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EVALUATION OF THREE-WAY MAIZE (*ZEA MAYS* L) HYBRIDS FOR YIELD AND RESISTANCE TO MAIZE STREAK VIRUS AND TURCICUM LEAF BLIGHT DISEASES

C. Karavina[1*], R. Mandumbu[1] and R. Mukaro[2]

[1]Bindura University of Science Education, Department of Crop Science, Private Bag 1020, Bindura, Zimbabwe
[2]Department of Research and Specialist Services, Crop Breeding Institute, P. O. Box CY550, Causeway, Harare, Zimbabwe
[*]Corresponding Author: ckaravina@hotmail.com

ABSTRACT

Maize, a staple food crop in sub-Saharan Africa and many other parts of the world, is affected by many diseases that reduce yield. Disease management has mainly been reliant on chemical and cultural control options. However, such options are unsustainable to the smallholder resource poor farmers and environmentally unfriendly. A study carried out at the Harare Research Station evaluated eight three-way and four commercial maize hybrids for yield and resistance to *Maize streak virus* using controlled leaf hopper infestation and Turcicum Leaf Blight under artificial inoculation. The objectives of the study were to identify hybrids that have multiple resistance to *Maize streak virus* and Turcicum Leaf Blight and to determine the relationship between disease severity and yield performance of the hybrids. The experiment was laid out in a split plot arrangement in a randomized complete block design with Disease type as the main plot factor while Maize hybrids were the subplot factor. Ratings of 1 (tolerant) to 5 (susceptible) based on streaked and blighted leaf surfaces were used. The hybrid 053WH54 had multiple resistance to Turcicum Leaf Blight and *Maize streak virus*. The hybrids 043WH61 and 043WH07 were high-yielding even at high disease pressure while 043WH41 and 013WH03 were relatively low yielding at low disease pressure. This showed the inherent genetic diversity of the hybrids. The hybrids ZS 225, 043WH61 and 043WH07 are recommended for production in areas with high prevalence of both diseases.

Key Words: *Maize streak virus*, Turcicum Leaf Blight, resistance, severity, hybrid, yield

INTRODUCTION

Maize (*Zea mays* L.) is world's third most important cereal food crop after wheat and rice. In sub-Saharan Africa, it provides food and income to over 300 million households (Tefera *et al*., 2011). The crop is affected by many diseases that reduce both the quality and quantity of production. In Zimbabwe, the most economically important maize diseases are Grey Leaf Spot caused by *Cercospora zea-maydis*, ear, kernel and cob rots, *Maize streak virus* (MSV) disease and Turcicum Leaf Blight (TLB) caused by *Helminthosporium turcicum* (Seed Co, 2010-11).

Under field conditions, MSV can cause up to 100% yield loss in susceptible varieties (Barrow, 2000; Magenya *et al*., 2008). MSV disease incidence and severity vary according to maize genotype and plant age at the time of infection (Adipala *et al*., 1993). MSV symptoms are characterized by broken to almost continuous chlorotic stripes centered initially on the tertiary leaf veins. These later develop into rectangular tan-coloured lesions that run parallel with leaf veins. As the disease spreads, the lesions coalesce, resulting in blighting of the whole leaf. This reduces the photosynthetic area, growth and yield of the plant (Agrios, 2005). Maize plants that are infected at the third leaf stage become severely stunted producing abnormal cobs or giving no yield at all (Ward *et al*., 1999; Chikoti, 2000).

TLB is characterized by long elliptical, greyish green or tan leaf lesions that first appear on the lower leaves and increase in size and number until very little living tissue is left. Yield is reduced due to lack of carbohydrates for grain filling (Paliwal *et al*., 2000). Yield losses range between 0 - 70% for hybrids and 5 - 44% for susceptible inbred lines, depending on the time of infection by pathogen (Levy, 1996).

In the short term, chemical control and cultural practices such as deep residue burial, crop rotation, irrigation and plant density manipulation can be used in effective management of MSV and TLB. However, the control of diseases using tillage practices destroys the soil structure and exposes the soil to erosion, leading to siltation of water bodies. Crop rotation implementation is limited by land size in the smallholder sector. Farmers do not have the luxury of leaving a piece of land fallow even for a season. Fungicides kill beneficial and non-targeted organisms and therefore adversely affect the food chain. Fungicides also need to be repeatedly sprayed and as a result may contaminate air and water bodies, and increase the cost of crop production. Therefore, the use of disease resistant varieties is relevant to the protection of the environment. It is also a sustainable and economically viable disease management option.

Given the dynamic nature of the environment tending to favour pest and disease development, a number of diseases can co-infect a crop. While research into the disease-resistant variety development has been going on, the main focus has been developing varieties with monogenic resistance. As a result, most varieties currently on the market are tolerant to a single disease, leaving them vulnerable to other diseases.

The objective of this study was to screen maize hybrids for yield and resistance to MSV and TLB to increase productivity in MSV and TLB disease prone areas.

MATERIALS AND METHODS

Research Site: The study was carried out at the Harare Research Station (17^o 48'S; 31^o 03E; 1506 metres above sea level), in Zimbabwe in the 2009/10 rainy season. The site has deep fersiallitic clay soils, classified as 5E.2 on the Zimbabwean Classification System, Rhodic Paleustalf (USDA Classification), or Chromic Luvisol on the FAO system (Nehanda, 2000). It receives approximately 800mm mean annual rainfall, with reliable distribution over 19.2 rainy pentads. Mean temperatures range from 21^{o}C between December and February to 14^{o}C in June and July (Crop Breeding Institute, 2004/5).

Experimental Design and Plot Management: The experiment was conducted using a split-plot arrangement in a randomized complete block design, with three replications. Disease type was the main plot factor, with four levels (MSV-inoculated, MSV-free, TLB-inoculated and TLB-free). Maize hybrid was the subplot factor with twelve levels (hybrids viz. 043WH41, 013WH03, 043WH61, 043WH77, 043WH07, 043WH14, 013WH31, 053WH54 and commercial checks SC403, SC513, SR52, and ZS225). The twelve hybrids were randomly allocated to plots within each disease type.

The field site was ploughed and disced using a tractor. Plots measuring 4m x 3m were marked out and each of the twelve hybrids planted at a spacing of 75cm x 25cm. Two pips were hand-planted per station. These were thinned to one plant per station at three weeks after planting, giving a population of 53 333 plants per hectare. Maizefert (7% N: 14% P_2O_5: 7% K_2O: 8.5% S) was applied at 400 kg/ha at planting and Ammonium Nitrate (34.5% N) was split-applied at 400kg/ha at three and six weeks after crop emergence (WACE). Hoe weeding was done before fertilizer applications, and the hybrids were hand-harvested six months after planting.

DISEASE INOCULATION AND ASSESSMENT

***Maize streak virus* Inoculation and Disease Assessment:** Plants were infested with viruliferous *Cicadulina mbila* leafhoppers obtained from CIMMYT-Harare. At three WACE, three leafhoppers were released into the leaf whorl of each plant after immobilization/anaesthetization with carbon dioxide. The leafhoppers were allowed an inoculation access period of two days and then killed with a Dimethoate 40 EC spray. Trap plants around the experimental area were sprayed with Furadan (carbosulfuran 5% m/v) to minimize the risk of leafhoppers disseminating the virus. Disease scoring was done using the scale developed by Kuhn (1997). In the control plots, no leafhoppers were introduced. All plots were assessed for disease symptoms from four WACE through to physiological maturity. This was done initially at weekly intervals until the presence of the disease was noted and thereafter, every two days. Dimethoate 40EC sprays were done at 21-day intervals until three weeks before physiological maturity.

Turcicum Leaf Blight Inoculation and Assessment: Plants were inoculated with a spore suspension of *Helminthosporium turcicum* supplied by CIMMYT-Harare. The spore suspension was sprayed into the leaf whorl of the plants at three WACE. A two-hour irrigation cycle was applied prior to inoculation in order to create an environment suitable for spore germination and disease infection. Disease severity was assessed for at flowering and grain filling. Disease assessments for control plots were done from four WACE through to physiological crop maturity. TLB was scored for using the scale developed by Bajet and Renfro (2002).

Parameters Measured and Data Analysis: Data on MSV and TLB disease scores and grain yield were collected. Disease scores were subjected to square root transformation before conducting analysis of variance. Scores of less than 2.5 were rated as good, those in the range of 2.6-3.5 as intermediate and above 3.5 as bad. All quantitative data were analyzed with Genstat (Payne *et al*., 2007). Where there were significant differences, the means were separated using LSD at 0.05 probability level.

RESULTS

Disease Type Effects

Table 1. Effect of Disease Type on Disease Severity and Grain Yield

Disease Type	Disease Score	Yield (t/ha)
TLB-free	3.389 a	10.1124 c
MSV-free	3.014 b	9.9810 c
TLB-inoculated	2.486 cd	10.2685 b
MSV-inoculated	2.264 d	10.6571 a
N	104	104
$LSD_{0.05}$	0.2241	0.1369
CV (%)	13.9	4.4

Disease type had significant effects (p<0.01) on both disease score (severity) and yield. The most severe disease was TLB with a disease score of 3.389 (about 31% of the leaf area blighted with large lesions), whilst MSV-inoculated was the least with a disease score of 2.264 (about 25% streaking). Plants sprayed to control MSV gave the highest yield of 10.657 t/ha, followed by those sprayed to control TLB that gave a yield of 10.27 t/ha. The yield of MSV-infected plants was not significantly (p<0.05) different from that of TLB-infected plants (Table 1).

Maize Hybrid Effects

Table 2. Effects of Maize Hybrid on Disease Severity and Yield

Hybrid	Disease Score	Yield (t/ha)
013WH31	3.750 a	9.1010 e
043WH77	3.292 bc	9.6857 d
043WH14	3.042 bc	10.3505 c
ZS255	3.042 bc	12.3142 a
SC403	3.042 bc	9.7962 d
043WH41	2.875 cd	9.6857 d
SR52	2.750 d	11.3981 b
043WH07	2.708 de	12.0381 a
043WH61	2.667 def	12.0552 a
013WH03	2.458 ef	8.3714 f
SC513	2.433 f	10.3505 c
053WH54	1.958 g	8.7771 e
N	104	104
$LSD_{0.05}$	0.262	0.344
CV (%)	11.6	4.14

Maize hybrid had a significant effect on disease severity (p<0.01). The hybrid, 053WH54 had the lowest score of 1.958 showing that it was tolerant to both diseases. SC513 and 013WH03 had scores of 2.433 and 2.458 respectively, indicating good tolerance to both diseases. The most susceptible hybrid to both diseases was 013WH31 with a score of 3.75 (Table 2).

Maize hybrids also showed significant differences on grain yield (p<0.01). The highest yielding hybrids were ZS225, 043WH07 and 043WH61. The least yielding hybrid was 013WH03 with 8.317 t/ha (Table 2).

There was significant interaction between the Hybrids and Disease Type. MSV and TLB severities were different on the hybrids. The hybrids 043WH14 and SR52 were the most susceptible to MSV with a score of at least 4 (over 60% streaking). The hybrids 043WH61, 043WH41, 053WH54, 013WH03 and SC 513 had the lowest MSV scores of at most 2.3 (25% streaking). About 41.7 % of the hybrids had good MSV scores (2.0-2.3 score range) whilst the other 41.7% had bad MSV scores ranging from 3.7 to 4.2 (55-65% streaking). Only two hybrids 043WH07 (3.5) and SC 403 (2.7) had intermediate scores.

The most tolerant hybrids to TLB were ZS 225, SR 52 and 053WH54 with a score of at most 2.5 (about 15% leaf area blighted with small lesions). The hybrids 043W61 and 013WH31 were most susceptible to TLB with a disease score of 4.3 (53% leaf blighting). The hybrids 043WH77 (3.5), SC513 (3.3), 043WH07 (3.2) and 043WH14 (2.8) had intermediate scores to TLB (Table 3).

Disease Type x Maize Hybrid Effects

Table 3. Yield Performance of Hybrids under MSV and TLB infestation

Hybrid	MSV Score	TLB Score	Yield (t/ha)
ZS 255	3.7 bc	2.2 d	12.3142 a
043WH61	2.0 e	4.3 a	12.0552 a
043WH07	3.5 c	3.2 c	12.0381 a
SR52	4.0 ab	2.5 d	11.3981 b
SC 513	2.0 e	3.2 c	10.3505 c
043WH14	4.2 a	3.5 bc	9.9848 d
SC 403	2.7 d	3.8 b	9.7962 d
043WH77	3.8 bc	3.5 bc	9.6857 d
043WH41	2.0 e	3.8 b	9.1867 e
013WH31	3.8 bc	4.2 a	9.1010 e
053WH54	2.3 e	2.3 d	8.7771 e
013WH03	2.2 e	3.2 c	8.3714 f
N	104	104	104
$LSD_{0.05}$	0.3	0.3	0.344
CV (%)	11.6	11.6	4.14

Only 053WH54 was tolerant to both MSV (2.3) and TLB (2.3) infections. The hybrid 043WH07 had intermediate scores to both diseases (Table 3). Of the seven hybrids (043WH61, 043WH07, SC 513, SC 403, 043WH41, 053WH54 and 013WH03) with good to intermediate MSV scores, only four hybrids (043WH07, SC 513, 053WH54 and 013WH03) had good to intermediate TLB scores. Of the eight hybrids (ZS 255, 043WH07, SR 52, SC 513, 043WH14, 043WH77, 053WH54 and 013WH03) with good to intermediate TLB scores, only 50% of them (043WH07, SC513, 053WH54 and 013WH03) also had good to intermediate MSV scores. Only 013WH31 was highly susceptible to both MSV (3.8) and TLB (4.2) (Table 3).

The highest yielding hybrids were ZS 225, 043WH07 and 043W61 (Table 3). The hybrid ZS 225 was susceptible to MSV and resistant to TLB, while the opposite was true for 043W61. The hybrid 013WH03 was the least yielding hybrid with an output of 8.371 t/ha. It had good tolerance to MSV and intermediate tolerance to TLB. The hybrid 013WH31, with high susceptibility to both MSV and TLB, yielded higher than 013WH03.

DISCUSSION

The differences amongst the hybrids for grain yield and resistance to MSV and TLB diseases indicated the potential inherent genetic diversity in the hybrids. Hybrids which were tolerant to TLB (053WH54, ZS225 and SR52) had few lesions on their foliage despite being subjected to the same disease pressure as the susceptible hybrids. Both monogenic and polygenic resistance to *Helminthosporium turcicum* has been reported. The genes conferring resistance are *Ht1*, *Ht2*, *Ht3*, *Htm1* and *Htn1* (Welz and Geiger, 2000). The first three genes reduce lesion size and sporulation in the lesion tissues (Lipps and Pratt, 1998). The *Htn1* gene reduces lesion numbers but not size, and increases the time between infection and lesion development prior to flowering (Brewester *et al*., 1992). MSV tolerance is monogenic, and is controlled by the *msv1* gene (Magenya *et al*., 2008). MSV-susceptible hybrids suffered at least 51% streaking and chlorosis of photosynthetic tissues. The hybrids that were susceptible to TLB suffered from blighting and necrosis of photosynthetic tissues and had at least 32% blighting.

MSV causes severe damage if it infects susceptible hybrids at the third leaf stage. It can cause severe stunting, production of fewer kernels and total crop failure (Magenya *et al*., 2008). TLB infection prior to grain filling restricts the accumulation of photosynthates in the developing kernels resulting in the production of fewer kernels, increased shriveling and poor grain quality (CIMMYT, 1998). In this study, no crop failure was observed. This was because CIMMYT germplasm is bred for resistance to both TLB and MSV.

The hybrids 053WH54 (good tolerance to both MSV and TLB) and 013WH03 (good tolerance to MSV and intermediate tolerance to TLB) yielded 28.7% and 32% less respectively than the best yielding hybrid. This is because both are short-statured and early maturing. As short-statured hybrids, they were probably shaded by taller hybrids, and so did not access adequate light for photosynthesis. As early maturing hybrids, the time available for radiation capture is less since crop development is rapid. So the hybrids will yield lower than late maturing slow growing hybrids (Banziger *et al.*, (2000). However, such hybrids will be ideal for marginal areas where the rainy season is short and temperatures are high.

The significant Maize hybrid x Disease type interaction suggests that some hybrids performed better under one of the factors. The hybrid 043WH61 was highly susceptible to TLB, but high yielding. This indicates that the hybrid was able to tolerate high disease pressure. In areas where TLB is prevalent, the hybrid 043WH61 can be grown and high yields still be realized.

Late maturing hybrids such as 043WH14 and 043WH77 were low yielding and also susceptible to both diseases. They yielded 18.9 – 21.3% lower than the best-yielding hybrids. This is attributed to the severe blighting and chlorosis that occurred on the foliage. As a result, there was poor grain filling and shriveled kernels. Unlike 043WH61 which tolerated high disease pressure, this was not the case with 043WH14 and 043WH77.

Conclusion: Only 053WH54 had multiple resistance to MSV and TLB diseases, but was one of the lowest yielding hybrid. The hybrid 013WH31 was susceptible to both diseases and yielded similarly to 053WH54, a hybrid with multiple resistance to MSV and TLB. The hybrid 043WH07 had intermediate resistance to both diseases and was a high yielder. The hybrid 043WH61 was high yielding under high TLB pressure while 043WH07 and ZS 225 were high yielding under high MSV disease severity. The hybrids 043WH61, 043WH07 and ZS 255 can be grown in areas with high disease pressure of either MSV or TLB diseases without yield being compromised.

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