nematode, with potential high yield and good quality kernels, were planted at Vaalharts (planted 05/11/03), Cedara (planted 14/11/03) and Burgershall (planted 20/11/03). These localities represent a hot dry, a cool humid and a hot humid climatic zone respectively. As the number of seeds was limited, single rows of 3m were planted, with 46 entries (including 28 ICRISAT lines) at all three localities and 13 entries (selected from ICRISAT-Malawi lines) at Cedara and Burgershall only. The latter had been classed as rust resistant (RR) in Malawi. Trials were planted by hand with an intra-row spacing of 7.5cm and an inter-row spacing of 30cm.

Cultivar (cv) Sellie (susceptible to all the foliar diseases) was used as a spreader and control and planted as side rows to counteract the side-row effect and to give protection against grazing animals such as rabbits, guinea fowl, porcupine and antelope.

4.2 Replicated trials at Brits (Elite and ICRISAT)

The Elite trials (planted routinely every year) consisted of selections of the best entries planted in previous trials (based on the pod-, kernel- and yield grading results of previous years). For the 2003/04 season, they consisted of 21 PC short/medium and 15 long growth season entries (13 PC and two ICRISAT lines). Plots consisted of two 9m rows. These trials were planted during November 2003 in a randomised block design with three replications

The advanced ICRISAT lines were selected for high yield, good quality and resistance to foliar diseases and were planted in two trials. One trial consisted of seven short/medium and the second of six long growth season lines. Plots consisted of single 9m rows as seeds were limited. Inter-row spacing was 90cm and intra-row spacing was 7.5cm. These trials were planted on November 2003 in a randomised block design with three replications

Akwa was chosen as control for the short/medium growth season entries as this cultivar is always included in the Elite trials as it is widely planted and liked by the industry and Billy for the long growth season entries as this cultivar has good potential resistance to foliar diseases and is easily distinguishable by its dark-green leaves and variegated testa colour (red with white stripes). Cv Makatini has small, dark green leaves that is easily identifiable and was planted as border rows.

4.3 Micro-plot trials at Potchefstroom

Resistance to the groundnut pod nematode (*Ditylenchus africanus*, Wendt) was evaluated on these plots, but entries were also rated for ELS, LLS and WB. Rust did not occur. The trials were planted during November 2003 in a randomised block design with three replicates and 16 entries. Plots consisted of four rows each, with an inter-row spacing of 15cm and an intra-row spacing of 7.5cm (10 plants per row).

4.4 Trials with new ICRISAT lines planted in brick boxes at Potchefstroom

This trial was unreplicated as seeds were limited. The eight entries were planted by hand at a depth of 5cm on 8/11/03. Rows were 300cm long, with an inter-row spacing of 45cm and an intra-row spacing of 7.5cm.

Treatments

Plant depth

The seeds in all the trials were planted by hand at a depth of 5cm.

Weed control

The herbicide Lasso was applied one week before planting at the prescribed dosage to control weeds and thereafter weeds were controlled by hand hoeing when necessary.

Pest and disease control

Seeds were treated with thiram powder to inhibit seed borne diseases. No insecticides or fungicides for the control of foliar diseases were used in any of the trials.

Measured characteristics

Ratings were done on ELS, LLS and rust infection according to the International Modified 9-Point Scale for ELS, LLS and Rust (Tables 1a, 1b and 1d in Appendix 1) (Subrahmanyam *et al.,* 1992; Subrahmanyam *et al.,* 1995). These tables were adapted for the rating of WB (Table 1c, Appendix 1) as no existing scale was available. For all scales, a rating of three or lower was regarded as an indication of resistance, a rating of between three and four as an indication of tolerance and a rating of >4 to 9 as susceptible.

The highest maximum rainfall and the highest maximum temperature for each month were recorded to evaluate for their influence on LLS infection and the average maximum daily temperature ($Tmax_A$, °C) and the average minimum daily relative humidity (RHn_A, %) for their influence on WB and rust infections. High temperatures and high rainfall resulted in LLS infection. WB prefers cool, humid conditions and rust moderate to high temperatures and humid conditions. Climatic data for October 2003 to April 2004 (supplied by the Institute for Soil, Climate and Water, Agromet Section, Pretoria, South Africa, 0001) is shown in Appendix 7.

Statistical analyses

Analysis of variance (ANOVA) was done on all trial data except on the unreplicated trials planted at the three localities, Vaalharts, Cedara and Burgershall. Statistical components used in the discussion were coefficient of variation percentage (CV), genetic coefficient of variation (GCV) and repeatability. Maxiplan and Microsoft Office software (including Excel and Word) were used to determine the parameters.

The formulae used were

CV: $\sqrt{\{[(C2\text{-}A2\text{-}B2)/[(\text{treatments}-1) \times (\text{trial mean})]\}} \times 100$

GCV: $\sqrt{\{[(E2\text{-}F2)/\text{replications}]/\text{trial mean}\}} \times 100$

A2	Σ of squares, replications
B2	Σ of squares, treatments
C2	L – N
L	Σ[(original raw data – trial mean)^2]
N	[mean(original raw data – trial mean)]
E2	mean of squares, treatments
F2	mean of squares, error
G	Σ all data over all replications
	Trial mean = [G/(treatments x replications)]

The correlation variation (CV) is defined as the sample standard deviation expressed as a percentage of the sample mean (Steel and Torrie, 1960). Pearce (1965) suggested from experience that the level of CV to be expected depends upon species, the quantity measured, the choice of experimental material and the number of organisms that make up an experimental unit. According to Mandel (1964) the only transformations of scale that leave the CV unaffected is the proportional one, such as a change of grams into pounds.

The data will thus not automatically be rejected if the CV is high. Other components such as GCV that represents genetic variation between entries as to certain traits such as resistance to foliar diseases will then be discussed.

Repeatability indicates the consistency between, for example, trial yield of an entry across replications (Van der Merwe, 1984).

RESULTS AND DISCUSSION

Unreplicated trials planted at Vaalharts, Cedara and Burgershall (Trial 4.1)

Results for the average LLS, WB and rust ratings for the unreplicated trials at three localities (Vaalharts, Cedara and Burgershall) are presented in Tables 4.1, for replicated trials at Brits (Elite and ICRISAT) in Tables 4.5 to 4.7, for the trials planted on the micro-plots at Potchefstroom in Table 4.12 and for the ICRISAT lines in the brick boxes at Potchefstroom in Table 4.13.

The average foliar disease ratings for LLS, WB and rust are presented in Table 4.1. A summary of entries that showed resistance/tolerance to LLS, WB and rust is presented in Table 4.1.1. Summaries of the applicable weather data are shown in Tables 4.2, 4.3 and 4.4 for Vaalharts, Cedara and Burgershall respectively. The highest maximum rainfall and the highest maximum temperature for each month (Tmax, °C) are shown in Figures 4.1, 4.3 and 4.5 for Vaalharts, Cedara and Burgershall respectively. The average maximum daily temperature ($Tmax_A$, °C) and the average minimum daily relative humidity (RHn_A, %) are shown in Figures 4.2, 4.4 and 4.6.

Average LLS, WB and rust ratings at Cedara, Vaalharts and Burgershall

An ANOVA for these trials could not be computed, as they were not replicated.

Table 4.1 Average late leaf spot (LLS), web blotch (WB) and rust ratings on 59 groundnut entries at Cedara, Vaalharts and Burgershall during 2003/04

		Cedara			Vaalharts			Burgershall		
E	Entries	LLS	WB	Rust	LLS	WB	Rust	LLS	WB	Rust
1	ICGMS-28	7	3	3	1.5^{1}	2	1.5^{3}	7	7	7
2	ICGMS-29	7	3	5	5	2	1.3^{2}	6	6	6
3	ICGMS-30	7.5	2.5	7.5	4.8	1.5^{3}	2	7	7	7
4	ICGV 90078	1.5^{2}	2.5	3	2.5	3	1^{1}	7	7	1^{1}
5	ICGV 90092	3.5#	3	3	2.8	3	1^{1}	7	7	1^{1}
6	ICGV 90077	2^{3}	1^{1}	1.5^{3}	2.3	1.5^{3}	1.5^{3}	6	7	1^{1}
7	ICGV 90197	2.5	1^{1}	1^{1}	2^{3}	1^{1}	1.5^{3}	5	5	1^{1}
8	ICGV 90103	4.5	1^{1}	5.5	2.5	1^{1}	1^{1}	7	7	7
9	ICGV 90080	3.5#	1^{1}	2	2^{3}	1^{1}	1.3^{2}	7	7	4#
10	ICGV 90071	1^{1}	1.5^{2}	2	1.5^{1}	1^{1}	1.3^{2}	4#	4#	2^{3}
11	ICGV 90096	2.5	1^{1}	1^{1}	2^{3}	1^{1}	1.3^{2}	4#	5	1.5^{2}
12	ICGV 90099	1^{1}	1^{1}	1.3^{2}	1.5^{1}	1.3^{2}	1^{1}	4#	3	1.5^{2}
13	ICGV 90087	1.5^{2}	1^{1}	1.3^{2}	1.5^{1}	1.3^{2}	1^{1}	5	2^{3}	1.5^{2}
14	89R/23	5.5	1.5^{2}	1^{1}	4#	2.3	1^{1}	4#	6	2^{3}
15	92R/199/12/04	5	2^{3}	5.5	2.5	1^{1}	1^{1}	7	7	7
16	92R/70/4	4.5	1^{1}	1^{1}	3	1^{1}	1.3^{2}	4#	4#	1.5^{2}
17	86-87/175	2.5	1^{1}	1^{1}	1.8^{2}	1.8	1.3^{2}	7	2	1^{1}
18	86-87/175-	2.5	1.5^{2}	1^{1}	1.5^{1}	2.5	1.3^{2}	6	1.5^{2}	1^{1}
19	89R/61	1.5^{2}	1^{1}	1^{1}	2^{3}	2.5	1.3^{2}	3	1.5^{2}	1^{1}
20	88/115-11-1	1.5^{2}	1^{1}	1.3^{2}	2^{3}	2.3	1.3^{2}	2^{3}	1^{1}	1^{1}
21	88/115	2.5	1.5^{2}	1^{1}	2^{3}	2	1^{1}	4#	1^{1}	1^{1}
22	ICGV 93555	5	1^{1}	3	2^{3}	2	1^{1}	5	5	5
23	ICGV 95342	3	1^{1}	1^{1}	1.5^{1}	1^{1}	1^{1}	2^{3}	2^{3}	1^{1}
24	ICGV 95343	6	1.5^{2}	1^{1}	3	1^{1}	1^{1}	5	4#	1.5^{2}
25	ICGV 95344	5.5	1^{1}	1^{1}	3	1^{1}	1^{1}	6	5	7
26	ICGV 95345	6	1^{1}	4#	3	1^{1}	1.5^{3}	7	7	3
27	ICGV 95346	4.5	1^{1}	1.5^{3}	3.5#	1^{1}	1.3^{2}	5	7	3
28	ICGV 95349	4#	1^{1}	1.5^{3}	3.5#	1^{1}	1^{1}	5	6	1.5^{2}
29	ICGV 95350	4#	1.5^{2}	2	4.5	1.3^{2}	1^{1}	6	6	4#
30	ICGV 95352	4#	1^{1}	1.5^{3}	4#	2	1.3^{2}	1^{1}	6	5
31	ICGV 95353	5.5	1^{1}	3	2^{3}	2	1.3^{2}	1^{1}	6	6
32	ICGV 95355	7	1^{1}	7.5	2.5	2.5	1.3^{2}	7.5	7.5	5
33	ICGV 95357	7.5	1^{1}	7.5	2.5	2.5	1.3^{2}	7	6	7
34	ICGV 95359	7.5	1^{1}	7.5	4.5	2.5	1.3^{2}	7	7	7
35	ICGV 95360	7.5	1^{1}	7.5	4#	3	1^{1}	6	7.5	7.5
36	ICGV 95262	4.5	1.5^{2}	5	2^{3}	1^{1}	1^{1}	7	7	7
37	PC299-K19	7.5	1.5^{2}	7.3	4#	1.3^{2}	1.3^{2}	7.5	6.5	6
38	PC299-K5	5.5	1.5^{2}	7.8	4.5	1.3^{2}	2.3	7	7	7

		Cedara			Vaalharts			Burgershall		
E	Entries	LLS	WB	Rust	LLS	WB	Rust	LLS	WB	Rust
39	Jasper	5	1.5^{2}	5.5	4.5	3	1^{1}	7.5	7	7
40	Akwa	5.5	1.5^{2}	4.5	4.5	2	1.3^{2}	7	7.5	7
41	Kwarts	5	1.5^{2}	5.5	4.8	2	1.3^{2}	7	7	7
42	Billy	5	1^{1}	6	2^{3}	1.3^{2}	1^{1}	7	7.5	7
43	Rambo	5	1^{1}	5.5	2^{3}	1.3^{2}	1^{1}	6	6	7
44	Kano	5	1^{1}	7	2^{3}	1.3^{2}	1^{1}	6	7.5	7
45	RG611	5	1^{1}	5.5	4#	1.3^{2}	1^{1}	6.5	6.5	7
46	Sellie (control)	7	2.5	5.5	5	5	1.3^{2}	6.5	6.5	7
47	RR line 1	6	1^{1}	1^{1}				6.5	6	4#
48	RR line 2	6.5	1.5^{2}	1^{1}				6	5	6
49	RR line 3	6.5	1^{1}	1^{1}				2^{3}	4#	4#
50	RR line 5	8	1^{1}	1^{1}				7	7	7.5
51	RR line 6	ng	ng	ng				ng	ng	ng
52	RR.line 7	4.5	1^{1}	1^{1}		Not planted as seeds were limited.		1.5^{2}	6	4#
53	RR. line 8	4.5	1.5^{2}	1^{1}				4#	6	1^{1}
54	RR Line 9	3.5#	1.5^{2}	1^{1}				4#	3	3
55	RR Line 10	3.5#	1.5^{2}	1^{1}				5	4#	1^{1}
56	RR Line 11	4.5	1^{1}	1^{1}				1^{1}	6	1^{1}
57	RR Line 12	4.5	1^{1}	1^{1}				1^{1}	6	1^{1}
58	RR Line 13	4.5	1^{1}	1^{1}				1^{1}	5	2^{3}
59	RR Line 14	4.5	1^{1}	2.5				7	6.5	1^{1}

ng — no germination

resistance is shaded in grey and tolerance marked "#"

PC — Potchefstroom cross

-K — progeny of single plant selections

RR — rust resistant germplasm entries

E — entry

ICG(V)(MS) — ICRISAT entry

x^{1}, x^{2}, x^{3} — ranks: (first, second and third)

Table 4.1.1 Summary of entry numbers that showed resistance/tolerance to late leaf spot (LLS), web blotch (WB) and rust at Vaalharts, Cedara and Burgershall during 2003/04

	Cedara	Vaalharts	Burgershall
LLS	4-7, 9-13, 17-21, 23, 28-30, 54, 55	1, 4-13, 18-21, 23-35, 42-45	10-12, 14, 16, 19-21, 23, 30, 31, 49, 52-54, 56-58
Best entries with resistance to LLS (ratings 1 to 1.5)	4, 10, 12, 13, 19, 20	1, 10, 12, 13, 18, 23	30, 31, 52, 56, 57, 58
WB	Climatical conditions not favourable for WB	Climatical conditions not favourable for WB	10, 12, 13, 16, 17-21, 23, 24, 49, 54, 55
Best entries with resistance to WB (ratings 1 to 1.5)			18, 19, 20, 21
Rust	1, 4-7, 9-14, 16-31, 47-50, 52-59	Climatical conditions not favourable for rust	4-7, 9-14, 16-21, 23, 24, 26-29, 47, 49, 52-59
Best entries with resistance to rust (ratings 1 to 1.5)	6, 7, 11-14, 16-21, 23-25, 27, 28, 30, 47-50, 52-58		4-7, 11-13, 16-21, 23, 24, 28, 53, 55, 56, 57, 59

Vaalharts

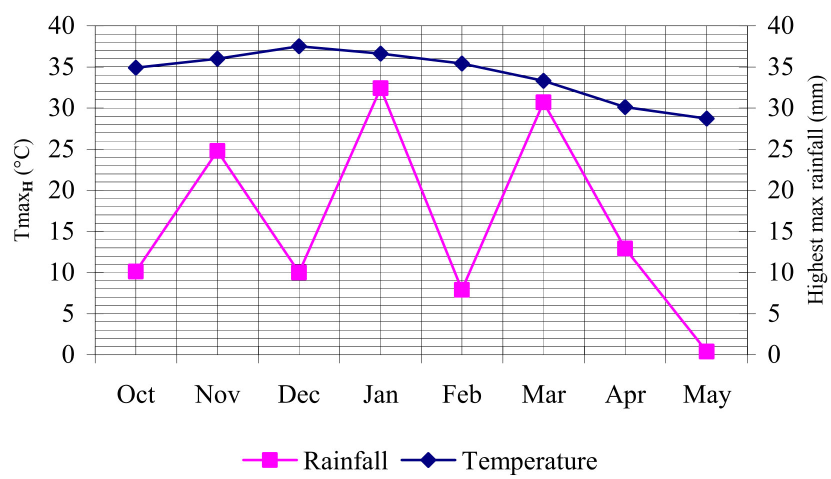

Figure 4.1 Highest maximum rainfall (mm) and temperature ($Tmax_H$, °C) during 2003/04 for Vaalharts.

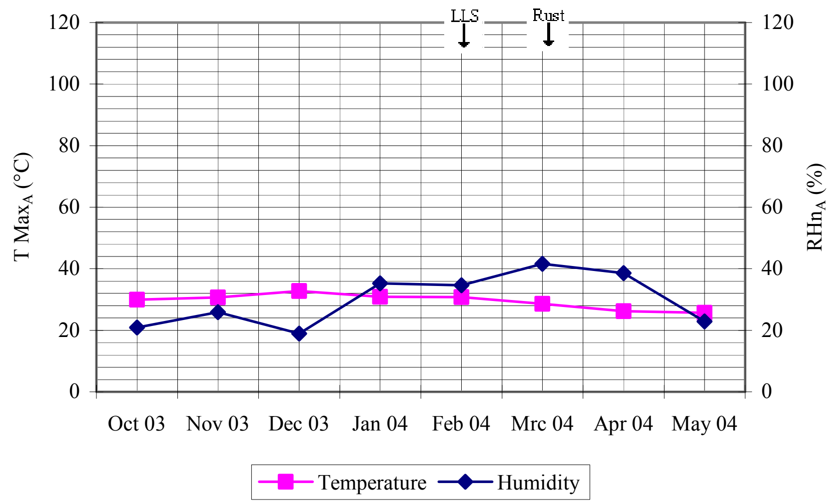

Figure 4.2 Average daily maximum temperature ($Tmax_A$, °C) and average daily minimum relative humidity (RHn_A, %) during 2003/04 for Vaalharts.

Table 4.2 Weather data for the season of 2003/04 at Vaalharts

Weather components	Summer season Oct	Nov	Dec	Jan	Feb	March	April	May
$Tmax_H$ (°C)	34.9	36.0	37.5	36.6	35.4	33.3	30.1	28.7
$Tmax_A$ (°C)	29.9	30.7	32.8	30.9	30.8	28.6	26.2	25.7
[$Tmax_A$-$Tmin_A$ (°C)]	19.3	16.6	19.4	14.7	15.5	14.6	17.4	21.0
RHn_A	20.9	25.9	18.9	35.2	34.6	41.6	38.6	22.9

$Tmax_H$, °C — highest maximum temperature

$Tmax_A$, °C and $Tmin_A$, °C — average daily maximum and minimum temperatures

RHn_A, %) — average daily minimum relative humidity

Cedara

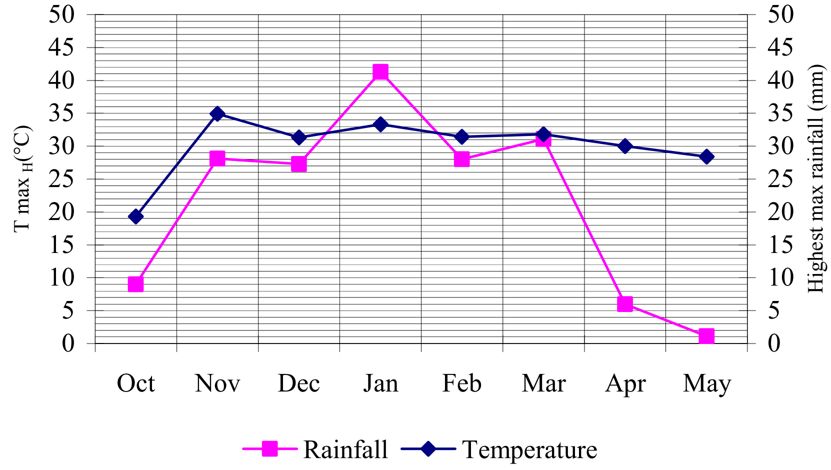

Figure 4.3 Highest maximum rainfall (mm) and temperature ($Tmax_H$, °C) during 2003/04 for Cedara.

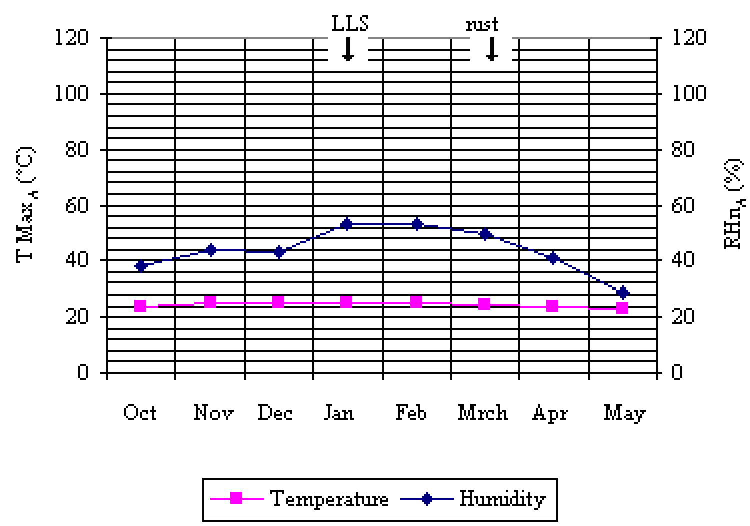

Figure 4.4 Average daily maximum temperature ($Tmax_A$, °C) and average daily minimum relative humidity (RHn_A, %) during 2003/04 for Cedara.

Table 4.3 Weather data for the season of 2003/04 at Cedara

Weather components	Summer season							
	Oct	Nov	Dec	Jan	Feb	March	April	May
$Tmax_H$ (°C)	19.3	34.9	31.3	33.3	31.4	31.8	30.0	28.4
$Tmax_A$ (°C)	23.9	24.9	25.3	25.4	25.3	24.3	24.0	23.1
[$Tmax_A$-$Tmin_A$ (°C)]	12.8	11.6	10.4	9.7	9.5	8.6	12.9	16.0
RHn_A	38.4	43.9	43.1	53.4	53.1	49.6	40.6	29.0

$Tmax_H$, °C — highest maximum temperature

$Tmax_A$, °C and $Tmin_A$, °C — average daily maximum and minimum temperatures

RHn_A, %) — average daily minimum relative humidity

Burgershall

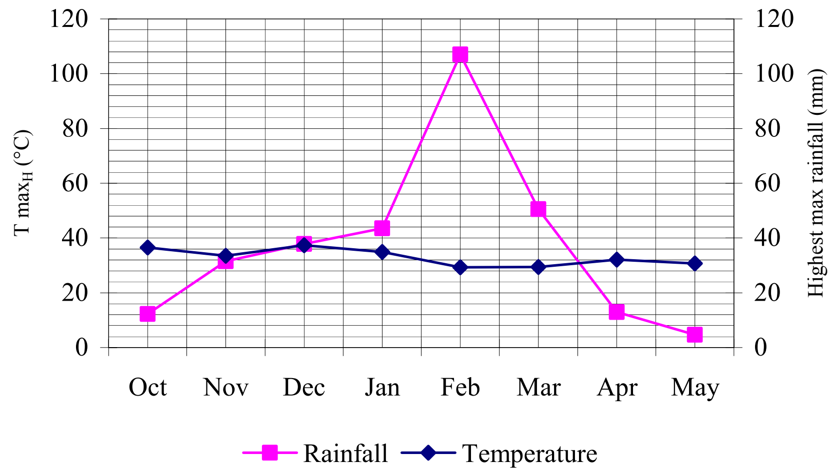

Figure 4.5 Highest maximum rainfall (mm) and temperature ($Tmax_H$, °C) during 2003/04 at Burgershall.

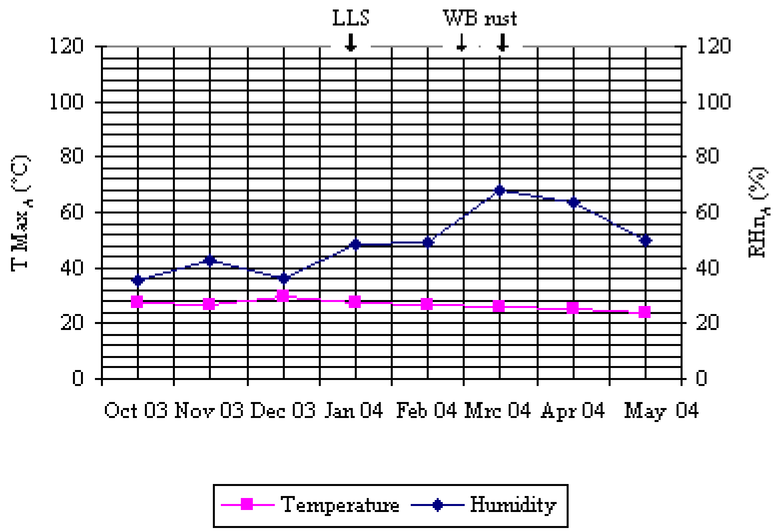

Figure 4.6 Average daily maximum temperature ($Tmax_A$, °C) and average daily minimum relative humidity (RHn_A, %) during 2003/04 for Burgershall.

Table 4.4 Weather data for the season of 2003/04 at Burgershall

Weather Components	Summer season							
	Oct	Nov	Dec	Jan	Feb	March	April	May
$Tmax_H$ (°C)	36.5	33.5	37.4	34.9	29.3	29.4	32.1	30.7
$Tmax_A$ (°C)	27.4	27.0	30.0	27.5	27.1	25.9	25.5	23.9
[$Tmax_A$-$Tmin_A$ (°C)]	12.2	10.0	12.1	8.8	8.4	8.1	9.6	12.3
RHn_A	35.1	42.7	36.0	48.6	49.4	68.3	63.7	50.2

$Tmax_H$, °C highest maximum temperature

$Tmax_A$, °C and $Tmin_A$, °C average daily maximum and minimum temperatures

RHn_A, %) average daily minimum relative humidity

Vaalharts

At Vaalharts LLS was more severe than rust or WB. LLS levels were generally moderate to high (highest rating was 5). Entries 1, 4-13, 15, 17-23, 31-33, 36 and 42-44 were resistant or tolerant to LLS (rated < 3). The entries with the best resistance to LLS were 1, 10, 12, 13, 18 and 23 and rated 1 to 1,5 (Table 4.1.1). The slightly low $Tmax_A$ of 30.9°C for January 2004 and the higher RHn_A of 53.4% resulted in moderate to high levels of LLS infection. WB did not occur during February and March as a result of the low average daily rainfall of 1.4 and 2.9mm and the high $Tmax_A$ of 30.8 and 28.6°C respectively. WB prefers cool conditions with high relative humidity (Mikunthan, 1997).

Rust infection did not occur during March and April as the $Tmax_A$, average rainfall and RHn_A were as low as 26.2°C and 0.7mm and 38.6% respectively (Figures 4.1 and 4.2 and Table 4.2). Rust develops at temperatures of 20-25°C and a relative humidity of >87% (Savary, 1986; Subrahmanyam *et al*., 1992). Heavy maximum daily rainfalls during January and March could have washed the spores off the leaves and prevented infection. Work done previously by Hammons (1977), Savary (1986), Nagarajan and Singh (1990), Kokalis-Burelle *et al.* (1997) and Hagan (1998) confirmed these results.

Cedara

At Cedara LLS and rust infections were more severe than WB infection. LLS levels were generally moderate to high (highest rating was eight). Entries 4, 5, 6, 7, 9, 10, 11, 12, 13, 17, 18, 19, 20, 21, 23, 28, 29, 30, 54 and 55 were resistant or tolerant to LLS. The resistant entries 4, 10, 12, 13, 19 and 20 rated between 1 and 1.5 for LLS (Table 4.1.1). For the season 2003/04 the highest $Tmax_A$ (25.4°C) was experienced during January and the lowest $Tmax_A$ (23.4°C) during May 2004. The high rainfall (41.3mm), $Tmax_A$ (25.4°C) and RHn_A (53.1%) during January favoured LLS. Less rain fell during February than during January and the highest Tmax was 31.4°C. More rain fell during March and together with the $Tmax_A$ of 24.3°C, a RHx_A of 92.2% and a RHn_A of 49.6%, rust infection was high (rating was 7.8) (Figures 4.3 and 4.4 and Table 4.3). Entries 1, 4-7, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 47, 48, 49, 50, 52, 53, 54, 55, 56, 57, 58 and 59 were resistant or tolerant to rust (Table 4.1.1). The rust resistant entries (ratings 1 to 1.5) were 6, 7, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 23, 24, 25, 27, 28, 30, 47, 48, 49, 50, 52, 53, 54, 55, 56, 57 and 58. The almost nightly occurrence of mist caused the high RHx_A of 92.2% and the RHn_A of 49.6% and this is conducive to WB, but the low average rainfall of 2.5mm and the $Tmax_A$ of 24.3°C during February created unfavourable conditions with the result that WB levels were lower than expected (Figures 4.3 and 4.4 and Table 4.3). WB prefers cool humid conditions (Marasas *et al.*, 1974; Swanevelder, 1998).

Burgershall

LLS was severe at Burgershall, whereas WB and rust, although considerable, was less severe. From October 2003 to May 2004 the highest Tmax (37.4°C) was experienced during December and the lowest Tmax during February (29.3°C). From November to December $Tmax_A$ increased, an average of 7.5mm daily rainfall was measured and the RHn_A of 48.6% was conducive to LLS with the highest rating of 7.5 (Figures 4.5 and 4.6 and Tables 4.1 and 4.4). Entries 10, 11, 12, 14, 16, 19, 20, 21, 23, 30, 31, 49, 52, 53, 54, 56, 57 and 58 were resistant or tolerant to LLS. The LLS resistant entries 30, 31, 52, 56, 57 and 58 rated between 1 and 1.5 (Table 4.1.1). The highest daily rainfall was in February (107mm) as was the lowest $Tmax_H$ (29.3°C). $Tmax_A$ was 27.1°C and RHn_A were 49.4%. Low temperatures and high humidity are conducive to WB (Figures 4.5 and 4.6 and Table 4.4). Entries that showed resistance or tolerance to WB were 10, 12, 13, 16-18, 19, 20, 21, 23, 24, 49, 54 and 55. The entries that were most resistant to WB rated 1 to 1.5 and were 18, 19, 20 and 21 (Table 4.1.1). During March the average daily rainfall was 5.4mm (Appendix 8), $Tmax_A$ was 25.9°C while $Tmax_H$ for March (29.4°C) was slightly higher than $Tmax_H$ for February (29.3°C). The RHn_A for March (68.3%) was higher than RHn_A for February (49.6%). ($Tmax_A$ – $Tmin_A$) differed only 8.1°C. These warmer humid conditions resulted in rust infection (highest rating was 7.5) (Figures 4.5 and 4.6). Rust develops at temperatures of 20-25°C and a relative humidity of >87% are optimal (Savary, 1986; Subrahmanyam *et al*, 1992). Entries resistant or tolerant to rust were 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 23, 24, 26, 27, 28, 29, 47, 49, 52, 53, 54, 55, 56, 57, 58 and 59 (Table 4.1). The most resistant entries were 4, 5, 6, 7, 11, 12, 13, 16, 17, 18, 19, 20, 21, 23, 24, 28, 53, 55, 56, 57 and 59 (Table 4.1.1).

CONCLUSIONS

Unreplicated trials planted at Vaalharts, Cedara and Burgershall (Trial 4.1)

Disease ratings at Vaalharts were generally low to moderate likely due to the relatively dry, hot climate. WB did not occur, as the temperatures were high and the humidity low. The particularly low levels of rust were probably due to the low humidity experienced throughout the season, combined with high maximum temperatures, especially during the first half of the season. Conclusions as to the relative disease resistance of entries at Vaalharts must therefore be tentative. However, all entries appear to be more resistant to LLS compared to the control (Sellie). LLS levels were generally moderate to high. Table 4.1.1 shows that entries 10, 11, 12, 19, 20, 21, 23 and 30 were resistant or tolerant to LLS at all three localities and 54 (an entry with limited seed, planted at only two localities) at Cedara and Burgershall. However, entries 1 and 30 were rated as susceptible at Cedara and/or Burgershall. This and other similar discrepancies may be an indication of pathotype differences and warrant further study.

At Cedara, only fairly low levels of WB were recorded (maximum rating was 3). This may have been due to a high average maximum temperature and low average relative humidity during the season. Entries 10, 12, 13, 16, 17, 18, 19, 20, 21, 23, 24, 49, 54 and 55 showed resistance or tolerance to WB at Burgershall, but cannot be compared with the ratings at the other two localities, so the resistance to WB of the entries that showed potential at Burgershall warrant further studies.

Burgershall and Cedara both had high levels of rust due to the moderate average maximum highest temperature (<30 °C) and the high relative humidity (>55%) at both localities. As explained, Vaalharts was not taken into consideration when the entries that were resistant and tolerant to rust were selected. Entries 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 23, 24, 26, 27, 28, 29, 47, 49, 52, 53, 54, 55, 56, 57, 58 and 59 were resistant and tolerant to rust at Cedara and Burgershall.

As these trials were not replicated and the pathotypes present (if there is variation) may differ from year to year, the above results on resistant entries need to be confirmed in future replicated trials. For this reason, a limited number of lines were selected for planting in a second set of trials planned for 2004/05. Six of the first 46 entries, namely 10, 12, 19, 20, 21 and 23, exhibited resistance to LLS, WB and rust over the three localities and one of the RR resistant entries, 54, at Cedara and Burgershall. These entries were selected for further evaluation. Although they were disease resistant, entries 19, 20 and 21 were not selected as they have undesirable red testas and their pods were not uniform. These entries were chosen from the germplasm list and all their traits were not known. The other entries selected were 7, 11, 13, 17, 18, 24 and 29. Although they were not the most resistant or tolerant to LLS, WB and rust they have traits such as tan testas and uniform pods and kernels demanded by the industry. Entries 19, 20 and 21 might be useful as resistant donor parents in the breeding programme. Entries 11 and 24 were selected for rust resistance and other desirable pod and seed qualities. Of the 13 rust resistant (RR) entries planted at Cedara and Burgershall entries 49, 52, 53, 54 (resistant to LLS, WB and rust), 55 and 56, which were the most resistant to rust, were selected. These entries were included in the 2004/05 trials.

Growth habit (runner or bunch) and length of the growth season were noted. The short, medium and long growth season entries were planted in separate trials during the 2004/05 season to facilitate harvesting.

RESULTS AND DISCUSSION

Replicated trials at Brits (Trial 4.2)

Average LLS, WB and rust ratings at Brits on the Elite and ICRISAT entries

Ratings for the short/medium growth season entries of the Elite and the ICRISAT trials are shown in Tables 4.5 and 4.6 respectively and those for Elite and the ICRISAT long growth season entries in Tables 4.8 and 4.9 respectively. In Table 4.7 and 4.10 comparisons of the short/medium growth season and long growth season entries with the best potential resistance to LLS, WB and rust are given, respectively. The highest maximum rainfall and the highest maximum temperature on any day of the month ($Tmax_H$, °C) are shown in Figure 4.7. The average maximum daily temperature ($Tmax_A$, °C) and the average minimum daily relative humidity (RHn_A, %) are shown in Figure 4.8. The summary of the applicable weather data is shown in Table 4.11.

Table 4.5 The analysis of variance on the average late leaf spot (LLS), web blotch (WB) and rust ratings on 21 Elite short/medium growth season groundnut entries at Brits during 2003/04

E	Entries	LLS	Rank	WB	Rank	Rust (ns)
1	Akwa (control)	3.9#		3.9#	10	3.65#
2	Kwarts	2.9	5	3	3	3.65#
3	Harts	3	8	4.15	11	3.4#
4	Anel	5.25		7.5		4.15
5	Kan red	2.95		3.65#	8	2.65
6	Kano	3.55#		4.15	11	3.25#
7	PC327-K1	2.6	2	1.95	1	3.65#
8	-K2	3.4#		3.05#	4	4.35
9	-K7	3.6#		3.5#	7	3.45#
10	-K11	4.9		4.9	13	4.45
11	-K13	3.3#		3.8#	9	4.3
12	PC280- K1	3	6	3.05#	4	3.55#
13	-K2	2.5	1	3.25#	5	3.4#
14	-K4	2.9	4	3.4#	6	3.8#
15	-K5	3.15#	9	3.4#	6	4.05
16	PC299 – K1	3	7	2.9	2	3.4#
17	-K2	4.1		3.5#	7	4#
18	-K5	3.9#		5.05	14	4.75
19	-K14	2.8	3	5.15	15	3.9#
20	-K17	3.4#		4.9	13	4.45
21	-K19	3.85#		4.65	12	4.55
	MS (blocks; df=2)	78.252		90.382		106.91
	MS (treatments; df=20)	1.541		4.242		0.854
	MS (error; df=40)	0.844		0.712		0.751
	Trial mean	3.4		3.92		3.82#
	F-ratio (Treatments)	1.83**		5.96**		1.14ns
	CV %	26.70		21.40		22.53
	LSD (5%)	1.52**		1.39**		na
	LSD (1%)	2.03**		1.86**		na
	SEM	0.5		0.5		0.5
	GCV%	14.0		27.5		4.8
	Intra-class correlation (t)	0.2159		0.6231		0.0435
	Standard error of t	0.1449		0.1093		0.1342
	Repeatability %	45		83		12

resistance shaded in grey and tolerance marked "#"

PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)
ns	not significant
na	not applicable
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)

Table 4.6 The analysis of variance on average late leaf spot (LLS), web blotch (WB) and rust ratings on 10 ICRISAT short/medium growth season groundnut entries at Brits during 2003/04

E	Entries	LLS (ns)	WB	Rank	Rust (ns)
1	Akwa	3.2#	5.6		4.1
2	Kwarts	2.8	5.25		4.55
3	Sellie	3.65#	7.85		3.8#
4	ICGV-SM-95714	3.4#	1.95	1	3.95#
5	ICGV-SM-93541	2.85	2.25	2	3.55#
6	ICGV-SM-96677	3.1#	5.25	7	2.8
7	ICGV-SM-99543	3.6#	4.55	5	4#
8	ICGV-SM-95741	2.25	2.35	3	3.4#
9	ICGV-SM-99529	2.95	4.9	6	3.85#
10	ICGV-SM-99574	4.45	3.15#	4	3.95#
	MS (blocks; df=2)	46.244	41.815		68.651
	MS (treatments; df=9)	1.206	11.763		0.736
	MS (error; df=18)	0.558	1.219		0.333
	Trial mean	3.22	4.31		3.79
	F-ratio (treatments)	2.16ns	9.65**		2.21ns
	CV %	23.17	25.62		15.21
	LSD (5%)	na	1.89		na
	LSD (1%)	na	2.59		na
	SEM	0.4	0.6		0.3
	GCV%	14.4	43.5		9.7
	Intra-class correlation (t)	0.2790	0.7424		0.2874
	Standard error of t	0.2162	0.1232		0.2160
	Repeatability %	54	90		55

resistance shaded in grey and tolerance marked "#"

E entry
df degrees of freedom
MS mean squares
* and ** significance indicated for F-probabilities of treatments by * (p<0.05) and ** (p<0.01). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)
ns not significant
na not applicable
CV% coefficient of variation (percentage)
SEM standard error of means
GCV% genetic coefficient of variation (percentage)

Table 4.7 Comparison of average late leaf spot (LLS), web blotch (WB) and rust ratings of best short/medium growth season Elite and ICRISAT groundnut entries at Brits during 2003/04

Entries	LLS	Rank	WB	Rank	Rust	Rank
Kwarts (in Elite trial)	2.9		3.0		3.65#	
Harts	3.0		4.15		3.4#	
Kan Red	2.95		3.65#		2.65	1
Kano	3.55#		4.15		3.25#	3
PC327-K1	2.6	3	1.95[1]	1	3.65#	
PC280-K2	2.5	2	3.25#		3.4#	
PC299-K1	3.0		2.9		3.4#	
PC299-K14	2.8		5.15		3.9#	
Kwarts (in ICRISAT trial)	2.8		5.25		4.55	
ICGV-SM-95714	3.4#		1.95	1	3.95#	
ICGV-SM-93541	2.85		2.25	2	3.55#	
ICGV-SM-96677	3.1#		5.25		2.8	2
ICGV-SM-95741	2.25	1	2.35	3	3.4#	

resistance shaded in grey and tolerance marked "#"

PC Potchefstroom cross

-K progeny of single plant selections

E entry

ICGV-SM ICRISAT entry

Table 4.8 The analysis of variance on average late leaf spot (LLS), web blotch (WB) and rust ratings on 15 Elite long growth season groundnut entries at Brits during 2003/04

E	Entries	LLS	Rank	WB	Rank	Rust(ns)
1	Billy	3	2	3.7#	2	3.3#
2	Rambo	3.5#	3	4.26	3	4.1
3	PC297-K2	2.7	1	3.26#	1	3.3#
4	-K6	4.06	7	4.4	5	3.86#
5	-K7	4.36		4.5	6	4.26
6	PC322-K5	5.6		6.2		4.4
7	-K7	5.1		6.16		4.36
8	-K8	5.06		6.76		4.6
9	PC323- K1	3.8#	5	5.5	8	4.8
10	PC324-K1	4.8		6.2		4.3
11	PC325-K1	4.76		7		3.6#
12	-K5	5.1		7.8		4.7
13	PC328 –K1	5		5.86		4.6
14	ICGV-SM-92736	3.9#	6	4.8	7	4.3
15	ICGV-SM-92760	3.6#	4	4.3	4	3.6#
	MS (blocks; df=2)	99.011		61.386		78.471
	MS (treatments; df=14)	2.388		5.629		0.789
	MS (error; df=28)	0.69		0.745		0.399
	Trial mean	4.29		5.37		4.1
	F-ratio (treatments)	3.46*		7.56**		1.98ns
	CV %	19.37		16.04		15.27
	LSD (5%)	1.39		1.44		na
	LSD (1%)	na		1.95		na
	SEM	0.5		0.5		0.4
	GCV%	17.5		23.7		8.7
	Intra-class correlation (t)	0.4506		0.6861		0.2460
	Standard error of t	0.1612		0.1149		0.1736
	Repeatability %	71		87		50

resistance shaded in grey and tolerance marked “#”

PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * (p<0.05) and ** (p<0.01). Means were separated using Fisher’s protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)
ns	not significant
na	not applicable
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)

Table 4.9 The analysis of variance on average late leaf spot (LLS), web blotch (WB) and rust ratings on nine ICRISAT long growth season groundnut entries at Brits during 2003/04

E	Entries	LLS (ns)	Rank	WB	Rank	Rust (ns)	Rank
1	Billy	3	2	3.7#	1	4.3	
2	Rambo	3.1#	3	4.3	3	4.36	
3	CG7	3.6#		4.6		4#	3
4	ICGV-SM-99821	3.4#		4.7		4.5	
5	ICGV-SM-90704	3.2#		5.2		3.6#	1
6	ICGV-SM-99844	2.9	1	3.9#	2	4.2	
7	ICGV-SM-99847	3.4#		6.1		3.76#	2
8	ICGV-SM-99841	2.9	1	3.9#	2	4.5	
9	ICGV-SM-95740	3.5#		4.6		4.2	
	MS (blocks; df=2)	40.111		60.083		64.032	
	MS (treatments; df=8)	0.238		1.921		0.34	
	MS (error; df=16)	0.274		0.6		1	
	Trial mean	3.2		4.56		4.15	
	F-ratio (Treatments)	0.87ns		3.20**		0.34ns	
	CV %	16.23		17.00		24.05	
	LSD (5%)	na		1.34		na	
	LSD (1%)	na		1.85		na	
	SEM	0.3		0.4		0.6	
	GCV%	0.0		14.6		0.0	
	Intra-class correlation (t)	0.0000		0.4235		0.0000	
	Standard error of t	0.2041		0.2174		0.2041	
	Repeatability %	0.0		69		0.0	

resistance shaded in grey and tolerance marked "#"

E	entry
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)
ns	not significant
na	not applicable
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)

Table 4.10 Comparison of average late leaf spot (LLS), web blotch (WB) and rust ratings of the best long growth season Elite and ICRISAT groundnut entries at Brits during 2003/04

Entries	LLS	Rank	WB	Rank	Rust	Rank
Billy	3	3	3.7#	2	3.3#	1
PC297-K2	2.7	1	3.26#	1	3.3#	1
PC297-K6	4.06		4.4		3.86#	3
PC325-K1	4.76		7		3.6#	2
ICGV-SM-92760	3.6#		4.3		3.6#	2
Billy	3	3	3.7#	2	4.3	
Rambo	3.1#		4.3		4.36	
CG7	3.6#		4.6		4#	
ICGV-SM-90704	3.2#		5.2		3.6#	2
ICGV-SM-99844	2.9	2	3.9#	3	4.2	
ICGV-SM-99847	3.4#		6.1		3.76#	
ICGV-SM-99841	2.9	2	3.9#	3	4.5	

resistance shaded in grey and tolerance marked “#”

PC Potchefstroom cross

-K progeny of single plant selections

E entry

ICGV-SM ICRISAT entry

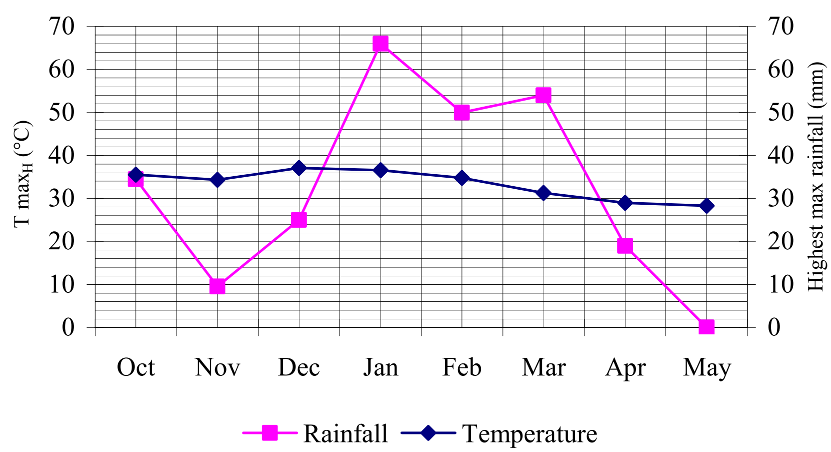

Figure 4.7 Highest maximum rainfall (mm) and temperature (Tmax$_H$,°C) during 2003/04 at Brits.

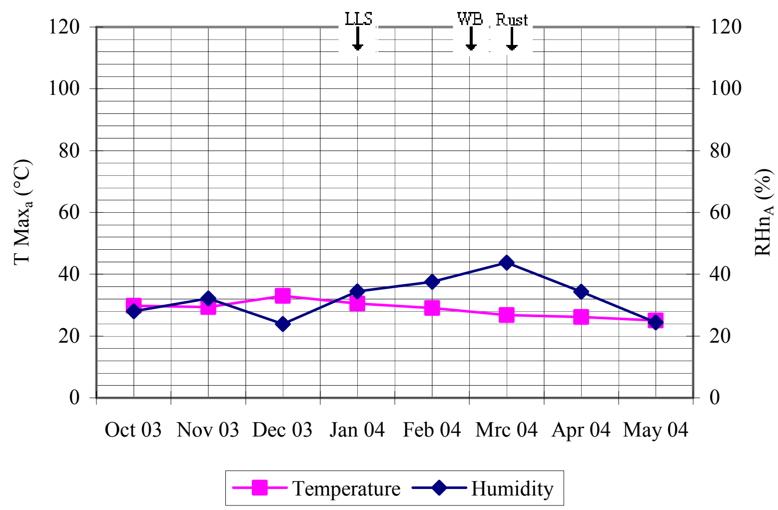

Figure 4.8 Average daily maximum temperature ($Tmax_A$, °C) and average daily minimum relative humidity (RHn_A, %) during 2003/04 for Brits.

Table 4.11 Weather data for the season of 2003/04 at Brits

Weather components	Summer season Oct	Nov	Dec	Jan	Feb	March	April	May
$Tmax_H$ (°C)	35.0	34.3	37.1	36.6	34.8	31.3	29.0	28.3
$Tmax_A$ (°C)	29.8	29.4	33.0	30.5	29.1	26.8	26.2	25.0
[$Tmax_A$-$Tmin_A$ (°C)]	15.3	12.6	15.2	12.4	12.4	10.7	14.1	19.4
RHn_A	28.0	32.2	23.9	34.5	37.6	43.8	34.3	24.4

$Tmax_H$, °C highest maximum temperature

$Tmax_A$, °C and $Tmin_A$, °C average daily maximum and minimum temperatures

RHn_A, %) average daily minimum relative humidity

Although the CV's of the analysis of variance (ANOVA) tables (Table 4.5) were high the F ratios still indicated that nine of the 21 Elite short/medium growth season entries differed highly significantly in LLS resistance from the other 12 entries ($p<0.01$) and 20 of the 21 entries on WB ratings ($p<0.01$). The lowest rating for LLS was 2.5 (entry 13) and 1.95 for WB (entry 7). The GCV for WB was 27.5 indicating genetic variation for resistance to WB between the 21 entries and selection for resistance to WB among these entries could be successful. The $Tmax_A$ dropped from 29.1 to 26.8°C and RHn_A increased from 37.6 to 43.8% during February and March. $Tmin_A$ was 16.7°C for February and 16.1°C for March. These cooler humid conditions benefited WB (Figures 4.7 and 4.8). During January the highest daily rainfall was measured (66mm), RHn_A increased from

23.9 to 34.5% and the $Tmax_A$ was 30.5°C. LLS was less severe than expected (Table 4.11).

Of the 21 entries, 15 exhibited higher resistance to LLS (rating <3.9) than the susceptible control Akwa (rating: 3.9) (Table 4.5) and 12 entries exhibited higher resistance to WB (ratings <3.9) than Akwa (rating: 3.9). PC280-K2 exhibited the highest resistance to LLS (rating: 2.5). Anel was the most susceptible entry to WB (rating: 7.5) and more susceptible to WB than Akwa.

The F ratios in the ANOVA table on rust ratings (Table 4.5) did not indicate significant differences between the entries. The genetic coefficient of variation was 4.8 and could be an indication of the low genetic variation present among the entries with regard to rust resistance. The entries have a restricted genetic base as many of them are closely related. For example: PC280-K1 to -K5 were selected from the same single plant selection derived from the F_2 progeny of the cross between cv Jasper and 73-30 (a germplasm entry). Jasper was developed from a cross between Harts and Sellie.

Nine of the 21 short/medium growth season Elite entries exhibited resistance to LLS and three to WB. Three exhibited resistance to LLS and WB and one to rust.

Although rust ratings were not significantly different, it appeared as if Kan Red (highest rating of 2.65) might be slightly more resistant to rust than the other entries. However, it is evident that there were no highly resistant entries among those tested. The most resistant entries were PC327-K1 (which ranked first and second in resistance to WB and LLS respectively), PC299-K1 (WB and rust), PC280-K2 (LLS) and Kan Red (rust). Anel was highly susceptible to LLS, WB and rust. PC299-K5 and PC299-K14 were highly susceptible to WB. PC327-K1 can be improved by crossing it with one of the entries that exhibited resistance to rust. PC280-K2 (tan testa) is preferable to both Kan Red and Kano, which have, to the industry, unacceptable red testas. PC299-K5, K14, K17 and K19 were all susceptible to WB and rust. PC299-K5 is an important high O/L ratio entry and crosses with resistant entries such as PC327-K1 should improve its resistance to foliar diseases.

The F ratios in the ANOVA table (Table 4.6) on WB ratings indicated seven entries that differed highly significantly from the other three short/medium growth ICRISAT entries ($p<0.01$). Entry 4 gave the lowest WB rating (1.95). The repeatability of the WB ratings is 89.63%. Although LLS and rust ratings were not significantly different according to the F ratios in the ANOVA tables there were four entries exhibiting resistance to LLS and one to WB under the short growth season entries. These entries also exhibited tolerance to rust. Entry four exhibited tolerance to LLS and rust and resistance to WB.

ICGV-SM-93541 and ICGV-SM-95741 exhibited tolerance to WB and LLS. The low levels of LSS and rust on these two lines may be due to resistance but needs confirmation. Sellie was used as spreader and was highly susceptible to all the foliar diseases. Sellie was more susceptible to WB (rating: 7.85) than Akwa (control) (rating: 5.6).

The CV percentages on the LLS, WB and rust ratings on the Elite long growth season entries were <20% and the F ratios of the ANOVA table on LLS indicated two entries had resistance to LLS and differed highly significantly from the other 13 susceptible entries. Eight entries differed highly significantly from the other seven entries as to their resistance to WB ($p<0.01$) (Table 4.8). Entry 3 gave the lowest LLS and WB ratings (2.7 and 3.26 respectively).

During March the average daily rainfall at Brits was 4.2mm, the highest daily rainfall 54mm, $Tmax_A$ was 26.8°C and the RHn_A 43.8%. The slightly cooler but humid conditions usually benefit rust infection (Figures 4.7 and 4.8). Savary (1986) reported that temperatures of 20-25°C and high relative humidity (>87%) are optimal for rust development. Although the F ratios of the ANOVA table on the rust ratings for the Elite long growth season entries showed non-significant differences between the entries, five entries exhibited some resistance to rust. The GCV (8.7), however, indicated that there is not much genetic variation for resistance to rust among the entries (Table 4.8).

Entries 1 and 3 exhibited the highest resistance to LLS and 2, 9, 14 and 15 tolerance to LLS. Entries 1 and 3 exhibited tolerance to WB and 1, 3, 4, 11 and 15 tolerance to rust. PC297-K2 ranked first in potential resistance to LLS, WB and rust (highest ratings were 2.7, 3.26 and 3.3 respectively). Billy and Rambo (controls) ranked third in resistance to LLS and WB (3.0 and 3.7 respectively). Only PC297-K2 exhibited more resistance to LLS and WB than Billy (control). PC297-K2 exhibited more resistance to WB than Rambo and PC322-K5 was more susceptible to LLS and WB than Billy.

Although the F ratios of the ANOVA tables for the LLS and rust ratings (Table 4.9) showed non-significant differences between the ICRISAT long growth season entries 1, 6 and 8 showed more resistance to LLS than the other entries. Billy and Rambo (controls) exhibited resistance to LLS and WB and CG7 to rust. Although ICGV-SM-90704 ranked first for resistance to rust it is highly susceptible to WB. ICGV-SM-99844 and ICGV-SM-99841 ranked first in resistance to LLS and second to WB.

The CV was 17% for the rating on WB. The F ratios in the ANOVA table on WB ratings (Table 4.9) indicated that four entries differed highly significantly from the other five ICRISAT long growth season entries ($p<0.01$). None of the entries exhibited more resistance to WB than Billy (control) (highest rating: 3.7). ICGV-SM-99847 was the most susceptible (highest rating: 6.1) to WB. The cultivar Rambo was more susceptible to WB than Billy but more resistant than ICGV-SM-99847.

CONCLUSIONS

Replicated trials planted at Brits (Trial 4.2)

The average WB infection on both Elite and ICRISAT short and long growth season entries was more severe than LLS and rust. The cooler humid conditions during February and March benefited WB. Rust was more severe on the long than on the short growth season entries as it had more time to build up inoculations and during the cooler conditions. During January the high rainfall and average humidity benefited LLS on the long growth season entries although LLS was less severe than expected.

Resistance to WB existed among the short/medium entries, such as Kwarts, PC327-K1, PC299-K1, ICGV-SM-95714, ICGV-SM-93541 and ICGV-SM-95741 and could be used to improve commercial cultivars by backcrossing. Some high oleic acid cultivars such as PC299-K5 is susceptible to almost all the foliar diseases and will benefit if resistance to foliar diseases could be incorporated in them.

RESULTS AND DISCUSSION

Trials planted on the micro-plots (Trial 4.3) and ICRISAT entries in brick blocks at Potchefstroom (Trial 4.4)

Average LLS, WB and rust ratings on entries in the micro-plots and the brick blocks at Potchefstroom

In Table 4.12 and 4.13 the average ratings on ELS, LLS and WB of the entries on the micro-plots and in the brick boxes at Potchefstroom are presented respectively. The highest maximum rainfall and the highest maximum temperature on any one day of the month (Tmax, °C) are shown in Figure 4.9 and the average maximum daily temperature ($Tmax_A$, °C) and the average minimum daily relative humidity (RHn_A, %) in Figure 4.10. The summary of the applicable weather data is presented in Table 4.14.

Table 4.12 The analysis of variance on the average early leaf spot (ELS), late leaf spot (LLS) and web blotch (WB) ratings on 16 groundnut entries on micro-plots at Potchefstroom during 2003/04

E	Entries	ELS(ns)	LLS	Rank	WB	Rank
1	PC287(F)	2.3	1.3	2	6	
2	PC287	1	2	4	4.7	
3	Kwarts(F)	2	2	4	5	
4	Kwarts	2.3	1.7	3	4.3	
5	RG453(73-30)F)	1.3	2	4	3.3#	
6	RG453(73-30)	1.7	1	1	2.7	2
7	Sellie(F)	1.3	2.3		6	
8	Sellie	1.3	4.7		5	
9	PC254-K1(F)	1	1.7	3	2.7	2
10	PC254-K1	1.3	1.3	2	2.7	2
11	PC223(F)	1.3	4.3		6.3	
12	PC223	1	3.7#		5	
13	UF85(F)	1	1.3	2	3	3
14	UF85	1.3	1.3	2	2.3	1
15	RG716(73-30)(F)	1	1	1	3	3
16	RG716(73-30)	1	1.7	3	3.3#	
	MS (blocks; df=2)	0	8		18	
	MS (treatments; df=15)	1	4		6	
	MS (error; df=30)	0	2		2	
	Trial mean	1.40	2.08		4.08	
	F-ratio (treatments)	1.95ns	1.66*		2.64**	
	CV %	40.75	73.41		35.62	
	LSD (5%)	na	2.55		2.42	
	LSD (1%)	na	na		3.27	
	SEM	0.3	0.9		0.8	
	GCV%	23.0	34.5		26.3	
	Intra-class correlation	0.2410	0.1809		0.3530	
	Standard error of t	0.1677	0.1663		0.1645	
	Repeatability %	49	40		62	

resistance is shaded in grey and tolerance marked "#"

PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry
RG	germplasm collection entries
F	soil was fumigated
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * (p<0.05) and ** (p<0.01). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)
ns	not significant
na	not applicable
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)

Table 4.13 Average early leaf spot (ELS), late leaf spot (LLS) and web blotch (WB) ratings on eight ICRISAT groundnut entries in the brick boxes at Potchefstroom during 2003/04

E	Entries	ELS	Rank	LLS	Rank	WB	Rank
1	ICGV-SM-99543	2.3		3.6#		2.3	
2	ICG 12991	2.3		4.7		2.3	
3	ICGV-SM-95714	2.0		3.0#	4	2.0	
4	ICGV-SM-95714	3.0		2.7	3	2.3	
5	ICGV-SM-96677	2.7		2.7	3	2.7	
6	ICGV-SM-99529	2.3		2.3	2	2.3	
7	ICGV-SM-93541	1.7	1	2.0	1	1.3	1
8	AKWA(C)	2.3		3.7		2.7	
	MS (treatments; df=7)	0.554		0.667		2.641	
	MS (error; df=14)	0.315		0.411		0.548	
	Trial mean	2.30		3.10		2.30	
	F-ratio (treatments)	1.76*		1.62**		4.82*	
	CV %	24.07		27.47		24.00	
	LSD (5%)	0.98		1.12		1.30	
	LSD (1%)	na		1.56		na	
	SEM	0.3		0.4		0.4	
	GCV%	12.1		12.5		27.1	
	Intra-class correlation	0.2023		0.1720		0.5600	
	Standard error of t	0.2445		0.2428		0.2035	
	Repeatability %	43		39		79	

resistance shaded in grey and tolerance marked "#"

E	entry
ICG/ICGVSM	ICRISAT entries
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)
ns	not significant
na	not applicable
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)

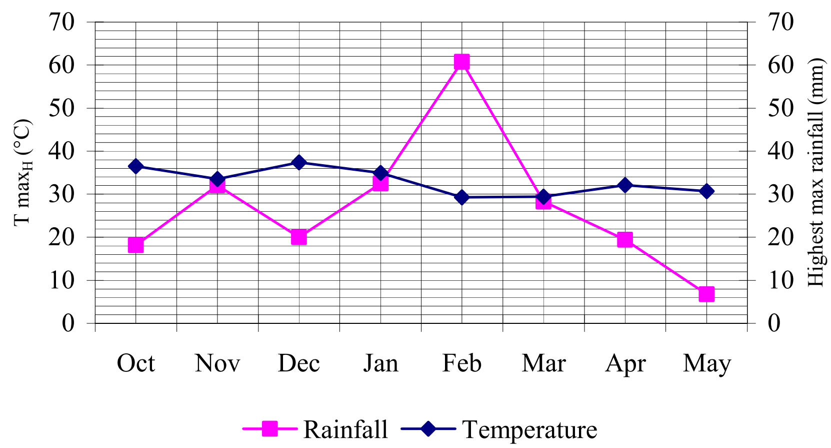

Figure 4.9 Highest maximum rainfall (mm) and temperature ($Tmax_H$, °C) during 2003/04 at Potchefstroom.

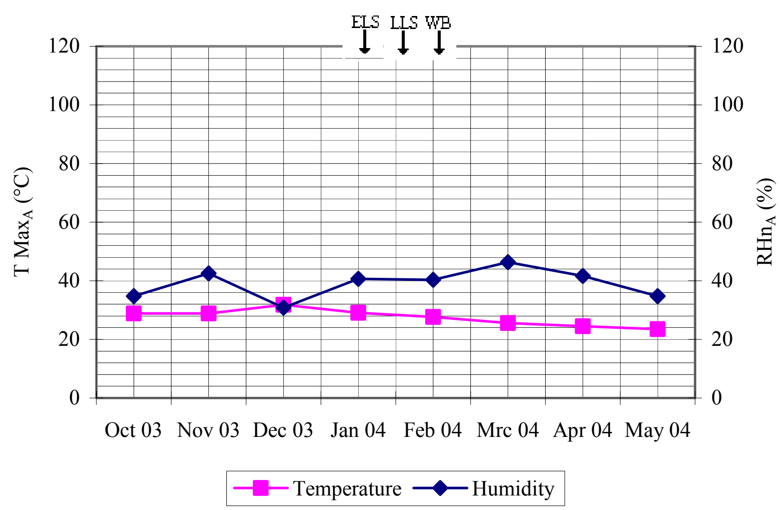

Figure 4.10 Average daily maximum temperature ($Tmax_A$, °C) and average daily minimum relative humidity (RHn_A, %) during 2003/04 for Potchefstroom.

Table 4.14 Weather data for 2003/04 at Potchefstroom

Weather components	Summer season							
	Oct	Nov	Dec	Jan	Feb	March	April	May
$Tmax_H$ (°C)	35.0	34.5	36.5	34.0	33.5	29.5	27.0	26.0
$Tmax_A$ (°C)	28.8	28.8	31.8	29.1	27.7	25.6	24.5	23.5
[$Tmax_A$-$Tmin_A$ (°C)]	14.8	12.8	14.4	11.2	10.8	10.4	13.2	17.1
RHn_A	34.7	42.5	30.8	40.7	40.3	46.3	41.6	34.7

$Tmax_H$, °C highest maximum temperature

$Tmax_A$, °C and $Tmin_A$, °C average daily maximum and minimum temperatures

RHn_A, %) average daily minimum relative humidity

Six entries tested in the micro-plots (Table 4.12) exhibited resistance to both LLS and WB. Rust did not occur and ELS infection will not be considered, as the disease pressure in the micro-plots was too low. Thirteen entries exhibited resistance to LLS although infection rates were low. Entries 6, 9, 10, 13, 14 and 15, were resistant to both LLS and WB (Table 4.12). The cooler conditions during March as a result of $Tmax_A$ of 25.6°C and RHn_A of 46.3°C (Figures 4.9 and 4.10) resulted in moderate to high WB. Mikunthan (1997) reported that average relative humidity of 79-85% and average temperature of 15-20°C benefited WB. RG453 and RG716 (both germplasm entries are of the line 73-30 collected from different sources in the world) both ranked first in potential resistance to LLS and exhibited resistance to WB. PC254-K1 (a line with possible resistance to *D. africanus*) exhibited resistance to LLS and WB. Entries 6 and 15 gave the lowest LLS rating of 1 and entry 14 the lowest WB rating of 2.3 (Table 4.12).

The ICRISAT entries tested in the brick blocks in Potchefstroom (Table 4.13) were obtained from ICRISAT breeders and were selected for tolerance to ELS in Malawi. Although both the micro-plots and the brick blocks were in Potchefstroom, ELS occurred in the brick blocks. These entries were more densely populated than the entries in the micro-plots. The leaves could have formed a humid microclimate in the brick blocks and ELS benefited. $Tmax_A$ for December 2003 was 31.8°C and for January 2004, 29.1°C. RHn_A and the average daily rainfall increased from 30.8% and 0.8mm (December) to 40.7% and 2.6mm during January. As a result ELS infection of entries in the brick blocks was moderate (Figures 4.9 and 4.10). Although all the entries exhibited resistance or tolerance to ELS because of the low levels of inoculum, further trials are needed for confirmation. ICGV-SM-93541 ranked first in resistance to ELS, LLS and WB (ratings were 1.7, 2 and 1.3 respectively)(Table 4.13). This entry also exhibited resistance in the ICRISAT short growth season trials at Brits. Entries 4, 5, 6 and 7 exhibited resistance to LLS. ICGV-SM-95714 ranked second in exhibiting resistance to ELS and WB.

During February, the cooler $Tmax_A$ of 27.7°C, RHn_A of 40.3% and the average daily rainfall of 5.6mm (total of 162.4mm for February) (Figures 4.9 and 4.10 and Table 4.14) resulted in LLS infection of the entries in the micro-plots and brick blocks. The more severe WB in the micro-plots could be attributed to the intra-row spacing of 15cm. Intra-row spacing in the brick plots was 45cm. The plant density in the micro-plots was higher and the cooler humid air could have been trapped for a longer period between and under the leaves before evaporation.

CONCLUSIONS

Trials planted on the micro-plots (Trial 4.3) and ICRISAT entries in brick blocks at Potchefstroom (Trial 4.4)

In the Elite and ICRISAT trials at Brits, Kan Red and Kano (rust), PC327-K1 (LLS and WB), PC280-K2 (LLS), ICGV-SM-95714 (WB), ICGV-SM-93541 (WB), ICGV-SM-96677 (rust) and ICGV-SM-95741 (LLS and WB) were the short/medium growth season entries with the highest potential for resistance to LLS, WB and rust (Table 4.7) and were further evaluated during 2004/05 trials. Kwarts, Akwa, Anel, PC299-K5 and PC299-K14 (high O/L ratios) are entries with good quality kernels when produced in fungicide spray programmes where foliar diseases are controlled. Crosses of these entries with ICGV-SM-95741, ICGV-SM-95714, ICGV-SM-93541 and ICGV-SM-96671, followed by backcrosses can be used to improve their resistance to LLS, WB and rust. ICGV-SM-96677 ranked second for resistance to rust, but is susceptible to WB. PC327-K1 can be improved by crossing it with one of the entries that exhibited resistance to rust. Kan Red and Kano have red testas that is not acceptable to the industry, so the best choice for a parent would be PC280-K2 (tan testa).

The long growth season entries (Table 4.10) that will be chosen should preferably have upright growth habits. Billy, a long growth season entry and the control, ranked first, second and third for potential resistance to rust, WB and LLS respectively but is not in demand by the industry as the cultivar has a red and white variegated testa. PC297-K2 (tan testa) from the Elite trial at Brits exhibited the highest resistance to LLS, WB and rust and could be developed as a commercial cultivar if the quality and yield characteristics are acceptable. ICGV-SM-90704 and ICGV-SM-99847 were the most susceptible to WB, but by crossing these entries with ICGV-SM-99844 or PC297-K1 their resistance to LLS and/or WB can be improved.

PC287, Kwarts, RG453, PC254-K1 PC223, ICGV-SM-95714, ICGV-SM-96677, ICGV-SM-99529 and ICGV-SM-93541 are short/medium growth season entries from the micro- and brick plots with potential resistance to ELS, LLS and WB and were evaluated in the 2004/05 trials. ICGV-SM-93541 ranked first in exhibiting resistance to ELS in the brick boxes and second for WB resistance in the ICRISAT trials at Brits. ICGV-SM-95714 ranked first for WB resistance in the ICRISAT trials at Brits. UF85 and PC254-K1 are medium growth season entries with potential resistance to *D. africanus* and a high oleic acid ratio. They could be improved for resistance to foliar diseases by crosses and backcrosses (to PC254-K1) to entries with resistance to LLS, WB and rust from other trials, such as ICGV-SM-96677, ICGV-SM-95741 and ICGV-SM-93541.

RG453 and RG716 (selections made at different localities from the same long growth season line 73-30) both ranked first in potential resistance to LLS and exhibited resistance to WB.

For Chapter 5 the following entries were selected for the next series of trials for 2004/05 and were planted at five localities in South Africa (Potchefstroom, Brits, Vaalharts, Cedara and Burgershall). The short/medium growth season entries included ICGV 90197, ICGV 90099, ICGV 90087, ICGV 95342, ICGV 90096, ICGV 95343, 86/87/175, 86/87/175, RR line8, RR line10, RR line11, RR line12, PC327-K1, PC299-K1, PC280-K2, Kan Red, ICGV-SM-93541, ICGV-SM-95741, ICGV-SM-95714. The long growth season entries included PC297-K2, Billy, Rambo, RG453 (73-73) and RG716 (73-73). These entries and other entries selected from other sources were thoroughly evaluated for possible resistance to ELS, LLS, WB and rust. Grading procedures were carried out on all the entries and potential yield estimated. The correlation between UBS% (unsound, blemished and soiled) on kernels and the quality of the kernels as well as the yield were studied. The results of the best entries were compared with the results of the commercial cultivars.

CHAPTER 5

EVALUATION OF SELECTED GROUNDNUT GERMPLASM FOR RESISTANCE TO EARLY LEAF SPOT, LATE LEAF SPOT, WEB BLOTCH AND RUST DURING THE 2004/05 SEASON

INTRODUCTION

In South Africa (SA), agricultural production is under pressure with high input costs and relatively low commodity prices for the commercial farmer, where as the subsistence farmer does not have the financial means for costly fungicide applications to control foliar diseases, which is probably the most significant limiting factor. For these reasons resistance breeding is an important component of integrated foliar disease management strategies.

The breeding programme at Agricultural Research Council - Grain Crops Institute (ARC-GCI) focuses on seed quality, as South Africa is well known for high quality groundnuts, which play a key in the competitive export market, as can be seen from the export figures of shelled choice grade kernels. During 2003/04 and 2004/05 totals of 20 400 and 21 100t, of the 52 027 and 107 717t produced respectively, were exported, 8 478 and 5 768 t to Japan alone. Exports totalled 39 and 20% of the total production of groundnuts respectively, of which 42 and 27% respectively to Japan. (South African Peanut Company for Export Information on SA Groundnuts, 2005; SAGIS, 2006). Akwa, Kwarts, Billy, Rambo and Sellie are all examples of registered cultivars with the potential for high yield and quality as pursued in the breeding programme as indicated in the ARC-GCI progress report of 2005 (Pretorius, 2005).

Groundnut oil is composed of mixed glycerides and contains a high proportion of unsaturated fatty acids, in particular oleic (O) (18:1) and linoleic (L) acids (18:2) (Gorbet, 2003). The ratio 18:1 represents a mono-unsaturated fatty acid consisting of 18 carbons and one double bond that prevent the saturation of the fatty acid with hydrogen. Oleic acid is less susceptible to oxidation than polyunsaturated fatty acids (Bryan, 2006). Linoleic acid (18:2) has two double bonds and a high percentage of this acid results in a short shelf life (Mozingo *et al*., 2005). A high oleic acid and low linoleic acid content is desirable as it improves the shelf life of roasted groundnuts and groundnut products and the shelf life of high O/L groundnuts decreased when cooked in conventional groundnut oil with a low O/L ratio (Bolton and Sanders, 2006). ARC-GCI breeding lines with a high oleic acid and low linoleic acid content (favourable O/L ratio) have been identified.

In the industry, grading information is used to classify kernels as choice, standard, sundry, or crushing grade. Choice and standard grade are the best quality, followed by poor quality sundry and crushing grades with a much lower market value**.** Unsound, blemished and soiled kernels (UBS) adversely affect grades. A low UBS% (<13% on the 200g randomly selected kernels affected) will result in good choice grade kernels while a UBS% >13 will result in standard, sundry and crushing grades. Choice grade groundnuts are exported, while both choice and standard grades are used for confectionary groundnuts in SA. Peanut butter is made from sundry grade and oil is pressed from the crushing grade groundnuts. The groundnut oilcake is used for animal feed (J.P. van Heerden - personal communication).

The aim of this study was: a) the further evaluation of promising entries, selected from the 2003/04 trials, as well as breeding lines with a high O/L ratio for resistance to four foliar diseases, namely early leaf spot (ELS), late leaf spot (LLS), web blotch (WB) and rust, b) a study of the relationship between the grading results, quality and yield (kg/ha) of these entries and c) the evaluation of the effect of fungicides on qualitative traits.

MATERIAL AND METHODS

Localities

The trials were planted and evaluated at one, two, three, four or five of the following localities: Potchefstroom, Vaalharts, Brits, Cedara and Burgershall. These were representative of the different climatic areas where groundnuts are grown in SA and were also selected for climatic conditions conducive to the development of fungal diseases. Latitude, longitude, altitude, pH, soil type and climatical data (all of which can influence the severity of infection) for localities are presented in Appendix 2.

Germplasm entries

Entries selected for further evaluation in the replicated trials at the five localities (Trial 5.1a, b and c) are listed in Table 5.1. Elite short/medium and long (Trial 5.2a and b) and ICRISAT long (Trial 5.2c) growth season entries at Brits are given in Tables 5.11, 5.13 and 5.14 and for the Elite short/medium and long growth season entries at Vaalharts (Trial 5.3a and b) in Tables 5.20 and 5.21. The entry numbers used for the diseases ratings will be the same as the entry numbers used in the yield and grading tables.

Table 5.1 The list of 49 selected groundnut entries planted at Potchefstroom, Vaalharts, Brits, Cedara and Burgershall) for disease evaluation during the 2004/05 season

E	Entry	Origin	Favourable characteristic or resistance to	E	Entry	Origin	Favourable characteristic or resistance to
	Short growth season			22	PC297-K2	PC	LLS
1	Harts	PC	black pod rot	23	PC299-K1	PC, O/L%	WB
2	Kan.red	SA	LLS, rust	24	PC299-K19	PC, O/L%	high O/L%
3	Kano	Nigeria	good cultivar	25	PC299-K5	PC, O/L%	high O/L%
	Medium growth season			26	PC324-K1	PC	good line
1	73-30(RG453)	Senegal	parent of good lines	27	PC327-K1	PC	good line
2	73-30 (RG716)	A. Mayeux	parent of good lines	28	RR line 10	Puerto Rico	WB, rust
3	86-87/175 (RG 784)	ICRISAT	WB, rust	29	RR line 11	Puerto Rico	LLS, rust
4	86-87/175 (RG 783)	ICRISAT	LLS, WB, rust	30	RR line 3	Puerto Rico	WB, rust
5	Akwa (control)	PC	good cultivar	31	RR line 7	Puerto Rico	LLS, rust
6	ICGV 90071	ICRISAT	LLS, WB, rust	32	RR line 8	Puerto Rico	LLS, rust
7	ICGV 90096	ICRISAT	LLS, WB, rust	33	RR line 9	Puerto Rico	LLS, WB, rust
8	ICGV 90099	ICRISAT	LLS, WB, rust	34	Streeton	Australia	nematode resistance
9	ICGV 90197	ICRISAT	LLS, WB, rust	35	Swallow	Zimbabwe	LLS
10	ICGV 95342	ICRISAT	LLS, WB, rust		Long growth season		
11	ICGV 95350	ICRISAT	ELS	1	Billy (control)	USA	LLS, WB, rust
12	ICGV-SM- 93541	ICRISAT	ELS, LLS, rust	2	CG7= ICGMS42 (RG453)	ICRISAT	wide adaptability
13	ICGV-SM- 95714	ICRISAT	recommended	3	ICGMS42=CG7 (RG716)	ICRISAT	wide adaptability
14	ICGV-SM- 95741	ICRISAT	LLS, WB, rust	4	ICGV 90087	ICRISAT	LLS, WB, rust
15	ICGV-SM-99543	ICRISAT	ELS	5	ICGV 95343	ICRISAT	WB, rust
16	ICGV-SM- 99529	ICRISAT	ELS	6	ICGV-SM- 99821	ICRISAT	ELS
17	JL 24	Kongo	good cultivar	7	ICGV-SM- 99841	ICRISAT	LLS
18	Kwarts	PC	black pod rot	8	ICGV-SM- 99844	ICRISAT	ELS
19	PC254-K1	PC	*D. africanus,* high O/L%	9	Rambo	ICRISAT	LLS, WB, rust
20	PC280-K2	PC, O/L%	LLS, high O/L%	10	RR line 12	Puerto Rico	LLS, rust
21	PC287	PC, O/L%	*D. africanus*	11	TMV1	Australia	LLS, WB

RR	rust resistant entries from Puerto Rico
RG	ARC germplasm entry numbers
PC	Potchefstroom cross (ARC-Grain Crops Institute breeding line)
-K	progeny of single plant selections
E	entry number
ICGV (SM)	ICRISAT entries
ELS	early leaf spot
LLS	late leaf spot
WB	web blotch

Short (±120 days) and medium growth season lines (±150 days) are of the bunch type groundnuts and the long growth season lines (±180 days) are of the runner or semi-runner type.

The trials (2004/05 summer season)

Three groups of trials were planted during the 2004/05 summer season, namely

Trial 5.1a (short), b (medium) and c (long growth season): Replicated trials with no fungicide applications, using promising material (49 entries) at five localities (Potchefstroom, Vaalharts, Brits, Cedara and Burgershall), representing different climatic zones (Appendices 3, 4.1 and 5).

Trial 5.2a, b and c: Replicated trials at Brits using a) 25 short/medium and b) 15 long Elite and c) nine advanced ICRISAT long growth season entries, all with no fungicide applications (Appendices 4.2 and 6).

Trial 5.3a and b: Replicated Elite trials at Vaalharts using a) 25 short and medium growth season entries and b) 15 long growth season entries, both with fungicide applications (Appendix 8).

The cultivar (cv) Akwa was included as control for both the short and medium growth season trials as this cultivar is widely planted and preferred by the industry, although it is susceptible to foliar diseases. Cv Billy was used as control for the long growth season entries as this cultivar has good resistance to foliar diseases and is easily distinguishable by its dark-green leaves and variegated testa colour (red with white stripes). Cv Makatini has small, dark green leaves that is easily identifiable and was planted as border rows.

Trail 5.1a, b and c: Replicated randomised trials planted at five localities, Potchefstroom, Vaalharts, Brits, Cedara and Burgershall, with no fungicide applications

Identical replicated randomised trials were planted during November and early December 2004 at the above mentioned five localities. The 49 entries (Table 5.1) were planted in single 3m rows, with 30 seeds per row. Intra-row spacing was 7.5cm and inter-row spacing was 90cm. Cv Sellie (very susceptible to all the diseases concerned) was used as a spreader.

Trials 5.2a, b and c: Replicated randomised Elite and ICRISAT trials at Brits with no fungicide applications

Three trials were planted during November 2004 in a randomised block design with three replications each. a) Twenty-five Elite short/medium and b) 15 Elite long growth season entries were planted in double 9m rows and c) nine ICRISAT long growth season entries in single 9m rows only, as seed was limited. Intra-row spacing was 7.5cm and inter-row spacing was 90cm. Cultivar Akwa was planted as spreader.

Trials 5.3a and b: Replicated randomised Elite trials at Vaalharts with fungicide application

Two trials, a) for 25 short/medium and b) for 15 long growth season entries (identical in layout to the Elite short/medium and Elite long growth season trials at Brits) were planted in double 9m rows during November 2004 in a randomised block design with three replications. Intra-row spacing was 7.5cm and inter-row spacing was 90cm.

For trials 5.3a and b the fungicide Punch (flusilazole and carbendazim) was applied four times during the growing season at regular intervals to control ELS, LLS, WB and rust.

Treatments

Plant depth

The seeds in all the trials were planted by hand at a depth of 5cm.

Weed control

The herbicide Lasso was applied one week before planting at the prescribed dosage to control weeds and thereafter weeds were controlled by hand hoeing when necessary.

Pest and disease control

Seeds were treated with thiram powder to inhibit seed borne diseases. No insecticides were used in any of the trials.

Irrigation

Potchefstroom, Vaalharts and Brits were flood- or overhead irrigated once a week to prevent water stress. Cedara and Burgershall were not irrigated, as the average rainfall per week/month was high (Appendix 7).

Measured characteristics

Ratings were done for ELS, LLS and rust infection according to the International Modified 9-Point Scale for ELS, LLS and Rust (Tables 1a, 1b and 1d in Appendix 1) (Subrahmanyam *et al.,* 1992; 1995). These tables were adapted for the rating of WB (Table 1c, Appendix 1) as no existing scale was available. For all scales, a rating of <3 was regarded as an indication of resistance. Disease ratings were done on all entries except on entries in trial 5.3a and b at Vaalharts where fungicides were applied for the control of foliar diseases.

The percentage of unsound, blemished and soiled kernels (UBS%) was calculated by grading 200g of the shelled kernels taken from a 500g representative pod sample. Yield in kg/ha, was calculated from the weight of the kernels derived from 500g of shelled pods.

Statistical analyses

Analysis of variance (ANOVA) was done on all trial data using Maxiplan (a ARC-GCI developed programme) and Excel. Components used in the discussion were the coefficient of variation (CV) and the genetic coefficient of variation (GCV). The formulae used were explained in Chapter 4.

Canonical Variate Analysis (CVA), also known as linear discriminant analysis, is used when it is of more interest to show differences between groups (such as groups of germplasm entries showing similar characteristics) than between individuals (Snedecor and Cochran, 1980; Digby and Kempton, 1987). Data were analysed using the statistical programme GenStat (Payne, 2003).

In this study, CVA was used to determine which characteristics (for instance resistance to ELS, LLS, WB and rust and yield), discriminated most between entries, localities and the interaction between entries and localities. In this method, the variability in a data set is reduced to those variables that make the largest contribution to the variability. The new set of variables, referred to as canonical variates, consist of linear combinations of the original measurements and are thus given as vectors of loadings for the original measurements. With this approach a three dimensional set of data is obtained in which the ratio of between group variability to within group variability in each direction is maximised (Snedecor and Cochran, 1980). In this study the variates that distinguished one group from the next, were the characteristics such as resistance to ELS, LLS, WB and rust and yield. The scores calculated for each of the canonical variates are then correlated with the original variates to find those that are the most important in discriminating between the groups (Digby and Kempton, 1987).

Plots of the canonical variate means for each group show the group positions relative to one-another. In such a plot, points closer together are similar and points further apart are dissimilar with respect to the variates that discriminate between them. The 95% confidence region of the group mean is indicated by a circle with a radius of $2.4/\sqrt{n}$ about the mean. When circles overlap, the groups concerned do not differ at the 5% significance level (Krzanowski, 1988).

CVA's were calculated for the 49 entries (Table 5.1) planted at all localities (Trials 5.1a, b and c) and for the Elite short/medium (Trial 5.2a) and long (Trial 5.2b) and ICRISAT long (Trial 5.2c) growth season entries planted at Brits in irrigated 2004/05 trials.

RESULTS AND DISCUSSION

Trials planted at Potchefstroom, Vaalharts, Brits, Cedara and Burgershall (Table 5.1 and Trials 5.1a, b and c)

Average disease ratings

Results of the ANOVA tables on the average ELS, LLS, WB and rust ratings for the replicated trials at Potchefstroom, Vaalharts, Brits, Cedara and Burgershall [Trial no 5.1a (short), b (medium) and c (long)] are presented in Appendix 3 (Tables 3.1-3.5). Disease ratings for individual entries at each locality are visualized by means of bar diagrams in Appendix 4.1. Those entries exhibiting resistance are summarized in Table 5.2 below.

Table 5.2 Summary of those groundnut entries resistant to ELS, LLS, WB and rust at Potchefstroom, Vaalharts, Brits, Cedara and Burgershall during 2004/05. A rating of <3 was regarded as an indication of resistance

Growth season	Disease			
	ELS	LLS	WB	Rust
Short	2		2, 3	
Medium	10	3, 6, 7, 8, 9	1, 2, 3, 4 6, 8, 9, 10, 11-15, 17-20, 22, 24, 26, 27, 29, 30-35	3, 6, 7, 8, 9, 10, 28
Long	2, 4	4	1-11	4

ELS early leaf spot

LLS late leaf spot

WB web blotch

Weather data

Weather data (Appendix 7) for the five localities for 2004/05 are presented in Figures 5.1-5.10 and are summarised in Tables 5.3-5.7.

Potchefstroom

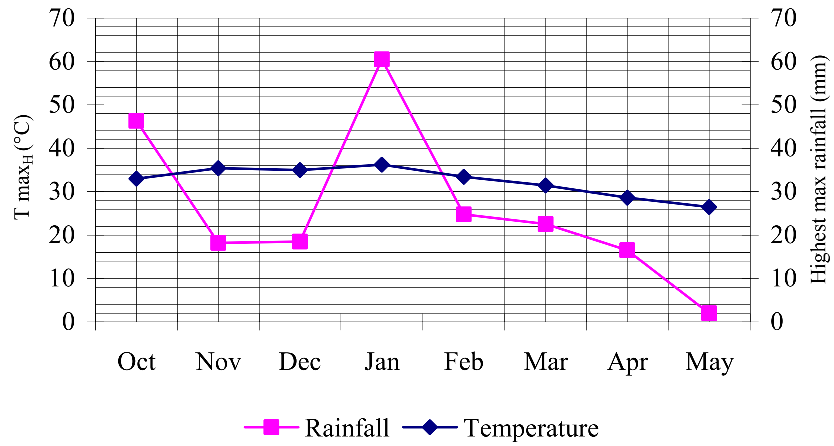

Figure 5.1 Highest maximum rainfall (mm) and temperature (Tmax$_H$, °C) during 2004/05 at Potchefstroom.

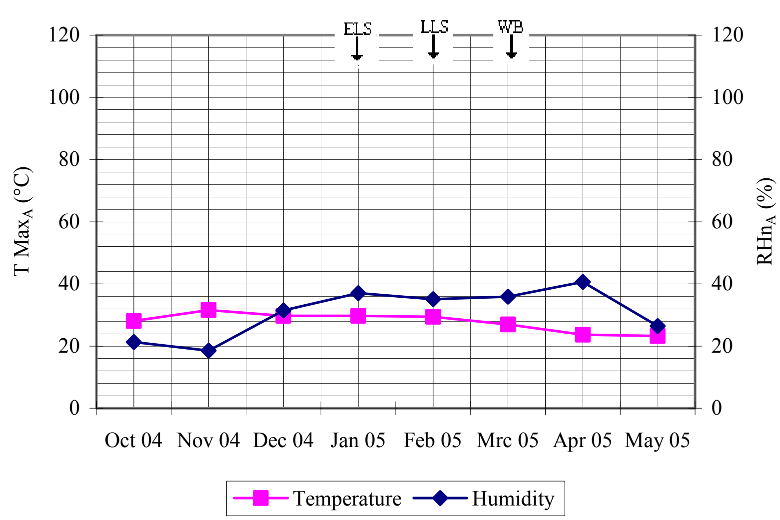

Figure 5.2 Average daily maximum temperature (Tmax$_A$, °C) and average daily minimum relative humidity (RHn$_A$, %) during 2004/05 for Potchefstroom.

Table 5.3 Weather data for the season of 2004/05 at Potchefstroom

Weather components	Summer season							
	Oct	Nov	Dec	Jan	Feb	March	April	May
$Tmax_H$ (°C)	33.0	35.4	35.0	36.2	33.4	31.4	28.6	26.5
$Tmax_A$ (°C)	28.1	31.6	29.7	29.7	29.4	26.9	23.7	23.2
[$Tmax_A$-$Tmin_A$ (°C)]	15.9	16.0	13.2	12.4	12.9	13.3	13.3	17.8
RHx_A (%)	75.2	75.8	89.3	89.7	90.9	91.2	94.6	91.1
RHn_A (%)	21.3	18.5	31.5	37.0	35.1	35.9	40.6	26.4

$Tmax_H$, °C highest maximum temperature

$Tmax_A$, °C and $Tmin_A$, °C average daily maximum and minimum temperatures

RHn_A, %) average daily minimum relative humidity

Vaalharts

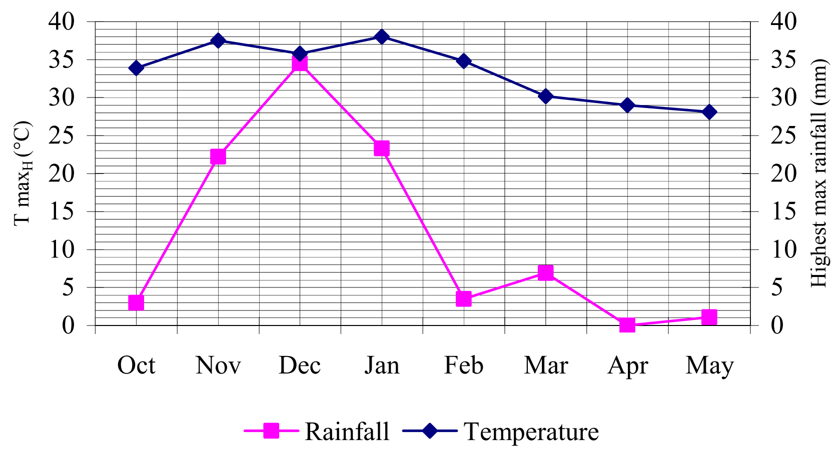

Figure 5.3 Highest maximum rainfall (mm) and temperature ($Tmax_H$, °C) during 2004/05 at Vaalharts.

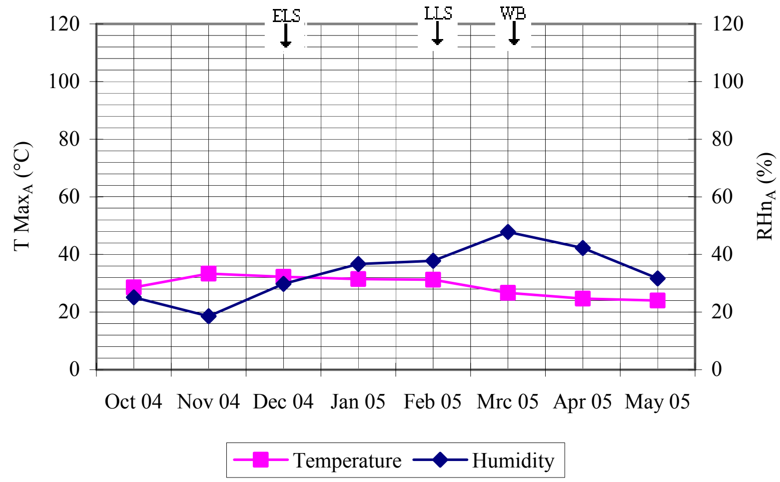

Figure 5.4 Average daily maximum temperature ($Tmax_A$, °C) and average daily minimum relative humidity (RHn_A, %) during 2004/05 for Vaalharts.

Table 5.4 Weather data for the 2004/05 season at Vaalharts

Weather components	Summer season							
	Oct	Nov	Dec	Jan	Feb	March	April	May
$Tmax_H$ (°C)	33.9	37.5	35.9	38.0	34.8	30.2	29.0	28.1
$Tmax_A$ (°C)	28.6	33.4	32.2	31.5	31.2	26.7	24.7	24.0
[$Tmax_A$-$Tmin_A$ (°C)]	19.3	19.9	16.8	15.9	15.7	13.1	16.0	19.4
RHx_A (%)	90.3	87.3	94.2	91.9	97.9	98.0	97.9	96.3
RHn_A (%)	25.1	18.6	29.8	36.7	37.8	47.8	42.3	31.7

$Tmax_H$, °C	highest maximum temperature
$Tmax_A$, °C and $Tmin_A$, °C	average daily maximum and minimum temperatures
RHn_A, %)	average daily minimum relative humidity

Brits

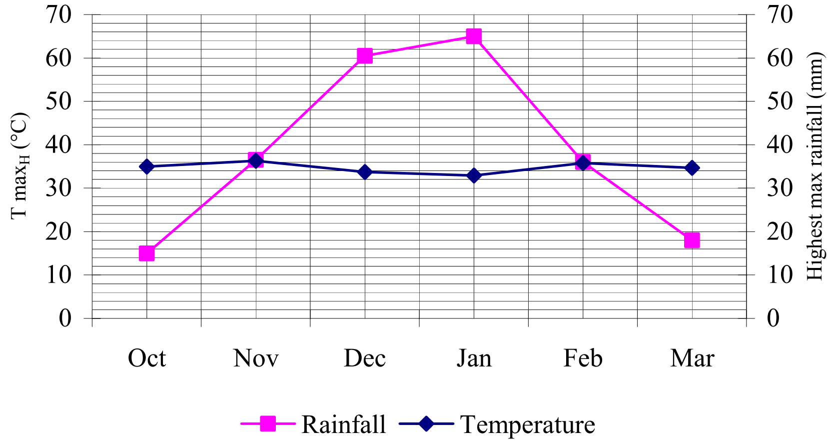

Figure 5.5 Highest maximum rainfall (mm) and temperature ($Tmax_H$, °C) during 2004/05 at Brits.

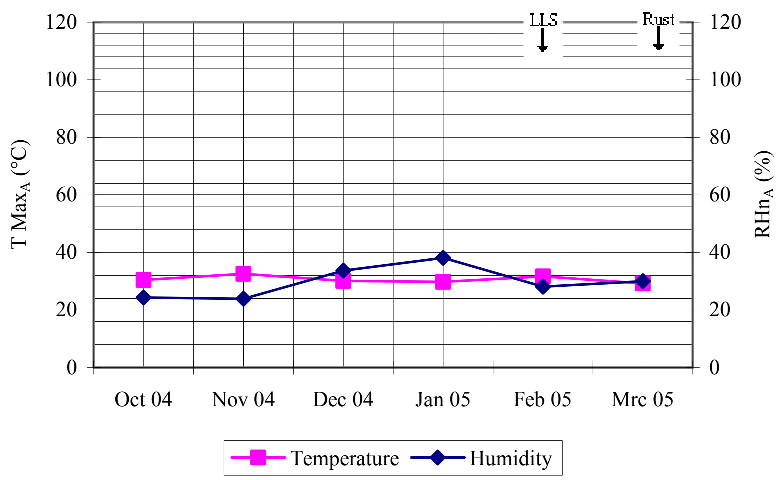

Figure 5.6 Average daily maximum temperature ($Tmax_A$, °C) and average daily minimum relative humidity (RHn_A, %) during 2004/05 for Brits.

Table 5.5 Weather data for the season of 2004/05 at Brits

Weather components	Summer season							
	Oct	Nov	Dec	Jan	Feb	March	April	May
$Tmax_H$ (°C)	35.0	36.3	33.7	32.9	35.8	34.7	30.8	29.5
$Tmax_A$ (°C)	30.5	32.6	30.1	29.8	31.7	29.2	25.2	25.6
[$Tmax_A$-$Tmin_A$ (°C)]	17.7	16.4	12.8	11.2	14.5	14.2	12.7	19.5
RHx_A (%)	77.5	79.8	89.9	90.5	86.9	90.5	91.7	90.4
RHn_A (%)	24.4	23.9	33.7	38.2	28.1	30.0	35.6	21.9

$Tmax_H$, °C highest maximum temperature

$Tmax_A$, °C and $Tmin_A$, °C average daily maximum and minimum temperatures

RHn_A, %) average daily minimum relative humidity

Cedara

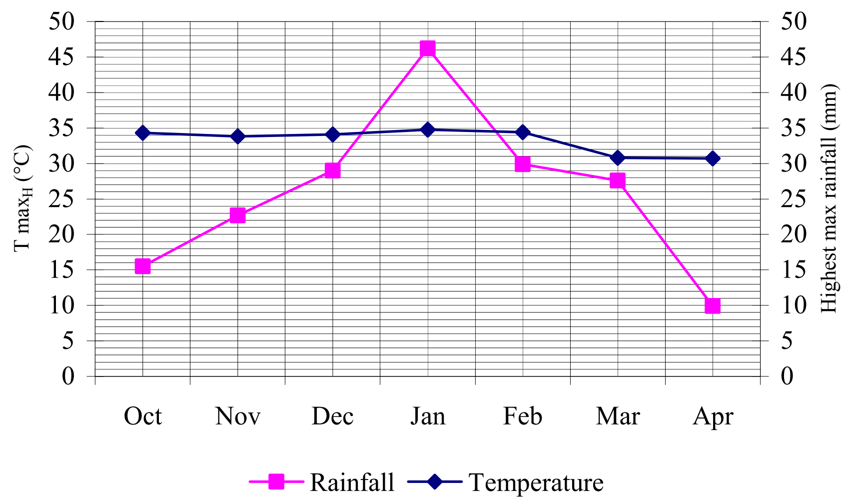

Figure 5.7 Highest maximum rainfall (mm) and temperature ($Tmax_H$, °C) during 2004/05 at Cedara.

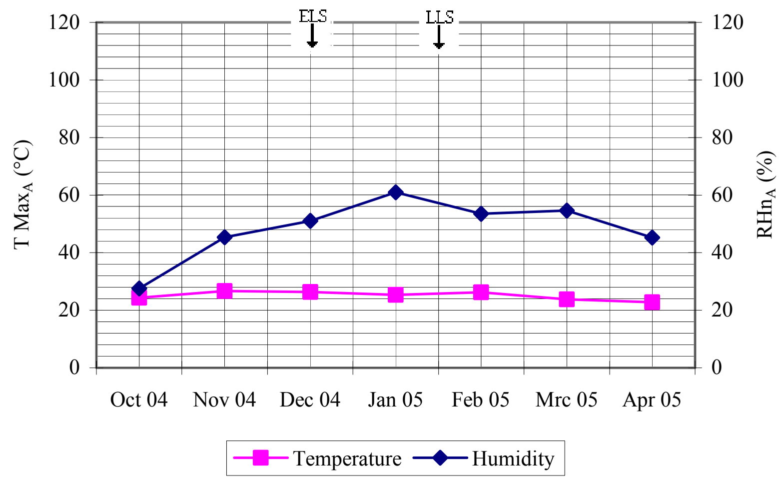

Figure 5.8 Average daily maximum temperature ($Tmax_A$, °C) and average daily minimum relative humidity (RHn_A, %) during 2004/05 for Cedara.

Table 5.6 Weather data for the 2004/05 season at Cedara

Weather components	Summer season						
	Oct	Nov	Dec	Jan	Feb	March	April
$Tmax_H$ (°C)	34.3	33.8	34.1	34.7	34.4	30.8	30.7
$Tmax_A$ (°C)	24.4	26.7	26.4	25.4	26.3	23.8	22.8
[$Tmax_A$-$Tmin_A$ (°C)]	13.0	12.2	11.0	9.6	10.2	10.2	11.9
RHx_A (%)	87.4	92.9	93.9	93.8	94.5	95.6	93.9
RHn_A (%)	27.6	45.4	51.0	60.9	53.5	54.6	45.3

$Tmax_H$, °C highest maximum temperature

$Tmax_A$, °C and $Tmin_A$, °C average daily maximum and minimum temperatures

RHn_A, %) average daily minimum relative humidity

Burgershall

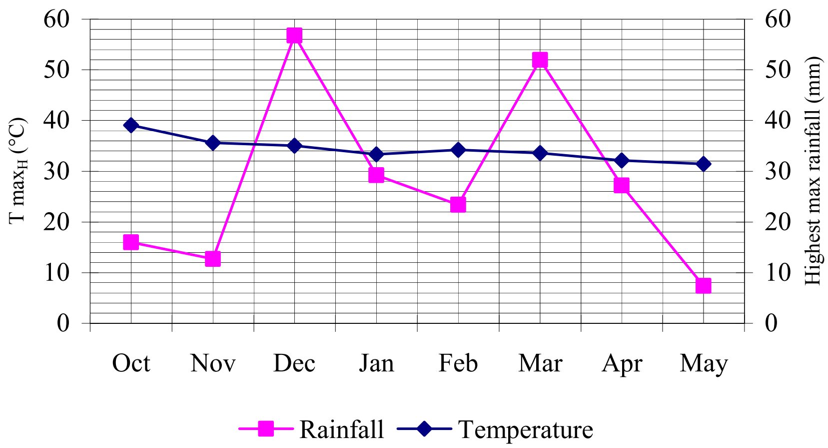

Figure 5.9 Highest maximum rainfall (mm) and temperature ($Tmax_H$, °C) during 2004/05 at Burgershall.

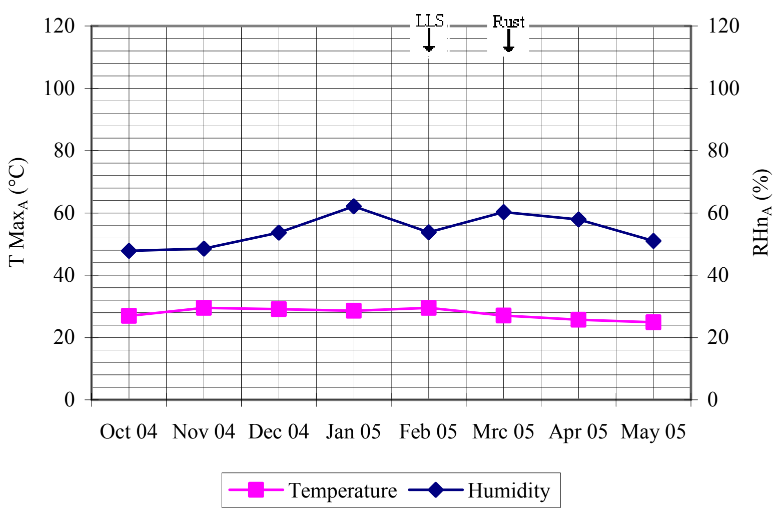

Figure 5.10 Average daily maximum temperature ($Tmax_A$, °C) and average daily minimum relative humidity (RHn_A, %) during 2004/05 for Burgershall.

Table 5.7 Weather data for the 2004/05 season at Burgershall

Weather components	Summer season							
	Oct	Nov	Dec	Jan	Feb	March	April	May
$Tmax_H$ (°C)	39.1	35.6	35.0	33.3	34.2	33.6	32.1	31.4
$Tmax_A$ (°C)	26.9	29.5	29.1	28.6	29.5	27.0	25.7	24.9
[$Tmax_A$-$Tmin_A$ (°C)]	11.9	12.1	10.4	9.0	10.5	9.4	10.1	11.7
RHx_A (%)	94.4	97.9	98.2	98.0	97.9	98.1	97.7	97.7
RHn_A (%)	47.8	48.5	53.7	62.1	53.8	60.3	57.9	51.0

$Tmax_H$, °C highest maximum temperature

$Tmax_A$, °C and $Tmin_A$, °C average daily maximum and minimum temperatures

RHn_A, %) average daily minimum relative humidity

Grading results on kernels

Trials planted at Potchefstroom, Vaalharts, Brits, Cedara and Burgershall (Table 5.1 and Trials 5.1a, b and c)

The grading results of the short, medium and long growth season entries are shown in Appendix 5. A summary of this data is shown in Table 5.8.

Two graphs were selected to demonstrate the relationship between UBS% and the quality of the kernels derived at from the grading results. Figures 5.11 and 5.12 show the relationship between UBS% and the percentages of choice and crushing grade kernels respectively.

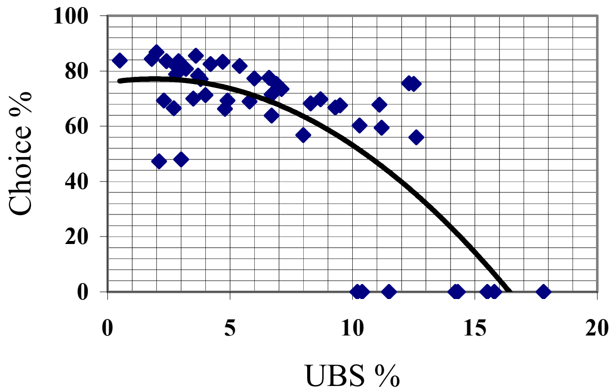

Figure 5.11 The relationship between the percentages of unsound, blemished and soiled (UBS%) and choice grade groundnut kernels for the 49 short, medium and long growth season entries during the 2004/05 season at Potchefstroom (Trials 5.1a, b and c).

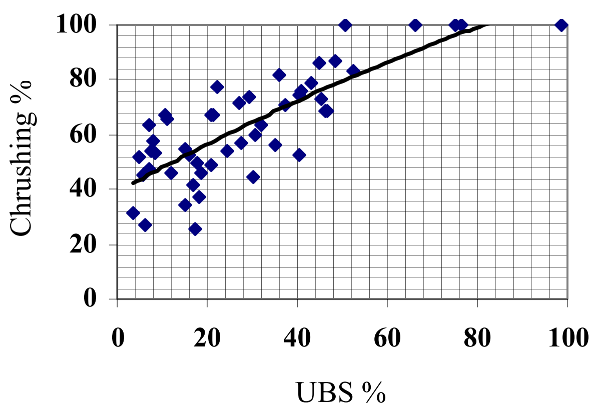

Figure 5.12 The relationship between the percentages of unsound, blemished and soiled (UBS%) and crushing grade groundnut kernels for 49 short, medium and long growth season entries during the 2004/05 season at Burgershall (Trials 5.1a, b and c).

Table 5.8 A summary of the number of short, medium and long growth season entries that gave choice, standard, sundry and crushing grade kernels (a 200g sample from the 500g shelled pods sample), from Potchefstroom, Vaalharts, Brits, Cedara and Burgershall during 2004/05 (Trials 5.1a, b and c; Appendix 5)

Trial		Localities										
		Potchefstroom		Vaalharts		Brits		Cedara		Burgershall		
	UBS%	≤13	13-50	≤13	13-50	≤13	13-50	≤13	13-50	≤13	13-50	≥50
	Grade											
Short	choice	3		3		3		3				
	standard											
	sundry	2				3		3				1
	crushing	3		3		3		3				3
Medium	choice	30		34		32		29		3		
	standard	2	3	1		1	1	2	1	3	4	
	sundry	30	4	35		34	1	31	4	4	30	1
	crushing	32	3	35		34	1	31	4	4	30	1
Long	choice	8		11		11		10		2		
	standard	1	2					1		2	1	
	sundry	9		10		11		11		2	9	
	crushing	9	2	11		11		11		2	9	

UBS unsound, blemished and soiled

The ANOVA tables on yield (kg/ha) for the short (Trial 5.1a), medium (Trial 5.1b) and long (Trial 5.1c) growth season entries, are summarised in Tables 5.9, 5.10 and 5.11 respectively. Two data sets were selected to demonstrate the relationship between the UBS% and the average kernel mass of 500g of shelled pods. Brits (Figure 5.18) was selected because disease levels were representative of those normally experienced, whereas Burgershall (Figure 5.13) was selected because of the abnormally high disease pressure.

Table 5.9 The ANOVA table on the average kernel yield (kg/ha) (Trial 5.1a) of three short growth season groundnut entries at the five localities (Potchefstroom, Vaalharts, Brits, Cedara and Burgershall) during 2004/05

E	Entries	Localities				
		Brits (ns)	Burgershall	Cedara(ns)	Potchefstroom	Vaalharts(ns)
1	Harts	1798.3	107.3[3]	338	972[1]	525.5
3	Kano	1920.8	135[1]	841.3	846.2[2]	764.8
2	Kan Red	1693	119.5[2]	710.2	325.5	394.6
	MS (blocks; df=2)	60390	63	91481	207898	50670
	MS (treatments; df=2)	521601	1156	409067	705005	211520
	MS (error; df=4)	254093	28	56258	68077	94777
	F-Ratio (treatments)	2.05ns	40.71**	7.27ns	10.36*	2.23ns
	Trial mean	1804	121	630	715	562
	CV%	29.77	4.42	37.66	36.51	54.82
	LSD (5%)	na	12.08	na	591.39	697.79na
	LSD (1%)	na	20.03	na	na	na
	SEM	291.0	3.1	136.9	150.6	177.7
	GCV%	17.6	16.1	54.4	64.5	35.1
	Intra class correlation	0.2598	0.9298	0.6764	0.7572	0.2911
	Standard error of t	0.4592	0.082	0.3108	0.2492	0.4579
	Repeatability%	51	98	86	90	56

E entry

df degrees of freedom

MS mean squares

* and ** significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers did not differ significantly from the highest yield at the 5% and 1% level (per column)

ns not significant

na not applicable

CV% coefficient of variation (percentage)

SEM standard error of means

GCV% genetic coefficient of variation (percentage)

x^1, x^2, x^3 ranks: (first, second and third)

Table 5.10 The analysis of variance on the average kernel yield (kg/ha) (Trial 5.1b) of 35 medium growth season groundnut entries at the five localities (Potchefstroom, Vaalharts, Brits, Cedara and Burgershall) during 2004/05

E	Entries	Localities				
		Brits	Burgershall	Cedara	Potchefstroom	Vaalharts
3	86-87/175 (RG784)	2700.0	242.1	1149.1[4]	3250.0[1]	1001.6
22	PC297-K2	2119.4	173.2	416.6	3092.6[2]	545.5
7	ICGV 90096	3049.2	178.2	579.7	2939.8[3]	1348.0
26	PC324-K1	2281.0	312.1[1]	423.1	2935.2[4]	1068.2
20	PC280-K2	2930.2	172.8	1593.0[1]	2787.0[5]	809.8
8	ICGV 90099	3545.9[5]	198.4	393.3	2527.8[6]	1537.9[8]
24	PC299-K19	1031.6	168.8	294.5	2509.2[7]	340.9
11	ICGV 95350	2004.7	202.9	490.7	1361.1	962.6
13	ICGV-SM-95714	2261.0	175.1	323.4	2500.0[8]	920.0
30	RR Line 3	2676.9	168.8	325.5	2407.4[9]	1664.7[6]
23	PC299-K1	2615.7	89.6	1457.4[2]	2398.1[10]	1310.9
5	Akwa	2458.3	66.4	424.7	2381.2[11]	919.7
35	Swallow	2318.0	125.4	680.0	2370.4[12]	764.7
6	ICGV 90071	2113.0	136.8	529.6	2361.1[13]	864.3
15	ICGV-SM-99543	4041.3[2]	203.9	1063.3	2333.3[15]	1179.4
19	PC254-K1	2188.2	176.1	548.1	2333.3[14]	917.0
16	ICGV-SM-99529	2589.8	188.7	866.3	2092.6[16]	745.0
33	RR Line 9	2265.0	149.6	580.4	2074.1[17]	1712.6[3]
27	PC327-K1	2562.7	218.4	935.9	2037.0	748.0
4	86-87/175(bl)(RG783)	3035.4	177.6	309.4	2027.8	1507.8[10]
25	PC299-K5	3229.3	145.0	353.6	1925.9	1444.0[11]
1	73-30 (RG453)	3815.0[3]	181.8	861.6	1870.4	2086.7[2]
17	JL 24	2320.4	127.1	593.8	1824.1	1124.3
14	ICGV-SM-95741	1803.6[4]	190.7	1191.6[3]	1740.7	1671.3[4]
31	RR Line 7	2249.1	172.5	534.9	1713.0	1015.2
12	ICGV-SM-93541	3686.0	128.8	515.0	1675.9	862.9
9	ICGV 90197	2520.3	162.2	466.4	1601.9	489.0
18	Kwarts	1961.8	125.4	492.7	1564.8	1604.2[7]
34	Streeton [Austr]	3248.7	139.2	1015.0	1518.5	1129.1
28	RR Line 10	3100.6	195.6	680.8	1324.1	1341.4
2	73-30 (RG716)	2805.1	131.7	691.7	1291.7	1668.8[5]
32	RR Line 8	3298.2	158.1	893.6	1064.8	2128.6[1]
10	ICGV 95342	3051.3	233.2	1100.0	1000.0	1421.0[12]
29	RR Line 11	1017.5	190.4	134.4	935.2	792.8
21	PC287	4485.5[1]	176.6	675.4	574.1	1525.7[9]
	MS (blocks; df=2)	1044418	474	552943	255644	40489
	MS (treatments; df=34)	1724890	6039	362802	1289270	580373
	MS (error; df=68)	293477	693	49594	327626	122123
	F-Ratio (treatments)	5.88**	8.72**	7.32**	3.94**	4.75**
	Trial mean	2668	171	674	2010	1176
	CV%	20.31	15.4	33.05	28.48	29.72
	LSD (5%)	884.65	42.98	363.66	934.7	570.67
	LSD (1%)	1176.58	57.16	483.67	1243.16	758.99
	SEM	312.8	15.2	128.6	330.5	201.8
	GCV%	25.9	24.7	48.0	28.2	33.2
	Intra class correlation	0.6192	0.7201	0.678	0.4945	0.5557

E	Entries	Localities				
		Brits	Burgershall	Cedara	Potchefstroom	Vaalharts
	Standard error of t	0.0844	0.0676	0.0751	0.0995	0.0929
	Repeatability%	83	89	86	75	79

PC Potchefstroom cross

-K progeny of single plant selections

E entry

ICGV/ICGVSM ICRISAT entries

df degrees of freedom

MS mean squares

* and ** significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers (x^1,x^2,x^3 etc) did not differ significantly from the highest yield at the 5% and 1% level (per column)

ns not significant

CV% coefficient of variation (percentage)

SEM standard error of means

GCV% genetic coefficient of variation (percentage)

x^1, x^2, x^3 ranks: (first, second and third)

Table 5.11 The analysis of variance on the average kernel yield (kg/ha) (Trial 5.1c) of 11 long growth season groundnut entries at five localities (Potchefstroom, Vaalharts, Brits, Cedara and Burgershall) during 2004/05

E	Entries	Localities				
		Brits	Burgershall	Cedara	Potchefstroom	Vaalharts
10	RR Line 12	4098.3^{1}	172.8^{6}	1063^{3}	2569^{2}	2166^{3}
6	ICGV-SM 99821	3817.6^{2}	194.2^{3}	946.7^{6}	1362.3	1092.2
5	ICGV 95343	3747.9^{3}	173.1^{5}	1026.7^{4}	2200.5^{3}	1574.2^{6}
7	ICGV-SM 99841	3471.2^{4}	215.3^{2}	867.5^{8}	1724.4^{7}	1516.4
8	ICGV-SM 99844	3337.7^{5}	215.9^{1}	1384.7^{1}	2578.5^{1}	1813.5^{4}
3	ICGMS42=CG7	2868.9^{6}	144.4	947.9^{5}	1872.2^{5}	2331.8^{1}
1	Billy	2498.1	98.6	766.7^{9}	1464.2	1761.5^{5}
2	CG7=ICGMS42	2484.4	188.3^{4}	1226.9^{2}	2089.2^{4}	2188.6^{2}
9	Rambo	2170.7	164.1	924.3^{7}	1767.5^{6}	1436.8
4	ICGV 90087	1016.9	80.6	359.3	843.6	565.8
11	TMV1	973.6	152.5	507.6	884.7	965.9
	MS (blocks; df=2)	455440	147	40108	204904	41263
	MS (treatments; df=10)	3819077	6246	284410	1164139	1011488
	MS (error; df=20)	468150	441	97978	191779	120616
	F-Ratio (treatments)	8.16**	14.17**	2.9**	6.07**	8.39**
	Trial mean	2772	164	911	1760	1583
	CV%	24.69	12.83	34.36	24.89	21.94
	LSD (5%)	1165.36	35.76	533.13	745.88	591.52
	LSD (1%)	1589.39	48.77	727.11	1017.27	806.75
	SEM	395.0	12.1	180.7	252.8	200.5
	GCV%	38.1	26.9	27.4	32.4	34.4
	Intra class correlation	0.7047	0.8144	0.3881	0.6283	0.7112
	Standard error of t	0.1299	0.0891	0.1984	0.1531	0.1277
	Repeatability%	88	93	66	84	88

E entry number x^1, x^2, x^3 ranks: (first, second and third)

ICGV/ICGV-SM ICRISAT entries

df degrees of freedom

MS mean squares

* and ** significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers (x^1,x^2,x^3 etc) did not differ significantly from the highest yield at the 5% and 1% level (per column)

ns not significant

na not applicable

CV% coefficient of variation (percentage)

SEM standard error of means

GCV% genetic coefficient of variation (percentage)

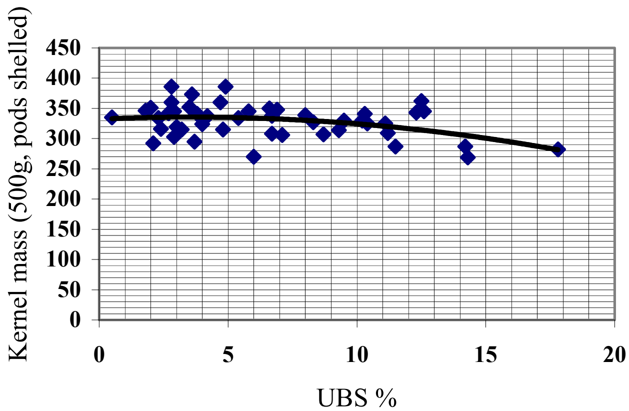

Figure 5.13 The relationship between the percentages unsound, blemished and soiled kernels (UBS%) and kernel mass (500g pods, shelled) of the 49 short, medium and long growth season entries during the 2004/05 season at Brits (Trials 5.1a, b and c).

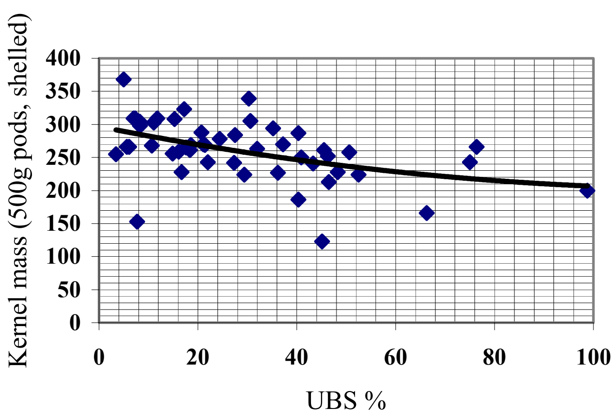

Figure 5.14 The relationship between the percentages unsound, blemished and soiled kernels (UBS%) and kernel mass (500g pods, shelled) of the 49 short, medium and long growth season entries during the 2004/05 season at Burgershall (Trials 5.1a, b and c).

Short growth season entries

Although the F ratios in the ANOVA tables (Appendix 3: Table 5.2) on the ELS, LLS, WB and rust ratings (Trial 5.1a) did not indicate significant differences among the entries at any of the five localities, it was noted that entry 2 (Kan Red) exhibited resistance to ELS at all five localities.

Entry 1 (Harts) contained 95.5% choice grade kernels at a UBS≤13% at Brits, 85% at Vaalharts, 68.8% at Cedara and 0% at Burgershall. With an UBS≥50% at Burgershall (Appendix 5: Table 5.1), a 100% crushing grade was recorded. The results show that, with a UBS≤13%, the above three entries gave a high percentage of choice grade kernels at Brits, Potchefstroom, Cedara and Vaalharts (Table 5.8).

There were no significant differences between the three entries for kernel mass (500g pods, shelled) at Potchefstroom, Brits, Cedara and Vaalharts (Table 5.9).

Medium growth season entries

Potchefstroom

Although disease pressure was not high, the F ratios of the ANOVA tables (Trial 5.1b) indicated that 23 entries (for ELS resistance), 23 entries (for LLS resistance) and 6 entries (for rust resistance) differed highly significantly ($p<0.01$) from the 35 entries in the trial (Appendix 3: Table 3.2). Due to unfavourable climatic conditions rust did not occur. During January 2004 the highest maximum daily rainfall of 60.5mm and $Tmax_H$ of 36.2 was measured. The RHn_A was 37%. ELS infection was moderate. Average daily rainfall decreased from 6.1mm in January 2005 to 2.5mm during February 2005. The $Tmax_H$ decreased from 36.2 to 33.4°C during February, but the RHn_A of 35.1% increased to 35.9% during March (Table 5.3). These conditions resulted in slight LLS and WB infection (Figures 5.1 and 5.2).

Vaalharts

The F ratios of the ANOVA tables (Appendix 3: Table 3.2) indicated that eight entries differed highly significantly as to ELS resistance from the rest of the entries in the trial ($p<0.01$). Entry 10 gave the lowest ELS rating of 2.9. The F ratios of the ANOVA tables on LLS and WB ratings indicated that 29 entries differed significantly in LLS resistance and 23 entries in WB resistance from the rest of the 35 entries. Due to unfavourable climatic conditions, rust did not occur. The $Tmax_H$ during December 2004 and January 2005 were 35.9 and 38°C. The highest daily rainfall of 34.5mm was measured during December. The RHn_A was 29.8% and 36.7% during December and January respectively. These hot humid conditions resulted in severe ELS infection. Venkataraman and Kazi (1979) also reported that optimum temperatures of 25-31°C, high minimum (18-23°C) and maximum (31-35°C) temperatures and high humidity, as well as a late rainy season favour ELS. A slight decrease in $Tmax_A$ of 31.5 to 31.2% from January to February, less rain (0.5mm average daily) and a RHn_A of 37.8% during February resulted in LLS infection. Cooler humid conditions ($Tmax_A$ of 26.7°C and RHn_A of 47.8%) resulted in WB infection (Table 5.4 and Figures 5.3 and 5.4), which was in accordance with the findings of Blamey *et al*. (1997). They reported that temperatures lower than 29°C and high relative humidity are favourable for WB.

Brits

The F ratios of the ANOVA tables on ELS ratings (Appendix 3: Table 3.2) did not indicate highly significant differences ($p<0.01$) between the entries but 21 entries (for LLS resistance) and19 entries (for rust resistance) differed significantly from the rest of the 35 entries. Due to high temperatures and low humidity WB did not occur. Rust infection was more severe than LLS (Appendix 3: Table 3.2). The highest daily maximum rainfall of 65mm and RHn_A of 38.2% were recorded during January 2005. RHn_A decreased from 38.2% to 28.1% but increased to 30% during March. $Tmax_H$ decreased from 31.7°C to 29.2°C during March. LLS infection followed. The highest RHx of 97%, RHn_A of 30%, $Tmax_A$ of 29.2°C and ($Tmax_A$-$Tmin_A$) of 14.2% was recorded during March (Table 5.5). Rust infection followed (Figures 5.5 and 5.6).

Subrahmanyam *et al*. (1992) recorded rust outbursts at temperatures of 20-25°C and high relative humidity (>87%).

Cedara

Although the CV's were high, the F ratios of the ANOVA tables on ELS, LLS, WB and rust ratings (Appendix 3: Table 3.2) indicated 23 entries for ELS resistance, 33 entries for WB resistance and 31 entries for rust resistance differing highly significantly from the rest of the entries in the trial ($p<0.01$). The GCV was 42.6% for the ELS ratings, 39.53% for the LLS ratings, 37.43% for the WB ratings and 39.9% for the rust ratings. LLS infection was more severe than ELS, WB and rust. During December 2004 the average daily rainfall was 4.1mm and $Tmax_H$ decreased from 33.8°C in November 2004 to 34.1°C in December 2004. RHn_A increased from 45.4% (November) to 51% (December). ELS infection occurred. Maximum daily temperature of 31-35°C and a high average daily rainfall that triggered ELS, was reported in a study undertaken by Venkataraman and Kazi (1979). $Tmax_H$ (34.7°C), maximum daily rainfall (46.2mm) and RHn_A (60.9%) were measured during January 2005. RHn_A decreased from 60.9 to 53.5% and the average daily rainfall from 7.5mm to 4.6mm during February to March. LLS infection was severe, but the lower RHn_A and the higher $Tmax_A$ of 26.3°C during February and March did not favour WB and WB infection was lower than during the 2003/04 season. WB prefers relative humidity >80% and average temperature lower than 29°C (Blamey *et al*., 1997). This trial was planted early (October 2004) and was therefore harvested before rust became severe. The lower $Tmax_A$ of 23.8°C did not favour rust (Table 5.6 and Figures 5.7 and 5.8).

Burgershall

The F ratios of the ANOVA tables (Appendix 3: Table 3.2) on ELS ratings did not indicate significant differences between the entries. Due to the simultaneous occurrence of LLS and rust, WB was not rated. RHn_A (62.1%) was the highest during January, but $Tmax_A$ decreased from 29.1°C to 28.6°C from December 2004 to January 2005. RHn_A decreased from 62.1% to 53.8% from January to February 2005 (Table 5.7). The result was that ELS infection was not severe. These results are in accordance with findings by

Blamey *et al*. (1997). During March $Tmax_A$ decreased from 29.5°C to 27°C and RHn_A increased from 53.8% to 60.3%. The average daily rainfall during March was 3.5mm and the slightly lower temperature and high RHn_A resulted in severe LLS infection. During March and April RHn_A was 60.3% and 57.9% respectively and although $Tmax_A$ was moderate (27.0°C and 25.7°C respectively), the ($Tmax_A$-$Tmin_A$) were 9.4°C and 10.1°C respectively. These mild to hot and humid conditions resulted in rust infection (Table 5.7 and Figures 5.9 and 5.10). The F ratios of the ANOVA tables on LLS and rust ratings indicated highly significant differences ($p<0.01$) between entries 3, 4, 6, 7, 8, 9 (lowest rating 1.9), 10 and 33 (LLS) and entries 3, 6, 7, 8, 9, 10 and 28 (rust) and the remainder of the 35 entries. Savary (1986) stated that rust sporulates at a temperature >21°C and needs a high relative humidity and Pattee and Young (1982) reported that LLS sporulates at 25-30°C.

The grading results (Appendix 5) indicated that the disease pressure at Burgershall was much higher than at the other four localities. With a UBS≤13%, 32 entries at Brits, 30 at Potchefstroom and 34 at Vaalharts, 29 at Cedara and 3 at Burgershall, gave a high percentage of choice grade kernels (Table 5.8). With an UBS of 13-50%, one entry at Brits and Cedara, three at Potchefstroom and four at Burgershall, gave standard grade kernels. The exceptions were two entries at Potchefstroom with UBS of 10.2-11.5% that did not give choice grade kernels and one entry at Vaalharts with an UBS of 4.2% that gave standard grade kernels. Entries 3, 27 and 30 gave choice grade kernels at all five localities (Appendix 5). Entries 1-14, 16 to 18, 20, 21, 26, 27, 29, 30, 34 and 35 gave choice grade kernels at Brits, Potchefstroom, Cedara and Vaalharts, entry 15 at Brits and Vaalharts, but not at Cedara and Potchefstroom. Entry 19 gave choice grade at Brits, Potchefstroom and Vaalharts, but sundry and crushing grades at Cedara. Entry 22 gave choice grade at Potchefstroom and Vaalharts, but sundry and crushing grades at Cedara and Brits. Entry 25 gave choice grade at Brits, Potchefstroom and Vaalharts and standard grade at Cedara. Entry 28 gave standard grade at Brits, Potchefstroom, Cedara and Vaalharts. Entry 31 gave choice grade at Brits, Cedara and Vaalharts, but standard grade at Potchefstroom. Entry 32 gave choice grade at Cedara and Vaalharts and standard grade at Brits and Potchefstroom. Entry 33 gave choice grade at Brits and Vaalharts and standard grade at Cedara and Potchefstroom and entries 2, 5, 10, 13, 20, 23 and 24 gave standard grade at Burgershall (Table 5.8). The results demonstrated that a high UBS% resulted in low kernel grades.

Although the CV's were high the F ratios of the ANOVA tables on yield (Tables 5.9, 5.10 and 5.11) at the five localities indicated highly significant differences between 17 entries at Potchefstroom, five at Vaalharts, 12 at Brits, four at Cedara and one at Burgershall for differences in yield and the remainder of the 35 entries respectively. At Potchefstroom 11 entries gave higher yields than Akwa (control), 23 at Vaalharts, 20 at Brits, 25 at Cedara and 35 at Burgershall. At Potchefstroom entry 3 [86-87/175 (RG784)], gave the highest yield (37.1% higher than that of Akwa), at Vaalharts entry 32 was 231.4% higher, at Brits entry 21 was 82.4% higher, at Cedara entry 20 (PC280-K2) performed 275% better and at Burgershall entry 26 (PC324-K1) yielded more than three and a half times higher than Akwa. Akwa gave the lowest yield of the 35 entries at Burgershall. Although entries 3, 32 and 21 were not the best entries at all the localities they still had higher yields (kg/ha) than Akwa (control) at all the localities. These entries have the potential for high yields under different climatic conditions that influence the severity of the foliar diseases and will be incorporated in the breeding programme to improve the yield of commercial cultivars. Entry 11 (ICGV 95350) gave the lowest yield at both Brits and Cedara.

Long growth season entries

Potchefstroom and Brits

The F ratios of the ANOVA tables (Appendix 3: Table 3.3) on ELS, LLS, WB and rust (Trial 5.1c) ratings did not indicate significant differences between the entries. Rust did not occur in Potchefstroom.

Vaalharts

The F ratios of the ANOVA tables on LLS and rust ratings (Trial 5.1c) (Appendix 3: Table 3.3) did not indicate significant differences between the entries. Although the CV's were between 20 and 30% the F ratios of the ANOVA tables on ELS and WB ratings indicated highly significant differences between five and eight entries for ELS and WB respectively and the remainder of the 11 entries in the trial. GCV's were 24.7% and 33.76% for ELS and WB ratings respectively.

Cedara

The F ratios of the ANOVA tables on ELS and WB ratings (Trial 5.1c) (Appendix 3: Table 3.3) did not indicate significant differences between the entries. The F ratios of the ANOVA tables indicated that four entries differed highly significantly in LLS and rust resistance from the remainder of the 11 entries. GCV's were 33.06 and 28.16% and the CV's, 36.66 and 42.76% for the LLS and rust ratings respectively.

Burgershall

The F ratios of the ANOVA tables on ELS and LLS ratings (Trial 5.1c) (Appendix 3: Table 3.3) did not indicate significant differences between the entries. The F ratios of the ANOVA table indicated that entries 4 and 5 differed significantly for rust resistance from the remainder of the 11 entries ($p<0.05$).

The grading results (Appendix 5) showed that, with a UBS≤13%, 11 entries at Brits, 10 at Cedara, eight at Potchefstroom, 11 at Vaalharts and two at Burgershall gave choice grade kernels. With a UBS% between 13 and 50%, two entries at Potchefstroom and one at Burgershall gave standard grade kernels.

Entries 1, 2, 3, 7, 8 and 11 gave choice grade kernels at all the localities, except at Burgershall. Entries 4, 6 and 10 gave choice grade at Brits, Cedara and Vaalharts and standard grade at Potchefstroom. Entry 9 gave choice grade at Brits, Potchefstroom and Vaalharts and standard grade at Cedara. Entries 5 and 9 gave choice and entry 6 standard grade at Burgershall (Appendix 5).

Although the CV's were between 12 and 35%, the F ratios of the ANOVA tables on yield (Table 5.11) indicated highly significant differences ($p<0.01$) for four of the 11 entries at

Potchefstroom (1, 4, 6 and 11), five at Vaalharts (4, 6, 7, 9 and 11), four at Brits (1, 2, 4 and 9) and for five at Burgershall (1, 3, 4, 9 and 11). These entries gave the poorest yields. At Cedara the F ratios of the ANOVA tables on yield indicated significant differences between entries 1, 4, 6 and 11 and the rest of the high yielding entries.

At Potchefstroom seven of the 11 entries gave a higher yield than Billy (resistant control), four at Vaalharts, six at Brits, eight at Cedara and nine at Burgershall. Entry 8 was the best entry at Potchefstroom, Cedara and Burgershall and gave between 70 and 120% higher yield than Billy. This entry, although a long season growth entry, exhibited resistance to ELS, LLS, WB and rust and will be included in crosses with commercial cultivars to improve their resistance to leaf diseases. Entries 10, 5 and 2 gave better yields than Billy at all the localities.

The GCV for the short growth season entries on ELS at all five localities varied between 6.63 and 46.26%, on LLS between 15 and 41.15%, on WB between 23 and 47.2% and on rust between 11 and 86.6% and for ELS, LLS and WB ratings on the medium growth season entries, all <43%. LLS ratings were significant at all five localities on the medium growth entries, ELS and WB at Cedara, Potchefstroom and Vaalharts and rust at all five localities except Vaalharts. The GCV's for ELS, LLS, WB and rust ratings on the long growth entries were all <45% overall.

Average rating results at the five localities show that medium growth season entries 3, 6, 8 and 9 exhibited resistance to LLS, WB and rust, 7 to LLS and WB and 10 to ELS, WB and rust. Entries 11-15, 17-20, 22, 24, 26, 27, 29 and 30-35 exhibited resistance to WB only and 28 to rust only. The entries with the highest resistance to ELS, LLS, WB and rust, high yield and choice grade kernels were 1, 3, 7, 10, 14, 15, 20-22,6, 27, 30, 32 and 33 (Appendix 4.1).

WB was rated on the long growth season entries at four of the five localities (Burgershall excluded) but gave non-significant results. Although ELS ratings were only significantly different at Vaalharts the disease was severe and the ratings accurate and entries 1, 2, 4, 7 and 9 exhibited resistance to ELS (Appendix 4.1: Figure 4.1.2). LLS ratings indicated significant differences between entries 1, 4 and 7 at Cedara (Appendix 4.1: Figure 4.1.4). Entries 4 and 5 showed significant differences at Burgershall and Cedara. Long growth season entry 4 exhibited resistance to ELS, LLS and rust and 1 and 7 to ELS and LLS (Appendix 4.1: Figure 4.1.4 and 4.1.5).

Graphs (Figure 5.11 and 5.12) demonstrated the relationship between the UBS% and the quality of the kernels. A high UBS% resulted in inferior kernels and this will affect the percentage of the harvest chosen for choice grade, so, the higher the UBS%, the lower the grade. The quality of the pods and kernels harvested at Burgershall was the lowest, followed by Cedara, Potchefstroom, Brits and then Vaalharts (Table 5.8).

The GCV's for yield on the long growth season entries were between 25 and 45% and for the medium, between 20 and 50% (Table 5.11 and 5.10). These results indicated that moderate genetic variation existed between the entries for yield.

Entries with resistance to ELS, LLS, WB and rust have the potential for higher yield as the plant does not defoliate as quickly as susceptible entries and can use its full potential to produce and mature seeds. These results are in accordance with results noted by Swanevelder and Blamey (1981). Figures 5.13 and 5.14 indicated that yield is affected negatively by high UBS percentages**.** Entries with resistance to foliar diseases and exhibiting good yield potential under unfavourable weather conditions will be incorporated in the conventional breeding programme with the purpose of improving the yield and the foliar disease resistance of commercial cultivars and other breeding lines with good traits such as a high oleic acid percentage.

CONCLUSIONS

Trials planted at Potchefstroom, Vaalharts, Brits, Cedara and Burgershall (Table 5.1 and Trials 5.1a, b and c)

Results showed moderate genetic variation among all the entries for resistance to ELS, LLS, WB and rust. Climatic factors influenced the severity of infection at the different localities and further trials are needed to confirm the results. Results showed that entries with resistance to foliar diseases tended to give a higher kernel quality and yield.

Although resistance to foliar diseases is polygenic and climatic factors influence the occurrence and severity of the diseases it can be concluded that breeding for resistance to foliar diseases is possible. The entries with resistance to foliar diseases will be included in the breeding programme to improve commercial cultivars and to develop new breeding lines with resistance. These lines will be selected and evaluated in trials for favourable qualitative traits such as uniform kernels, a high oleic acid ratio and a high yield until they can be registered as new cultivars.

Genetic variation must be expanded by importing high yielding foreign material with traits such as resistance to foliar diseases and a high oleic acid percentage.

RESULTS AND DISCUSSION

Replicated randomised Elite [Trials 5.2a (short/medium growth) and b (long growth)] and ICRISAT [Trial 5.2c (long growth)] trials at Brits without fungicides

Average foliar disease ratings

ANOVA tables on the average ELS, LLS, WB and rust ratings for short/medium and long growth season entries of the Elite Trials are given in Tables 5.12 and 5.13 respectively and for the ICRISAT long growth season entries in Table 5.14. Bar diagrams (Appendix 4.2) visualise the resistance, tolerance and susceptibility of the entries to ELS, LLS, WB and rust.

Table 5.12 The analysis of variance on the average ratings for early leaf spot, late leaf spot web blotch and rust on Elite short/medium growth season groundnut entries during 2004/05 at Brits

E	Entries	ELS (ns)	LLS (ns)	WB (ns)	Rust	Rank
1	Akwa (susceptible control)	2.4	1.9	2.3	4.7	
2	Anel	2.5	1.8	2.8	4.6	
3	Harts	2.0	1.5	2.3	2.7	1
4	ICGV-SM-95714	2.3	1.1	1.8	3.5	
5	Kan Red	2.5	1.0	1.0	3.0	3
6	Kano	1.9	1.6	3.1	4.3	
7	Kwarts	2.5	1.5	1.0	4.2	
8	Mwenje	2.6	2.1	1.6	2.9	2
9	Nyanda	2.4	1.9	1.0	3.5	
10	PC280-K1	2.0	1.6	1.4	3.6	
11	PC280-K2	2.3	1.4	1.5	3.2	
12	PC280-K4	2.4	1.5	1.4	3.6	
13	PC280-K5	2.2	1.8	1.6	3.1	
14	PC299-K1	2.1	2.0	1.5	3.8	
15	PC299-K14	2.2	2.0	1.5	3.6	
16	PC299-K17	2.0	1.8	1.6	3.9	
17	PC299-K19	2.4	1.9	2.3	4.4	
18	PC299-K2	2.4	1.4	1.6	4.0	
19	PC299-K5	2.0	2.0	2.3	4.4	
20	PC327-K1	2.3	2.1	1.0	3.3	
21	PC327-K11	1.9	1.9	1.8	4.2	
22	PC327-K13	2.9	1.5	1.5	4.7	
23	PC327-K2	2.3	1.3	2.0	4.1	
24	PC327-K31	2.5	1.9	1.3	4.4	
25	PC327-K7	2.1	1.6	1.5	4.1	
	MS (blocks; df=3)	3.67	0.93	0.47	11.2	
	MS (treatments; df=24)	0.39	0.48	2.43	1.99	
	MS (error; df=72)	0.29	0.49	1.05	0.81	
	Trial mean	2.3	1.675	1.695	3.8	
	F-ratio (treatments)	1.395ns	0.95ns	1.64ns	2.24**	
	CV %	23.3300	40.02	40.97	25.39	
	LSD (5%)	na	na	na	1.26	
	LSD (1%)	na	na	na	1.675	
	SEM	0.25	0.35	0.4	0.45	
	GCV%	7.0	0	17.75	12.55	
	Intra class correlation (t)	0.0876	0	0.1251	0.223	
	Standard error of (t)	0.0957	0.0833	0.0964	0.1053	
	Repeatability%	27		29	51	

resistance shaded in grey
PC Potchefstroom cross
-K progeny of single plant selections
E entry
ICGV-SM ICRISAT entry
df degrees of freedom
MS mean squares
* and ** significance indicated for F-probabilities of treatments by * (p<0.05) and ** (p<0.01). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)
ns not significant
na not applicable
CV% coefficient of variation (percentage)
SEM standard error of means
GCV% genetic coefficient of variation (percentage)

Table 5.13 The analysis of variance on the average ratings for early leaf spot, late leaf spot web blotch and rust on Elite Long growth season groundnut entries during 2004/05 at Brits

E	Entries	ELS (ns)	LLS (ns)	WB (ns)	Rust	Rank
1	Billy (resistant control)	1.3	1.0	1.4	2.8	2
2	ICGV-SM-92736-K2	2.0	1.8	1.0	3.5	
3	ICGV-SM-92760-K2	2.0	1.1	1.0	3.3	
4	PC294-K2	1.0	1.0	1.0	2.7	1
5	PC297-K6	1.6	2.1	1.0	4.0	
6	PC297-K7	2.0	2.1	1.0	3.9	
7	PC322-K5	2.0	3.0	1.6	4.4	
8	PC322-K7	1.6	2.3	1.6	4.6	
9	PC322-K8	1.6	2.4	2.3	3.6	
10	PC323-K1	1.4	1.7	1.6	3.1	
11	PC324-K1	2.3	1.8	1.9	4.0	
12	PC325-K1	1.8	2.5	2.2	3.2	
13	PC325-K5	2.0	2.1	1.0	3.7	
14	PC328-K1	1.5	2.6	1.5	4.2	
15	Rambo	1.5	1.0	1.0	2.8	2
	MS (blocks; df=3)	0.18	3.12	5.46	2.87	
	MS (treatments; df=14)	0.54	2.86	1.65	2.33	
	MS (error; df=42)	0.31	0.57	0.57	1.24	
	Trial mean	1.58	1.896	1.41	3.575	
	F-ratio (treatments)	1.685ns	3.63ns	2.61ns	2.025*	
	CV %	34.86	37.09	38.74	38.035	
	LSD (5%)	na	na	na	1.555	
	LSD (1%)	na	na	na	na	
	SEM	0.25	0.35	0.3	0.55	
	GCV%	14.25	27.25	25.85	20.15	
	Intra-class correlation (t)	0.1458	0.329	0.2845	0.1999	
	Standard error of (t)	0.1336	0.130	0.1441	0.1387	
	Repeatability%	40	58	61	49	

resistance is shaded in grey

PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry
ICGV-SM	ICRISAT entry
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)
ns	not significant
na	not applicable
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)

Table 5.14 The analysis of variance on the average ratings for early leaf spot, late leaf spot web blotch and rust on ICRISAT long growth season groundnut entries during 2004/05 at Brits

E	Entries	ELS (ns)	LLS (ns)	WB (ns)	Rust	Rank
1	Billy	1.9	1.0	1.0	3.3	
2	CG7	2.1	1.0	1.0	3.9	
3	ICGV-SM-90704	1.9	1.1	1.3	2.5	1
4	ICGV-SM-99821	1.8	1.1	1.0	3.1	
5	ICGV-SM-99840	1.8	1.6	1.3	2.8	2
6	ICGV-SM-99841	1.9	1.1	1.0	3.0	3
7	ICGV-SM-99844	1.4	1.5	1.0	3.1	
8	ICGV-SM-99847	1.8	1.0	1.4	3.0	3
9	Rambo	1.5	1.8	1.0	3.8	
	MS (blocks; df=3)	0.48	0.28	0.18	1.63	
	MS (treatments; df=8)	0.29	0.59	0.41	1.39	
	MS (error; df=24)	0.68	0.18	0.51	0.86	
	Trial mean	1.765	1.25	1.0972	3.153	
	F-ratio (treatments)	0.44ns	2.3ns	0.41ns	1.585ns	
	CV %	45.92	30.68	31.24	34.56	
	LSD (5%)	na	na	na	na	
	LSD (1%)	na	na	na	na	
	SEM	0.45	0.2	0.2	0.45	
	GCV%	0	15.65	0	12.35	
	Intra-class correlation (t)	0	0.1985	0	0.127	
	Standard error of (t)	0.1443	0.1707	0.1443	0.174	
	Repeatability%	0	36	0	36	

resistance is shaded in grey

PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry
ICGV-SM	ICRISAT entry
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)
ns	not significant
na	not applicable
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)

Grading results on kernels for Elite short/medium (Trial 5.2a), Elite long growth (Trial 5.2b) and the ICRISAT long (Trial 5.2c) growth season entries

The grading results of the Elite short/medium, the Elite long growth and the ICRISAT long growth season entries are presented in Appendix 6. A summary of the entries that gave choice, standard, sundry and crushing grade kernels are presented in Table 5.15. Two graphs were selected to demonstrate the relationship between the UBS% and the quality of the kernels. Figures 5.15 and 5.16 show low and high UBS% and the correlated high percentage choice and crushing grade kernels respectively.

Table 5.15 A summary of grading results for choice, standard, sundry and crushing grade kernels of the Elite short/medium and Elite and ICRISAT long growth season entries planted at Brits during 2004/05 (Appendix 6)

Growing season	UBS Grades	≤13%	13–50%
Elite short/medium	Choice entries	1, 2, 4, 7, 9, 11-22, 24, 25	
	Standard entries	8, 23	
	Sundry entries	1, 2, 4, 7 – 25	3, 5, 6
	Crushing entries	1, 2, 4, 7 – 25	3, 5, 6
Elite long	Choice entries	4, 10, 12	
	Standard entries	1, 3, 15	2, 7, 11
	Sundry entries	1, 3, 4, 10, 12	5 - 9, 11, 13, 14, 17
	Crushing entries	1, 3, 4, 10, 12	5 - 9, 11, 13, 14, 17
ICRISAT long	Choice entries	3, 7	
	Standard entries	5, 6, 9	1, 4
	Sundry entries	3, 5, 6, 7, 9	1, 2, 4, 8
	Crushing entries	3, 5, 6, 7, 9	1, 2, 4, 8

UBS unsound, blemished and soiled

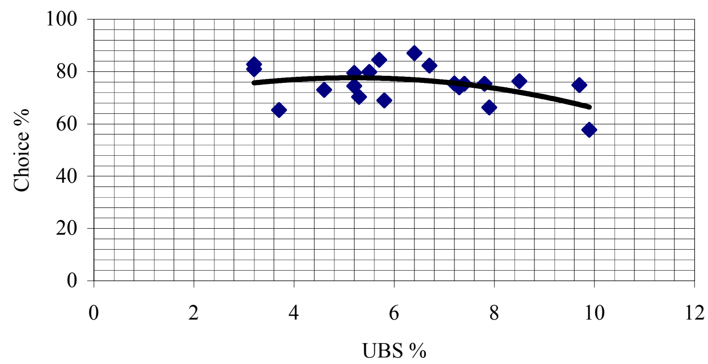

Figure 5.15 The relationship between the percentages of unsound, blemished and soiled kernels (UBS%) and kernel quality of Elite short/medium growth season entries during 2004/05 at Brits (Trial 5.2a).

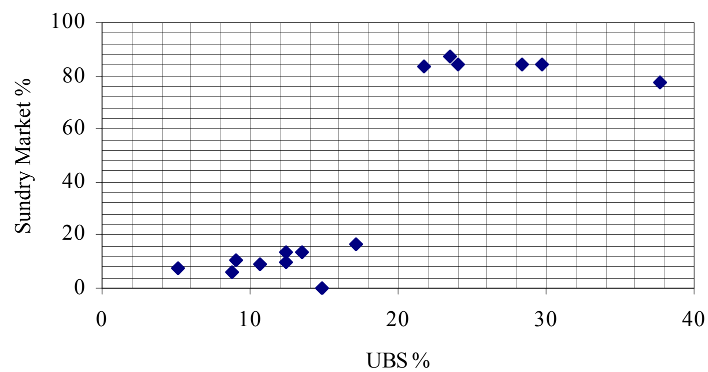

Figure 5.16 The relationship between the percentages of unsound, blemished and soiled kernels (UBS%) and the kernel quality of Elite long growth season entries during 2004/05 at Brits (Trial 5.2b).

Results from the ANOVA tables on the average kernel yield (kg/ha) for Elite short/medium are presented in Table 5.16, Elite long in Table 5.17 and the ICRISAT long growth season entries in Table 5.18. Two graphs (Figures 5.17 and 5.18) are taken as examples to show the relationship between the UBS% and kernel mass after shelling 500g of pods.

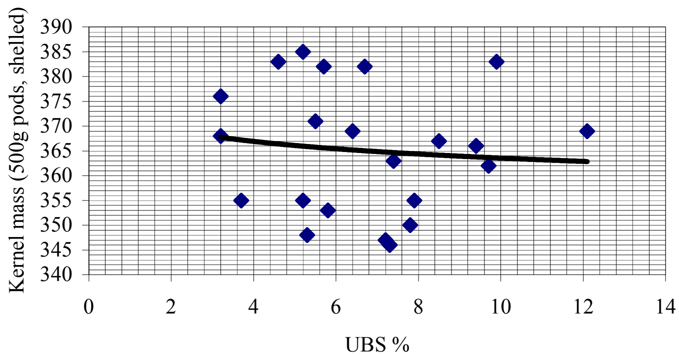

Figure 5.17 The relationship between the UBS% and the kernel mass (500g pods, shelled) of Elite short/medium growth season entries during 2004/05 at Brits (Trial 5.2a).

Kan Red (UBS of 29%) was not taken into consideration for the graph (Figure 5.17) as it was much higher than the UBS% of the other entries and would not reflect the true picture of the relationship between the UBS% and the kernel mass.

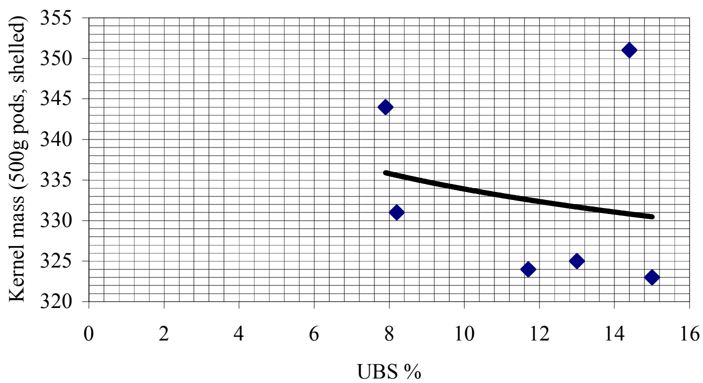

Figure 5.18 The relationship between the UBS% and the kernel mass (500g of shelled pods) of ICRISAT long growth season entries during 2004/05 at Brits (Trial 5.2c).

ICGV-SM-99847 (22%) was not taken into consideration in the graph (Figure 5.18) as it was considerably higher than that of the other entries and would not reflect the true picture of the relationship between the UBS% and the kernel mass.

Table 5.16 The analysis of variance on the average kernel yield (kg/ha) of Elite short/medium groundnut entries at Brits during 2004/05

E	Entries	Yield (kg/ha)	Rank
1	Akwa	3847.4	5
2	Anel	3896.6	4
3	Harts	2276.0	
4	ICGV-SM95714	2847.0	
5	Kan Red	2286.7	
6	Kano	1852.8	
7	Kwarts	3233.4	
8	Mwenje	2814.2	
9	Nyanda	2701.6	
10	PC280-K1	3991.9	1
11	PC280-K2	3372.3	9
12	PC280-K4	3929.3	3
13	PC280-K5	3951.9	2
14	PC299-K1	3394.7	8
15	PC299-K14	3029.2	
16	PC299-K17	3149.0	
17	PC299-K19	2891.5	
18	PC299-K2	3439.5	7
19	PC299-K5	2608.8	
20	PC327-K1	3368.1	10
21	PC327-K11	3333.1	11
22	PC327-K13	3222.6	
23	PC327-K2	3312.1	12
24	PC327-K31	3686.0	6
25	PC327-K7	3025.0	
	MS (blocks; df=3)	2601845	
	MS (treatments; df=24)	1316571	
	MS (error; df=72)	154541	
	F-Ratio (treatments)	8.52**	
	Trial mean	3178	
	CV %	12.37	
	LSD (5%)	555.95	
	LSD (1%)	739.42	
	SEM	196.6	
	GCV%	17	
	Intra-class correlation	0.6528	
	Standard error of t	0.0856	
	Repeatability%	88	

PC Potchefstroom cross
-K progeny of single plant selections
E entry
ICGV-SM ICRISAT entry
df degrees of freedom
MS mean squares
* and ** significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers (x^1,x^2,x^3 etc) did not differ significantly from the highest yield at the 5% and 1% level (per column)

CV% coefficient of variation (percentage)
SEM standard error of means
GCV% genetic coefficient of variation

Table 5.17 The analysis of variance on the average kernel yield (kg/ha) of Elite long growth groundnut entries at Brits during 2004/05

E	Entries	Yield (kg/ha)	Rank
4	PC294-K2	3251.8	1
1	Billy (control)	3094.5	2
10	PC323-K1	2981.3	3
12	PC324-K1	2437.2	
15	Rambo	2141.1	
11	PC325-K1	2130.1	
14	PC328-K1	2017.9	
13	PC325-K5	1912	
8	PC322-K7	1766.8	
2	ICGV-SM92760-K2	1729.8	
3	ICGV-SM92736-K2	1514	
7	PC322-K5	1343.1	
9	PC322-K8	1234.8	
6	PC297-K7	993.1	
5	PC297-K6	934.4	
	MS (blocks; df=3)	141542	
	MS (treatments; df=14)	2300276	
	MS (error; df=42)	178677	
	F-Ratio (treatments)	12.87**	
	Trial mean	1966	
	CV %	21.51	
	LSD (5%)	604.07	
	LSD (1%)	808.21	
	SEM	211.4	
	GCV%	37.1	
	Intra-class correlation	0.748	
	Standard error of t	0.0892	
	Repeatability%	92	

PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry
ICGV-SM	ICRISAT entry
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers (x^1,x^2,x^3 etc) did not differ significantly from the highest yield at the 5% and 1% level (per column)
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)

Table 5.18 The analysis of variance on the average kernel yield (kg/ha) of ICRISAT long growth groundnut entries at Brits during 2004/05

E	Entries	Yield (kg/ha)	Rank
1	Billy (control)	3647.6	1
6	ICGV-SM99841	2330.8	2
3	ICGV-SM90704	2286.4	3
2	CG7	2221.2	4
9	Rambo	2096	
7	ICGV-SM99844	2055.5	
5	ICGV-SM95740	1962	
4	ICGV-SM99821	1867.1	
8	ICGV-SM99847	736.3	
	MS (blocks; df=3)	190030	
	MS (treatments; df=8)	2527247	
	MS (error; df=24)	601368	
	F-Ratio (treatments)	4.2**	
	Trial mean	2134	
	CV%	36.35	
	LSD (5%)	1131.79	
	LSD (1%)	1533.73	
	SEM	387.7	
	GCV%	32.5	
	Intra-class correlation	0.4446	
	Standard error of t	0.1871	
	Repeatability%	76	

E	entry
ICGV-SM	ICRISAT entry
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers (x^1,x^2,x^3 etc) did not differ significantly from the highest yield at the 5% and 1% level (per column)
ns	not significant
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)

Elite short/medium growth season entries

The F ratios of the ANOVA tables (Table 5.12) on ELS, LLS and WB ratings did not indicate differences between Elite short/medium growth season entries but three entries (3, 5 and 8, $p<0.01$) differed highly significantly in rust resistance from the other 22 entries. From February to April the average humidity increased from 86.9% to 91.7%. From February to April $Tmax_H$ fluctuated between 30.8 and 35.8°C. These conditions resulted in rust infection (Table 5.5 and Figures 5.5 and 5.6). Savary (1986) reported that rust sporulates at a temperature >21°C and needs a high relative humidity.

Although entries 3 and 8 exhibited resistance to ELS, LLS, WB and rust, they gave a UBS of 34.3% and 12.1% respectively. Entry 3 gave 87.5% sundry and 12.5% crushing grades and 8 gave 73.3% standard, 16.3% sundry and 10.5% crushing grades. The performance of entry 3 can be explained, as it is a short growth season cultivar (120 days) and was harvested with the medium growth season genotypes at 150 days. The 30 extra days in the soil caused the blemished appearance of the kernels. Entry 8 was still a relatively unknown cultivar and may also be a short growth season genotype. Entry 5 had a UBS of 29.1% and gave 81.5% sundry grade kernels. Entry 6 had a UBS of 28.5% and gave 80.8% sundry and 19.25% crushing grade kernels. Entries 1, 2, 4, 9, 11, 12, 15, 16, 19, 20, 24 and 25 gave choice grade kernels (Table 5.15 and Appendix 6).

The F ratio of the ANOVA table (Table 5.16) on yield for the Elite short/medium growth season entries indicated that the yield of 15 entries differed highly significantly (entries 3, 5, 6, 8, 9, 15, 16, 17, 19, 20, 21, 22, 23, 24 and 25) ($p<0.01$) from the other entries in the trial. PC280-K1 (entry 10) gave the highest yield and the yield of entries 1, 2, 11, 12, 13 and 14 did not differ significantly from that of entry 10, but differed highly significantly from the rest of the 25 entries.

Four entries had a higher yield than Akwa (control). Entry 10 gave a 3.76% higher yield than Akwa. The three short growth season entries gave the lowest yields. Entry 6 (a short growth season entry) gave a 99% lower yield than Akwa. Entries with longer growth seasons have more time to produce and mature pods before the leaves die off.

Elite long growth season entries

The F ratios of the ANOVA tables (Table 5.13) on ELS, LLS and WB ratings on the Elite long growth season entries did not indicate significant differences between the entries. Although the CV's were high (37-38%), three entries (1, 4 and 15) exhibited higher rust resistance than the rest of the entries. Entries 4 and 15 gave choice and standard grade kernels (Table 5.15 and Appendix 6). During January $Tmax_H$ was 32.9°C and 65mm of rain fell. These conditions resulted in ELS infection. Venkataraman and Kazi (1979) reported that optimum temperatures of 25-31°C, high minimum (18-23°C) and maximum (31-35°C) temperatures and high humidity, as well as a late rainy season favour sporulation. $Tmin_A$ in March was 15.0 and in April 12.5°C. RHn_A in April was 35.6% and in March 30.0% (Table 5.5 and Figures 5.5 and 5.6). Overhead irrigation took place as the rainfall decreased. These cool humid conditions resulted in WB infection. Kokalis-Burelle *et al.* (1997) reported that the lower the temperature and the higher the humidity, the larger the WB conidia grow. Entries 2 and 3 were resistant to LLS and WB and 1 (control), 4 and 15 exhibited resistance to LLS, WB and rust. Twelve of the 15 entries had a UBS%≥13% and gave no choice grade kernels. Entries 4, 10 and 12 had a UBS%≤13 and gave 87.5%, 88.8% and 84.5% choice grade kernels respectively.

The F ratio of the ANOVA table (Table 5.17) on yield for the Elite long growth season entries indicated highly significant differences for yield among the entries. Entry 4 was the best and gave a 5.1% higher yield than Billy (control). Billy yielded almost three times higher than entry 5 that gave the lowest yield.

ICRISAT long growth season entries

Although the F ratios of the ANOVA tables (Table 5.14) on ELS, LLS, WB and rust ratings did not indicate significant differences between the entries, entries 3 and 5 showed some resistance to rust. Entry 3 and 7 (Table 5.15 and Appendix 6) gave choice grade kernels and exhibited some resistance to ELS, LLS and WB while entry 7 also exhibited resistance to rust. Entries 1, 4 (UBS≤13%) and 5, 6 and 9 (UBS between 13 and 50%) gave standard grade kernels and exhibited some resistance to ELS, LLS and WB. Entry 5 also exhibited resistance to rust.

Although the CV of the F ratio of the ANOVA table on yield for the ICRISAT long growth season entries (Table 5.18) was high (36.35%), highly significant differences were indicated for four (5, 7, 8 and 9) ($p<0.01$) of the nine entries. Billy (control) yielded almost four times higher than entry 8 (gave the lowest yield in the trial). Entries 1 (highest yield), 6, 3 and 2 did not differ significantly in yield from each other but differed highly significantly from the rest of the entries.

RESULTS AND DISCUSSION

Replicated randomised Elite trials (Trials 5.3a and b) planted at Vaalharts (fungicides used for the control of ELS, LLS, WB, and rust)

Grading results on kernels at Vaalharts [Trials 5.3a (short/medium) and b (long) growth season entries]

Grading results for Elite short/medium growth season entries at Vaalharts are presented in Appendix 8. The results of the ANOVA tables on yield are presented in Tables 5.20 (Elite short/medium growth season) and 5.21 (Elite long growth season). The relationship between UBS% and quality is presented in Figure 5.19 and the relationship between UBS% and kernel mass in Figure 5.20.

Table 5.19 A summary of the choice, standard, sundry and crushing grade groundnut kernels of the Elite short/medium and Elite long growth season groundnut entries at Vaalharts during 2004/05 (Appendix 8)

UBS Growth season	Grades	≤13%	13 – 50%
Elite short/medium	Choice entries	1, 2, 4-24	
	Standard entries		
	Sundry entries	1, 2, 4-25	3
	Crushing entries	1, 2, 4-25	3
Elite long	Choice entries	1-3, 6, 7, 9-14	
	Standard entries		4, 5, 8, 15
	Sundry entries	1-3, 6, 7, 9-14	4, 5, 8, 15
	Crushing entries	1-3, 6, 7, 9-14	4, 5, 8, 15

UBS unsound, blemished and soiled

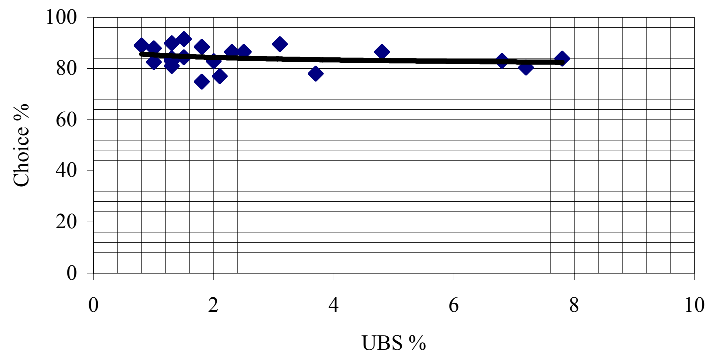

Figure 5.19 The relationship between the UBS% and the % choice grade kernels of Elite short/medium growth season groundnut entries during 2004/05 at Vaalharts (Trial 5.3a).

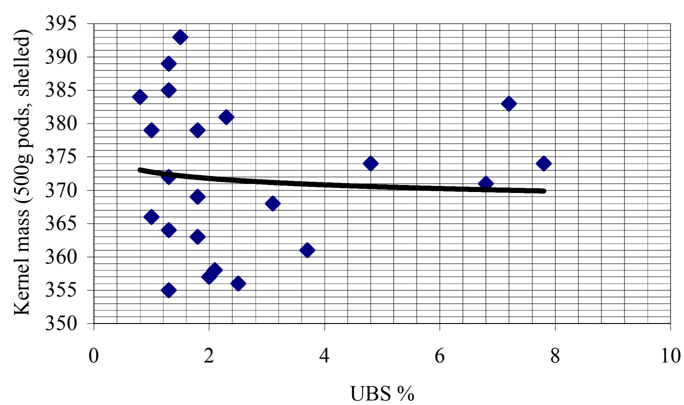

Figure 5.20 UBS% effect on kernel mass (500g pods, shelled) of Elite short/medium growth season entries during 2004/05 at Vaalharts (Trial 5.3a).

Table 5.20 The analysis of variance on the average kernel yield (kg/ha) of Elite medium growth season groundnut entries at Vaalharts during 2004/05

E	Entries	Yield (kg/ha)	Rank
4	Anel	4458.3	1
13	PC280-K1	4258.3	2
12	PC327-K31	4250.0	3
14	PC280-K2	4197.9	4
23	ICGV-SM-95714	4025.0	5
15	PC280-K4	4002.1	6
11	PC327-K13	3981.3	7
1	Akwa	3972.9	8
10	PC327-K11	3941.7	9
26	PC280-K5	3922.9	10
21	PC299-K17	3914.6	11
8	PC327-K2	3847.9	12
9	PC327-K7	3777.1	13
20	PC299-K14	3758.3	14
17	PC299-K1	3716.7	15
6	Kano	3693.8	16
22	PC299-K19	3627.1	
7	PC327-K1	3508.3	
19	PC299-K5	3414.6	
5	Kan Red	3350.0	
18	PC299-K2	3337.5	
25	Mwenje	3243.8	
2	Kwarts	3110.4	
24	Nyanda	3037.5	
3	Harts	2810.4	
	MS (blocks; df=3)	1467619	
	MS (treatments; df=24)	716434	
	MS (error; df=72))	167851	
	F-Ratio (treatments)	4.27**	
	Trial mean	3726	
	CV%	10.99	
	LSD (5%)	579.4	
	LSD (1%)	770.6	
	SEM	204.8	
	GCV%	9.9	
	Intra-class correlation	0.4497	
	Standard error of t	0.1077	
	Repeatability%	77	

PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry
ICGV-SM	ICRISAT entry
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers (x^1,x^2,x^3 etc) did not differ significantly from the highest yield at the 5% and 1% level (per column)
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)

Table 5.21 The analysis of variance on average yield (kg/ha) of Elite long growth season groundnut entries at Vaalharts during 2004/05

E	Entries	Yield (kg/ha)	Rank
10	PC324-K1	5841.7	1
1	Billy	5027.1	2
7	PC322-K7	4864.6	
9	PC323-K1	4604.2	
6	PC322-K5	4556.3	
13	PC328-K1	4460.4	
11	PC325-K1	4254.2	
15	ICGV-SM-92760-K2	4168.8	
5	PC297-K7	4050.0	
14	ICGV-SM-92736-K2	4033.3	
3	PC294-K2	4018.8	
2	Rambo	3731.3	
4	PC297-K6	3716.7	
12	PC325-K5	3689.5	
8	PC322-K8	3541.7	
	MS (blocks; df=3)	434278	
	MS (treatments; df=14)	1615824	
	MS (error; df=42))	239056	
	F-Ratio (treatments)	6.76**	
	Trial mean	4304	
	CV%	11.36	
	LSD (5%)	698.72	
	LSD (1%)	934.85	
	SEM	244.5	
	GCV%	13.6	
	Intra-class correlation	0.5901	
	Standard error of t	0.1239	
	Repeatability%	85	

PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry
ICGV-SM	ICRISAT entry
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * (p<0.05) and ** (p<0.01). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers (x^1,x^2,x^3 etc) did not differ significantly from the highest yield at the 5% and 1% level (per column)
na	not applicable
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)

The UBS% of Harts (24.4%) was not included in the calculations as it was abnormally high. This was due to the fact that, although it is has a short growing season, it could only be harvested 20 days after the due harvest date, with the medium growth season entries. The extra 20 days in the soil (and the plant already defoliated), resulted in blemished kernel testas resulting in high UBS readings.

Elite short/medium growth season

Twenty-four of the 25 Elite short/medium growth entries (Appendix 8) had an UBS≤13% and gave choice grade kernels. Entry 3 (Harts) with an UBS of 24.4% gave 95.8% sundry grade kernels.

The F ratio in the ANOVA table on average kernel yield for the Elite short/medium growth season entries (Table 5.20) indicated highly significant differences for 16 of the 25 entries. These entries gave much higher yields than the other nine entries in the trial. Seven entries (4, 11, 12, 13, 14, 15 and 23) gave a higher yield than Akwa (control). Anel (entry 2) performed 12.2% better than Akwa. Akwa gave a 31.1% higher yield than Nyanda (entry 9).

Elite long growth season entries

Eleven of the 15 entries had an UBS≤13% and gave choice grade kernels (Appendix 8). Four entries with UBS of 13-50% gave standard grade kernels.

There were no significant differences between the Elite long growth season entries but the F ratio in the ANOVA table on kernel yield (Table 5.21) indicated highly significant differences for 13 ($p<0.01$) of the 15 entries. PC324-K1 (entry 10) was the best performer and gave a 16% higher yield than Billy (control). Billy yielded 42% higher than PC322-K8 (entry 8). Entries 10 and 1 gave much higher yields than the rest of the 15 entries.

CONCLUSIONS

On the replicated trials at Brits [Trials 5.2a (Elite short), b (Elite long) and c (ICRISAT long)] and Vaalharts [Trials 5.3a (Elite short/medium) and b (Elite long)]
Although the trials with and without fungicide applications were planted on two different localities, certain interesting observations were made.

The GCV's for ELS, LLS, WB and rust on the Elite short/medium and long growth season entries as well as for the ICRISAT long growth season entries were small (12-28%) and gave an indication of little genetic variation between the entries for resistance to the foliar diseases. Many of the entries are also closely related (see chapter 4: Elite short/medium trial at Brits) and there could have been too few entries in the ICRISAT (long) trial.

The results, however, showed that the UBS% influences the quality of the kernels (Table 5.15 and 5.19) and that climatic factors affect the severity of infection by the foliar diseases, which in turn, affect the UBS% of the kernels. With an increase in the UBS% of an entry, the sundry and crushing grade kernels increased. A low UBS% generally gave a higher percentage choice and standard grade kernels (Figure 5.19). Entries that exhibited resistance to ELS, LLS, WB and rust generally also exhibited a lower UBS% and gave better quality kernels. A correlation existed between the kernel mass (500g of pods, shelled) and the UBS% (Figures 5.17, 5.18 and 5.20). The kernel mass came down steadily as the UBS% increased. These results are in accordance with results noted by Swanevelder and Blamey (1981). So, the UBS% increased as the resistance to ELS, LLS, WB and rust decreased and the grades of the kernels decreased as the UBS% increased.

The GCV for yield potential of 9.9% was very low for the Elite medium growth season entries indicating that little genetic variation is available to select for higher yield among the restricted genetic base of the entries. An example of closely related entries is the single plant selections of PC280-K1, -K2, -K4 and -K5 (entries 10, 11, 12 and 13) in the F_3 generation. The GCV's (37.19% and 32.5%) for the Elite and ICRISAT long growth season entries indicated that genetic variation existed between the entries for the trait "yield", but if yield is to be increased, new additions with the potential for a higher yield, will have to be made to the germplasm.

Twenty-four of the 25 short/medium Elite entries gave choice grade kernels at Vaalharts (sprayed), while 20 entries gave choice grade kernels for the same trial at Brits (unsprayed).

Eleven of the 15 Elite long growth entries at Vaalharts (sprayed) gave choice grade kernels while only three entries, namely 4, 10 and 12, gave choice grade kernels at Brits (unsprayed) and Vaalharts.

In the Elite short/medium growth season Akwa (control) gave a 3.3% higher yield at Vaalharts where fungicides were applied, than at Brits (no fungicides used for the control of leaf diseases). Medium growth season entries that performed better at Vaalharts than at Brits were Anel (14.4% better), PC280-K1 (6.7% better) and PC280-K4 (1.9% better) (Table 5.20 and 5.16). All these entries performed better than Akwa at both Vaalharts and Brits. PC322-K8 (long growth entry 8) gave the lowest yield at Vaalharts (3 541.7kg/ha), but performed better than the best entry (PC294-K2: 3 251.8kg/ha) at Brits (Table 5.21 and 5.17). These results indicated that ELS, LLS, WB and rust have a negative influence on the grades as well as the yield, even although some of the entries showed resistance to these diseases. These results are in accordance with results obtained by Swanevelder and Blamey (1981).

New additions from foreign sources will have to be made to the germplasm. These additions will not be closely related to the commercial cultivars in SA and will provide essential genetic variation as to resistance to ELS, LLS, WB and rust. Entries with foliar disease resistance, good quality kernels and a high yield will be incorporated in the breeding programme with the purpose of improving commercial cultivars and to develop breeding lines with traits such as a high oleic acid percentage combined with foliar disease resistance and a high yield.

CANONICAL VARIATE ANALYSIS

A Canonical Variate Analysis (CVA) was done on a) the 49 entries in the replicated trials (Table 5.1; Trials 5.1a, b and c) at Potchefstroom, Vaalharts, Brits, Cedara and Burgershall and b) the replicated Elite trials at Brits (Trial 5.2a, b and c) for ELS, LLS, WB and rust ratings and yield.

RESULTS AND DISCUSSION

a) Replicated trials planted at Potchefstroom, Vaalharts, Brits, Cedara and Burgershall (Trials 5.1a, b and c)

The codes (Co) for the 49 entries used in the Canonical Variate Analysis are shown in Table 5.22.

The first, second and third disease ratings for each locality, indicated ELS1 to 3, LLS1 to 3, WB1 to 3 and rust1 to 3, as well as yield, were used as variates. The Canonical Variate Analysis (CVA) will be used to discuss the groups that these 49 entries clustered into, at each locality.

Table 5.22 Codes (Co) for the 49 groundnut entries used in the Canonical Variate Analysis planted at five localities during 2004/05

Co	Entries	Co	Entries	Co	Entries	Co	Entries
73	73-30(RG453)	S3	ICGV-SM-99543	Ka	Kano	R0	RRline10
76	73-30(RG716)	S2	ICGV-SM-99821	KR	Kan Red	R1	RRline11
83	86-87/175(RG783)	S8	ICGV-SM-99841	K5	Kwarts	R2	RRline12
84	86-87/175(RG784)	S4	ICGV-SM-99844	51	PC254-K1	R3	RRline3
Ak	Akwa	I1	ICGV 90071	82	PC280-K2	R7	RRline7
Bi	Billy	I7	ICGV 90087	27	PC287	R8	RRline8
C2	CG7=ICGMS42	I6	ICGV 90096	22	PC297-K2	R9	RRline9
Ha	Harts	I9	ICGV 90099	91	PC299-K1	SA	Streeton
C7	ICGMS42=CG7	I0	ICGV90197	99	PC299-K19	SW	Swallow
S1	ICGV-SM-93541	I2	ICGV 95342	95	PC299-K5	T1	TMV1
S5	ICGV-SM-95714	I3	ICGV 95343	21	PC324-K1		
S7	ICGV-SM-95741	I5	ICGV 95350	31	PC327-K1		
S9	ICGV-SM-99529	JL	JL24	Ra	Rambo		

PC Potchefstroom cross; ICGV-SM ICRISAT entry

-K progeny of single plant selections

E entry; RG germplasm number

The mean CVA scores for a) the five localities are illustrated in Figures 5.21-5.25 and for b) the Elite trials at Brits in Figures 5.26-5.28 without drawing in the circles. Examples where circles are drawn in are presented in Figure 5.21b and 5.27b.

Circles are 95% confidence regions (Payne, 2003). Without the circles it is easier to see the center of the circles where the name of the entry is typed. At the top (in the middle) and on the right (on the 0.0 line that can be drawn in) of the presentation in the figure, the variates influencing the position of the group as to resistance to diseases and yield are given. The figure can be divided in quarters on the x and y axes on the 0.0 lines. The arrows indicating right, left, up and down, indicate the direction in which, for example, yield will be potentially high or low. If a group containing an entry falls for example, in the first quarter, the arrows can be followed and an idea formed as to the foliar disease resistance and yield potential in kg/ha of the entry and also of new entries on which disease ratings and yield calculations, but not a CVA, have been done. The group is named after the first entry from which characteristics it originated.

Potchefstroom

Five of the 13 variates used in the correlation matrix namely LLS2, LLS3, WB2, WB3 and yield, contributed significantly to the grouping of the 49 entries (Figure 5.21a). Figures 5.21a and b represent the a) presentation of the mean CVA scores of the 49 entries without completing the circles and b) completing the circles.

a) Presentation of the mean CVA scores on the 49 entries at Potchefstroom without the completed circles

high◄-0.840WB3►low

high◄-0.779LLS3►low

high◄-0.622WB2►low

high◄-0.605LLS2►low

low◄+0.182yield►high

```
         3.0 I
C            I                            KR
a            I             27
n            I
o            I                     KaR8    R1        I2
n            I
i        1.5 I            Ha                    I7
c            I                   R0     76           I5 Bi
a            I                         T1     S2
l            I                                 SA          I0 S8
             I                                 S7          Ra          low
v            I                                             C7            ↑
a        0.0 I   Kw            73   S1    JL              83I3      -0.949yield
r            I                                  R9                         ↓
I            I                   31                                      high
a            I                         R3                           S4
t            I        95             51   I1          Sw
e            I                  S9     S3     S5     I9   R2
        -1.5 I          Ak
2            I         91  8299              21
             I                                            84 I6
             I
             I                                          22
             I
        -3.0 I
             -+--------+--------+--------+--------+--------+--------+--
           -3.6      -2.4      -1.2       0.0       1.2       2.4       3.6

                              Canonical variate 1
```

Figure 5.21a Mean CVA scores of 49 entries at Potchefstroom during 2004/05.

This two-dimensional representation of the data accounted for nearly 79% of the total variation in the data.

b) Presentation (Figure 5.21b) of the mean CVA scores on the 49 entries at Potchefstroom with the circles drawn in.

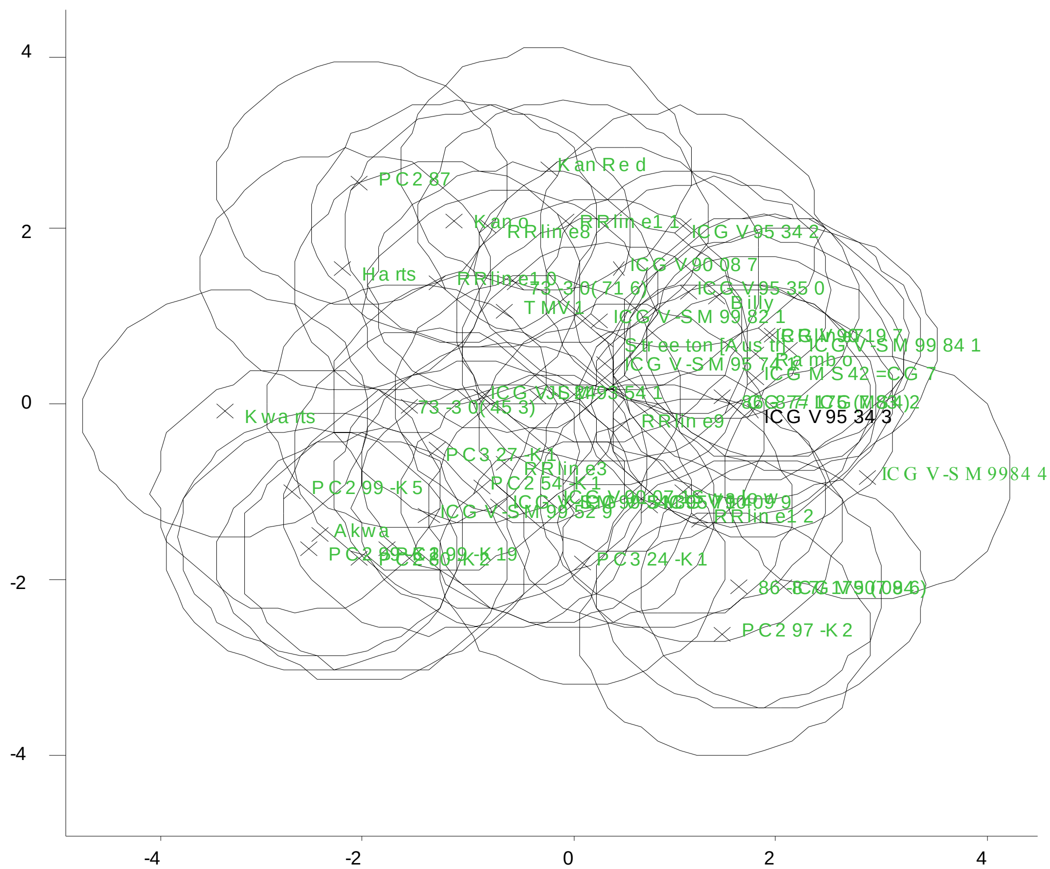

Figure 5.21b Mean CVA scores of 49 entries at Potchefstroom during 2004/05.

Entry 3 [86-87/175 (RG784)] and the PC324-K1 (entry 26) groups did not differ significantly from each other. The 86-87/175 (RG784) (entry 3) and the PC280-K2 (entry 20) groups did not differ significantly from the Akwa group, but the PC324-K1 group did. The 86-87/175 (RG784) (entry 3) group exhibited average yield potential and average resistance to LLS and WB, whereas the Akwa and PC280-K2 group exhibited susceptibility to LLS and WB and had a low yield potential. The PC287 (entry 21) and RRline8 (entry 32) groups did not differ significantly from each other but did differ from the Akwa group. The PC287 (entry 21) and RRline8 (entry 32) groups exhibited resistance to LLS and WB and had good yield potential.

Vaalharts

In the correlation matrix 13 variates were used and three variates, WB2, WB3 and yield, contributed significantly to the separation of the 49 entries into groups (Figure 5.22).

high◄-0.967yield►low

high◄-0.301WB3►low

low◄+0.113WB2►high

```
         3.0 I
             I
             I
             I
             I
             I
         1.5 I     C7               R3 I9
C            I         C2                           T1
a            I                 Bi       I2  I6                  I0
n            I                             R0  S3        R1
o            I       R2            S7 83       SA 84I5  S9            low
n            I                                 S2JL      Ka            ↑
i        0.0 I                       S8          R7   I1SwI7 22    -0.908WB3
c            I                        Ra             S5                ↓
a            I   R8                                                   high
l            I        73      76   Kw               S1             KR
             I                      95                      Ha
v            I                             91     Ak
a       -1.5 I              S4                      82
r            I                              21                 99
i            I
a            I
t            I
e            I
        -3.0 I
2            I
             I
             I
             I        27
             I
        -4.5 I
             -+--------+--------+--------+--------+--------+--------+--
           -3.6      -2.4      -1.2       0.0       1.2       2.4       3.6

                              Canonical variate 1
```

Figure 5.22 Mean CVA scores of 49 entries at Vaalharts during 2004/05.

This two-dimensional representation of the data accounted for nearly 87% of the total variation in the data.

The RRline8 and PC287 groups differed significantly from each other and from the Akwa, PC280-K2, PC324-K1 and 86-87/175 (RG784) groups. The last four groups did not differ significantly from each other and exhibited low yield and resistance to WB potential. The RRline8 (entry 32) and PC287 (entry 21) groups exhibited tolerance to WB and a high yield potential.

Brits

In the correlation matrix nine variates were used and three variates, rust1, rust 2 and yield, contributed significantly to the separation of the 49 entries into groups (Figure 5.23).

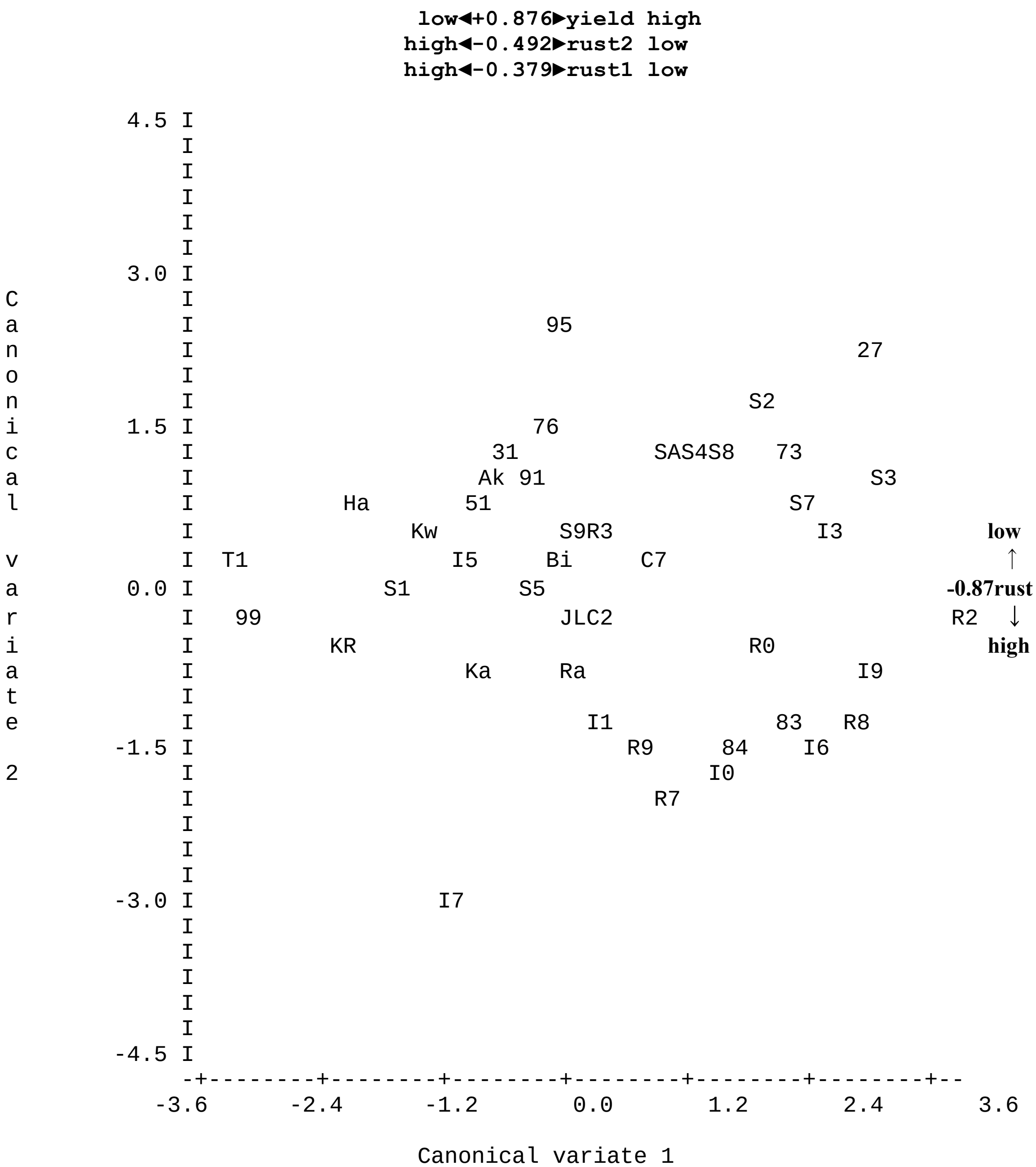

Figure 5.23 Mean CVA scores of 49 entries at Brits during 2004/05.

This two-dimensional representation of the data accounted for nearly 94% of the total variation in the data.

The PC280-K2 (entry 20) and PC287 (entry 21) groups did not differ significantly from each other, but differed significantly from the Akwa group. The Akwa group showed susceptibility to rust and a low yield potential while the PC280-K2 (entry 20) and PC287 (entry 21) groups expressed resistance to rust and a high yield potential. The RRline8 (entry 32) and 86-87/175 (RG784) (entry 3) groups did not differ significantly from each other, had good yield and rust resistance potential and differed significantly from the Akwa group. The PC280-K2 and PC287 groups and the RRline8 and 86-87/175 (RG784) groups also differed significantly from each other. The PC324-K1 group did not differ significantly from the Akwa group, was susceptible to rust and had a low yield potential.

Cedara

In the correlation matrix 13 variates were used and five variates, ELS1, ELS2, ELS3, rust3 and yield, contributed significantly to the separation of the 49 entries into groups (Figure 5.24).

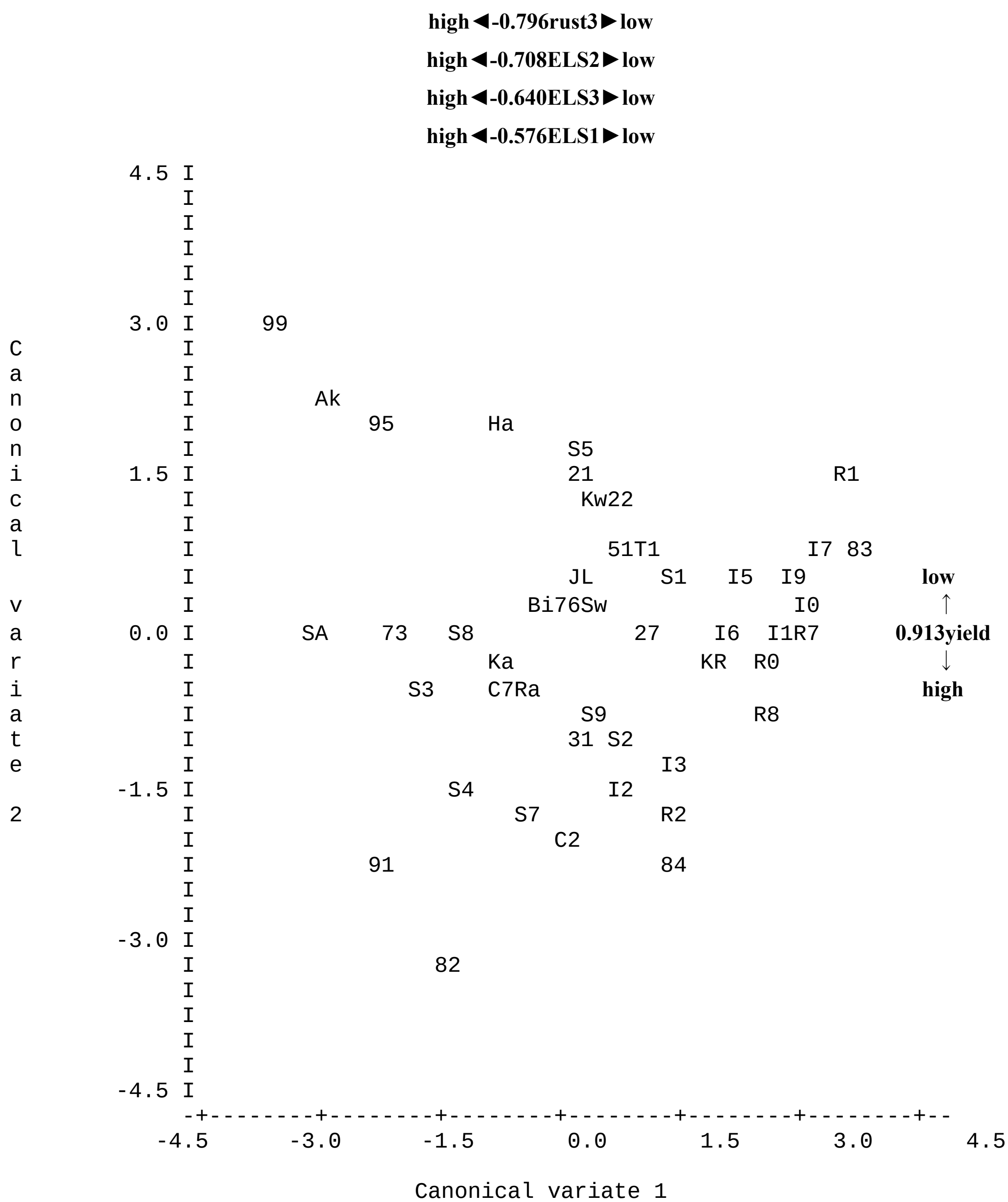

Figure 5.24 Mean CVA scores of 49 entries at Cedara during 2004/05.

This two-dimensional representation of the data accounted for nearly 78% of the total variation in the data.

The RRline8, 86-87/175 (RG784) and PC287 (entries 32, 3 and 21 respectively) groups did not differ significantly from each other, had good yield, rust and ELS resistance potential and differed significantly from the Akwa group. The PC280-K2 (entry 20) group differed significantly from the Akwa group, although both groups were susceptible to rust and ELS. PC280-K2 exhibited a better yield potential than Akwa under the specific climatical conditions at Cedara. The PC324-K1 group did not differ significantly from the Akwa group and both groups were susceptible to ELS and rust and exhibited a low yield potential.

Burgershall

In the correlation matrix 13 variates were used and six variates, LLS1, LLS2, LLS3, rust2, rust3 and yield, contributed significantly to the separation of the 49 entries into groups (Figure 5.25).

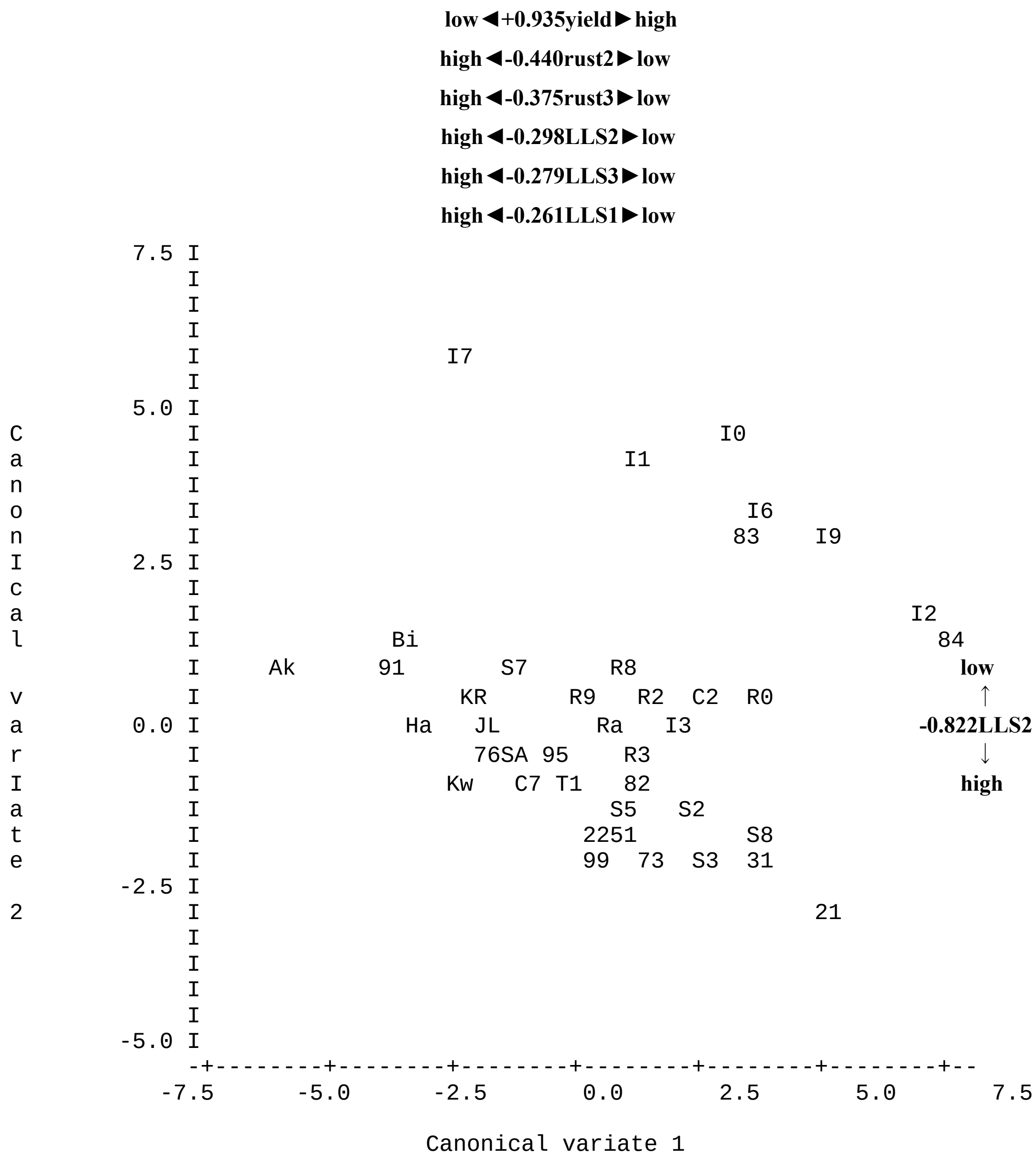

Figure 5.25 Mean CVA scores of 49 entries at Burgershall during 2004/05.

This two-dimensional representation of the data accounted for nearly 89% of the total variation in the data.

PC324-K1, PC280-K2 and PC287 groups did not differ significantly from each other but differed significantly from the Akwa group. All the groups were susceptible to LLS and rust and exhibited a low yield potential. The RRline8 (entry 32) group differed significantly from the Akwa group, exhibited average resistance to LLS and rust and exhibited average yield potential under the specific climatical conditions at Burgershall.

A summary of the CVA performance (the 49 entries were placed in groups according to their characteristics in terms of diseases resistance and yield) of five entries that exhibited the best yield potential at the five localities during 2004/05 is presented in Table 5.23.

Table 5.23 CVA performance of five entries that exhibited the best yield potential at the five localities during 2004/05

Entries	Potchefstroom	Vaalharts	Brits	Cedara	Burgershall
86-87/175 (RG784)	□□□	□	□□□	□□□	□□□
PC324-K1	□□□	□□	□	□	□□□
PC280-K2	□	□	□□□	□	□□□
PC287	□	□□□	□□□	□□	□□
RRline8	□	□	□□□	□□□	□□
Akwa (control)	□	□	□	□	□

□□□ good yield potential

□□ average yield potential

□ low yield potential

PC280-K2 and PC287 were selected from crosses with PC137 (Harts x Sellie) and have an almost similar genetic base. They differed only in that PC280 had 73-73 (from Senegal) and PC287 Swallow (from Zimbabwe) as a parent as well. Throughout the five localities (Potchefstroom was an exception) the groups into which they sorted did not differ much from each other, indicating that characteristics as to their yield and resistance to foliar diseases, were similar. Akwa and Kwarts were also selected from PC137 with the result that their groups throughout the five localities did not differ from each other. PC280-K2 and PC287 were different from RRline8 (from Puerto Rico) and RG784 (from ICRISAT) at all five localities. Their genetic sources are different. It is interesting that the characteristics of PC324-K1, derived from a cross between MarcI (from the USA) and US 40-1 (from the USA) did not differ much from Akwa except at Burgershall, although they sorted into different groups. RR784 has genetic variation as to yield that enabled it to give high yield at all five localities, despite the climatic factors that influenced the infection by the foliar diseases and the effect this had on yield. PC324-K1, PC280-K2, PC287 and RRline8 all gave high yields under the different climatic conditions and differed from Akwa (control). A good yield potential under different climatic conditions is a good trait for any entry (Table 5.23).

b) Replicated randomised Elite and ICRISAT trials at Brits (no applications of fungicides for control of ELS, LLS, WB and rust) (Trials 5.2a, b and c)

Elite short/medium growth season entries at Brits

In Table 5.24 the 25 Elite short/medium growth season entries used in the Canonical Variate Analysis (CVA) can be identified by their codes.

In the correlation matrix nine variates were used and three variates, WB2, rust2 and yield, contributed significantly to the separation of the 25 entries into groups (Figure 5.26).

Table 5.24 Twenty-five Elite short/medium growth season groundnut entries planted at Brits during 2004/05, with codes (Co) used in the Canonical Variate Analysis (CVA)

Co	Entries	Co	Entries	Co	Entries
Ak	Akwa	81	PC280-K1	95	PC299-K5
An	Anel	82	PC280-K2	21	PC327-K1
Ha	Harts	84	PC280-K4	31	PC327-K11
I5	ICGV-SM-95714	85	PC280-K5	33	PC327-K13
Ka	Kano	91	PC299-K1	32	PC327-K2
KR	Kan Red	94	PC299K14	27	PC327-K31
Kw	Kwarts	97	PC299K17	37	PC327-K7
Mw	Mwenje	99	PC299-K19		
Ny	Nyanda	92	PC299-K2		

PC Potchefstroom cross
-K progeny of single plant selections
E entry
ICGV-SM ICRISAT entry

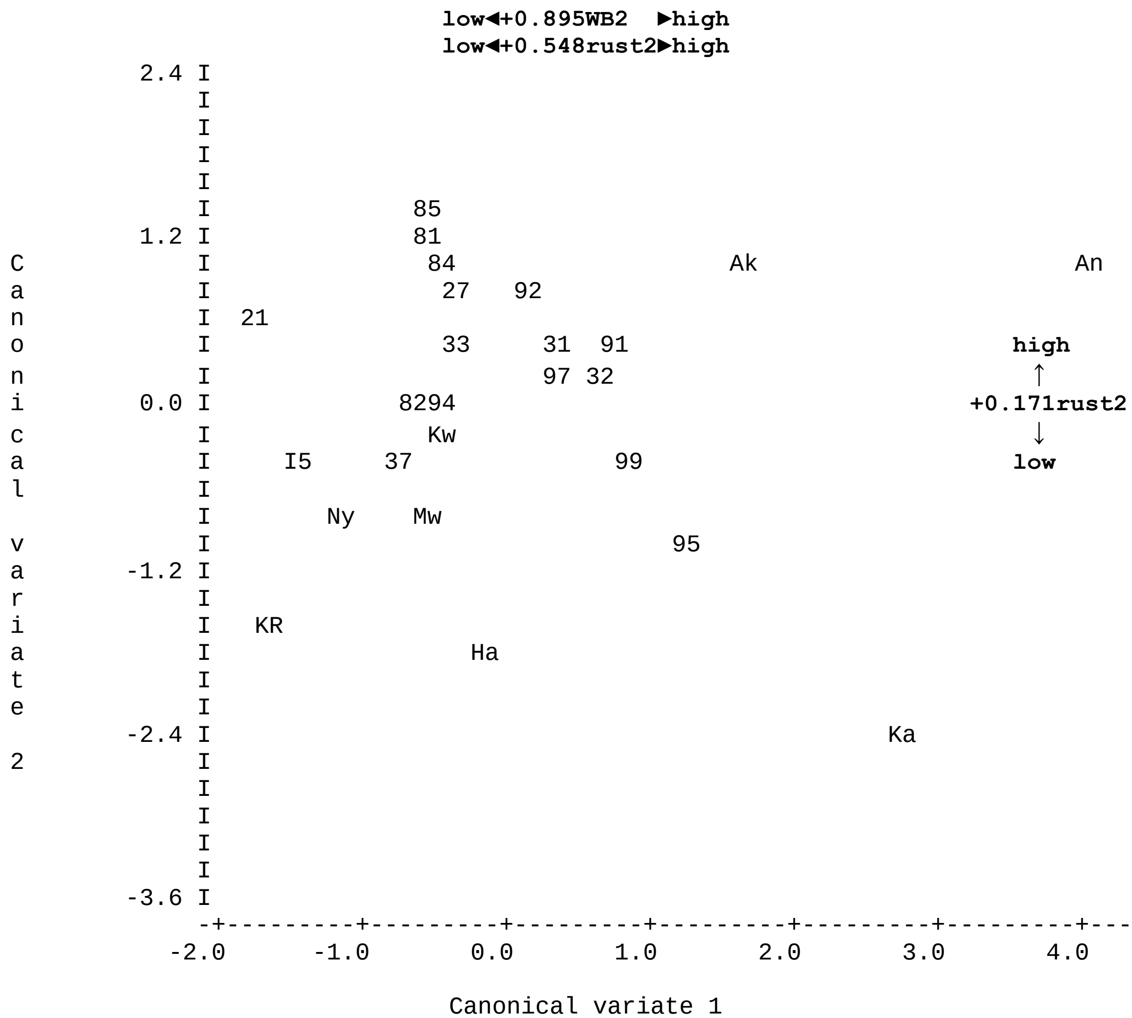

Figure 5.26 Mean CVA scores of 25 Elite short/medium growth season groundnut entries at Brits during 2004/05.

This two-dimensional representation of the data accounted for nearly 91% of the total variation in the data.

Many PC (Potchefstroom crosses) entries had the same parent(s) and these groups did not differ significantly from the Akwa group (Akwa is also a PC cross, developed into a cultivar). Akwa was developed from Harts x Sellie and Sellie from Natal Common x Namark. The last two entries came from a totally different gene pool than Harts (Van der Merwe, 1981). ICGV-SM-95714 (entry 4), Kano (6), Kan Red (5), Mwenje (8) and Nyanda (9) groups differed significantly from the Akwa (entry 1) group. These entries came from different gene pools than Akwa. The PC299-K14 (UF85 x PC137-K30) group differed significantly from Akwa.

PC280-K1, PC280-K4, PC280-K5, PC327-K1, PC327-K7 and PC327-K13 (entries 10, 12, 13, 20, 25 and 22 respectively) groups exhibited high resistance to WB and rust, but an average to low yield potential that did not agree with the results of the ANOVA on kernel mass (500g pods, shelled) that showed that PC280-K1 was the best entry. The CVA indicated that the PC299-K5 group should give a high yield and be susceptible to WB, but the ANOVA on the kernel mass (500g pods, shelled) showed a lower than average yield and high susceptibility to WB. Between this CVA and the ANOVA on the Elite short/medium growth season entries there are thus contradictions. It can be noted that PC299-K5 gave a yield of 3414kg/ha at Vaalharts where fungicides were used to control foliar diseases compared to 2608kg/ha at Brits where no fungicides were used. The entries in question should be re-evaluated in further trials.

PC280-K1, PC280-K4, PC280-K5, PC327-K1, PC327-K7 and PC327-K13 (entries 10, 12, 13, 20, 25 and 22 respectively) showed some similar traits. It is possibly because they shared parents such as Akwa and Jasper (derived from a cross between Harts and Sellie). The PC280 and the PC327 selections differed as they had 73-73 (from Senegal) and UF 85 (a high O/L ratio cultivar from the USA) respectively in their parentage.

Elite long growth season entries at Brits

In Table 5.25 the 15 Elite long growth season entries used in the Canonical Variate Analysis (CVA) can be identified by their codes.

In the correlation matrix nine variates were used and four variates, LLS2, WB2, rust2 and yield, contributed significantly to the separation of the 15 entries into groups (Figure 5.27).

Table 5.25 Fifteen Elite long growth season groundnut entries planted at Brits during 2004/05, with codes (Co) used in the Canonical Variate Analysis (CVA)

Co	Entries	Co	Entries	Co	Entries
BI	Billy	P7	PC297-K7	P4	PC324-K1
I3	ICGV-SM-92736	P5	PC322-K5	P0	PC325-K1
I6	ICGV-SM-92760	P3	PC322-K7	P9	PC325-K5
P2	PC294-K2	P8	PC322-K1	K1	PC328-K1
P6	PC297-K6	P1	PC323-K1	Ra	Rambo

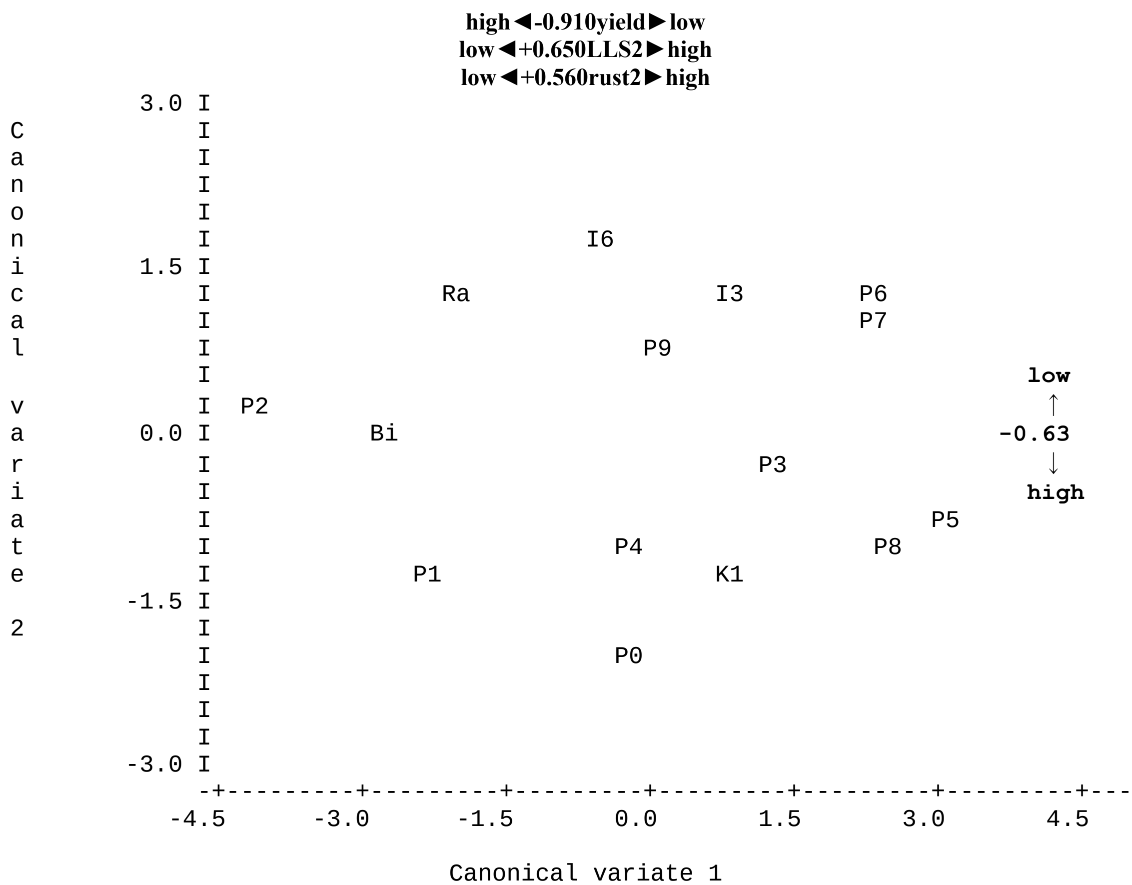

Figure 5.27 Mean CVA scores of 15 Elite long growth season groundnut entries at Brits during 2004/05.

This two-dimensional representation of the data accounted for nearly 97% of the total variation in the data.

The PC294-K2 (entry 4) and Rambo (entry 15) groups did not differ significantly from the Billy (entry 1) group (control). These groups exhibited resistance to LLS and rust and gave good yields. The PC323-K1 (entry 10) group also did not differ significantly from the Billy group, but exhibited resistance to LLS, rust and WB and gave a good yield. The PC322-K5 and K8 (entries 7 and 9) groups differed significantly from the Billy (entry 1) group, were susceptible to WB, LLS and rust and gave a lower yield. The PC297-K6 and K7 groups differed significantly from the Billy group, but not from the PC322-K5 and K8 groups. The PC297-K6 and K7 groups exhibited WB resistance but were susceptible to LLS and rust and had a low yield potential.

Although PC294-K2 (entry 4) and PC297-K6 and K7 shared X1303 (from USA) in their parentage, they differed significantly from each other. The other parents (UF 40-1 from the USA and Selmani from Zimbabwe) contributed other traits to their genetic bases. Billy and PC294-K2 shared UF 40-1 in their parentage and the genetic contribution of this parent was strong enough to influence certain traits that they shared such as high yield.

ICRISAT long growth season entries at Brits

In Table 5.26 the nine ICRISAT long growth season entries used in the Canonical Variate Analysis (CVA) can be identified by their codes.

In the correlation matrix nine variates were used and four variates, LLS2, WB2, rust2 and yield, contributed significantly to the separation of the nine entries into groups (Figure 5.28).

Table 5.26 Nine ICRISAT long growth season entries planted at Brits during 2004/05, with codes (Co) used in the Canonical Variate Analysis (CVA)

Co	Entries	Co	Entries	Co	Entries
BI	Billy	I0	ICGV-SM-99840	I4	ICGV-SM-99844
CV	CG	I2	ICGV-SM-99821	I7	ICGV-SM-99847
I9	ICGV-SM-90704	I1	ICGV-SM-99841	Ra	Rambo

E entry

ICGV-SM ICRISAT entry

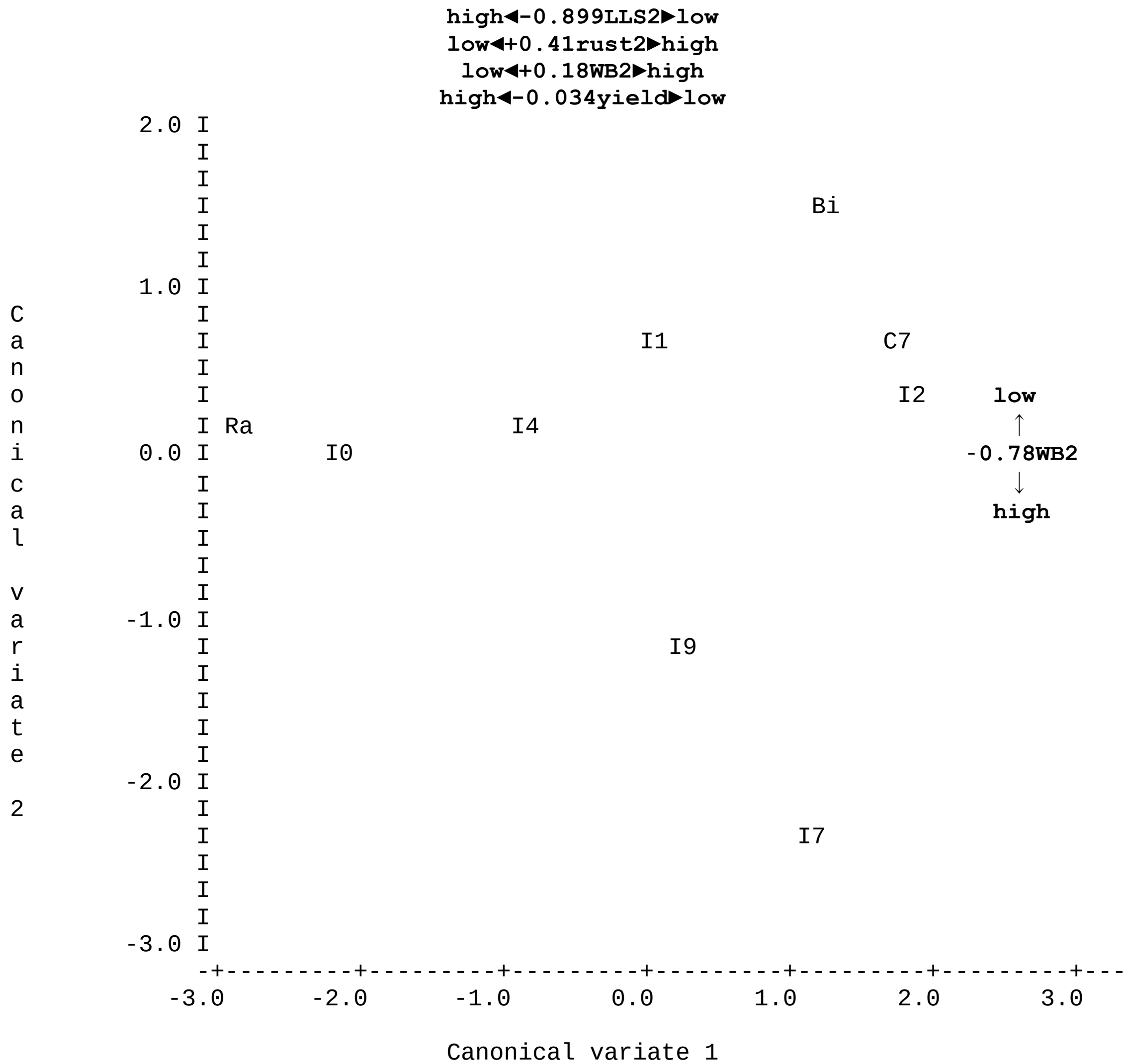

Figure 5.28 Mean CVA scores for nine ICRISAT long growth season groundnut entries at Brits during 2004/05.

This two-dimensional representation of the data accounted for nearly 89% of the total variation in the data.

The F ratio in the ANOVA table on yield showed that Billy's (entry 1) (control) (from the USA) yield was almost four times that of ICGV-SM-99847 (from ICRISAT Malawi). The gene sources of these two entries differed significantly as to resistance to foliar diseases and yield potential. The CVA showed that the ICGV-SM-99847 group differed significantly from the Billy group and exhibited no resistance to WB and rust while the

Billy group exhibited resistance to LLS and WB. The ICGV-SM-99841, ICGV-SM-99821 and CG7 groups did not differ significantly from the Billy group or from each other, but differed significantly from the ICGV-SM-99847 (entry 8), Rambo (entry 9) and ICGV-SM-99840 (entry 5) groups. The last two groups exhibited resistance to rust and WB and had a good yield potential.

CONCLUSIONS ON CVA RESULTS

Five entries [86-87/175 (RG784), PC324-K1, PC280-K2, PC287 and RRline8] with the best yield at the five localities are presented in the summary in Table 5.23. Although every entry reacted to the specific climatic conditions at each of the five localities where no fungicides were applied, it is noteworthy that the Akwa group (control) exhibited low resistance to ELS, LLS, WB and rust and a low yield at all five localities. The entry 3 [86-87/175 (RG784)] group exhibited a high yield potential at four of the five localities Table 5.23). The PC287 (entry 21) group exhibited a high yield at Vaalharts, although no extreme climatical conditions were recorded (Figures 5.3 and 5.4 and Table 5.4). Four of the entry groups exhibited high yield potential at Brits where the disease pressure was average and three groups exhibited high yield potential at Burgershall where the disease pressure was high as has been explained under the effect of climatic conditions on infection rates of ELS, LLS, WB and rust previously in the chapter.

The entries that performed well will be incorporated in the breeding programme. Commercial cultivars and breeding lines will be crossed with these entries with the purpose of transferring the foliar disease resistance and improve the ability of the commercial cultivars and breeding lines to accommodate climatic factors and still give high yields.

The Billy group in the ICRISAT long growth season trial at Brits differed significantly from the Rambo (entry 9) group, while these groups did not differ significantly from each other in the Elite long growth season trial at Brits.

The parentage of entries is important. If the parents, used in crosses, are known and characterised in groups by the CVA, a prediction could be made as to traits that should be present in the progenies.

The results of the CVA mean scores plotted in the graphs will be used when new germplasm entries are evaluated. The new entry will be planted in a replicated randomised trial and rated for resistance to ELS, LLS, WB and rust. The grading results will be used to calculate the potential yield of the entry. The CVA graph done on entries at the specific locality where the new entry is evaluated will then be used to place the new entry into a specific group. For example, if a long growth entry is tested in the Elite trials at Brits the results of the new entry will be incorporated in the following formula with results obtained from the CVA of the Elite long growth season entries (Figure 5.27b) of 2004/05:

1. $(x \text{ and } y)_{\text{new entry}} = (LV_{LLS2}CVA_{\text{longBrits}})(\text{LLS2 rating}_{\text{new entry}}) + (LV_{WB2}CVA_{\text{long Brits}})(\text{WB2 rating}_{\text{new entry}}) + (LV_{\text{rust2}}CVA_{\text{long Brits}})(\text{rust rating}_{\text{new entry}}) + (LV_{\text{yield}}CVA_{\text{longBrits}})(\text{yield}_{\text{new entry}})$ + adjustment term 1

The four variates that contributed the most to separate the 15 entries into groups during 2004/05 were the second ratings on LLS, WB and rust (LLS2, WB2, rust2) and the calculated yield (kg/ha).

2. Latent vectors (LV) in $CVA_{\text{longBrits}}$ on disease ratings and yield results during 2004/05

	x	y
	1	2
1 (LLS2)	+0.4929	-0.8035
2 (WB2)	+0.2335	-0.7244
3 (rust2)	+0.3607	+0.1968
4 (yield)	-0.0014	-0.0007

$x_{new\ entry}$ =(0.4929LLS2 + 0.2335WB2 + 0.3607rust2 -0.0014yield) + (0.475)

≈ -2 (hypothetically)

$y_{new\ entry}$ =(-0.8035LLS2 + -0.7244WB2 + 0.1968rust – 0.0007yield + 0.42

≈ -1 (hypothetically)

LV	latent vectors
LLS	late leaf spot
WB	web blotch

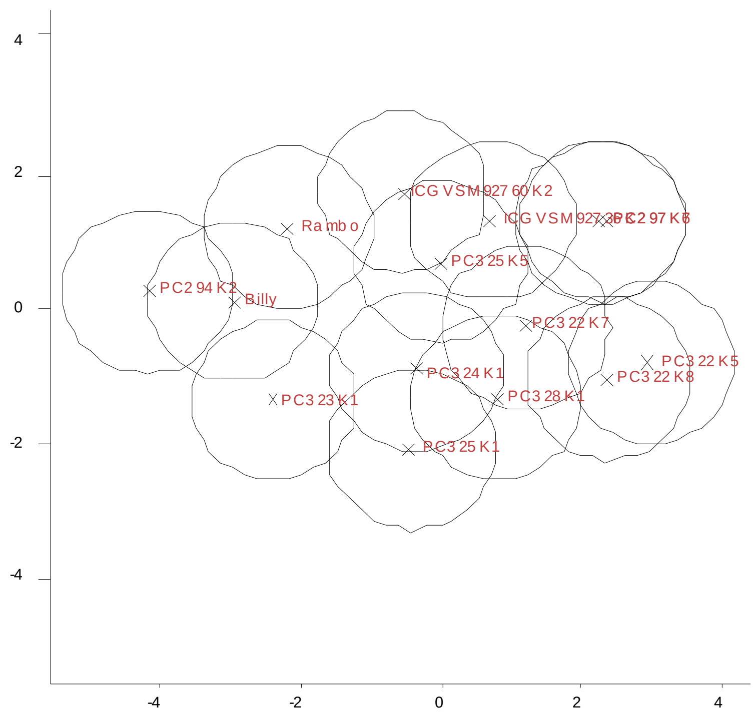

Figure 5.27b Mean CVA scores of 15 Elite long growth season groundnut entries at Brits during 2004/05 indicating a hypothetical new only.

The new entry will therefore (hypothetically), fall in the PC327-K1 group (Figure 27b) when tested in the Elite long growth season trials at Brits. It should have a high potential yield and resistance to LLS and rust, but exhibit susceptibility to WB. This procedure will save valuable research resources.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

In this study the germplasm collection of the Grain Crops Institute at Potchefstroom has been characterised and can therefore be better utilised in future. However, bringing in divergent germplasm from foreign sources should increase genetic diversity. These entries could provide the breeding programme with specific genes needed to improve traits such as the resistance of our commercial cultivated groundnut cultivars to foliar diseases and to improve and increase groundnut production in general in South Africa and in other Southern African Development Community (SADC) countries.

According to the results of this study, commercial production of groundnut in the high altitude production regions of South Africa appears not to be severely affected by rust (caused by *Puccinia arachidis*), but in the regions such as Kwazulu-Natal Province where subsistence farmers plant groundnuts, rust is a problem. In the rest of Africa fungal foliar diseases such as early leaf spot (ELS) (caused by *Cercospora arachidicola),* late leaf spot (LLS) (caused by *Cercosporidium personatum*), web blotch (WB) (caused by *Phoma arachidicola)* and rust are destructive diseases. Foliar diseases weaken the leaves and defoliation takes place. Fungicides controlled infection by foliar diseases resulting in less defoliation. The result was higher quality kernels and higher yields.

The results of this study will be used as a guideline in the improvement of resistance to foliar diseases of local high-yielding commercial cultivars. Although some of the entries such as 86-87/175 (RG784), PC324-K1, PC280-K2, PC287 and RRline8 in this study yielded higher than local cultivars, they cannot be used as the industry demands other qualities that they do not posses. SA Juweel (PC299-K5) has recently been released to fulfil the demand for a high oleic acid content cultivar in SA. A high oleic acid content improves the shelf life of groundnut products. However, SA Juweel is susceptible to foliar diseases. SA Juweel and other commercial cultivars could be improved by conventional breeding for disease resistance, which can be achieved by backcrossing resistance from entries such as 73-30, 86-87/175, ICGV 90096, ICGV 95342 and ICGV-SM 99543 that showed resistance to ELS, LLS, WB and rust in this study.

The results from unsprayed trials (2003 to 2005) planted at five localities in SA, namely Potchefstroom (North West Province; Highveld), Burgershall (Mpumalanga Province), Brits (North West Province), Vaalharts (Northern Cape Province) and Cedara (Kwazulu Natal Province), indicated that there are 14 short/medium and 10 long growth season germplasm entries with resistance to three or four of the leaf diseases (ELS, LLS, WB and rust). These entries, which include 86-87/175 (RG784), PC324-K1, PC280-K2, PC287 and RRline8 also gave good yields and choice grade kernels (derived from the grading procedure).

Overall it can be suggested that, for both commercial and subsistence farmers, medium growth season (±150 days) groundnut cultivars can be planted in relatively dry climates with high summer temperatures. Localities with hot humid climates conducive to foliar diseases will need fungicidal applications to ensure good quality kernels. Even in localities with hot dry climates fungicides will improve kernel quality and yield. In SA, farmers prefer the short/medium growth season cultivars (±150 days from planting to harvesting) as they do not have the costly equipment to plant and harvest the larger and especially the longer kernels produced by the long growth season cultivars (±180 days). However, this type is generally high yielding. In wet humid climates farmers can plant short growth cultivars such as Harts as soon as the night temperatures stay above 15°C. Early planting sometimes makes it possible for the plants to escape rust as this fungi usually appears late in the season when the temperatures are starting to decline (20-25°C).

No evidence could be found that cytoplasmic factors are responsible for inheritance of resistance to ELS, LLS, and WB, testa colour and mutations such as the one responsible for the cup leaf phenotypes.

The application of the M*lu*I/*Mse*I AFLP restriction enzyme combination used by Herselman (2003) to distinguish between closely related groundnut genotypes may facilitate more efficient detection of polymorphisms in both wild and cultivated groundnut genotypes and will be indispensable in any breeding programme. Research to find genetic markers linked to genes responsible for resistance to any foliar disease is essential. Progenies can then be tested at an early stage for identification of these genes and valuable research time saved.

A high yield is important as a selection criterion but other characteristics such as resistance to foliar diseases should also be considered. Commercial farmers use fungicides to control foliar diseases to ensure good yields and quality kernels while subsistent farmers do not have the financial means to do so. In future it is suggested that high potential yield and resistance to important foliar diseases such as ELS, LLS, WB and rust be combined. Other destructive diseases such as black pod rot (caused by *Chalara elegans*) should also be considered and an acceptable level of resistance to the peanut pod nematode (*Ditylenchus africanus*) is important. Peanut pod nematode and leaf diseases adversely affect quality of kernels, which results in a lower price per ton of groundnuts. Fungicides can be useful in the control of ELS, LLS, WB, and rust, but costs involved in the price of the chemicals, labour in the implementation of the spraying program, the maintenance of the equipment and protective clothing necessary for the spraying should be considered. Resistant and partially resistant cultivars will favour both the subsistence and the commercial farmers.

SUMMARY

Early leaf spot (ELS) caused by *Cercospora arachidicola*, late leaf spot (LLS) caused by *Cercosporidium personatum*, web blotch (WB) caused by *Phoma arachidicola* and rust caused by *Puccinia arachidis*, are serious diseases of groundnut in South Africa. The aims of this study were to evaluate ARC-GCI germplasm for resistance to the important foliar diseases such as ELS, LLS, WB, and rust and to ascertain if cytoplasmic factors influence the pattern of inheritance of resistance to ELS, LLS, and WB, testa colour and mutations such as the one responsible for cupleaf phenotypes.

Twenty-one reciprocal crosses were made to study the cytoplasmic factors but the F_1 progenies gave no evidence of cytoplasmic factors directly responsible for any of the above-mentioned traits.

During 2003/04, 138 ARC-GCI germplasm entries were evaluated for resistance to ELS, LLS, WB and rust at Potchefstroom (North West Province; Highveld), Burgershall (Mpumalanga Province), Brits (North West Province), Vaalharts (Northern Cape Province) and Cedara (Kwazulu Natal Province). No fungicides were used to control the foliar diseases. In trials at Vaalharts, Cedara, and Burgershall entries 1, 10-13, 18-21, 23, 30, 52 and 56-58 were resistant to two of the three (LLS, WB, and rust) foliar diseases and entries 18, 19 and 20 (best) to LLS, WB and rust. At Brits, Elite (E) and ICRISAT (I) short/medium growth entries 8I and 7E, were resistant to LLS and WB and the long growth entries 1E and 3E were resistant to WB, LLS and rust. In micro-plots at Potchefstroom entries 6, 9, 10 and 13-15 were resistant to LLS and WB and in the brick plots 1-3, 6 and 7 to ELS and LLS.

Entries with resistance to ELS, LLS, WB, and rust as well as other favourable traits, such as a high yield and oleic acid percentage, from the 2003/04 trials were included in the 2004/05 trials for further assessment. All the entries were evaluated for resistance to ELS, LLS, WB and rust, were graded and grouped by using the Canonical Variate Analysis (CVA). From the results on the five locality trials (2004/05) medium growth entries 1, 3, 7, 10, 14, 15, 20-22, 26, 27, 30, 32 and 33 were resistant to three or four of the foliar diseases, gave good yields and choice grade kernels. The CVA identified separate groups, containing entries 3, 20, 21 and 32, with resistance to two or more foliar diseases and with high yield. No choice grade entries were reported for unsound blemished and soiled (UBS) kernels with an UBS>13%.

In the Elite short/medium trials at Brits (2004/05) entries 3 and 8 were resistant to rust, 1, 2, 4, 7, 11-13, 15, 17, 19-22, 24 and 25 gave choice grade kernels, and 10, 13 and 12 the highest yield. Entries 1-6, and 8-15 (Elite long) were resistant to LLS, 1-15 to WB, and 1, 4 and 15 to rust, 4, 10 and 12 gave choice grade kernels and 4, 1 and 10 the highest yields. ICRISAT (long) entries 5 and 7 gave choice grade kernels, and 1, 6 and 3 the highest yields. The CVA identified the groups containing medium growth entries 10, 12, 13, 22 and 23, Elite long 1, 4, 10 and 15 and ICRISAT long 5, 8 and 9 as groups with resistance to two or more foliar diseases (ELS, LLS, WB, and rust) and good yield. Twenty-three medium and 11 long growth entries in the Elite trials at Vaalharts (an extra trial planted where fungicides were used to control foliar diseases) gave choice grade kernels and good yields.

In this study, some ARC-GCI germplasm entries were resistant to ELS, LLS, WB, and rust, but climatic factors influenced the severity of infection. Foliar diseases lowered the quality and grade of the kernels and resulted in lower yields. CVA simplifies the evaluation and grouping of new germplasm entries and will save valuable research resources.

Keywords

Arachis hypogaea; groundnut; germplasm; early leaf spot; late leaf spot; web blotch; rust; climate; grading; resistance; inheritance; South Africa

OPSOMMING

Vroeë blaarvlek, (VBV), veroorsaak deur *Cercospora arachidicola*, laat blaarvlek (LBV) deur *Cercosporidium personatum,* spatselvlek (*Phoma*) deur *Phoma arachidicola* en roes deur *Puccinia arachidis,* is ernstige grondboonsiektes in Suid Afrika. Die doelwitte van hierdie studie was om LNR-IGG kiemplasma vir weerstand teen VBV, LBV, *Phoma* en roes te evalueer en om vas te stel of sitoplasmiese faktore betrokke is by die oorerwing van weerstand, saadhuid kleur en mutasies, soos die een wat die "cup leaf" fenotipe veroorsaak.

Tydens hierdie studie is 21 resiproke kruise gemaak om die sitoplasmiese faktore te bestudeer. Geen bewyse dat sitoplasmiese faktore direk verantwoordelik is vir enige van die bogemelde eienskappe is in die F_1 nageslagte gevind nie.

Gedurende 2003/04 is 138 LNR-IGG kiemplasma inskrywings vir weerstand teen VBV, LBV, *Phoma* en roes by Potchefstroom (Noordwes Provinsie, Hoëveld), Burgershall (Mpumalanga Provinsie), Brits (Noordwes Provinsie), Vaalharts (Noord Kaap Provinsie) and Cedara (Kwazulu Natal Provinsie) in SA geëvalueer. Geen swamdoders is gebruik om die blaarsiektes te beheer nie. In proewe by Vaalharts, Cedara en Burgershall het inskrywings 1, 10-13, 18-21, 23, 30, 52 en 56-58 weerstand teen twee van die drie (LBV, *Phoma*, en roes) blaarsiektes en 18, 19 en 20 (beste) teen LBV, *Phoma* en roes getoon. By Brits was die Elite (E) en ICRISAT (I) kort/medium groeiseisoen inskrywings 8I en 7E, die mees weerstandbiedend teen LBV en *Phoma* en die lang groeiers 1E en 3E, teen *Phoma*, LBV en roes. Inskrywings 6, 9, 10 en 13-15 het weerstand teen LBV en *Phoma* in mikroplot proewe en in steenplot proewe het die inskrywings 1-3, 6 en 7 weerstand teen VBV en LBV getoon.

Die beste inskrywings met betrekking tot weerstand teen VBV, LBV, *Phoma* en roes, goeie opbrengs en 'n hoë oleiensuur persentasie uit die 2003/04 proewe was in die 2004/05 proewe ingesluit vir verdere evaluasie. Al die inskrywings is vir weerstand

teen die blaarsiektes geëvalueer, gegradeer en die Liniêre Diskriminant Analise (LDA) is op hulle gedoen. Resultate op die vyf lokaliteite het getoon dat kort/medium groeiseisoen inskrywings 1, 3, 7, 10, 14, 15, 20-22, 26, 27, 30, 32 en 33, weerstand teen drie van die vier blaarsiektes (VBV, LBV, *Phoma* en roes) getoon het en goeie opbrengs en keurgraad pitte gelewer het. Met behulp van die LDA is afsonderlike groepe met goeie weerstand teen twee of meer van die blaarsiektes, asook ‘n goeie opbrengs, waarin inskrywings 3, 20, 21 en 32 geval het, geïdentifiseer. Geen keurgraad inskrywings is vir siek, gevlek en vuilgesmeerde pitte (SGV)>13% gerapporteer nie.

In die Elite kort/medium proewe op Brits was inskrywings 3 en 8 weerstandbiedend teen roes. Inskrywings 1, 2, 4, 7, 11-13, 15, 17, 19-22, 24 en 25 het keurgraad pitte en 10, 13 en 12 die hoogste opbrengste gelewer. Inskrywings 1-6 en 8-15 (Elite lank) het weerstand getoon teen LBV, 1-15 teen *Phoma* en 1, 4, en 15 teen roes. Inskrywings 4, 10, en 12 het keurgraad pitte gelewer en 4, 1 en 10 die hoogste opbrengste. ICRISAT (lank) inskrywings 5 en 7 het keurgraad pitte gelewer en 1, 6 en 3 die beste opbrengste. LDA het afsonderlike groepe met medium groeier inskrywings 10, 12, 13, 22, and 23, Elite lank 1, 4, 10, en 15 en ICRISAT lank 5, 8, and 9 met goeie weerstand teen twee of meer van die blaarsiektes en ‘n goeie opbrengs, geïdentifiseer. Drie en twintig medium en 11 lang groeiers in die Elite proewe by Vaalharts (‘n ekstra proef waarin swamdoders gespuit is) het keurgraad pitte en goeie opbrengste gelewer.

Tydens die studie was sommige LNR-IGG kiemplasma inskrywings weerstandbiedend teen VBV, LBV, *Phoma* en roes, maar klimaatsfaktore het die graad van infeksies beïnvloed. Blaarsiektes verlaag dan ook die kwaliteit van die pitte en die opbrengs. LDA sal evaluasie en plasing van nuwe kiemplasma inskrywings vergemaklik en vir die navorser tyd en geld bespaar.

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APPENDIX 1

Table 1 International Modified 9-Point Field Scale for rating late leaf spot (Table 1b), rust (Table 1d) (Subrahmanyam *et al.*, 1995) and early leaf spot (Table 1a) (Subrahmanyam *et al.*, 1992). A constructed 9-Point Field Scale for rating web blotch (Table 1c)

1b late leaf spot / 1d rust

Late leaf spot Description	Score	Infection %	Score	Rust Description
No disease	1	0	1	No disease
Few, small necrotic spots on older leaves.	2	1-5	2	Few, small necrotic spots on older leaves
Small spots, mainly on older leaves, disease evident.	3	6-10	3	Few pustules, mainly on older leaves, some ruptured, poor sporulation.
Many spots, mostly on lower and middle leaves, disease evident.	4	11-20	4	Pustules small or large, mostly on lower and middle leaves, disease evident.
Spots easily seen on lower and middle leaves, moderately sporulating on lower leaves.	5	21-30	5	Many pustules, mostly on lower and middles leaves, yellowing and necrosis of some lower and middle leaves, moderately sporulating.
As rating 5 but spots heavily sporulating.	6	31-40	6	As rating 5 but pustules heavily sporulating.
Spots present all over the plant; defoliation of lower and middle leaves	7	41-60	7	Pustules all over plant; lower and middle leaves withering.
As rating 7 but defoliation is more severe	8	61-80	8	As rating 7 but withering is more severe.
Plants severely affected, 50-100% defoliation	9	81-100	9	Plants severely affected, 50-100% leaves withering.

1c web blotch / 1a early leaf spot

Web blotch	Score	Infection %	Score	Early leaf spot
No disease.	1	0	1	No disease.
Lesions on some leaflets, no defoliation.	2	1-5	2	Lesions present largely on older leaves; no defoliation.
Many lesions on some and few on other leaves, defoliation of some leaflets.	3	6-10	3	Lesions present largely on older leaves; few lesions on middle leaves; defoliation of some leaflets.
Lesions severe on infected leaves, defoliation of some leaflets.	4	11-20	4	Lesions present on older and middle leaves; defoliation of some lower leaves.
Lesions severe on infected leaves, plant starts getting a dead leaf appearance.	5	21-30	5	Lesions are present on all older and middle leaves; over 50% defoliation of older leaves.
Lesions severe and present on top leaves, defoliation and dead leaves evident all over the plant.	6	31-40	6	Lesions severe on older and middle leaves; lesions present on top leaves but less severe; 30-40% defoliation of infected leaves.
Lesions present on all leaves; defoliation and dead leaves evident all over plant.	7	41-60	7	Lesions present on all leaves, less severe on top leaves; 41-60% defoliation.
Lesions severe on all leaves with some defoliation on 3/5 of plant stem, shows dead leaves.	8	61-80	8	Defoliation of all older and middle leaves; lesions severe on top leaves and 61-80% defoliation evident.
Few leaves present, lesions will be present on all of them.	9	81-100	9	Defoliation of almost all leaves leaving bare stems.

APPENDIX 2

Table 2 Average climatic data over 10 years (1996-2005) for Potchefstroom, Vaalharts, Brits, Cedara, and Burgershall (only months involved during planting season taken into account: October, November, December, January, February, March and April)

Localities	Potchefstroom	Vaalharts	Brits	Cedara	Burgershall
Latitude	26.7361 (S)(25-30°)	27.95 (S)(25-30°)	25.5833 (S)(25-30°)	29.5333 (S)(25-30°)	25.1094 (S)(25-30°)
Longitude	27.0757 (E)(25-30°)	24.8333 (E)(25-30°)	27.7667(E)(25-30°)	30.2833 (E)(30-35°)	31.0838 (E)(30-35°)
Altitude (m)	1347	1175	1107	1076	754
Average min. rainfall (mm)	0 - 188	0 – 16.1	0 – 50.8	1.1 – 70.7	0 – 146.5
Average min. RHn (%)	18.5 – 40.6	14.2 – 25.9	21.2 – 28.8	27.6 – 48.9	32.3 – 62.1
Average min. RHx (%)	67.4 – 94.6	72.9 – 89.5	65.4 – 72.2	86.0 – 92.0	81.7 – 98.0
Average min. Tmax (°C)	19.7 – 30.3	19.8 – 30.6	21.0 – 27.9	18.6 – 23.9	22.4 – 29.5
Average min. Tmin (°C)	2.3 – 17.3	2.0 – 14.0	4.1 – 16.7	6.0 – 14.3	10.9 – 19.6
pH	5.4	5.1	5.3	5.4	5.4
soil	clayish	sandy	sandy	loamy to sandy	clayish

Rain	mm/day	Rainfall
RHn	%	Minimum daily relative humidity
RHx	%	Maximum daily relative humidity
Tmax	°C	Daily maximum temperature
Tmin	°C	Daily minimum temperature

APPENDIX 3

Table 3.1 The analysis of variance on the average early leaf spot (ELS), late leaf spot (LLS), web blotch (WB) and rust ratings on short growth season groundnut entries (Trial 5.1a) at five localities (Potchefstroom, Vaalharts, Brits, Cedara and Burgershall) during 2004/05

		Brits				Burgershall			Cedara				Potchefstroom			Vaalharts		
E	Entries	ELS(ns)	LLS(ns)	WB(ns)	rust(ns)	ELS(ns)	LLS(ns)	rust(ns)	ELS(ns)	LLS(ns)	WB(ns)	rust(ns)	ELS(ns)	LLS(ns)	WB(ns)	ELS(ns)	LLS(ns)	WB(ns)
1	Harts	1.8	1.5	na	4.4	1.7	5.8	7.2	4.8	3.9	3.2	3.1	2.7	1.9	2.6	4.2	1.4	1.9
2	Kan Red	2.3	2.3		3.5	1.3	7.2	5.2	2.4	2.2	2.6	1.4	2.1	1.7	1.7	2.7	1.0	2.0
3	Kano	2.0	1.3		2.8	2.4	7.1	5.7	3.8	4.6	1.4	2.3	2.9	1.8	2.7	2.9	1.2	1.2
	MS (blocks; df=2)	0.22	0.28		0.26	3.15	0.9	2.6	7.96	3.12	3.6	2.41	1.11	1.18	0.62	13.54	7.6	4.19
	MS (treatments; df=2)	0.44	1.89		6.03	4.24	3.64	6.87	10.6	9.46	5.1	5.48	1.11	0.37	2.46	4.74	0.9	1.26
	MS (error; df=4))	0.31	0.23		4.81	2.76	1.99	6.05	1.96	6.34	1.041.046	4.294.36	1.05	0.12	0.4	1.51	0.19	0.35
	F-ratio (treatments)	2.25ns	7.25ns		1.21ns	1.48ns	1.84ns	1.38ns	5.15ns	1.52ns	4.78ns	1.49ns	1.08ns	2.66ns	9.16ns	3.44ns	1.2ns	3.52ns
	Trail mean	2.05	1.72		3.64	1.81	5.58	6.02	3.55	3.57	2.39	2.29	2.55	1.77	2.31	3.26	1.22	1.70
	CV %	25.88	28.63		53.00	80.31	32.00	37.84	40.33	70.82	43.67	76.85	40.72	21.71	27.91	56.93	21.26	32.36
	LSD (5%)	na	na		na	na	na	na	na	na	na	na	na	na	na	na	na	na
	LSD (1%)	na	na		na	na	na	na	na	na	na	na	na	na	na	na	na	na
	SEM	0.3	0.3		1.15	0.86	0.8	1.3	0.8	1.4	0.6	1.1	0.5	0.2	0.36	0.66	0.166	0.33
	GCV%	12.25	41.15		14.25	32.8	17.95	11.5	48.26	22.7	47.2	26.2	6.63	15.0	23.32	31.33	20.3	28.53
	Intra-class correlation	0.2500	0.6735		0.0666	0.1596	0.2178	0.1174	0.5563	0.3794	0.5407	0.1337	0.0833	0.3333	0.5352	0.3931	0.2851	0.4050
	Std error of t	0.4082	0.3122		0.4316	0.4421	0.4576	0.4363	0.3752	0.4326	0.3829	0.3136	0.4252	0.4422	0.2758	0.4202	1.2237	0.4188
	Repeatability%	38	86		18	32	45	25	78	25	77	29	17	58	61	63	44	65

	no WB at Burgershall, no rust at Potchefstroom and Vaalharts
RR	rust resistant germplasm entries
	resistance shaded in grey
PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry
ICGV-SM	ICRISAT entry
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)
ns	not significant
na	not applicable
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)
ELS	early leaf spot
LLS	late leaf spot
WB	web blotch
x^1, x^2, x^3	ranks: (first, second and third)

Table 3.2 The analysis of variance on the average early leaf spot (ELS), late leaf spot (LLS), web blotch (WB) and rust ratings on medium growth season groundnut entries (Trial 5.1b) at five localities (Potchefstroom, Vaalharts, Brits, Cedara and Burgershall) during 2004/05

E	Entries	Brits				Burgershall			Cedara				Potchefstroom			Vaalharts		
		ELS(ns)	LLS	WB(ns)	rust	ELS(ns)	LLS	Rust	ELS	LLS	WB	Rust	ELS	LLS	WB	ELS	LLS	WB
1	73-30 (RG453)	2.5	1.9	2.0	3.7	2.6	6.2	6.8	3.6[16]	5.4	2.7[12]	2.7[15]	2.5	1.6[5]	2.5	3.5	1.3[4]	1.9
2	73-30 (RG716)	2.7	2.3	1.7	3.8	1.6	7.0	6.8	6.8	4.8	1.0[1]	2.1[10]	2.9	1.6[5]	2.7	3.5	1.6	1.8
3	86-87/175 (RG784)	1.7	1.5	1.3	1.2	1.7	2.9[4]	1.3[1]	1.7[4]	2.3[5]	1.6[5]	1.0[1]	1.6[3]	1.4[4]	1.1[2]	4.7	1.1[2]	1.4[5]
4	86-87/175 (RG783)	2.0	1.2	2.1	1.2	1.3	3.0[5]	4.3	1.4[1]	1.8[3]	2.1[9]	1.0[1]	1.8[5]	1.0[1]	2.1	3.8	1.0[1]	1.0[1]
5	Akwa	2.5	1.5	2.5	4.2	2.7	6.7	6.9	6.2	5.8	1.7[6]	3.4	3.6	2.2	2.8	6.1	1.3[4]	2.1
6	ICGV 90071	2.0	1.2	1.6	1.7	1.8	2.6[3]	2.3[2]	1.6[3]	1.8[3]	2.6[11]	1.0[1]	1.3[1]	1.3[3]	2.6	4.8	1.1[2]	1.3[4]
7	ICGV 90096	2.2	1.8	1.5	1.0[1]	1.9	2.4[2]	2.4[3]	1.96	1.7[2]	3.1	1.4[4]	1.7[4]	1.6[5]	1.0[1]	3.8	1.1[2]	1.2[3]
8	ICGV 90099	1.7	1.0[1]	1.2	1.3	1.6	2.9[4]	1.3[1]	2.2[8]	1.8[3]	2.9[13]	1.1[2]	1.8[5]	1.3[3]	1.7	3.4	1.2[3]	1.0[1]
9	ICGV 90197	1.5	1.3	1.2	1.0[1]	1.8	1.9[1]	1.3[1]	1.4[1]	1.6[1]	2.6[11]	1.2[3]	2.1[8]	1.1[2]	1.4[4]	3.3[5]	1.3[4]	1.0[1]
10	ICGV 95342	1.7	1.3	1.0	1.0[1]	1.9	3.1	2.9[4]	1.8[5]	2.4[6]	1.3[3]	1.9[8]	1.7[4]	1.1[2]	1.8	2.9[1]	1.3[4]	1.0[1]
11	ICGV 95350	2.5	2.2	1.7	3.3	3.7	7.3	5.4	2.3[9]	3.9	1.2[2]	1.4[4]	2.8	1.0[1]	2.2	3.1[3]	1.3[4]	1.1[2]
12	ICGV-SM-93541	2.2	1.5	1.3	3.9	2.2	7.1	7.0	2.3[9]	4.7	1.2[2]	2.7[15]	2.0[7]	2.0[9]	1.9	3.2[4]	1.6	1.9
13	ICGV-SM-95714	2.0	1.5	1.0	3.1	1.7	5.8	7.1	4.2	5.0	1.2[2]	2.2[11]	2.1[8]	1.8[7]	2.2	3.6	1.4[5]	1.2[3]
14	ICGV-SM-95741	2.0	1.2	1.3	2.7	3.2	5.7	5.2	2.7[10]	3.0[10]	2.3[10]	2.1[10]	1.8[5]	1.9[8]	1.4[4]	3.0[2]	1.4[5]	1.4[5]
15	ICGV-SM-99543	1.8	3.1	1.3	2.4	1.3	6.1	6.9	4.9	2.8[9]	1.0[1]	2.8[16]	1.9[6]	1.7[6]	2.4	4.2	1.1[2]	1.1[2]
16	ICGV-SM-99529	2.2	2.4	2.3	3.2	2.6	6.9	6.4	3.3[14]	6.5	1.0[1]	2.0[9]	2.2	2.2	2.5	3.1[3]	1.3[4]	1.2[3]
17	JL24	2.5	2.2	1.0	2.6	1.4	5.6	6.8	4.2	5.3	2.6[11]	1.9[8]	2.4	1.6_5	1.9	3.8	1.2[3]	1.4[5]
18	Kwarts	2.2	2.0	1.0	3.8	2.9	7.0	6.6	3.7[17]	5.5	1.2[2]	2.9[17]	2.6	2.4	2.7	5.7	1.8	2.0
19	PC254K1	2.2	1.7	1.0	3.7	1.8	6.6	6.8	2.8[11]	2.2[4]	1.0[1]	2.6[14]	1.9	1.9[8]	2.1	4.1	1.4[5]	1.2[3]
20	PC280-K2	2.3	1.7	1.7	3.2	2.2	7.4	5.1	2.9[12]	6.4	1.8[7]	2.2[11]	2.7	2.4	2.4	4.3	1.2[3]	2.3
21	PC287	1.7	2.2	2.5	3.7	2.0	6.6	6.7	3.1[13]	1.7[2]	5.4	2.0[9]	2.4	1.8[7]	2.6	4.0	1.0[1]	2.4
22	PC297-K2	1.8	1.8	1.5	3.7	2.4	7.3	6.8	4.9	2.8[9]	1.0[1]	1.4[4]	2.1[8]	1.6[5]	1.3[3]	3.5	1.2[3]	1.4[5]
23	PC299-K1	2.2	1.7	1.2	4.0	1.9	7.2	5.6	4.8	5.3	3.0[14]	2.4[13]	3.1	2.6	2.5	4.7	1.4[5]	2.3
24	PC299-K19	2.2	1.3	2.3	4.1	1.2	7.1	6.8	5.9	4.3	2.6[11]	5.2	2.0[7]	2.1[10]	2.7	5.4	1.2[3]	1.9
25	PC299-K5	2.7	3.0	2.2	5.0	1.6	6.2	6.0	5.4	3.2	2.0[8]	3.9	2.0[7]	2.0[9]	3.1	5.3	1.4[5]	2.1
26	PC324-K1	2.8	1.5	1.3	3.8	2.4	7.3	7.1	4.1	3.0[10]	2.0[8]	2.3[12]	2.7	1.4[4]	2.2	3.8	1.1[2]	1.8
27	PC327-K1	2.3	2.3	2.0	4.2	2.3	7.3	5.8	3.4[15]	5.6	2.0[8]	1.8[7]	2.6	2.0[9]	1.8	4.2	1.3[4]	1.6

E	Entries	Brits				Burgershall			Cedara				Potchefstroom			Vaalharts		
		ELS(ns)	LLS	WB(ns)	rust	ELS(ns)	LLS	Rust	ELS	LLS	WB	Rust	ELS	LLS	WB	ELS	LLS	WB
28	RRLine 10	1.7	1.2	1.0	1.8	1.6	6.3	2.4^{3}	1.7^{4}	3.2	1.0^{1}	1.2^{2}	1.6^{3}	1.6^{5}	2.2	4.6	1.2^{3}	1.1^{2}
29	RRLine 11	1.8	2.2	1.0	1.0^{1}	2.3	4.9	3.7	2.1^{7}	2.7^{8}	1.0^{1}	1.0^{1}	1.6^{3}	1.4^{4}	1.8	4.2	1.4^{5}	1.0^{1}
30	RRLine 3	2.0	1.2	1.5	3.1	1.4	6.4	4.9	1.6^{3}	2.8^{9}	1.3^{3}	1.6^{5}	1.9^{6}	1.4^{4}	2.7	4.2	1.3^{4}	1.0^{1}
31	RRLine 7	2.0	2.3	1.0	1.0^{1}	1.6	6.3	4.2	1.5^{2}	2.6^{7}	1.0^{1}	1.0^{1}	1.6^{3}	1.0^{1}	1.5	3.3^{5}	2.0	1.2^{3}
32	RRLine 8	1.3	1.3	1.0	1.0^{1}	1.2	5.7	4.8	1.8^{5}	2.4^{6}	1.3^{3}	1.0^{1}	1.9^{6}	1.4^{4}	1.9	4.0	1.5	1.4^{5}
33	RRLine 9	1.3	3.0	1.0	1.5	2.1	4.5^{1}	6.2	2.8^{11}	3.0^{10}	1.7^{6}	1.0^{1}	1.3^{1}	1.6^{5}	1.8	4.7	1.6	1.0^{1}
34	Streeton[Austr]	2.2	2.3	1.0	3.4	1.7	6.2	6.8	4.1	4.3	2.1^{9}	3.9	1.4^{2}	1.7^{6}	1.6	3.2^{4}	1.2^{3}	1.2^{3}
35	Swallow	1.3	1.2	1.0	2.4	4.0	6.3	6.9	4.3	1.7^{2}	1.4^{4}	1.7^{6}	1.4^{2}	1.8^{7}	1.1^{2}	3.4	1.2^{3}	1.4^{5}
	MS (blocks; df=2)	0.98	3.95	1.73	4.92	2.26	3.67	6.76	19.69	10.17	1.35	0.31	1.62	0.22	0.73	0.45	0.6	0.18
	MS (treatments; df=34)	0.65	1.5	1.27	6.74	1.8	9.98	13.7	7.54	8.14	2.64	4.28	1.17	0.79	1.31	2.81	1.1	1.33
	MS (error; df=68))	0.48	0.67	0.98	1.24	1.64	1.75	2.82	1.62	2.37	1.15	1.0	0.44	0.28	0.58	1.72	0.39	0.6
	F-ratio (treatments)	1.23ns	1.82**	1.04ns	4.06**	1.23ns	5.64**	4.34**	4.61**	3.38**	2.17**	3.44**	2.52**	2.46**	2.1**	1.57**	2.56**	3.06**
	Trail mean	2.04	1.80	1.475	2.72	2.04	5.73	5.27	3.24	3.51	1.74	2.03	2.08	1.67	2.06	4.0	1.49	1.46
	CV %	33.36	40.45	50.9	40.72	54.17	23.36	31.50	39.93	45.78	61.09	48.21	32.25	31.64	37.6	31.74	39.68	50.07
	LSD (5%)	na	1.24	na	1.72	na	2.08	2.60	2.08	2.50	1.73	1.59	1.08	0.84	1.23	2.08	.098	1.19
	LSD (1%)	na	1.64	na	2.29	na	2.77	3.47	2.76	3.33	2.31	2.11	1.44	1.12	1.64	2.77	1.31	1.58
	SEM	0.35	0.45	0.5	0.6	0.6	0.73	0.9	0.7	0.8	0.6	0.5	0.36	0.3	0.46	0.73	0.35	0.4
	GCV%	8.35	20.5	12.25	36.05	10.0	29.03	31.9	42.6	39.53	37.43	39.9	21.7	18.1	20.1	13.76	29.2	37.166
	Intra-class correlation	0.0987	0.1948	0.0501	0.4303	0.069	0.6000	0.5057	0.5340	0.4357	0.2721	0.3902	0.3169	0.2656	0.2379	0.1585	0.3311	0.2688
	Std error of t	0.1049	0.1076	0.1030	0.0965	0.104	0.0865	0.0962	0.0942	0.1038	0.1102	0.1008	0.1080	0.1032	0.1073	0.1094	0.1085	0.3022
	Repeatability%	21	38	13	65	16	82	75	77	69	52	62	57	45	45	36	59	52

no WB at Burgershall, no rust at Potchefstroom and Vaalharts

RR rust resistant germplasm entries

resistance shaded in grey

PC Potchefstroom cross

-K progeny of single plant selections

E entry

ICGV-SM ICRISAT entry

df degrees of freedom

MS mean squares

* and ** significance indicated for F-probabilities of treatments by * ($p<0.05$) and ** ($p<0.01$). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)

CV% coefficient of variation (percentage)

SEM standard error of means

GCV% genetic coefficient of variation (percentage)

ELS early leaf spot

LLS late leaf spot

WB web blotch

x^1, x^2, x^3 ranks: (first, second and third)

Table 3.3 The analysis of variance on the average early leaf spot (ELS), late leaf spot (LLS), web blotch (WB) and rust ratings on long growth season groundnut entries (Trial 5.1c) at five localities (Potchefstroom, Vaalharts, Brits, Cedara and Burgershall) during 2004/05

		Brits				Burgershall			Cedara				Potchefstroom			Vaalharts		
E	Entries	ELS(ns)	LLS(ns)	WB(ns)	Rust(ns)	ELS(ns)	LLS(ns)	Rust	ELS(ns)	LLS	WB(ns)	Rust	ELS(ns)	LLS(ns)	WB(ns)	ELS	LLS(ns)	WB
1	Billy	2.2	1.3	1.0	3.2	3.0	4.6	7.3	2.5	1.4[1]	2.4	3.0	1.6	1.2	1.3	2.2[1]	1.0	1.0[1]
2	CG7= ICGMS42	2.0	1.2	1.0	2.6	2.3	4.0	6.2	2.0	2.0	1.6	1.8	2.1	1.3	1.3	2.9[5]	1.0	1.1[2]
3	ICGMS42=CG7	2.4	1.7	1.0	2.8	2.0	6.6	6.7	2.3	2.1	1.3	2.7	2.0	1.1	1.3	3.2	1.1	1.0[1]
4	ICGV 90087	1.3	1.0	1.7	1.0	1.6	1.7	2.7[1]	2.2	1.6[2]	1.7	1.0[1]	2.0	1.6	1.7	2.8[4]	1.2	1.2[3]
5	ICGV 95343	2.5	2.2	1.8	2.6	1.6	6.0	4.7[2]	2.8	2.6	2.6	1.0[1]	2.6	1.0	1.6	3.3	1.3	1.3[4]
6	ICGV-SM-99821	1.8	1.9	1.0	3.3	2.7	6.2	6.4	3.2	2.7	1.0	1.3[2]	1.8	1.4	1.8	3.7	1.2	1.3[4]
7	ICGV-SM-99841	2.2	1.2	1.0	3.3	3.6	6.6	5.9	3.1	1.6[2]	1.2	3.0	2.3	1.2	1.0	2.6[2]	1.1	1.6
8	ICGV-SM-99844	2.3	1.3	1.0	3.2	1.9	5.2	7.1	2.2	2.9	1.3	2.8	1.7	1.0	1.0	4.3	1.1	2.6
9	Rambo	1.7	1.3	1.0	2.3	2.3	5.4	6.4	3.0	2.3	1.8	2.4	2.0	1.2	1.2	2.7[3]	1.3	1.6
10	RR Line 12	2.0	2.8	1.0	1.3	2.3	4.5	5.7	2.1	3.3	1.4	1.0[1]	2.0	1.6	1.3	4.7	1.6	1.2[3]
11	TMV1	1.7	1.8	1.0	3.9	2.4	6.8	6.2	2.0	2.7	2.1	2.9	2.0	1.9	1.8	3.4	1.7	1.0[1]
	MS (blocks; df=2)	0.8	2.15	0.64	1.77	1.61	1.1	4.09	3.12	4.77	4.63	0.8	0.62	0.51	0.15	3.97	0.91	3.14
	MS (treatments; df=10)	0.74	1.52	1.25	4.47	1.54	7.16	6.62	0.8	2.46	1.1	4.4	0.35	0.5	0.39	2.32	0.52	0.9
	MS (error; df=20))	0.78	0.69	0.9	0.72	1.0	3.07	1.65	1.03	0.9	1.0	0.9	0.47	0.21	0.29	0.55	0.33	0.28
	F-ratio (Treatment)	1.06ns	1.74ns	1.38ns	5.34ns	1.34ns	2.51ns	3.69*	1.47ns	2.75*	1.17ns	3.54*	0.74ns	1.77ns	1.32ns	4.23**	1.55ns	3.80**
	Trail mean	2.01	1.60	1.13	2.69	2.3	5.23	5.93	2.55	2.62	1.67	2.09	2.0	1.32	1.39	3.25	1.36	1.33
	CV %	38.66	43.91	37.35	38.73	40.25	34.58	22.79	36.56	36.66	57.47	42.76	34.83	31.42	37.72	72.02	38.58	39.95
	LSD (5%)	na	na	na	na	na	na	2.11	na	1.61	na	1.51	na	na	na	1.26	na	0.86
	LSD (1%)	na	na	na	na	na	na	na	na	na	na	na	na	na	na	1.72	na	1.18
	SEM	0.5	0.4	0.25	0.4	0.56	0.9	0.7	0.5	0.5	0.7	0.53	0.4	0.2	0.3	0.4	0.3	0.3
	GCV%	3.5	19.05	13.3	20.35	11.7	17.86	21.03	6.93	28.16	8.9	33.06	0	12.7	9.43	24.6	16.35	33.76
	Intra-class correlation	0.0322	0.1742	0.0561	0.3770	0.1066	0.2881	0.4661	0.1453	0.3588	0.0506	0.3540	0	0.1652	0.0902	0.3709	0.1553	0.4390
	Std error of t	0.1877	0.1963	0.1905	0.1476	0.1939	0.1897	0.1868	0.186	0.1984	0.1891	0.1788	0.1826	0.1868	0.1932	0.1790	0.2021	0.1844
	Repeatability%	9	34	14	45	23	46	72	23	62	12	53	0	27	20	76	36	68

	no WB at Burgershall, no rust at Potchefstroom and Vaalharts
RR	rust resistant germplasm entries
	resistance shaded in grey
PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry
ICGV-SM	ICRISAT entry
df	degrees of freedom
MS	mean squares
* and **	significance indicated for F-probabilities of treatments by * (p<0.05) and ** (p<0.01). Means were separated using Fisher's protected t-test LSD at the 5% and 1% levels. Means followed by ranking numbers differed significantly from the highest rating at the 5% and 1% level (per column)
CV%	coefficient of variation (percentage)
SEM	standard error of means
GCV%	genetic coefficient of variation (percentage)
ELS	early leaf spot
LLS	late leaf spot
WB	web blotch
x^1, x^2, x^3	ranks: (first, second and third)

APPENDIX 4.1

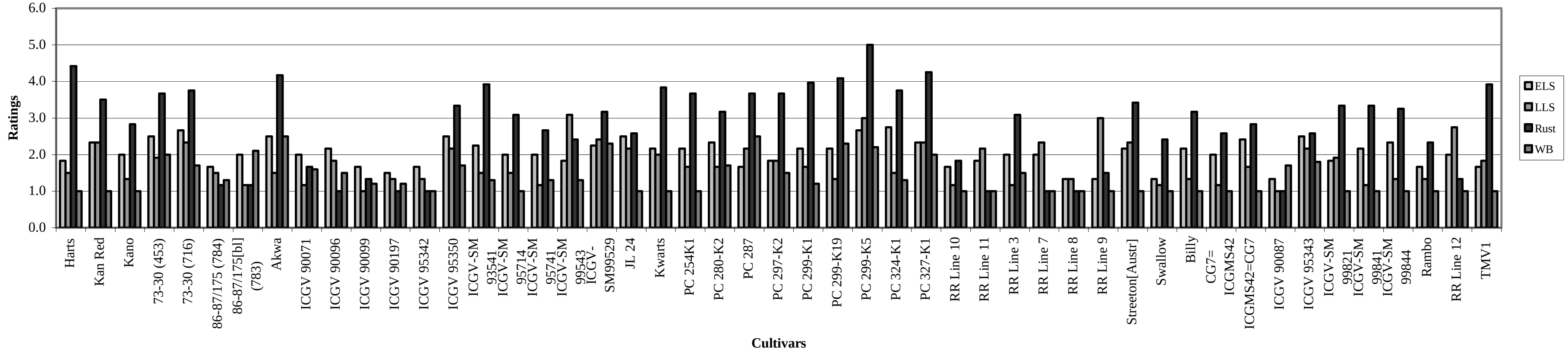

Figure 4.1.1 Comparison of the level of resistance to early leaf spot, late leaf spot, web blotch and rust of 49 entries at Brits during 2004/05.

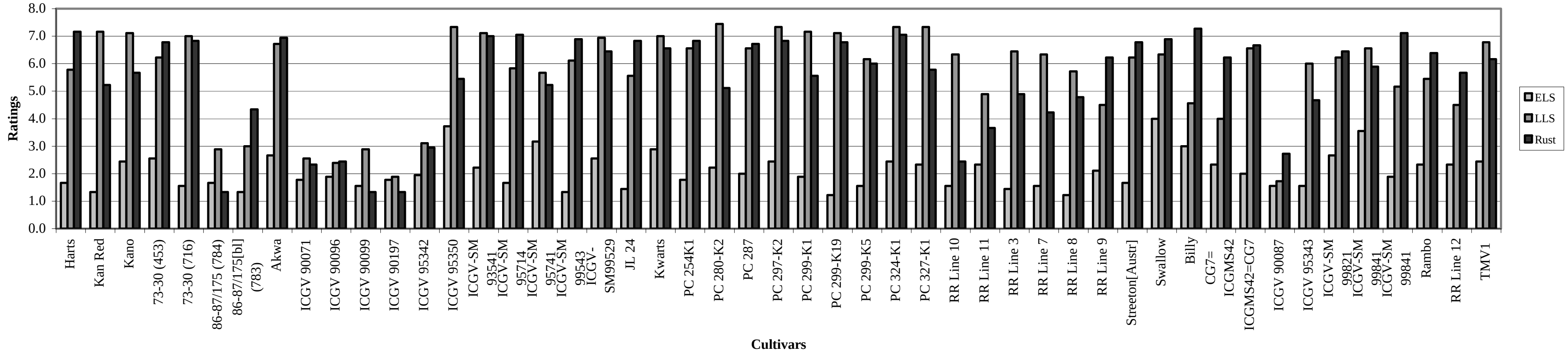

Figure 4.1.2 Comparison of the level of resistance to early leaf spot, late leaf spot, web blotch and rust of 49 entries at Burgershall during 2004/05.

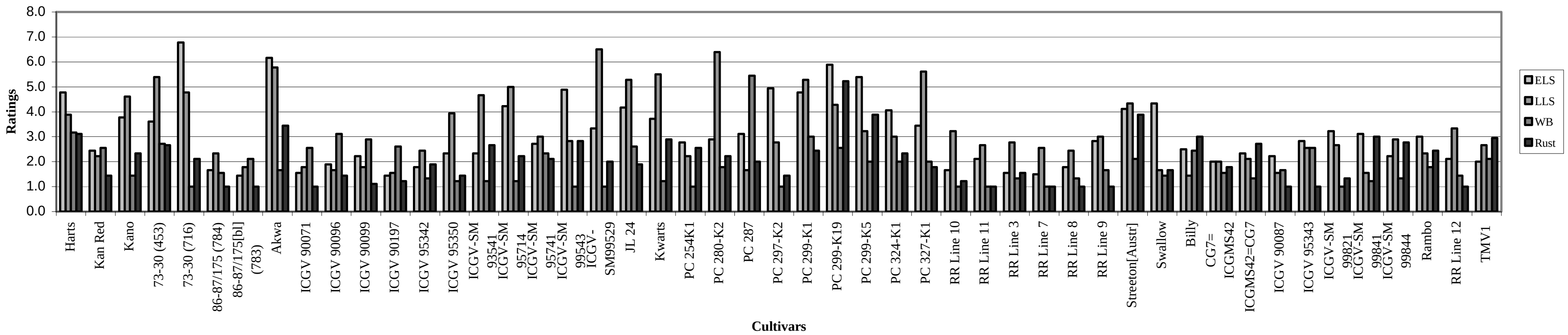

Figure 4.1.3 Comparison of the level of resistance to early leaf spot, late leaf spot, web blotch and rust of 49 entries at Cedara during 2004/05.

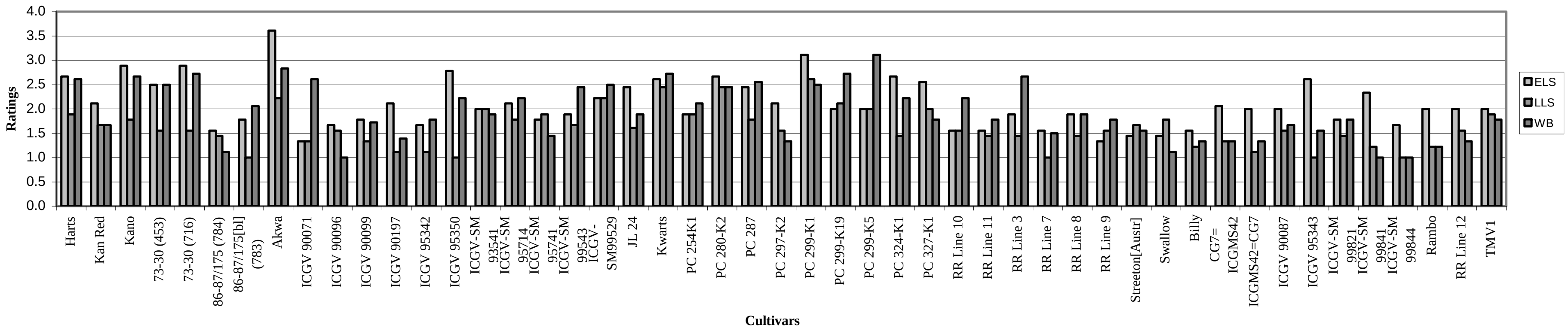

Figure 4.1.4 Comparison of the level of resistance to early leaf spot, late leaf spot, web blotch and rust of 49 entries at Potchefstroom during 2004/05.

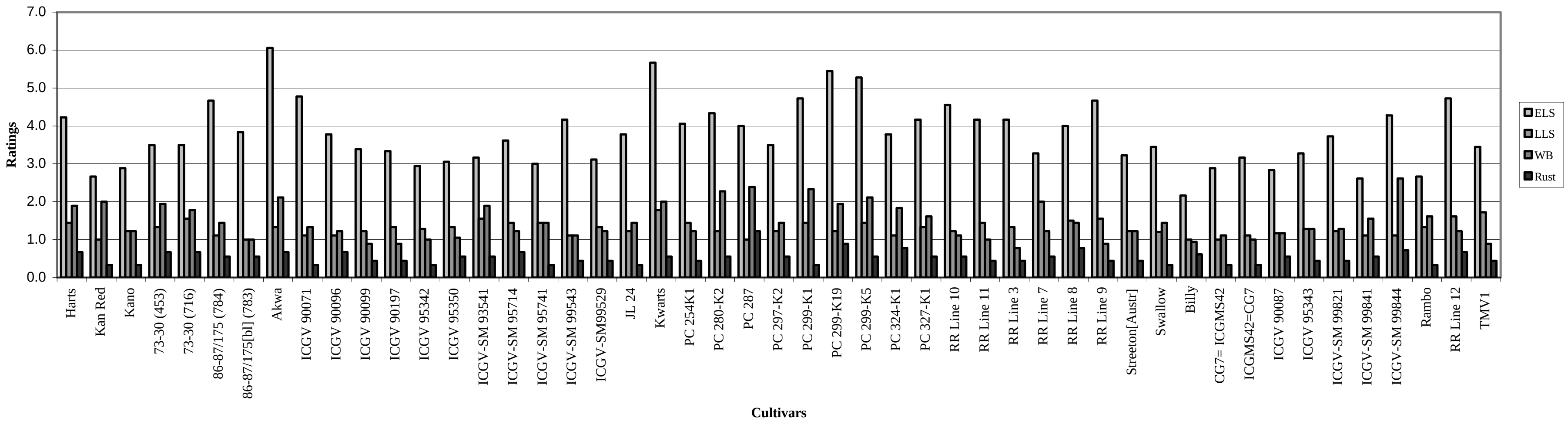

Figure 4.1.5 Comparison of the level of resistance to ELS, LLS, WB and rust of 49 entries at Vaalharts during 2004/05.

APPENDIX 4.2

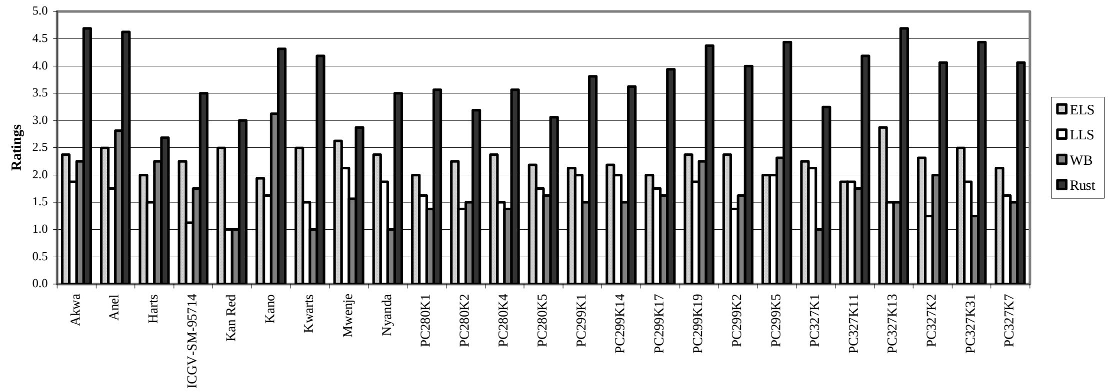

Figure 4.2.1 Comparison of the level of resistance to early leaf spot, late leaf spot and rust of the short/medium growth season Elite entries at Brits during 2004/05.

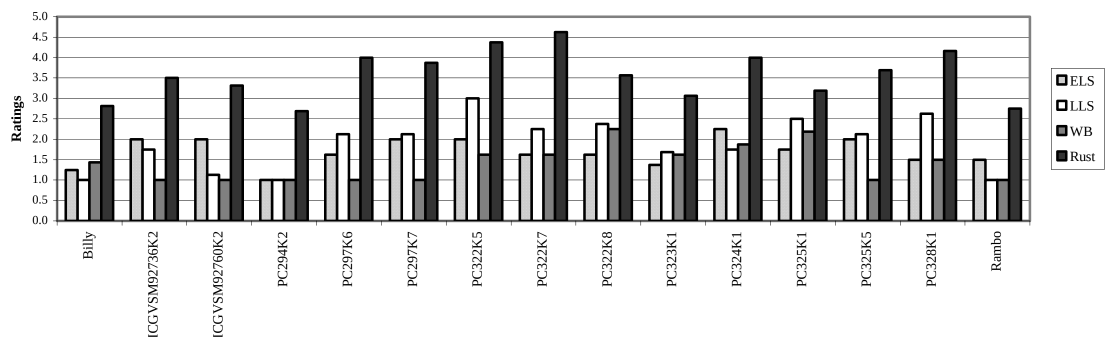

Figure 4.2.2 Comparison of the level of resistance to early leaf spot, late leaf spot and rust of the long growth season Elite entries at Brits during 2004/05.

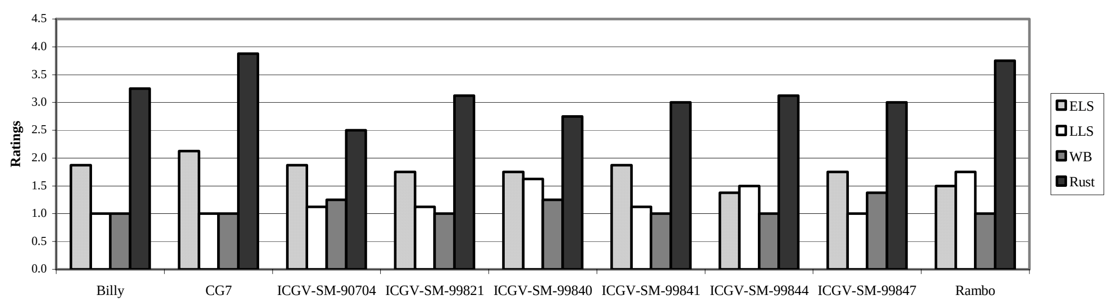

Figure 4.2.3 Comparison of the level of resistance to early leaf spot, late leaf spot and rust of the long growth season ICRISAT entries at Brits during 2004/05.

APPENDIX 5

Table 5.1 Grading results on short growth season groundnut entries (Trial 5.1a) at Potchefstroom, Vaalharts, Brits, Cedara and Burgershall during 2004/05

E	Entries	Pod mass (g)	Kernel mass (500 g)	Shel-ling %	Total kernel mass	Kernels above 9.00 (%)	Kernels above 8.25 (%)	Kernels above 7.50 (%)	Kernels above 6.75 (%)	Kernels above 6.00 (%)	Pan (%)	Total defec-tive (%)	Ubs (%)	Unsound (%)	Choice mark (%)	Stan-dard mark (%)	Sundry mark (%)	Chru-shing (%)	R/ton	R/ha	Splits (%)	1 Kernel pods (%)	2 Kernel pods (%)	3 Kernel pods (%)	Kernel size	Round kernels (%)
Locality: Brits																										
1	Harts	830	390	78	647	28	73	93.5	96.5	1	0.8	1	1	0.8	95.5	0	3	1.5	3740	2421.28	1.75	41.77	58.23	0	634.87	91.78
2	Kan Red	680	360	72	490	1	14.5	56.5	85.5	7.5	3.8	2.4	2.1	0.8	84	0	8.5	7.5	3565	1745.42	0.25	10.61	28.79	60.61	507.42	18.99
3	Kano	977	354	70.8	691	0.5	10.3	45.8	82.8	10.8	3.5	4.8	4.5	2.7	80	0	11	9	3510	2427.1	0.75	11.29	16.13	72.58	497	21.62
Locality: Burgershall																										
1	Harts	268	200	40	107	0	0	0	26.5	30	0	98.8	98.8	82	0	0	0	100	1800	193.2	0.25	91.71	8.29	0	477.48	49.55
2	Kan Red	267	224	44.8	119	0	0	3	14	17	38	52.5	52.5	43.9	0	0	16.5	83.5	1965	234.75	1	9.84	45.6	44.56	368.42	100
3	Kano	262	258	51.6	135	0	0	4.8	9.5	15.5	47.5	50.6	50.6	50.6	0	0	0	100	1800	243.04	2	15.87	40.08	44.05	500	50
Locality: Cedara																										
1	Harts	167	365	73	122	2	19.5	53.5	74.5	10.8	1.3	9.7	7.3	5.9	68.8	0	17.3	14	3347.5	407.28	5.5	29.27	70.73	0	524.65	92.96
2	Kan Red	340	376	75.2	256	0	11	54	88	8	2	2.6	2.6	0.8	86	0	10	4	3620	925.56	0.5	25	40.91	34.09	470.59	79.68
3	Kano	402	377	75.4	303	0	22	70.5	93.5	5	0	6.5	6	2	88.5	0	8	3.5	3650	1105.43	0	21.62	29.73	48.65	553.25	75.15
Locality: Potchefstroom																										
1	Harts	483	362	72.4	350	17.5	46.8	71	83.8	3.8	6.8	15.3	12.5	6.5	75.3	0	0	24.75	3305	1156.53	2	20.83	79.17	0	513.8	91.1
2	Kan Red	173	338	67.6	117	0	2	29	66.3	17	5.8	7.6	6.7	4.4	63.8	0	16.3	20	3237.5	379.35	0	25.32	22.78	51.9	500	85.66
3	Kano	447	341	68.2	305	2	12	37	67.5	15.3	7.5	13.8	10.3	5	60.3	0	19.5	20.25	3200	974.81	0.25	15.15	42.42	42.42	500	82.96
Locality: Vaalharts																										
1	Harts	257	369	73.7	189	38	67.3	84.8	91.5	2	1.8	6.9	3.8	2.3	85	0	10.5	4.5	3605	681.93	4	20.25	79.75	0	675.28	100
2	Kan Red	223	318	63.6	142	0.8	23.5	71.5	90.5	4.5	1.8	2.1	1.8	1.8	89	0	6.8	4.25	3647.5	518.09	2.25	30.12	24.1	45.78	543.54	8.41
3	Kano	393	350	70	275	2.5	23.5	68.5	90.3	3.5	1.3	3.8	2.8	2.6	87.3	0	7.8	5	3622.5	997.4	4.25	24.24	31.82	43.94	524.71	84.3

UBS% unsound, blemished and soiled
E entry

Table 5.2 Grading results on medium growth season groundnut entries (Trial 5.1b) at Potchefstroom, Vaalharts, Brits, Cedara and Burgershall during 2004/05

E	Entries	Pod mass (g)	Kernel mass (500 g)	Shel-ling %	Total kernel mass	Kernels above 9.00 (%)	Kernels above 8.25 (%)	Kernels above 7.50 (%)	Kernels above 6.75 (%)	Kernels above 6.00 (%)	Pan (%)	Total defec-tive (%)	Ubs (%)	Unsound (%)	Choice mark (%)	Stan-dard mark (%)	Sundry mark (%)	Chru-shing (%)	R/ton	R/ha	Splits (%)	1 Kernel Pods (%)	2 Kernel pods (%)	3 Kernel pods (%)	Kernel size	Round kernels (%)
Locality: Brits																										
1	73-30 (453)	1377	350	70	964	0	4.3	33	82.5	12	4.3	0.5	0.3	0.3	82	0	13.3	4.75	3572.5	3442.7	1	19.47	79.65	0.88	429.69	47.92
2	73-30 (716)	1477	370	74	1093	0	6.5	36.8	80.3	14	3.3	2.3	1.8	0.5	79.3	0	15.8	5	3542.5	3871.01	2	16.81	83.19	0	416.88	97.66
3	86-87/175 (784)	1350	360	72	972	1.3	41.8	70.5	82.5	2.5	5	3.7	0.8	0.3	79.8	0	14.5	5.75	3540	3440.88	10	18.18	71.43	10.39	567.01	89.35
4	86-87/175[bl]	1327	414	82.8	1098	11.8	36.5	63	71.3	3.3	2.5	1.5	0.3	0	70.3	0	26.8	3	3472.5	3814.47	23	12.16	77.03	10.81	650.69	19.18
5	Akwa	1827	442	88.4	1615	1.8	30.8	75.3	91.3	1.8	1.3	0.5	0.5	0.3	90.8	0	7.8	1.5	3692.5	5962.55	5.75	10.23	87.5	2.27	487.97	47.33
6	ICGV 90071	1940	329	65.8	1277	12.3	44.5	70.5	81	4	2.3	5.4	3.3	0.8	77.3	0	18	4.75	3525	4499.73	12.25	17.33	76	6.67	618.32	49.62
7	ICGV 90096	1673	328	65.6	1098	3.5	38.3	65	78.3	5.5	1.5	5.3	4.1	1	75.5	0	20	4.5	3510	3852.95	13.5	18.07	78.31	3.61	553	36.75
8	ICGV 90099	1167	347	69.4	810	2.8	34.3	64.3	77.3	7	3.8	6.5	1.8	0.3	72.3	0	22.3	5.5	3467.5	2807.52	11.25	15.58	81.82	2.6	587.45	20.53
9	ICGV 90197	1167	327	65.4	763	37.8	69.5	89	93.3	2.3	0	3.3	2.5	0.5	90.5	0	8.5	1	3695	2819.29	4	15.94	81.16	2.9	678.18	95.27
10	ICGV 95342	1107	371	74.2	821	3	32	72	91.8	3	2	0.3	0.3	0	91.8	0	5.5	2.75	3690	3030.03	2.75	38.14	61.86	0	615.77	71.48
11	ICGV 95350	1723	385	77	1327	5.3	49.3	81.8	89.5	1.3	0.5	3	2.5	2.5	87.3	0	9.5	3.25	3640	4830.16	8.25	23.53	76.47	0	586.89	47.87
12	ICGV-SM 93541	1477	396	79.2	1170	3	20	54	87.5	9.3	0.8	1.5	1.3	0.8	86.3	0	10.3	3.5	3627.5	4242.43	0.5	9.09	43.94	46.97	488.83	29.33
13	ICGV-SM 95714	1520	347	69.4	1055	3	21.5	63	90.3	5	0.3	1.5	1.5	0.8	89.5	0	7.5	3	3665	3866.14	2.5	36.71	44.3	18.99	481.33	47.47
14	ICGV-SM 95741	1377	342	68.4	942	7.5	31.5	65	88.5	7.8	1.5	2.6	1.8	1.5	86.3	0	9.3	4.5	3617.5	3406.38	1	10.71	41.07	48.21	558.36	93.38
15	ICGV-SM 99543	1263	369	73.8	932	2.8	26.3	60.3	85.3	4.8	1.3	7.5	6.5	2.3	80	0	13	7	3530	3291.16	6.25	18.52	79.01	2.47	606.76	58.72
16	ICGV-SM99529	1647	353	70.6	1163	0.3	14	58.5	89.8	4.5	0.3	1.8	1.5	0.5	88.5	0	10.5	1	3675	4272.36	5.5	24.14	75.86	0	417.44	98.84
17	JL 24	1140	366	73.2	834	4.8	35.3	79.7	88.2	4.3	1.6	1.5	1.3	0.5	87.4	0	9.5	3.1	3643	3040.01	5	11.11	73.61	15.28	568.71	45.48
18	Kwarts	1180	375	75	885	0.5	22.5	78	89.5	2.8	0.8	2.6	1.3	0.5	88	0	8	4	3640	3221.4	5	17	83	0	458.97	48.46
19	PC 254K1	1383	365	73	1010	2.8	40.5	73	90	1.8	0.8	1.8	1.5	0.8	89.5	0	8.3	2.25	3672.5	3708.61	6.75	22.06	75	2.94	647.48	35.61
20	PC 280-K2	1817	378	75.6	1373	0.5	12.5	57.5	86.5	5	0.5	1.3	1	0.5	86	0	8.3	5.75	3602.5	4947.67	3.75	18.1	81.9	0	505.85	55.56
21	PC 287	1152	342	68.4	788	0	0.5	12.3	58.8	30	4.8	0.6	0.6	0.3	58.8	0	30	11.25	3275	2579.85	0.25	17.68	73.17	9.15	171.53	98.39
22	PC 297-K2	1350	302	60.4	815	65.8	78.3	87.3	94.3	3.8	0	38.0 1	7.6	11.6	0	0	84.8	15.25	2647.5	2158.77	0.5	13.79	86.21	0	997.35	83.6
23	PC 299-K1	1563	357	71.4	1116	4.5	39.5	72	87.8	5.3	1.3	2	2	1.5	86.3	0	10.8	3	3632.5	4054.67	5.5	27.38	72.62	0	507.23	20.52
24	PC 299-K19	1257	361	72.2	907	0	12.5	49.3	82	10.5	1.8	1.5	1.5	0.8	80.8	0	15.8	3.5	3572.5	3241.38	4.75	22.68	77.32	0	480.94	29.03
25	PC 299-K5	1087	350	70	761	2.8	22.8	55.3	78.8	6.5	4.3	1.3	1.3	0.3	77.8	0	17.8	4.5	3532.5	2687.06	10.5	29.25	70.75	0	511.36	59.09
26	PC 324-K1	1640	362	72.4	1187	64.8	83	90.8	95.3	2.3	0.8	8.3	1.3	0.8	89.3	0	7.3	3.5	3657.5	4342.77	1	38.98	61.02	0	886.05	61.86
27	PC 327-K1	1240	372	74.4	923	6	51.3	77.3	88.8	3.8	0.8	3.5	3.5	2.8	85.8	0	10.5	3.75	3620	3339.67	6.75	34.65	65.35	0	531.44	84.43
28	RR Line 10	577	322	64.4	371	3.5	16.5	45.5	55.5	5	36.5	15.7	15.7	5.5	0	46.8	13	40.25	2631.25	977.18	2.5	33.33	45.45	21.21	575.13	12.95
29	RR Line 11	1140	357	71.4	814	3	22.5	60	86.8	8.5	2	3.3	3.1	1.3	84	0	12	4	3600	2930.26	1.75	19.35	39.78	40.86	488.73	29.01
30	RR Line 3	963	337	67.4	649	28	57.8	81.5	93.5	5.3	0	14.8	8.3	2.5	83.3	0	10.5	6.25	3570	2317.95	1	24.29	64.29	11.43	730.47	91.02
31	RR Line 7	930	388	77.6	722	8.8	42.8	71.3	87	6	3	4.7	4.5	1.3	83.3	0	9.5	7.25	3560	2569.18	1.5	28.26	47.83	23.91	542.06	29.91
32	RR Line 8	553	331	66.2	366	2.3	30.3	57.8	76	9.5	4.5	10.4	9.6	1.1	0	67.5	24	8.5	3052.5	1118.15	8	22.58	53.76	23.66	625.51	48.15
33	RR Line 9	1193	350	70	835	35.5	53	77.8	88.3	4.5	1.3	9.5	8.2	1.8	80.5	0	14.3	5.25	3552.5	2967.52	4.75	11.32	45.28	43.4	549.84	47.98
34	Streeton[Austr]	937	377	75.4	706	7	45.5	73.3	85.3	4.8	0.5	3	0.5	0.5	83.5	0	13.5	3	3605	2546.02	8.5	15.63	84.38	0	734.91	13.79
35	Swallow	2317	314	62.8	1455	16.3	54	70.5	77	3.8	1.5	9.4	0.8	0	69.8	0	26.5	3.75	3460	5033.84	17.5	12.7	85.71	1.59	631.15	36.07
Locality: Burgershall																										
1	73-30 (453)	277	305	61	169	0	0	3	24	21	40	30.6	30.6	15.3	0	0	40	60	2200	371.29	1	29.09	70.91	0	347.83	73.91
2	73-30 (716)	288	308	61.6	178	0	0	0	17.8	29.5	31	15.7	15.3	9.7	0	16.3	29.3	54.5	2336.25	414.95	3.75	30.53	65.65	3.82	365.98	95.88
3	86-87/175 (784)	455	266	53.2	242	3.5	12.3	26.5	41.5	21	19.5	8	6.1	4.8	39.8	0	33	27.25	2925	708.03	13.5	10.94	80.47	8.59	494.05	83.33
4	86-87/175[bl]	438	266	53.2	233	0	4.5	8.8	15.8	23.3	39	77.6	76.4	64.9	0	0	0	100	1800	419.75	0.5	11.94	76.87	11.19	437.5	81.94
5	Akwa	273	323	64.6	177	0	2.3	23.3	59.8	21	8.3	19.6	17.2	9.1	0	47	27.3	25.75	2777.5	490.43	0.75	13.92	83.54	2.53	410.65	82.82
6	ICGV 90071	412	241	48.2	198	1	2.5	8.5	20.5	22	20.5	61.9	43.3	40.5	0	0	21	79	2010	398.83	0.25	18.08	77.97	3.95	353.45	56.9
7	ICGV 90096	367	243	48.6	178	0	0	2.5	15	14	40	32.6	22	20.5	0	0	22.8	77.25	2027.5	361.3	0.75	9.47	86.98	3.55	340.91	84.09
8	ICGV 90099	385	224	44.8	172	0	2	5	15	18	36.8	35.3	29.4	24.8	0	0	26.3	73.75	2062.5	355.74	2	14.66	79.06	6.28	468.75	50
9	ICGV 90197	338	256	51.2	173	0	7.5	19	31.5	20	20.5	19.5	14.9	11.7	0	26	39.5	34.5	2585	447.79	21	20.34	76.27	3.39	583.33	72.22
10	ICGV 95342	505	309	61.8	312	0.5	5	24.8	38.8	19.8	17.5	14.6	11.8	8.9	0	35.3	18.8	46	2516.25	785.3	0.5	53	46.54	0.46	520.13	77.18
11	ICGV 95350	265	243	48.6	129	0	0	0	9.5	19	43	75	75	62.5	0	0	0	100	1800	231.82	0	41.38	58.62	0	200	60
12	ICGV-SM 93541	267	261	52.2	139	0	0	8	20.5	9.3	45.3	45.5	45.5	24.7	0	0	27	73	2070	288.14	4.5	16.94	46.99	36.07	759.26	40.74
13	ICGV-SM 95714	320	270	54	173	0	0	2	13.5	20.5	45	37.2	37.2	33.3	0	11.5	17.8	70.75	2150	371.52	1	36.18	54.27	9.55	428.57	90.48
14	ICGV-SM 95741	270	166	33.2	90	0	0	0	3.5	14.5	63	69.2	66.3	66.3	0	0	0	100	1800	161.35	0.75	6.86	57.35	35.78	500	0
15	ICGV-SM 99543	278	339	67.8	189	1.8	3.8	13.8	39.3	24	16.8	31.7	30.3	24.3	0	0	55.3	44.75	2352.5	443.94	4.25	24.71	71.76	3.53	475.76	91.52
16	ICGV-SM99529	280	259	51.8	145	0.8	3.3	14.3	32	18	36	16.1	16.1	16.1	0	0	47.6	52.4	2276	330.11	3.1	33.55	66.45	0	336.84	100
17	JL 24	275	228	45.6	125	0	0	19.5	36	28.5	25	20.4	16.7	1.5	0	30.8	28	41.25	2541.25	318.67	1.75	19.15	76.6	4.26	529.41	84.56

E	Entries	Pod mass (g)	Kernel mass (500 g)	Shel-ling %	Total kernel mass	Kernels above 9.00 (%)	Kernels above 8.25 (%)	Kernels above 7.50 (%)	Kernels above 6.75 (%)	Kernels above 6.00 (%)	Pan (%)	Total defec-tive (%)	Ubs (%)	Unsound (%)	Choice mark (%)	Stan-dard mark (%)	Sundry mark (%)	Chru-shing (%)	R/ton	R/ha	Splits (%)	1 Kernel Pods (%)	2 Kernel pods (%)	3 Kernel pods (%)	Kernel size	Round kernels (%)
18	Kwarts	270	123	24.6	66	0	0	4.5	18.5	34.8	11	50.6	45.1	45.1	0	14	0	86	2010	133.5	0	46.57	50.98	2.45	397.85	50.54
19	PC 254K1	290	227	45.4	132	0	0	2.5	7	13	50.8	42.5	36.2	36.2	0	7	11.3	81.75	2017.5	265.62	2.25	41.87	57.72	0.41	560	68
20	PC 280-K2	300	303	60.6	182	0	0.8	1.8	16.3	18.5	44.8	12.4	11.1	9.8	0	15.3	18.8	66	2216.25	402.91	1.5	75.53	24.47	0	411.39	100
21	PC 287	285	309	61.8	176	0	0	0.5	7	30.8	57.8	7	7	7	0	0	36.5	63.5	2165	381.32	0.5	20.12	77.44	2.44	297.87	91.49
22	PC 297-K2	287	261	52.2	150	12	23.3	39.3	61.3	13.5	4.3	37.5	18.4	9.4	0	43.3	19.3	37.5	2641.25	395.24	0.5	21.62	78.38	0	765.63	28.13
23	PC 299-K1	322	304	60.8	196	0.5	0.8	5.3	19.3	23.5	42.8	9.2	8.2	6.5	0	17.8	24.5	57.75	2311.25	452.02	1.75	15.98	84.02	0	427.78	10
24	PC 299-K19	282	288	57.6	162	0	0	2.3	10.3	23.5	37.3	21.3	20.7	19.5	0	10	22.5	67.5	2175	352.87	1.25	39.09	60.91	0	455.56	80
25	PC 299-K5	274	250	50	137	0	0	0	14	22	40	45.5	40.9	31.8	0	0	24	76	2040	279.14	2	31.31	68.69	0	318.18	81.82
26	PC 324-K1	298	265	53	158	1	5	16.5	36	22.5	13	32.4	17.6	17.2	0	0	50	50	2300	363.67	4.5	7.25	92.75	0	433.74	71.08
27	PC 327-K1	353	309	61.8	218	0.5	1.3	9.5	28.5	27	18.5	12.4	7.3	6.4	26.5	0	26	47.5	2590	565.55	0.75	8.7	91.3	0	425.37	100
28	RR Line 10	335	252	50.4	169	1.8	2.5	12.5	25	13.5	33.5	49.3	46.3	34.3	0	0	31.5	68.5	2115	357.1	6.25	7.41	46.91	45.68	595.24	19.05
29	RR Line 11	308	284	56.8	175	0	2.3	10.3	27.5	20.5	34.8	29.3	27.5	18.3	0	0	43.3	56.75	2232.5	390.99	6.25	30.77	48.29	20.94	470.09	62.39
30	RR Line 3	320	298	59.6	191	0.5	2	9	28.8	20	28.8	13.2	8.3	7.3	26.3	0	20.3	53.5	2527.5	482.04	0.75	16.43	68.57	15	467.48	73.98
31	RR Line 7	345	294	58.8	203	0.5	6	17	34.3	16.3	34.5	35.2	35.2	23	0	0	43.5	56.5	2235	453.39	1	18.89	62.22	18.89	402.94	94.12
32	RR Line 8	332	287	57.4	190	2.3	8.8	22.3	44.5	17	11	42.7	40.3	30.7	0	0	47.5	52.5	2275	433.11	1	15.89	53.64	30.46	385.28	90.48
33	RR Line 9	298	213	42.6	127	1.8	2.5	12.3	24.8	13.5	34	49.5	46.5	34	0	0	31.3	68.75	2112.5	268.48	6.5	23.7	58.38	17.92	500	67.68
34	Streeton[Austr]	275	228	45.6	125	0	0	0	6	15.5	25.5	55	48.3	48.3	0	0	13.5	86.5	1935	242.65	0.5	46.67	53.33	0	375	0
35	Swallow	367	278	55.6	204	0.5	3	13	32.3	21.5	24.3	26	24.4	23.6	0	0	46	54	2260	460.74	3	8.88	89.35	1.78	383.93	92.26
Locality: Cedara																										
1	73-30 (453)	173	338	67.6	117	0.5	5	38	80.5	11.5	3	4.7	4.2	1.6	78	0	13.5	8.5	3495	409.52	1.5	37.1	61.29	1.61	423.68	94.74
2	73-30 (716)	163	341	68.2	111	0	10	41.5	79.8	12.8	5.8	2.7	1.3	0	78	0	14.5	7.5	3505	390.43	0.5	47.37	52.63	0	415.36	95.31
3	86-87/175(784)	567	365	73	414	14.5	43	62	71.5	5	1	8.3	1.8	0.5	66	0	30.3	3.75	3422.5	1415.77	22.5	9.38	87.5	3.13	694.17	87.38
4	86-87/175[bl]	660	300	60	396	11.5	55	70	76	5	2	11.7	4.1	2.6	68.5	0	24	7.5	3410	1350.36	17	22.58	58.06	19.35	783.51	75.26
5	Akwa	313	388	77.6	243	1.5	23.3	63.3	91.8	5	1.3	1.5	1.5	0.5	91	0	6	3	3680	894.78	0.75	25	75	0	441.11	100
6	ICGV 90071	223	317	63.4	142	21	51	66	74	7	0.8	16.4	5.8	0.3	65	0	26.8	8.25	3367.5	476.82	16	41.94	51.61	6.45	778.95	90.53
7	ICGV 90096	370	282	56.4	209	11.5	30	54.5	65	4.5	19	9.9	6.2	2.2	60	0	16.5	23.5	3165	660.47	10.5	25	69.44	5.56	474.45	87.59
8	ICGV 90099	277	348	69.6	193	51.5	73.5	83	85.5	4	1.5	15.2	8.6	2	76.5	0	14	9.5	3470	668.18	7	36.92	61.54	1.54	1744.9	90.82
9	ICGV 90197	253	296	59.2	150	27.5	61.8	76.8	79.3	4.5	4.3	12	5.2	2.6	72.3	0	16.8	11	3412.5	511.78	11.75	32.14	64.29	3.57	740.65	90.65
10	ICGV 95342	213	357	71.4	152	2	40	74	87	3.5	1.3	3.6	1.3	0.8	84.8	0	12	3.25	3615	550.64	7.5	56.35	20.63	23.02	495.73	97.72
11	ICGV 95350	560	383	76.6	429	3.5	26.5	63.5	84	7	0.5	7.4	4.8	4.1	79.8	0	12.8	7.5	3522.5	1511.01	7	37.78	62.22	0	488.37	93.6
12	ICGVSM93541	473	386	77.2	365	2	26	60	86	9.5	1	3.3	2.8	0.5	84.3	0	11.3	4.5	3597.5	1314.58	1.25	26.09	56.52	17.39	459.89	97.86
13	ICGVSM95714	810	354	70.8	573	1.5	19	57	87	7.5	0	1.3	0.5	0.5	86.3	0	12.3	1.5	3647.5	2091.77	5	36.59	53.66	9.76	1029.59	86.98
14	ICGVSM95741	727	361	72.2	525	0.5	38	58.5	83.3	11	1.3	2.8	2.1	1	81.8	0	13.3	5	3567.5	1871.7	2	18.06	33.33	48.61	482.61	95.07
15	ICGVSM99543	460	339	67.8	312	1.5	37.5	70	83.5	4.5	0.5	22.7	20.2	11.9	0	0	86	14	2660	829.6	7.75	15.79	78.95	5.26	556.67	98
16	ICGVSM99529	203	313	62.6	127	0.5	9	43	73.8	12	4.3	3	1.6	1.1	72	0	18.8	9.25	3427.5	436.28	7	33.33	65.08	1.59	390.21	99.47
17	JL 24	340	360	72	245	0.5	11.5	46	80	9.5	3.5	4.3	3.2	1.6	78	0	13	9	3490	854.35	2.5	13.33	77.78	8.89	449.44	97.19
18	Kwarts	275	278	55.6	153	1.5	23.5	57.5	86	5.8	2.5	2.1	1.8	0.3	84.5	0	11.8	3.75	3607.5	551.59	5	44.26	55.74	0	467.39	99.46
19	PC 254K1	375	332	66.4	249	1	17	38	72.5	10.5	10	16.3	13.4	12.2	0	0	74	26	2540	632.46	1	41.07	57.14	1.79	496.58	60.27
20	PC 280-K2	397	391	78.2	310	0.5	6.5	42	79	14.5	3.5	3.2	2.1	0.8	78.3	0	14.3	7.5	3507.5	1088	1.25	24.14	75.86	0	434.07	96.15
21	PC 287	267	370	74	197	0	1.5	23	70.5	18	4	1.4	0.8	0.3	70.3	0	21	8.75	3415	673.89	3.5	34.04	65.96	0	316.14	99.1
22	PC 297-K2	310	337	67.4	209	54.5	73	88.8	94.8	1.3	2.8	37	13.4	12.3	0	0	81.3	18.75	2612.5	545.86	0.75	54.17	45.83	0	1052.78	63.33
23	PC 299-K1	337	364	72.8	245	0.5	16	53.5	87	8	3	2.1	1.6	0.5	86	0	9.5	4.5	3615	886.01	1	9.62	90.38	0	910.99	98.43
24	PC 299-K19	243	345	69	168	0.5	8.5	31.5	68.5	19	5	7.2	6.6	4.4	63.5	0	22.5	14	3295	553.23	2.5	56.06	43.94	0	444.81	96.75
25	PC 299-K5	263	362	72.4	191	1	19	47.5	81	10.5	1	12.2	11.9	6.6	0	70.8	21	8.25	3071.25	585.54	6.75	17.02	82.98	0	479.29	97.04
26	PC 324-K1	427	377	75.4	322	51.5	70	84	91.5	4	1.5	15.8	7.1	4.1	79	0	12.5	8.5	3505	1127.58	2.5	16.67	83.33	0	847.22	90.74
27	PC 327-K1	467	361	72.2	337	1.5	19.5	57	81.5	8.5	2.5	2.8	2.1	1	80	0	14.8	5.25	3547.5	1195.27	6	19.15	80.85	0	460.45	100
28	RR Line 10	187	284	56.8	106	2	28.5	52.5	71.5	9.5	3	18.2	15.3	6.3	0	62.8	21.8	15.5	2958.75	313.71	9.5	26.67	60	13.33	655.96	60.55
29	RR Line 11	197	296	59.2	116	4	19	55.5	86.5	9.5	1.5	4.6	4.1	2.5	83.5	0	11.5	5	3585	417.39	2	23.08	46.15	30.77	521.08	82.53
30	RR Line 3	263	352	70.4	185	4	44.5	75.5	86	5.5	1	11.4	7.9	3	77	0	17.3	5.75	3512.5	651.17	6.5	55.32	42.55	2.13	666.67	79.07
31	RR Line 7	240	368	73.6	177	26.5	56.5	74.3	87	5.8	3.5	3.9	3.9	2.9	84.3	0	9	6.75	3575	631.49	2.75	41.46	43.9	14.63	561.29	93.55
32	RR Line 8	73	330	66	48	8.5	46.5	67.5	79	4.5	1.5	8.4	6.8	2.1	74	0	17	9	3450	166.98	10.5	55.77	36.54	7.69	576.64	87.59
33	RR Line 9	320	334	66.8	214	5.5	41	70.5	84.5	10	0.5	18.1	6.5	5.5	0	73.8	14	12.25	3046.25	651.17	4.5	9.38	65.63	25	698.35	55.37
34	Streeton[Austr]	242	367	73.4	177	59	79.5	89.5	95	1.5	1	10.2	3.1	1.5	86	0	9.5	4.5	3615	641.24	1.5	29.27	70.73	0	1979.17	41.67
35	Swallow	580	330	66	383	41	66.3	81.3	85.8	3.5	1.8	9	5.9	3.1	79.8	0	12.3	8	3517.5	1346.5	7.5	17.65	82.35	0	675.2	94.49
Locality: Potchefstroom																										
1	73-30 (453)	673	345	69	465	0	6.3	30.8	62.5	20.5	8.8	14	12.6	3.9	56	0	26.8	17.25	3187.5	1480.91	4.75	30.7	69.3	0	508.13	83.74
2	73-30 (716)	465	330	66	307	0.3	10.8	42.8	73.5	13	3.3	10.3	9.5	4	67.5	0	22.8	9.75	3377.5	1036.56	6.75	21.1	77.06	1.83	474.19	89.68
3	86-87/175 (784)	1170	348	69.6	814	10.3	42.5	65.5	82.3	8	1	11.4	6.9	4.3	75.3	0	16.5	8.25	3470	2825.69	7	23.17	75.61	1.22	655.38	57.77

E	Entries	Pod mass (g)	Kernel mass (500 g)	Shel-ling %	Total kernel mass	Kernels above 9.00 (%)	Kernels above 8.25 (%)	Kernels above 7.50 (%)	Kernels above 6.75 (%)	Kernels above 6.00 (%)	Pan (%)	Total defec-tive (%)	Ubs (%)	Unsound (%)	Choice mark (%)	Stan-dard mark (%)	Sundry mark (%)	Chru-shing (%)	R/ton	R/ha	Splits (%)	1 Kernel Pods (%)	2 Kernel pods (%)	3 Kernel pods (%)	Kernel size	Round kernels (%)
4	86-87/175[bl]	730	324	64.8	473	13	35.8	58	75.3	9.8	5.8	5.9	4	1.6	71.3	0	19.5	9.25	3420	1617.8	7.25	15.94	75.36	8.7	621.9	64.05
5	Akwa	853	373	74.6	637	4.5	31.8	66	86	6	2.5	3.9	3.6	0	85.5	0	8.5	6	3595	2288.53	4.75	20.19	79.81	0	500	88.95
6	ICGV 90071	850	343	68.6	583	18	41.5	66.5	84.5	7.5	2	14.3	12.3	3.6	75.5	0	16	8.5	3470	2023.36	4.25	35.21	61.97	2.82	670.63	75
7	ICGV 90096	1058	306	61.2	648	9.3	26.8	54.5	76.8	10.8	4	8.2	7.1	4.1	73.5	0	12.8	13.75	3397.5	2200.56	2	12.5	84.38	3.13	577.07	69.55
8	ICGV 90099	910	308	61.6	561	10.8	24.3	49.5	76.5	15	3.8	7.5	6.7	1.1	71.5	0	19.3	9.25	3422.5	1918.52	0.75	14.29	85.71	0	556.36	77.45
9	ICGV 90197	577	307	61.4	354	14	33.5	53.3	75.8	13	3.3	10.6	8.7	4.5	69.8	0	19.5	10.75	3390	1200.31	4.5	20.9	74.63	4.48	613.36	66.4
10	ICGV 95342	360	350	70	252	3	27.8	65.5	80.3	6.8	1	8.1	6.6	4.8	77.5	0	14.3	8.25	3492.5	880.11	8	37.96	59.26	2.78	493.85	93.54
11	ICGV 95350	490	342	68.4	335	1.8	11.3	34.5	68.5	20.3	5	3.2	2.7	1.6	66.5	0	24.8	8.75	3377.5	1132	4	34.91	65.09	0	464.41	89.83
12	ICGVSM93541	603	360	72	434	7.8	31.3	61.8	86.3	8	1.3	4.9	4.7	2.1	83.3	0	10	6.75	3565	1548.64	1.25	27.38	29.76	42.86	500	95.94
13	ICGVSM95714	900	352	70.4	634	1.5	8.3	34.8	72.5	15.5	6.3	3.8	3.5	1.1	70	0	21.8	8.25	3417.5	2165.33	5	31.82	54.55	13.64	847.95	87.72
14	ICGVSM95741	627	334	66.8	419	9.3	37	68	86.5	7.5	2	6.5	5.4	2.6	81.8	0	11.5	6.75	3550	1486.08	2	22.06	39.71	38.24	549.21	89.84
15	ICGVSM99543	840	390	78	655	8.5	48	68	77.3	6.3	0.5	22.6	15.8	9.8	0	67	0	33	2805	1837.84	10	36.14	63.86	0	635.8	93.42
16	ICGVSM99529	753	334	66.8	503	0.5	18	49.5	71.8	7.8	2.5	4.6	2.3	0.5	69.3	0	25.5	5.25	3440	1731.1	15.75	44.25	54.87	0.88	449.84	96.87
17	JL 24	657	360	72	473	7.3	31.5	68.5	85.8	5.8	0.5	4.6	2.8	1	81.8	0	15.3	3	3587.5	1696.17	6.75	28.24	69.41	2.35	551.45	36.01
18	Kwarts	563	386	77.2	435	2	26	65.3	81.5	3.8	9.5	4.4	2.8	0.6	78.8	0	9.8	11.5	3472.5	1510.17	4.25	32	68	0	500	92.94
19	PC 254K1	840	314	62.8	528	2.3	15.3	44.3	73.5	13	5	12.5	9.3	5.3	66.8	0	20.3	13	3337.5	1760.6	5	46.84	51.9	1.27	556.82	74.62
20	PC 280-K2	1003	386	77.2	775	0	2.8	25	72.3	18	4	5.4	4.9	2.4	69.3	0	19.5	11.25	3380	2618.06	1.25	32.71	67.29	0	500	93.08
21	PC 287	207	319	63.8	132	0	1.3	14.3	48.8	24.3	16.3	3.6	3	0.6	48	0	32.8	19.25	3087.5	407.1	8.75	27.68	64.97	7.34	547.75	98.31
22	PC 297-K2	1113	270	54	601	27.8	49.3	67.5	83.8	6.3	2	8.8	6	4.9	77.3	0	8.8	14	3432.5	2063.62	0.75	53.85	46.15	0	1002.99	85.03
23	PC 299-K1	863	346	69.2	597	6.3	29	64	86.3	5.5	4.3	2.9	1.8	0.8	84.3	0	10	5.75	3585	2141.78	3.75	29.58	70.42	0	601.05	95.12
24	PC 299-K19	903	315	63	569	0.8	6.8	29.8	67.5	19.5	5.5	5.1	4.8	2.1	66.3	0	23.3	10.5	3357.5	1910.75	4.5	45.16	54.84	0	551.02	94.29
25	PC 299-K5	693	327	65.4	453	0.8	9	37.5	70.8	17.8	4.5	8.6	8.3	5.6	68.3	0	16.8	15	3332.5	1511.09	2.5	31.25	68.75	0	450.64	95.54
26	PC 324-K1	1057	351	70.2	742	37	57	77.3	89.8	4.3	0	3.8	2	1	86.8	0	10.8	2.5	3642.5	2701.93	4.75	33.33	66.67	0	902.01	78.89
27	PC 327-K1	733	341	68.2	500	5.3	26.3	57.5	81	6.5	1.8	5.9	3.8	2.5	77	0	18	5	3520	1760.47	10	34.31	65.69	0	549.15	98.98
28	RR Line 10	477	287	57.4	274	7.3	17.8	35.8	60.3	17.8	6.5	16.5	14.2	4.7	0	49.8	24.8	25.5	2793.75	764.39	0.5	12.5	67.19	20.31	528.51	59.21
29	RR Line 11	337	325	65	219	0.8	22.3	51.3	75.3	15.3	3.5	13.2	11.1	4.7	67.8	0	21.3	11	3367.5	736.92	2.5	27	44	29	813.51	48.65
30	RR Line 3	867	309	61.8	536	9.8	22.5	42.8	67.3	18.5	4.8	14	11.2	3.4	59.5	0	22.3	18.25	3212.5	1720.62	0	24.68	71.43	3.9	616.97	70.64
31	RR Line 7	617	287	57.4	354	1.3	9.8	23	50.8	25.8	8	13.7	11.5	7	0	44.3	27.8	28	2741.25	970.31	0.5	32.58	58.43	8.99	474.3	64.02
32	RR Line 8	383	269	53.8	206	4	15.5	35.5	60.5	15.0 1	3.3	22.1	14.3	4.2	0	49.3	20.8	30	2746.25	566.37	0.25	33.33	55.21	11.46	427.56	80.21
33	RR Line 9	747	330	66	493	18.3	40	58.3	74.8	15.5	1	11	10.2	4.4	0	65.8	20.8	13.5	2993.75	1475.32	0.25	30.23	36.05	33.72	661.5	56.64
34	Streeton[Austr]	547	345	69	377	3	20.3	48.8	74.3	15	4.8	8.9	5.8	1.9	69	0	18.5	12.5	3365	1269.28	0	35.79	62.11	2.11	629.24	8.47
35	Swallow	853	335	67	572	16	39.8	68.8	84.5	6.8	4	1.4	0.5	0.3	83.8	0	7.8	8.5	3552.5	2031.08	1	8.82	88.24	2.94	586.81	81.94
Locality: Vaalharts																										
1	73-30 (453)	807	367	73.4	592	0	16.5	63	87	4	2.3	2.3	2.3	0.3	85.3	0	11.8	3	3622.5	2144.86	6.25	17.53	82.47	0	491.53	40.68
2	73-30 (716)	767	354	70.8	543	0	23	73	89.8	4.8	1.3	1.8	1.8	0.3	88.5	0	9.5	2	3665	1989.36	4.25	19.57	80.43	0	495.86	37.57
3	86-87/175(784)	510	354	70.7	361	30.8	68.3	86.8	93	1	0.3	1	0.5	0	92.3	0	7.3	0.5	3717.5	1340.42	5.5	33.33	66.67	0	681.32	46.89
4	86-87/175[bl]	687	373	74.5	512	28.8	59.3	78	83.3	2.3	0.5	1.8	1.5	1	82	0	16.5	1.5	3605	1844.2	13.75	30.16	63.49	6.35	671.37	18.95
5	Akwa	713	385	77	549	2	42	79.5	85.8	1.5	1.5	2	1.3	0.3	84.5	0	13.3	2.25	3622.5	1989.72	11.25	22.43	77.57	0	519.7	42.42
6	ICGV 90071	770	360	71.9	554	32	69	86.5	90	1.8	0.5	2.3	1.5	1	88.3	0	9.8	2	3662.5	2027.67	7.25	32.39	66.2	1.41	775.86	65.52
7	ICGV 90096	720	337	67.4	485	42	67	76.5	80.5	6	0.5	5.6	2.5	1.5	76	0	21.3	2.75	3532.5	1714.25	11.75	15.87	82.54	1.59	721.97	99.1
8	ICGV 90099	487	376	75.1	365	37.8	72.3	85	89.5	3.5	0.5	3.3	2.5	0.5	88.8	0	8	3.25	3655	1335.85	5.25	25	75	0	742.74	62.66
9	ICGV 90197	297	331	66.2	196	27.5	61.8	75.8	81.8	5.5	1	8.1	3.3	1.5	76	0	20.3	3.75	3522.5	691.8	11.25	17.91	79.1	2.99	720.26	75.77
10	ICGV 95342	503	382	76.4	385	4.5	40.5	70.8	82.3	3.5	1.5	1.5	0.8	0.3	81	0	17	2	3590	1380.52	12.75	41.58	55.45	2.97	539.34	70.82
11	ICGV 95350	773	389	77.8	602	14.5	50.5	78	85.8	2.3	0.3	4	2	1	83.3	0	14.8	2	3612.5	2173.47	11.25	19.44	80.56	0	619.13	30.32
12	ICGVSM93541	573	355	70.9	406	10.5	36.3	69.3	86.3	8.5	1.5	1.8	1.5	0.8	85.3	0	10.8	4	3612.5	1468.46	2	24.1	36.14	39.76	522.73	94.85
13	ICGVSM95714	410	356	71.1	292	2.5	14.8	50	84.8	5.3	0.3	2.5	2.3	2.3	82.8	0	14.8	2.5	3602.5	1050.17	9.75	35.16	50.55	14.29	526.4	32.61
14	ICGVSM95741	680	347	69.4	472	4.5	34	75.5	90.8	3	2.3	2.8	2.6	1.8	88.5	0	7.3	4.25	3642.5	1718.97	3.75	24.29	42.86	32.86	585.48	100
15	ICGVSM99543	357	376	75.2	268	5.8	40	72.5	81.8	3	1	7.1	4.8	3.5	77.5	0	16.5	6	3515	942.77	14	28.21	71.79	0	643.7	85.43
16	ICGVSM99529	760	342	68.4	520	1.5	31	68.5	86.5	2.8	1.3	1.5	1	0.3	85.5	0	12.3	2.25	3632.5	1888.32	9.25	40.35	59.65	0	472.68	62.84
17	JL 24	370	372	74.4	275	2	34.8	81	88.5	2.8	2.5	2.1	1.5	0.5	87.3	0	9	3.75	3635	1000.64	5.75	29.11	68.35	2.53	558.36	36.91
18	Kwarts	427	388	77.6	331	0.3	22.3	71.8	89.3	3	0.8	3.3	1.5	1	86.8	0	11	2.25	3645	1206.84	7	29.7	70.3	0	449.62	48.87
19	PC 254K1	897	335	67	601	4	36.3	65.5	76.5	7	2.5	12.1	1.5	1.3	69.3	0	22.5	8.25	3410	2048.61	13.25	48.84	51.16	0	651.06	69.79
20	PC 280-K2	953	394	78.8	751	1.3	10.8	55.3	87.5	6.5	1.8	1.3	1	0.3	86.5	0	11	2.5	3640	2734.47	4	36.11	63.89	0	486.11	45.56
21	PC 287	360	374	74.8	269	0	3.5	28.5	76.3	11	4	1	0.5	0.5	76	0	19.3	4.75	3512.5	945.85	8.5	32.1	61.73	6.17	327.96	95.7
22	PC 297-K2	907	340	68	617	66	81	87.5	93.5	3.5	1	20.3	2.8	1.5	76.8	0	17.5	5.75	3510	2164.03	1.25	53.23	46.77	0.00 1	558.33	13.33
23	PC 299-K1	663	364	72.8	483	3.5	46.5	74.5	82.8	1	1.3	1	0.3	0	81.8	0	17	1.25	3605	1740.88	15	34.29	65.71	0	580.7	98.95
24	PC 299-K19	270	326	65.2	176	0.8	7.3	31.5	66.3	22.5	4.3	4	3.7	1.8	65.3	0	26.3	8.5	3367.5	592.81	5	31.75	68.25	0	501.89	91.29
25	PC 299-K5	433	359	71.8	311	2	30	68.8	81.3	5.3	1.3	0.8	0.5	0.5	80.8	0	17.5	1.75	3590	1116.97	12	26.32	73.68	0	479.35	30.97

E	Entries	Pod mass (g)	Kernel mass (500 g)	Shel-ling %	Total kernel mass	Kernels above 9.00 (%)	Kernels above 8.25 (%)	Kernels above 7.50 (%)	Kernels above 6.75 (%)	Kernels above 6.00 (%)	Pan (%)	Total defec-tive (%)	Ubs (%)	Unsound (%)	Choice mark (%)	Stan-dard mark (%)	Sundry mark (%)	Chru-shing (%)	R/ton	R/ha	Splits (%)	1 Kernel Pods (%)	2 Kernel pods (%)	3 Kernel pods (%)	Kernel size	Round kernels (%)
26	PC 324-K1	970	395	79	766	57.3	80.3	87.3	91.8	2.5	1.8	7.6	1.3	1.3	86.3	0	8.8	5	3612.5	2768.26	4	38.46	61.54	0	931.47	75.63
27	PC 327-K1	437	378	75.6	330	20	57	84.3	91	1	2	1.8	1.5	1.3	89.8	0	6.8	3.5	3662.5	1209.07	5.5	39.6	60.4	0	570.53	64.26
28	RR Line 10	197	312	62.4	123	15.3	38.8	66	81.8	6.5	1.8	16.0 1	4.2	4.6	0	71.3	19.8	9	3066.25	376.29	6.5	41.79	47.76	10.45	851.56	15.63
29	RR Line 11	450	368	73.6	331	9.3	45.3	81.5	93.3	1.8	1	6.1	4.5	2	88	0	8.8	3.25	3647.5	1208.05	3.5	37	34	29	871.5	31.78
30	RR Line 3	440	353	70.6	311	36.5	69.8	88.8	94.8	1.3	0.5	3	2.8	0.5	92.3	0	6.8	1	3712.5	1153.25	3.25	38.24	61.76	0	761.04	29.32
31	RR Line 7	477	364	72.7	347	3.8	32	71	83.5	5.5	2.5	5.4	4.9	3.1	79.8	0	14	6.25	3535	1225.01	7.75	31.52	58.7	9.78	528.48	97.78
32	RR Line 8	463	308	61.6	285	6	38.5	63.5	78	8	2.5	12.2	8.3	1.6	68.5	0	24.8	6.75	3417.5	975.4	10	19.72	60.56	19.72	687.22	27.31
33	RR Line 9	590	343	68.6	405	30.8	69.8	91.8	95	2	0.5	5.1	5.1	1.3	90.3	0	7	2.75	3675	1487.42	1.25	13.16	44.74	42.11	867.58	48.86
34	Streeton[Austr]	750	385	77	578	21	66.3	88.5	93.3	1.3	4.3	1	0.8	0.5	92.3	0	3	4.75	3675	2122.31	1.25	15.52	84.48	0	821.59	0.44
35	Swallow	710	299	59.8	425	47	77.3	87.5	91.8	2	1	0.8	0.5	0.3	91.3	0	7	1.75	3695	1568.82	5	13.24	79.41	7.35	674.63	15.07

UBS	unsound, blemished and soiled kernels
PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry
ICGV/ICGV-SM	ICRISAT entries
RR	rust resistant entries

Table 5.3 Grading results on long growth season groundnut entries (Trial 5.1c) at Potchefstroom, Vaalharts, Brits, Cedara and Burgershall during 2004/05

E	Entries	Pod mass (g)	Kernel mass (500 g)	Shel-ling %	Total kernel mass	Kernels above 9.00 (%)	Kernels above 8.25 (%)	Kernels above 7.50 (%)	Kernels above 6.75 (%)	Kernels above 6.00 (%)	Pan (%)	Total defec-tive (%)	Ubs (%)	Unsound (%)	Choice mark (%)	Stan-dard Mark(%)	Sundry Mark(%)	Chru-shing (%)	R/ton	R/ha	Splits (%)	1 Kernel pods (%)	2 Kernel pods (%)	3 Kernel pods (%)	Kernel size	Round kernels (%)
Locality: Brits																										
1	Billy	2163	341	68.2	1475	44.5	80	91.5	96	1.8	0.3	0.8	0.8	0.5	95.8	0	3	1.25	3745	5525.35	1.25	1.82	98.18	0	673.68	92.98
2	CG7= ICGMS42	1523	339	67.8	1033	36.8	74.8	86.3	89.3	3	0.5	6.8	0.8	0	85	0	12	3	3620	3738.81	7	31.25	67.19	1.56	740.66	59.34
3	ICGMS42=CG7	1300	344	68.8	894	34.5	68.5	82	89	1.8	6	7.7	0.5	0.3	84	0	7.8	8.25	3557.5	3181.83	3	25.37	71.64	2.99	936.84	82.11
4	ICGV 90087	1770	353	70.6	1250	2	41.8	77.8	88.3	2.3	1.8	2.8	1	0.5	86.5	0	9	4.5	3620	4523.62	6.25	72.45	27.55	0	590.3	64.88
5	ICGV 95343	1947	353	70.6	1374	0.3	16	59.8	85.3	5.5	2.5	1.6	0.5	0.3	84.5	0	10	5.5	3590	4933.91	4.5	8.75	80	11.25	532.81	76.56
6	ICGV-SM 9821	1853	364	72.8	1349	45.5	55.3	60.8	69.5	11	0.5	24.6	2.5	1	56.3	0	31	12.75	3235	4364.75	18.75	35.19	64.81	0	992.86	39.29
7	ICGV-SM 9841	1303	345	69	899	41.8	74.5	88	93	2.8	1	2.6	1.5	1	91.3	0	4.8	4	3672.5	3302.68	1.25	16.39	83.61	0	801.72	34.91
8	ICGV-SM 99844	1757	342	68.4	1202	59.3	79.5	89	96.5	1.8	0.8	5.6	1.8	1.8	92	0	4.5	3.5	3685	4427.75	0.25	6.67	93.33	0	869.37	33.33
9	Rambo	1173	333	66.6	781	51.8	75.3	85.8	92.5	3.5	1	6.6	4.1	0.8	88.3	0	7.3	4.5	3637.5	2842.49	1.75	23.91	69.57	6.52	880.95	23.33
10	RR Line 12	520	337	67.4	350	30.5	63.5	83.5	93.5	4	0	8.3	4.8	2.5	86.8	0	9	4.25	3625	1270.49	1	27.59	39.66	32.76	672.66	20.14
11	TMV1	567	323	64.6	366	1	17.8	57	80.5	7.5	5.8	0.8	0	0	79.8	0	13.3	7	3527.5	1291.3	5	15.48	79.76	4.76	543.92	75.68
Locality: Burgershall																										
1	Billy	320	270	54	173	1	5.5	14.5	32	27	21.8	24.5	21.1	18.8	0	0	51.3	48.75	2312.5	399.6	4	11.56	87.76	0.68	410.26	89.1
2	CG7= ICGMS42	298	242	48.4	144	0	0	4.8	11.8	20.8	30.8	32.3	27.3	24.8	0	0	28.3	71.75	2082.5	300.7	2.25	35.89	62.68	1.44	419.64	33.93
3	ICGMS42=CG7	350	269	53.8	188	0	0	6.5	17.5	18.5	30	22.6	21.4	21.4	0	0	33	67	2130	401.08	3	24.29	74.01	1.69	397.73	70.45
4	ICGV 90087	402	268	53.6	215	0.8	1.5	7.5	19.5	14.5	40.3	12.1	10.7	10.7	0	18.5	14.5	67	2222.5	478.49	2.25	59.9	40.1	0	520	96
5	ICGV 95343	365	266	53.2	194	0	3.8	13.3	33.5	18.5	23.5	6.1	5.6	5.6	31.8	0	22.8	45.5	2662.5	517	5.5	7.01	91.08	1.91	424.05	94.94
6	ICGV-SM 99821	322	269	53.8	173	6.5	15	27.3	45.8	16.5	16.3	31.7	18.6	16.4	0	35.8	18	46.3	2515.75	435.37	4.5	39.35	60	0.65	415.91	82.27
7	ICGV-SM 99841	265	186	37.2	99	0	0	9	27	20.3	20.5	53.7	40.3	31.3	0	0	25.5	74.5	2055	202.58		57.69	42.31	0	400	53.33
8	ICGV-SM 99844	293	368	73.6	216	3	12	24	36	11	34.5	24.4	5	4.1	0	28.5	19.5	52	2422.5	523	7.75	20.31	78.91	0.78	406.78	81.36
9	Rambo	322	255	51	164	8	16.5	34.5	52	17.5	11	6.5	3.4	3.4	51	0	17.3	31.75	2992.5	490.92	2.5	17.17	81.82	1.01	568.31	57.38
10	RR Line 12	290	263	52.6	153	4	9	17	27.3	14.5	24.8	34	32	24.4	0	0	36.3	63.75	2162.5	329.87	2.25	27.74	41.61	30.66	736.49	24.32
11	TMV1	263	153	30.6	81	0	0	0	8.5	13	26.5	11.6	7.7	3.9	0	0	45.8	54.25	2257.5	181.91	28.25	36.8	61.71	1.49	809.52	0
Locality: Cedara																										
1	Billy	547	350	70	383	34.5	68	86.5	94.5	4	0.5	5.6	5.1	1.5	91	0	5	4	3670	1404.39	0	18.92	81.08	0	684.78	86.96
2	CG7= ICGMS42	503	339	67.8	341	34.8	64.5	82.5	92.5	3	2.5	1.5	1	0.5	91	0	5.8	3.25	3677.5	1254.98	1.75	40.54	59.46	0	651.41	96.48
3	ICGMS42=CG7	697	317	63.4	442	13.5	59.5	73.5	77.5	3	1	9.2	3.6	0	71	0	24.5	4.5	3465	1530.44	16.5	18.75	75	6.25	673.91	80
4	ICGV 90087	450	347	69.4	312	4.5	33.5	64	78	6.5	3	13.9	7.7	1.5	74.5	0	12.5	13	3415	1066.51	8.5	78	22	0	684.21	87.72
5	ICGV 95343	480	355	71	341	2	10.5	44	74.5	15	2	15.8	11.6	2.6	67.5	0	18	14.5	3330	1134.86	3.5	11.36	88.64	0	1020.55	93.84
6	ICGV-SM 99821	560	330	66	370	63.5	73.5	82	86	6	0	22.3	2.8	2.3	70.5	0	21.8	7.75	3427.5	1266.8	7.25	15.38	84.62	0	868.69	88.89
7	ICGV-SM 99841	400	345	69	276	25	66	84	95.5	2	1	5.6	2	1.5	92	0	2.5	5.5	3665	1011.54	0	36.11	63.89	0	1414.82	62.96
8	ICGV-SM 99844	727	343	68.6	498	44	69	83	90.5	2.5	1.3	12.9	4.3	3.8	80	0	13	7	3530	1759.68	5.75	25.81	72.58	1.61	830.28	68.35
9	Rambo	517	322	64.4	333	60	77.5	90.3	95.8	2.5	0.8	15.4	11.9	5.6	0	81.3	12	6.75	3138.75	1044.37	0.25	28.57	71.43	0	938.73	58.82
10	RR Line 12	263	347	69.4	183	5.5	38.5	67.5	83	8.5	1.5	7.7	3.1	3.1	80	0	11	9	3510	641.46	4.5	41.18	41.18	17.65	685.95	56.2
11	TMV1	210	308	61.6	129	0	13.5	34.5	66	15	14	1.5	1.5	0.9	65.5	0	18.3	16.25	3292.5	425.92	3.5	34.62	63.46	1.92	500	81.82
Locality: Potchefstroom																										
1	Billy	1463	316	63.2	925	19.3	37.3	62.3	84.8	8.3	1.3	2.7	2.4	1.6	83.5	0	8.8	7.75	3557.5	3290.07	0.25	11.84	88.16	0	799.53	89.62
2	CG7= ICGMS42	1000	337	67.4	674	31.8	53	72.8	84.5	6.5	2.8	5	4.2	3.2	82.5	0	8.3	9.25	3532.5	2380.91	1.25	44.3	55.7	0	800.95	98.1
3	ICGMS42=CG7	1090	345	69	752	32.8	53	73	84.5	6	3	3.4	2.9	2.1	83.3	0	9	7.75	3555	2673.72	3	34.72	62.5	2.78	857.87	70.05
4	ICGV 90087	1101	282	56.4	621	10.5	31	63.5	80.5	8	4.5	19.5	15.5	9.3	0	70.3	0	29.75	2853.75	1771.54	1.25	50	50	0	657.14	71.02
5	ICGV 95343	723	339	67.8	490	0.5	8	31	60	19.5	7.3	10.2	8	4	56.8	0	18.5	24.75	3120	1530.11	0.5	18.56	79.38	2.06	506.33	63.71
6	ICGV-SM 99821	1197	331	66.2	792	43	70.3	85	93	2	2.5	34.4	17.8	4.7	0	64	0	36	2760	2186.45	0	22.45	77.55	0	958.76	65.98
7	ICGV-SM 99841	837	315	63	527	30	52.8	71	84.3	8	4.5	5.9	3.2	2.1	80.8	0	9	10.25	3505	1847.49	0.75	31.88	68.12	0	798.58	58.29
8	ICGV-SM 99844	1573	295	59	928	28.8	50.5	70.5	83.3	10.3	1.8	6.8	3.7	0.8	78.3	0	15.5	6.25	3520	3267.5	2	16.07	82.14	1.79	717.67	33.19
9	Rambo	1050	303	60.6	636	38	62.3	78	88.8	6.3	2.5	9.1	2.9	2.1	83.5	0	8.3	8.25	3552.5	2260.46	0	37.04	62.96	0	1199.32	14.19
10	RR Line 12	490	325	65	319	11.8	34.3	50	61.5	12	21.3	14	10.4	1.3	0	52	23.5	24.5	2815	896.58	3	35.38	38.46	26.15	476.74	31.78
11	TMV1	520	292	58.4	304	0	0.8	14.3	48.5	32	12	3.7	2.1	1.2	47.3	0	32.3	20.5	3067.5	931.54	0	21.21	78.79	0	433.04	62.95
Locality: Vaalharts																										
1	Billy	1080	361	72.2	780	74.8	86.8	90.8	93	1.8	0	2.5	0.5	0	91.3	0	7.8	1	3702.5	2887.06	5	11.39	88.61	0	830.36	88.84
2	CG7= ICGMS42	1113	377	75.4	839	70.3	83	90.5	93.5	2.5	0.8	4.1	1.8	0.8	90.3	0	6.8	3	3672.5	3082.89	1.75	30.16	69.84	0	842.34	97.75
3	ICGMS42=CG7	1053	374	74.8	788	65.5	83.5	91.3	94.5	2.3	1	3.1	1	1	92.3	0	4.3	3.5	3687.5	2905.36	1	26.15	72.31	1.54	904.31	70.33
4	ICGV 90087	790	346	69.1	546	7.8	42.3	65.3	69.5	6.8	0	1	0.8	0.5	69	0	30.3	0.75	3482.5	1901.06	23.25	40	58.33	1.67	776.54	57.54
5	ICGV 95343	563	349	69.8	393	2	17.5	57.5	78.5	9	6	2.5	1.9	1.4	77.5	0	11.8	10.75	3467.5	1363.44	3.5	14.63	81.71	3.66	568.84	70.65
6	ICGV-SM 99821	880	322	64.4	567	74	79.8	83.5	89	5.3	0	14.8	0.5	0.5	79.5	0	14.8	5.75	3537.5	2004.77	5.75	25	75	0	1227.59	13.79
7	ICGV-SM 99841	937	339	67.7	634	62.8	85.5	95	98.8	0.3	0	4	3	2.3	95.5	0	0	4.5	3710	2352.6	0	34.92	65.08	0	901.83	15.07
8	ICGV-SM 99844	937	349	69.7	653	55.5	69.5	77.5	87.3	6.8	2.8	15.4	2.1	1.8	73	0	22.5	4.5	3485	2275.21	2.75	19.64	76.79	3.57	1118.59	66.03
9	Rambo	777	333	66.6	517	68.3	76.8	85	91.3	3	0.8	12.9	5.1	1	79	0	18.5	2.5	3565	1844.03	4	41.38	58.62	0	1361.94	0
10	RR Line 12	533	326	65.2	348	34.3	66.3	85.8	93.3	2.5	0.3	7.3	4.5	2.8	87	0	9.3	3.75	3632.5	1263.14	2.75	32.61	26.09	41.3	783.61	47.9

11	TMV1	300	340	67.9	204	0.5	12.3	41.8	69.8	10	8.3	1.4	1.4	0.6	68.8	0	21.5	9.75	3390	690.54	11	18.89	80	1.11	549.21	85.04

UBS unsound, blemished and soiled kernels
PC Potchefstroom cross
-K progeny of single plant selections
E entry
ICGV/ICGV-SM ICRISAT entries
RR rust resistant entries

APPENDIX 6

Table 6.1 Grading results on Elite short/medium growth season groundnut entries at Brits during 2004/05

Plot size:16.2mS2T

E	Entries	Pod mass g	Kernel mass 500 g	Shel-ling %	Total kernel mass g	Kernel above 9%	Kernel above 8.25%	Kernel above 7.50%	Kernel above 6.75%	Kernel above 6%	Pan %	Total defec-tive %	Ubs %	Un-sound %	Choice mark %	Std mark %	Sundry mark %	Chru-shing %	R/ton	R/ha	Splits %	1 Kernel pods %	2 Kernel pods %	3 Kernel pods %	Kernel size	Round kernels %
1	Akwa	8288	376	75.2	6233	0.3	23.8	67.8	87	3.3	4.5	5	3.2	1.8	82.8	0	10.5	6.75	3242.75	12476.04	4.5	15.63	84.38	0	461.54	97.35
7	Kwarts	6856	382	76.4	5238	0.5	14.5	52.8	87.5	7	2	7.2	6.7	3.3	82.3	0	10.8	7	3234.75	10459.16	2.5	30.1	69.9	0	434.24	96.53
3	Harts	4983	370	74	3687	9.5	45.3	78.3	91	2	1.8	35	34.3	10	0	0	87.5	12.5	2275	5177.8	4.5	26.67	73.33	0	558.28	94.17
2	Anel	8263	382	76.4	6313	0.5	25	70.8	90.3	3.8	2.5	7	5.7	3.6	84.5	0	8.8	6.75	3262	12710.83	2.75	10.64	89.36	0	486.52	96.5
5	Kan Red	5145	360	72	3704	1	14.3	51.8	84.3	10.8	2.8	29.4	29.1	13.2	0	0	81.5	18.5	2215	5064.97	0.75	3.85	9.62	86.54	486.99	90.17
6	Kano	4480	335	67	3002	0.8	14.5	51.3	83	10.8	2.8	28.7	28.5	14.4	0	0	80.8	19.25	2207.5	4090.14	1.75	15.38	20	64.62	483.97	92.42
20	PC327-K1	7685	355	71	5456	1	41.5	72.8	86	3	3.3	7.8	5.2	2.6	79.5	0	14	6.5	3209.5	10809.97	7	12.99	87.01	0	500	99.13
23	PC327-K2	7330	366	73.2	5366	5	50.5	73.8	79.8	2.8	3.5	12.7	9.4	7.5	0	69	19.8	11.25	2701.5	8947.57	12.5	14.81	85.19	0	538.85	98.65
25	PC327-K7	6658	368	73.6	4900	1.3	25.8	66	84.5	6	4.8	4.2	3.2	1.3	81	0	12.5	6.5	3226	9758.53	4.25	16.82	83.18	0	449.47	98.14
21	PC327-K11	7438	363	72.6	5400	1.8	33	66	82.8	5.5	5.3	8.7	7.4	4	75.3	0	15.3	9.5	3132.75	10441.77	6.25	23.16	76.84	0	491.1	96.14
22	PC327-K13	7523	347	69.4	5221	1.8	25.3	58.5	82.5	7.8	5.3	9.3	7.2	4	75.5	0	14	10.5	3125.5	10072.24	3.75	16.19	83.81	0	443.55	96.24
24	PC327-K31	8048	371	74.2	5971	0	25.5	67	85.5	7.3	4.8	8.4	5.5	3.9	79.8	0	10	10.25	3174.75	11701.98	1.75	16.36	83.64	0	446.48	98.96
10	PC280-K1	8443	383	76.6	6467	0	0	19.5	64.8	21	4.5	12.3	9.9	3.5	57.8	0	30	12.25	2912.75	11627.55	7.25	32.28	67.72	0	431.67	98.33
11	PC280-K2	7095	385	77	5463	0	3.8	33	78.3	15.5	3.5	5.8	5.2	3.1	74.5	0	17	8.5	3134.5	10570.33	1	27.5	72.5	0	442.09	97.74
12	PC280-K4	8310	383	76.6	6365	0	2.3	30	76.3	15.5	5.8	5.4	4.6	1.6	73	0	17.5	9.5	3108	12212.25	0.5	30.77	67.69	1.54	422.44	97.51
13	PC280-K5	8675	369	73.8	6402	8.8	39.8	76.8	92	5	0.8	7.4	6.4	2	87	0	7.3	5.75	3299.5	13039.44	1.25	19.32	78.41	2.27	576.8	91.22
14	PC299-K1	7493	367	73.4	5499	7	37.8	70	85.5	3.5	3	11.6	8.5	5.7	76.3	0	14.3	9.5	3143.75	10672.25	6.5	9.76	90.24	0	521.34	94.51
18	PC299-K2	7960	350	70	5572	2.8	30.8	63.8	82.3	4.8	3.5	9.1	7.8	2.6	75.3	0	17.5	7.25	3155.25	10852.5	8.5	8.79	91.21	0	478.2	94.48
19	PC299-K5	5953	355	71	4226	2.3	14.5	47.5	70	5.5	4.3	6.3	3.7	2.4	65.3	0	27.8	7	3047.75	7951.01	19	10.59	89.41	0	479.45	95.89
15	PC299-K14	7051	348	69.6	4907	0.3	11.8	51.5	76.5	8	5.8	7.8	5.3	3.5	70.3	0	19.5	10.25	3070.25	9300.36	8.5	9.68	90.32	0	467.89	94.8
16	PC299-K17	7185	355	71	5101	1.8	13.5	47.3	73.3	7.5	4.8	10	7.9	4.2	66.3	0	23.5	10.25	3026.25	9529.6	13	13.13	85.86	1.01	475.65	94.81
17	PC299-K19	6635	353	70.6	4684	1.5	13.3	43.8	74	9	5.3	6.9	5.8	3.2	69	0	21.5	9.5	3064	8859.71	10.5	17.78	81.11	1.11	474.36	97.44
4	ICGV-SM95714	6665	346	69.2	4612	2.3	15	51.8	81.3	8.3	3.5	9.4	7.3	3.4	74	0	17.3	8.75	3126.5	8901.22	5.75	27.94	48.53	23.53	519.17	97.44
9	Nyanda	6045	362	72.4	4377	0	8.8	50.8	82.3	7.8	6.5	10.5	9.7	4	74.8	0	13.3	12	3102.25	8381.02	2.5	23.42	76.58	0	439.84	96.79
8	Mwenje	6178	369	73.8	4559	0.8	13.3	55.3	84.3	7	2.5	14.1	12.1	6.9	0	73.3	16.3	10.5	2734.5	7695.42	5	16.04	83.96	0	464.19	96.42

PC Potchefstroom cross
-K progeny of single plant selections
E entry. Entry no. the same as no. used for ratings
UBS% unsound, blemished and soiled kernels
ICGV (SM) ICRISAT entry

Table 6.2 Grading results on Elite long growth season groundnut entries at Brits during 2004/05

Plot size:16.2mS2T

E Entries	Pod mass g	Kernel mass 500 g	Shel-ling %	Total kernel mass g	Kernel above 9%	Kernel above 8.25%	Kernel above 7.50%	Kernel above 6.75%	Kernel above 6%	Pan %	Total defec-tive %	Ubs %	Un-sound %	Choice mark %	Std mark %	Sundry mark %	Chru-shing %	R/ton	R/ha	Splits %	1 Kernel pods %	2 Kernel pods %	3 Kernel pods %	Kernel size	Round kernels %
1 Billy	6905	363	72.6	5013	47	72.5	85.8	91	2.8	0.8	13.6	12.4	8.6	0	80	9.8	10.25	2777.5	8594.87	3.75	16.39	83.61	0	650	91.07
15 Rambo	5613	309	61.8	3469	64	82.8	90.8	95.3	1.5	0.8	15	10.7	7.1	0	81.8	9	9.25	2798	5990.7	1.5	20.45	77.27	2.27	680.36	32.14
4 PC294-K2	7958	331	66.2	5268	74.5	88.8	92.5	96	1.8	0.3	10.3	8.8	4.8	87.5	0	6.3	6.25	3300	10731.1	1.25	10.87	89.13	0	872.73	72.27
5 PC297-K6	2610	290	58	1514	69	82	89.5	94	4.3	0	37.5	29.7	13.4	0	0	84.3	15.75	2242.5	2095.49	0.75	55.56	44.44	0	1125.75	34.73
6 PC297-K7	2445	329	65.8	1609	81	88	92.8	96.8	1.8	0	31.2	28.4	14.1	0	0	84.5	15.5	2245	2229.49	0.75	42.86	57.14	0	1209.38	37.5
7 PC322-K5	3163	344	68.8	2176	71	87	92.5	95.3	3	0.8	16.6	14.9	7.6	0	81	0	19	2696	3620.96	0.5	13.95	86.05	0	1147.59	63.86
8 PC322-K7	3943	363	72.6	2862	81.5	91.3	95.5	98.3	1.5	0	27.5	23.5	12.3	0	0	87.3	12.75	2272.5	4015.11	0	13.51	86.49	0	1122.86	58.29
9 PC322-K8	3013	332	66.4	2000	66.3	84.3	91.8	95.3	2.5	1	25	24	13	0	0	84	16	2240	2765.85	0	33.33	66.67	0	1168.71	31.29
10 PC323-K1	7230	334	66.8	4830	37	73.5	89.5	95	1.5	1	7.4	5.1	1.3	88.8	0	7.5	3.75	3338.8	9953.68	1.25	10.64	80.85	8.51	798.32	62.18
12 PC324-K1	5350	369	73.8	3948	68.5	85	90	93.3	1.5	0.5	10.1	9	3.8	84.5	0	10.8	4.75	3282	7998.96	4.25	15.69	84.31	0	867.44	86.98
11 PC325-K1	5530	312	62.4	3451	29.3	61	80.5	90.3	3.5	0.5	16.3	13.5	7.7	0	75.8	13.8	10.5	2749.5	5856.64	3.75	6	84	10	681.13	69.81
13 PC325-K5	4555	340	68	3097	37.3	64.5	84	92.5	2.3	1.3	25.1	21.8	15	0	0	83.3	16.75	2232.5	4268.49	2.5	26.98	73.02	0	787.23	76.17
14 PC328-K1	4807	340	68	3269	39	70.3	84.8	93.3	1.5	1.8	37.9	37.7	20.6	0	0	77.8	22.25	2177.5	4394.03	1.5	54.41	45.59	0	740.08	90.08
2 ICGV-SM-92736-K2	3618	339	67.8	2453	57.3	79.5	91.3	96.5	1.3	0.5	20.7	17.2	6.1	0	76.5	16.3	7.25	2786.5	4218.87	1	12.96	83.33	3.7	731.06	87.12
3 ICGVSM-2760-K2	4365	321	64.2	2802	60.5	76.8	86.5	89.5	3.5	0.5	14.7	12.4	6.1	0	78.3	13.5	8.25	2787	4821.05	4.25	9.76	78.05	12.2	947.09	56.61

PC Potchefstroom cross
-K progeny of single plant selections
E entry. Entry no. the same as no. used for ratings
UBS% unsound, blemished and soiled kernels
ICGV (SM) ICRISAT entry

Table 6.3 Grading results on ICRISAT long growth season groundnut entries at Brits during 2004/05

Plot size:16.2mS2T

E Entries	Pod mass g	Kernel mass 500 g	Shel-ling %	Total kernel mass g	Kernel above 9%	Kernel above 8.25%	Kernel above 7.50%	Kernel above 6.75%	Kernel above 6%	Pan %	Total defec-tive %	Ubs %	Un-sound %	Choice mark %	Std mark %	Sundry mark %	Chru-shing %	R/ton	R/ha	Splits %	1 Kernel pods %	2 Kernel pods %	3 Kernel pods %	Kernel size	Round kernels %
4 ICGV-SM-99821	2154	351	70.2	1512	81.3	88.3	94	95.8	1.8	0.3	19.1	14.4	7.8	0	78	12.5	9.5	2773	5177.34	1.75	27.08	72.92	0	934.15	76.1
3 ICGV-SM-90704	2798	331	66.2	1852	3	20	56.3	78.5	9.5	5	9	8.2	4.2	73.8	0	14.8	11.5	3096.25	7079.12	5	17.39	82.61	0	596.96	79.09
7 I CGV-SM-99844	2420	344	68.8	1665	62	78.5	87.5	92.8	1.5	1.5	11	7.9	3.8	82.8	0	10.8	6.5	3245.25	6670.63	3	4.44	91.11	4.44	883.33	69.52
8 ICGV-SM-99847	965	309	61.8	596	61.3	75.5	84.3	89.5	5.8	0.8	25.8	21.9	11.5	0	0	84.8	15.25	2247.5	1654.74	1.5	6.38	89.36	4.26	908.63	66.5
6 ICGV-SM-99841	2923	323	64.6	1888	39.5	72.3	86.8	93.3	3.3	0.8	18.3	15	5.6	0	77	14.8	8.25	2779.5	6478.41	1.25	25	75	0	767.49	68.72
5 ICGV-SM-99840	2445	325	65	1589	35.3	73.5	89	93	2.3	1.3	17.6	13	5.9	0	77.3	14.5	8.25	2781	5456.42	2	21.31	77.05	1.64	681.32	86.81
2 CG7	2485	362	72.4	1799	51	74.5	86	92	2.5	1.3	17.8	16.8	11.1	0	0	85.3	14.75	2252.5	5003.16	1.75	20.63	77.78	1.59	747.97	81.3
9 Rambo	2620	324	64.8	1698	51.5	70.5	83	89.3	2.5	0.3	14.8	11.7	5.9	0	77.3	14.5	8.25	2781	5828.98	4.75	11.9	83.33	4.76	910.71	35.2
1 Billy	4115	359	71.8	2955	47.3	75.3	89.5	93	2	1.3	17.6	16.8	9.7	0	77.3	11	11.75	2746	10016.36	2.25	13.33	86.67	0	694.03	79.85

E entry. Entry no. the same as no. used for ratings
UBS% unsound, blemished and soiled kernels
ICGV (SM) ICRISAT entry

APPENDIX 7

2003/04

	October			November			December			January			February			March			April			May		
	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst
Brits																								
Rain	1.9	34.5	0	2	9.5	0	2.4	25	0	6.7	66	0	6.4	50	0	4.2	54	0	0.8	19	0	0	0	0
Tmax	29.8	35.5	10.8	29.4	34.3	22.7	33	37.1	24.7	30.5	36.6	18	29.1	34.8	22.7	26.8	31.3	17	26.2	29	23.5	25	28.3	20.7
Tmin	14.5	22.3	9	16.8	22	11.8	17.8	33.2	12.6	18.1	22	14.3	16.7	19.3	14.1	16.1	20.5	11	12.1	17.6	7.8	5.6	13.5	1.3
RHx	71.1	97	41	84.3	94	56	78.6	92	46	86.7	96	69	92.2	97	78	94.5	98	86	93.4	97	61	95.3	98	91
RHn	28	68	13	32.2	64	13	23.9	59	11	34.5	63	18	37.6	83	19	43.8	83	23	34.3	54	19	24.4	39	14
Burgershall																								
Rain	0.9	12.3	0	3.6	31.5	0	2.3	37.8	0	7.5	43.5	0	11.6	107	0	5.4	50.5	0	1	12.9	0	0.3	4.7	0
Tmax	27.4	36.5	11.9	27	33.6	17.8	30	37.4	18.9	27.5	34.9	19.4	27.1	29.3	23.3	25.9	29.4	17.5	25.5	32.1	21.6	23.9	30.7	18.8
Tmin	15.2	19.4	9.5	17	21.4	13.4	17.9	22.2	13	18.7	21.2	15.7	18.7	20.5	14.8	17.8	20.4	14.6	15.9	20.2	11.1	11.6	18	7.7
RHx	82.6	94	33	91	93	79	86.6	93	56	92.4	96	81	92.4	94	86	98	98	98	97.6	99.7	83.5	97.3	98.9	88.9
RHn	35.1	77	17	42.7	86	24	36	69	22	48.6	88	31	49.4	73	31	68.3	95.3	51.8	63.7	91.1	29.4	50.2	78	20.9
Cedara																								
Rain	0.7	9	0	3	28.1	0	3.5	27.3	0	4.7	41.3	0	4.8	28	0	2.5	31.1	0	0.5	6	0	0	1.1	0
Tmax	23.9	35.8	11.2	24.9	34.9	15.8	25.3	31.3	17.4	25.4	33.3	18.2	25.3	31.4	17.4	24.3	31.8	15.1	24	30	15	23.1	28.4	15.8
Tmin	11.1	19.3	4.3	13.3	18.3	8.5	14.9	18.5	10.3	15.7	18.8	11	15.8	18.8	10.5	15.7	18.9	12	11.1	16.6	7.1	7.1	12.2	0.3
RHx	88.3	94	54	90.6	97	70	90.1	93	60	92.4	94	90	92.3	93	88	92.2	94	79	92.6	94	85	86.1	96	50
RHn	38.4	89	14	43.9	79	19	43.1	84	15	53.4	87	29	53.1	89	29	49.9	76	24	40.6	64	19	29	60	16
Potchefstroom																								
Rain	1.7	18.2	0	3.5	32	0	0.8	20	0	2.6	32.5	0	5.6	60.8	0	3.1	28.3	0	0.6	19.4	0	0.2	6.8	0
Tmax	28.8	35	9.5	28.8	34.5	23.5	31.8	36.5	25	29.1	34	19	27.7	33.5	19	25.6	29.5	19	24.5	27	19.5	23.5	26	15
Tmin	14	21.5	6.5	16	19.5	9.5	17.4	22.5	9.5	17.9	22	14	16.9	19.5	14	15.2	18.5	11	11.3	17.5	5	6.4	11	1.5
RHx	68.2	93	44	85.2	95	64	70.8	91	47	80.5	90	58	82	88	75	87.5	96	73	91.6	96	81	90.8	96	83
RHn	34.7	75	25	42.5	64	28	30.8	52	21	40.7	72	28	40.3	71	24	46.3	64	33	41.6	55	29	34.7	62	28
Vaalharts																								
Rain	0.4	10.1	0	2.4	24.8	0	0.9	10	0	2.2	32.4	0	1.4	7.9	0	2.9	30.7	0	0.7	12.9	0	0	0.4	0
Tmax	29.9	34.9	15.9	30.7	36	23.4	32.8	37.5	22.7	30.9	36.6	22.5	30.8	35.4	19.1	28.6	33.3	23.6	26.2	30.1	18.7	25.7	28.7	18
Tmin	10.6	19.4	3.7	14.1	19.5	8.6	13.4	23.9	6	16.2	20.8	11.7	15.3	18.4	9.2	14	18.7	7.2	8.8	16.3	1.1	4.7	10.3	-3.5
RHx	83.2	100	62.8	89.5	100	66.4	81.4	100	40.4	93.7	100	74.2	95.7	100	81.2	97.8	99.1	90.8	97	99.4	84.1	87.7	98.5	73.4
RHn	20.9	53.4	7.8	25.9	73.8	10.3	18.9	56.1	9.2	35.2	75.2	11.1	34.6	84.1	9.8	41.6	64.2	19	38.6	64.2	17.6	22.9	33.2	16.4

2004/05

	October			November			December			January			February			March			April			May		
	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst	Mean	Highst	Lowst
Brits																								
Rain	1	15	0	2.7	36.5	0	5.5	60.5	0	4.7	65	0	1.8	36	0	2.2	18	0	2.5	42	0	0	0	0
Tmax	30.5	35	21.6	32.6	36.3	28.5	30.1	33.7	22.8	29.8	32.9	25.7	31.7	35.8	24	29.2	34.7	21.2	25.2	30.8	17.5	25.6	29.5	22
Tmin	12.8	18.4	4.5	16.2	21.5	8.5	17.3	21	14	18.6	20.5	16.7	17.2	20.2	14	15	18.3	12.9	12.5	18.4	7	6.1	11.8	0.2
RHx	77.5	96	40	79.8	94	56	89.9	96	78	90.5	95	76	86.9	97	64	90.5	97	61	91.7	96	72	90.4	97	66
RHn	24.4	47	14	23.9	34	17	33.7	65	22	38.2	64	26	28.1	64	17	30	73	14	35.6	87	22	21.9	34	13
Burgershall																								
Rain	1.6	16	0	2.4	12.7	0	2.9	56.8	0	4.7	29.2	0	2.5	23.4	0	3.5	52	0	1.9	27.2	0	0.6	7.4	0
Tmax	26.9	39.1	17.5	29.5	35.6	22	29.1	35	19.5	28.6	33.3	21.6	29.5	34.2	24.2	27	33.6	21	25.7	32.1	19.8	24.9	31.4	14
Tmin	15	18.4	10.4	17.4	22.9	10	18.7	21.5	15.7	19.6	21.7	17	19	20.8	16.2	17.6	20.6	15	15.6	19.8	11.1	13.2	18.3	10.3
RHx	94.4	99.9	63.8	97.9	99.9	91	98.2	99.9	98	98	99	96.7	97.9	100.1	90.3	98.1	99.9	98	97.7	98	90	97.7	99.7	92.3
RHn	47.8	92.5	10.7	48.5	85	21.6	53.7	88.5	33.3	62.1	90.2	39.1	53.8	77.1	33.5	60.3	93.2	34.8	57.9	89.9	27.5	51	91	16.1
Cedara																								
Rain	2.3	15.5	0	4	22.7	0	4.1	29	0	7.5	46.2	0	4.6	29.9	0	5.2	27.6	0	0.8	9.9	0	0.2	4.5	0
Tmax	24.4	34.3	13.8	26.7	33.8	16.7	26.4	34.1	16.9	25.4	34.7	18.3	26.3	34.4	18.3	23.8	30.8	16.4	22.8	30.7	15.4	22.5	27.5	11.3
Tmin	11.4	16.3	2.7	14.5	18.3	9.8	15.4	18.8	12.1	15.8	19.3	12.3	16.1	18.6	13.2	13.6	16.7	9.4	10.9	15.7	4.8	6.5	12.3	1.5
RHx	87.4	95	51	92.9	96	75	93.9	95	90	93.8	96	65	94.5	96	91	95.6	98	94	93.9	97	82	91.1	97	66
RHn	27.6	53	18	45.4	89	19	51	86	23	60.9	93	32	53.5	84	21	54.6	88	32	45.3	76	24	33.7	66	18
Potchefstroom																								
Rain	2.1	46.3	0	1.7	18.2	0	4	18.5	0	6.1	60.5	0	2.5	24.8	0	1.8	22.6	0	2	16.5	0	0.2	2	0
Tmax	28.1	33	17.6	31.6	35.4	24.8	29.7	35	24.4	29.7	36.2	21.8	29.4	33.4	22	26.9	31.4	17	23.7	28.6	18.3	23.2	26.5	8.3
Tmin	12.2	18.3	1.5	15.6	19.8	9.5	16.5	19	12.1	17.3	21.4	15.2	16.5	18.9	14.6	13.6	16.7	10.8	10.4	16	5.6	5.4	8.4	2
RHx	75.2	98.4	31.7	75.8	95	52.6	89.3	97.1	76	89.7	97.9	71.2	90.9	98.2	76.4	91.2	96.7	79.1	94.6	98.6	85.3	91.1	95.9	78.5
RHn	21.3	69.5	6.7	18.5	52.6	7.4	31.5	53	14.8	37	82.6	12.6	35.1	68	18.3	35.9	90.1	16.8	40.6	83.4	25.6	26.4	79.3	13
Vaalharts																								
Rain	0.1	3	0	1.6	22.2	0	4.3	34.5	0	2.7	23.3	0	0.5	3.5	0	0.8	6.9	0	0	0	0	0.1	1.1	0
Tmax	28.6	33.9	18.5	33.4	37.5	26.9	32.2	35.8	26	31.5	38	22.8	31.2	34.8	23.4	26.7	30.2	19.2	24.7	29	17.4	24	28.1	11.1
Tmin	9.3	15.9	-2.5	13.5	19.9	4.1	15.4	20.6	6.5	15.6	21.4	11	15.5	18.9	10.6	13.6	16.4	8.2	8.7	16.6	0.8	4.6	9.5	0.4
RHx	90.3	99.4	59.1	87.3	98	62.9	94.2	99.9	79.8	91.9	98.7	63	97.9	100.2	94.3	98	98	98	97.9	99.5	94.9	96.3	99.8	94.3
RHn	25.1	60.2	10.7	18.6	32.7	10.2	29.8	69.4	15.2	36.7	80.1	11.9	37.8	74.7	23.3	47.8	90.8	29.6	42.3	72.1	24.6	31.7	78.9	21.3

APPENDIX 8

Table 8.1 Grading results on Elite short/medium growth season groundnut entries at Vaalharts (fungicides used to control early leaf spot, late leaf spot, web blotch and rust) during 2004/05

Plot size:6mS2T

E Entries	Pod mass g	Kernel mass 500 g	Shel-ling %	Total kernel mass g	Kernel above 9%	Kernel above 8.25%	Kernel above 7.50%	Kernel above 6.75%	Kernel above 6%	Pan %	Total defec-tive %	Ubs %	Un-sound %	Choice mark %	Std mark %	Sundry mark %	Chru-shing %	R/ton	R/ha	Splits %	1 Kernel pods %	2 Kernel pods %	3 Kernel pods %	Kernel size	Round kernels %
1 Akwa	4768	379	75.8	3614	7.5	50.8	79.8	85.5	1.5	3.5	3.6	1	0.5	82.5	0	12.8	4.75	3260	19634.79	9	6.33	93.67	0	546.33	95.53
2 Kwarts	3733	384	76.8	2867	3.8	34.3	79.5	91.3	2.3	3.3	2.3	0.8	0	89	0	7.5	3.5	3344	15976.3	3	38.83	61.17	0	505.54	97.23
3 Harts	3373	363	72.6	2448	15.8	58.3	85.8	90.8	2	1.3	26.2	24.4	2.3	0	0	95.8	4.25	2357.5	9620.31	5.5	35.23	64.77	0	602.99	91.69
4 Anel	5350	381	76.2	4077	11.5	44.5	79.8	90	2.5	2.3	4.1	2.3	0.3	86.5	0	10.5	3	3321.5	22567.93	5	25	75	0	557.28	90.71
5 Kan Red	4020	371	74.2	2983	4.5	21.5	62.8	89.5	3.8	2.8	7.6	6.8	3.7	83	0	8.3	8.75	3225.5	16035.25	2	5	15	80	528.02	86.43
6 Kano	4433	374	74.8	3316	3.5	26.5	67	90.8	4	2	8.3	7.8	3.6	83.8	0	9.3	7	3251.25	17965.92	1.5	18.57	27.14	54.29	533.82	89.41
7 PC327-K1	4210	355	71	2989	24.5	59.8	81	86.8	2	4	3.1	1.3	0.3	84	0	11.8	4.25	3281.5	16347.89	7	32.97	67.03	0	590.14	97.96
8 PC327-K2	4618	368	73.6	3398	36.3	73.5	89.8	93	1.3	2	4.1	3.1	1.3	89.5	0	7	3.5	3349.5	18972.01	3.25	27.16	72.84	0	617.94	98.34
9 PC327-K7	4533	366	73.2	3318	16.3	49	80.8	91	1.8	2	3.3	1	0.3	87.8	0	9.8	2.5	3340.25	18470.41	5	17.02	82.98	0	524.5	95.39
10 PC327-K11	4730	351	70.2	3320	27	62.8	87.8	94.8	1	1.3	3.3	1.5	0.8	91.5	0	6.3	2.25	3384	18727.4	2.75	27.59	72.41	0	611.29	90.32
11 PC327-K13	4778	351	70.2	3354	3.5	43.5	74.3	84	2.3	5.3	3.7	1.3	0.5	81	0	12.8	6.25	3228.5	18046.26	8	24.24	75.76	0	498.52	97.63
12 PC327-K31	5100	364	72.8	3713	17.3	51.3	80.5	91.3	1.5	4.3	1.8	1.3	0	89.8	0	5.5	4.75	3339.75	20666.37	2.75	18.56	81.44	0	519.94	96.58
13 PC280-K1	5110	393	78.6	4016	0.3	18	55.3	87.3	9.8	2	3.3	1.5	0.3	84.3	0	12.5	3.25	3294.25	22052.04	0.25	16.98	83.02	0	505.8	93.33
14 PC280-K2	5038	389	77.8	3919	0.3	14.8	56.5	86.3	5.5	2.8	3.1	1.3	0.3	83.5	0	13	3.5	3283.5	21447.69	5.25	22.64	77.36	0	494.27	93.98
15 PC280-K4	4803	385	77	3698	0	15.3	54.5	84.5	9	2.8	1.8	1.3	0.5	83.5	0	12.5	4	3278.5	20206.08	3.5	37.72	62.28	0	484.24	96.28
16 PC280-K5	4708	379	75.8	3568	27.8	65.3	86.3	92.8	1.8	2.8	4.6	1.8	0.8	88.5	0	7.8	3.75	3336	19839.67	2.5	15.38	84.62	0	667.27	88.85
17 PC299-K1	4460	369	73.8	3291	24.8	63.8	86.5	91.3	1.5	2.3	3.3	1.8	1.3	88.3	0	8	3.75	3333.25	18285.54	4.75	29.49	70.51	0	625	93.84
18 PC299-K2	4005	356	71.2	2852	11.5	50.8	81.3	90.3	2	1	4	2.5	0.8	86.5	0	11.5	2	3331.5	15833.29	6.5	43.48	56.52	0	564.06	90.31
19 PC299-K5	4098	372	74.4	3049	21.3	52	79.5	86	1.5	3.5	3.4	1.3	0.3	82.8	0	13.3	4	3270.25	16615.81	8.75	36.96	63.04	0	620.94	92.42
20 PC299-K14	4510	358	71.6	3229	10.8	42	72.3	81.8	1.5	2.5	5.7	2.1	0.8	77	0	19.3	3.75	3209.5	17273.32	13.75	39	61	0	588.13	93.53
21 PC299-K17	4698	357	71.4	3354	7.3	42.8	76	86.5	2.3	2	4.6	2	0.5	82.8	0	13.8	3.5	3275.25	18308.73	9	26.37	73.63	0	580.54	93.29
22 PC299-K19	4353	363	72.6	3160	9.8	36.8	69.8	78.5	2.8	3	4.1	1.8	0.8	74.8	0	21.5	3.75	3184.75	16772.57	15.5	32.47	67.53	0	585.82	95.9
23 ICGV-SM95714	4830	361	72.2	3487	2.5	18.3	54	83.3	6.5	3.3	6.3	3.7	0.8	78	0	16.8	5.25	3205.5	18630.69	5.5	27.16	59.26	13.58	528.57	94.6
24 Nyanda	3645	383	76.6	2792	1.3	25.8	71.8	89	2.8	3	10.3	7.2	2.6	80.3	0	13.8	6	3222.75	14996.91	4.5	31.63	68.37	0	497.21	94.69
25 Mwenje	3893	374	74.8	2912	7.8	36.3	80.8	92	1.5	1.3	5.8	4.8	1.8	86.5	0	10.3	3.25	3319	16105.95	4.75	31.68	68.32	0	534.88	95.64

PC	Potchefstroom cross
-K	progeny of single plant selections
E	entry. Entry no. the same as no. used for ratings
UBS%	unsound, blemished and soiled kernels
ICGV (SM)	ICRISAT entry

Table 8.2 Grading results on Elite long growth season entries at Vaalharts (fungicides used to control early leaf spot, late leaf spot, web blotch and rust) during 2004/05

Plot size:6mS2T

E Entries	Pod mass g	Kernel mass 500 g	Shel-ling %	Total kernel mass g	Kernel above 9%	Kernel above 8.25%	Kernel above 7.50%	Kernel above 6.75%	Kernel above 6%	Pan %	Total defec-tive %	Ubs %	Un-sound %	Choice mark %	Std mark %	Sundry mark %	Chru-shing %	R/ton	R/ha	Splits %	1 Kernel pods %	2 Kernel pods %	3 Kernel pods %	Kernel size	Round kernels %
1 Billy	6033	327	65.4	3945	67.3	81.8	87.5	91.5	2.3	1.8	5.7	4.6	0.5	86.3	0	10	3.75	3311.3	21772.9	3.25	20.34	79.66	0	768.91	88.24
2 Rambo	4478	306	61.2	2740	72.3	83.3	88.8	92.3	2	0.8	11.1	5.9	1.8	82	0	12.8	5.25	3249.5	14840.6	2.25	20	72.5	7.5	1072.68	28.49
3 PC294-K2	4823	346	69.2	3337	70	80	83.8	87.5	1.8	0.5	11.1	6.8	0.3	77.3	0	20.5	2.25	3227.3	17949.8	9.5	16.67	83.33	0	902.06	63.92
4 PC297-K6	4460	338	67.6	3015	78.3	84.5	86.5	91.3	5	1.3	23.9	13.6	3.9	0	72.5	16.8	10.75	2727.5	13705.5	1	36.84	63.16	0	1258.62	17.24
5 PC297-K7	4860	338	67.6	3285	85.8	91	93.8	95.3	1.8	0.8	21.8	13.9	7.8	0	75.8	13.8	10.5	2749.5	15055.2	1.25	58.97	41.03	0	1380.44	10.87
6 PC322-K5	5468	342	68.4	3740	77.5	89.8	95.8	97	0.8	1.3	10.9	7.6	3	87	0	8.3	4.75	3309.5	20628	0.5	2.94	97.06	0	1114.94	34.48
7 PC322-K7	5838	347	69.4	4051	87	95	96	97.3	0.8	1.3	9.4	3.8	1	88.5	0	8.8	2.75	3346	22592.3	0.75	12.12	87.88	0	1254.84	21.29
8 PC322-K8	4250	331	66.2	2814	81	87.8	93	95.3	2.8	0.8	19.3	12.2	0.5	0	77.8	18.5	3.75	2829	13265.7	0.25	15.63	84.38	0	1332.17	10.49
9 PC323-K1	5525	318	63.6	3514	62.3	83.5	89.8	92.8	2.5	1.3	9.2	2	0.3	84.3	0	12.8	3	3296.8	19307.4	2.5	21.74	76.09	2.17	1030.56	27.78
10 PC324-K1	7010	383	76.6	5370	78	88.8	91.5	94.3	1.8	0.5	5	3	0.5	89.5	0	9	1.5	3369.5	30155.1	3.25	20	80	0	956.85	62.44
11 PC325-K1	5105	350	70	3574	47.3	75	85.5	89.3	2.5	2.5	10.5	8.2	3.1	80	0	14	6	3220	19177.8	5	25	71.67	3.33	759.57	66.81
12 PC325-K5	4427	334	66.8	2957	50.5	80.8	92.8	97	1.3	0.8	14.4	5.6	1.5	83.5	0	13.5	3	3288.5	16209.5	0.75	36.36	63.64	0	941.75	19.42
13 PC328-K1	5353	376	75.2	4025	41.3	72.8	87.3	92.3	3.3	2.5	11	7.7	0.5	82.3	0	14	3.75	3267.3	21918.2	1.75	62.5	37.5	0	768.75	70.42
14 ICGVSM92736K2	4840	350	70	3388	60.3	79.5	84.5	89.3	4.3	2	3.4	2.1	0.5	86.3	0	9.8	4	3308.8	18683.4	3	18.52	70.37	11.11	811.36	67.27
15 ICGVSM92760K2	5003	328	65.6	3282	74.8	85	87.8	90.8	2.5	2.5	11.5	10.4	2.9	0	80.8	11.5	7.75	2807	15352.6	2.25	5.26	89.47	5.26	1106.71	13.41

PC Potchefstroom cross
-K progeny of single plant selections
E entry. Entry no. the same as no. used for ratings
UBS% unsound, blemished and soiled kernels
ICGV (SM) ICRISAT entry