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Evaluation of maize introductions for resistance to turcicum leaf blight, maize streak virus disease and tropical maize rust in Uganda

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Abstract

In the tropics, turcicum leaf blight (TLB) (*Exserohilum turcicum*), maize streak gemini virus disease (MSVD), and tropical maize rust (*Puccinia polysora*) are endemic and the most important maize foliar diseases in many countries. Thus deployment of varieties with multiple resistance to these diseases is key in increasing production. This study evaluated the disease reactions of elite Ugandan varieties and Pioneer hybrid introductions by considering the rate of disease increase (r), intercept or initial amount of inoculum (Yo*), area under disease progress curve (AUDPC), lesion numbers and percentage leaf area blighted. Significant differences in susceptibility of Ugandan varieties ($P \leq 0.05$) to TLB blight were observed. Population 28 was most susceptible while Babungo 3 was most resistant. Regression analysis revealed a linear relationship between yield and turcicum leaf blight severity ($R^2 = 0.50^{**}$), but there was no significant difference ($P \geq 0.05$) in yield of Ugandan elite varieties. No significant differences were observed among Pioneer hybrids in susceptibility to all the three diseases and they were in general, considered resistant to all the three diseases and comparable to the elite Ugandan varieties. Epidemiological models and their resultant disease indices fitted to TLB and rust disease progress distinguished between the various varieties studied.

Key words: Epidemiological models, *Exserohilum turcicum*, maize streak gemini virus, *Puccinia polysora*, resistance, Uganda, *Zea mays*

Introduction

Maize (*Zea mays* L.) is a major staple grain in Uganda were it doubles as a source of livelihood to many households and of recent, a mainstay to the economy as a non traditional cash crop (Anon. 1984; 1990). The crop is grown in virtually all parts of the country although largest production occurs in the northern periphery of Lake Victoria and the higher altitude areas of Kigezi, Rwenzori, west Nile plateau, Mount Elgon and the fertile Sebei highlands (Anon., 1990).

In the typical cropping system, maize is grown from farmer saved seeds of mainly local land races, with less than 40% of the land planted to improved varieties. In the 1980's, yields averaged 890 kg/ha in Teso (Soroti and Kumi), to 2240 kg/ha in Buganda and central Uganda (Anon, 1984) and in the 1990s, they ranged from 900 to 2500 kg/ha with a national average of close to 1400 kg/ha; but yields of up to 4000 kg/ha have been achieved under good weather and management (Anon., 1984; 1990). Therefore, there is a possibility of doubling present production levels through improved seed selection, development and maintenance of high yielding varieties.

Low production has also been mainly attributed to various pests and diseases with maize streak gemini virus disease (MSVD), turcicum leaf blight (TLB) (*Exserohilum turcicum* (Pass) K.J. Leonard and E.G. Suggs (teliomorph: *Setosphaeria turcica* (Luttrell) K.J. Leonard and E.G. Suggs and, the tropical and southern rusts (*Puccinia polysora* Underw and *Puccinia sorghi* Schw, respectively) (Anon, 1990; Adipala., *et al.*, 1993 a & b; Bigirwa *et al.*, 1993; Okori *et al.*, 1999). Over the years, attempts have been made to study resistance mechanisms to these diseases and develop resistant varieties mainly to TLB and MSVD (Storey and Howland, 1967; Adipala *et al.*, 1993a; Bigirwa *et al.*, 1993; Kyetere, 1995; Ojulong *et al.*, 1996; Okori, 1999). However, very limited efforts have been made with respect to the maize rust (Hemingway, 1954; Storey *et al.*, 1958). These studies focused on the individual diseases and did not consider multiple resistance to the major diseases, which, accounts for the paucity of information on this phenomenon. Yet, all these three diseases are endemic in many areas of the tropics (Damsteegt and Bonde, 1993; Okori *et al.*, 1999) and several seed companies and the national programmes are releasing varieties into the market. Hence, we investigated the phenomenon of multiple disease resistance in elite local and exotic maize varieties, focusing on disease TLB, MSVD and maize rust.

Materials and Methods

The study was conducted at Kabanyolo, in central Uganda. (Latitude 0°28'N and longitude 30, 37°E, 17 km north of Kampala Uganda at an altitude of 1200 m above sea level). Two experiments were conducted during the first and second seasons of 1993. In the first study, nine varieties i.e., five pioneer hybrids (obtained from Pioneer Seed Company, Harare Zimbabwe) and four elite Ugandán maize varieties obtained from the National Maize Programme, were used to investigate the multiple resistance phenomenon in the test lines to the three major diseases TLB, MSVD, and maize rust and their adaptability to Uganda (Tables 1). In the second study, seven open- pollinated varieties and two hybrids were obtained fromthe Namulonge Agricultural and Animal Research Institute (Table 2) and used to study yield loss due to TLB in improved Ugandan varieties. In both studies, Population 28 (EV8428-SR), an introduction from Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), was used as a susceptible check to compare the levels of resistance to *E. turcicum*.

Table 1. Origin and sources of maize germplasm used in the first study.

Germ plasm	Source
YIF64W	Pioneer seed company Harare
PHB3242	Pioneer seed company Harare
PHB3407	Pioneer seed company Harare
PHB 3253	Pioneer seed company Harare
PHB3452	Pioneer seed company Harare
TOPCROSS	Namulonge Agricultural and Animal Research Institute
SINGLECROSS	Namulonge Agricultural and Animal Research Institute
LONGE 1	Namulonge Agricultural and Animal Research Institute
KWCA-SR	Namulonge Agricultural and Animal Research Institute

Table 2. Origin and sources of maize germplasm used in the second study.

Genotype	Origin	Known resistance
KWCA-SR	Uganda[a]	M.R.[e]
Pop 28	CIMMYT[b]	S[e]
Pop 29	CIMMYT[b]	S[e]
Gusau	I.I.TA.[c]	M.R.[e]
Babungo 3	I.I.T.A.[c]	R[e]
Single cross	Uganda	M.R.[d]
Topcross	Uganda	M.R.[d]
Longe 1	Uganda	M.R.[d]

[a]Kawanda composite – a streak resistant variety
[b]Centro Internacional de Mejoramiento de Maiz Y Trigo, Mexico
[c]International Institute of Tropical Agriculture, Nigeria
[d] Bigirwa *et al.*, 1993
[e]Adipala *et al.*, 1993b

The first experiment was arranged following a completely randomised block design (CRBD), with three replications. Each replicate had nine treatment units comprising of nine varieties, maize was initially seeded at a rate of two seeds per hill but was later thinned to one plant per hill at the four leaf stage. Each plot measured 4 x 2 m with a 1.5 m spacing between blocks and 1 m between the plots (cultivars). Two rows of a local commercial variety (KWCA-SR) bordered the experimental plots to reduce exogenous inoculum inflow. The land was prepared by conventional tillage, and weeded using handhoe whenever necessary. No fertilisers, fungicides or insecticides were applied during the experimental period.

The second experiment was arranged following a split-plot design of a completely randomised block design (CRBD), with three replications. Plants were established in two row plots, 3 m long, using the same spacing and seed rate as described in the first experiment. Each replicate contained three main inoculation plots i.e., no inoculation (control), one inoculation at Growth stages (G.S.4), and two inoculations one at G.S. 4 and the second at G.S. 5 with the nine varieties in the sub-plots. Experimental plots and replicates were boardered by three rows of a resistant variety Babungo-3 to reduce inter-plot spread of *E. turcicum*.

Exserohilum turcicum inoculum was prepared from conidia isolated from Kabanyolo originated infected maize leaves as described by Adipala *et al.* (1993a). In both experiments, plants were inoculated by placing about 30 infested sorghum kernels into the leaf whorls of each maize plant at (G.S.) 4, early whorl with four leaves) and 5, mid whorl with eight leaves). (Ritchie *et al.*, 1989). During the first season, plants were inoculated on 15 May 1993 at G.S. 4 and 4 June 1993 at G.S. 5 (Ritchie *et al.*, 1989). During the second season, plants were inoculated on 20 November 1993 (G.S. 4) and on 4 December (G.S. 5). In the case of maize rust and MSVD, epiphytotics depended on field based inoculum owing to the rather high inoculum load of the two diseases being endemic in the area. All disease recordings commenced approximately one week before tasseling (G.S. 6, late whorl) and continued at one week interval for four weeks. Ten plants per entry were sampled and the two leaves above the ear of the test plants were used for assessment (Adipala *et al.*, 1993c). In the case of TLB, disease severity was measured by visually estimating the total percentage leaf area blighted (Elliott and Jenkins, 1946), as modified to 0,1,5,10,25,50, > 75% by Adipala *et al.* (1993 a and b). The total number of lesions on the ear leaf and the leaf above the ear were also counted (Adipala *et al.*, 1993b). Incidence of MSVD and its severity was assessed using a 0,1,2,3,4 and 5 quantitative scale (Kyetere, 1995). Rust severity were rated using the severity scale used for rating MSVD.

Weekly severity data were used to characterise disease progression by calculating initial and final severities and area under disease progress curve (AUDPC) (Campbell and Madden, 1990). The weekly severity (%) data were also fitted to the linearised logistic model (TLB) and exponential model (rust and MSVD). The logistic model had earlier on been shown to best describe TLB disease progress (Adipala *et al.*, 1993a and b). While the exponential model was the most preferred model in the case of rust and MSVD because it best suits cases where the initial amount of inoculum is low and plant tissue un-limiting (Vanderplank, 1963; Campbell and Madden, 1990) as was the case in this study where epiphytotics were due to field borne inoculum. For both models, the apparent infection rates or slopes "r" and estimated disease at the beginning of the epidemics (Yo*), were computed using Microsoft Excel programme. Due to differences in assessment intervals, AUDPC values were standardised by dividing by the total number of days between the first and the last disease assessment dates (Campbell and Madden, 1990). The final severity at the different assessment, AUDPC, r and Yo* were subjected to analysis of variance (ANOVA) (Steel *et al.*, 1997), using Statview [513] Brain Power incorporated programs for Macintosh Computer. Where significant differences were recorded, means were compared using Fisher's protected least significant difference (LSD) test at 5% probability level.

A simple linear regression between final disease severity of TLB and yield was also run in order to determine the effects of TLB on maize yield because of its resurgence and extensive damage in some introduced varieties.

Results and Discussion

Maize rust disease

In general, there was more rust during the first than the second season of 1993 (Table 3) with the mean final severities ranging from 1.22 to 1.4 during the first and 0.67 – 0.96 during the second season. More disease developed perhaps due to higher resultant relative humidity during the first rains. Consequently, the AUDPC values were higher during the first than the second season (Table 3). Genotype reactions were significant during the second season (Table 3). In general, elite Ugandan varieties exhibited slower disease progress and pairwise comparisons among them revealed no significant differences in AUDPC and final severity during both seasons but significant differences between some Ugandan and Pioneeer hybrids. For example, the Pioneeer hybrid PHB3407 was significantly different from Topcross.

The apparent rate of infection rate (r) varied across seasons and varieties although no significant differences among genotypes occurred during the first rains (Table 4). The highest apparent infection rate was recorded on Longe 1 and PHB 3435 during the first season and on PHB 3253 and KWCA-SR during the second season (Table 4). The computed initial amcount of inoculum or intercept (Yo*) followed the same trend as the apparent infection rate during both seasons. The low but significant r and non significant Yo* values suggest that the mode of resistance to *P. polysora* among the cultivars studied was the rate-reducing resistance (Nelson, 1978, Parlevleit, 1979) corroborating Vander plank (1963) earlier reports.

Maize streak virus disease

Incidence of maize streak virus disease was generally low throughout the experimental period, but was more common during the second than during the first season (Table 3). The hybrids YIF64W and PHB 3407 were not affected during the first season. Therefore, because of the low incidence the MSVD, data in Table 3 should be interpreted with caution: artificial infestation of the maize varieties may be needed.

Low disease incidence in part could have accounted for these observations coupled with the fact that most of the lines had MSV resistance genes incorporated. Additionally, MSVD severity is generally lower in late infected plants than those infected at seedling stage (Gibson and Page, 1997). This could perhaps explain why even infected plants showed low disease progress values. Increased MSVD incidence during second season, is similar to real field cases where higher incidences occur in fields where no closed seasons are observed or when a prolonged rain season occurs providing plenty of both host and alternative hosts for the vector (*Ciccadulina* sp.) (Storey and Howland, 1967; Gibson and Page, 1997).

Turcicum leaf blight

All plants developed wilt type (susceptible) lesions (Hilu and Hooker, 1963) with the mean final severities being higher during the first than the second season. The higher disease levels recorded during the first rains were attributed to the relatively wetter conditions and higher relative humidity which provided conducive conditions for disease development (Abadi *et al.*, 1989; Carson, 1995). AUDPC values followed the same trend as final severity (Table 3) with non significant differences ($P \geq 0.05$) among genotypes for AUDPC-PLAA during the first season but significant differences during the second season. On the contrary AUDPC for lesion numbers were significantly different during both seasons with the highest AUDPC recorded on YIF64W, PHB3424 and Longe 1.

Differences in apparent infection rates were significant ($P \leq 0.05$) only during the first season (Table 4). The hybrid YIF 64W had the highest r values during both seasons while hybrid PHB 3253 recorded

Table 3. Area under disease progress curve (AUDPC) of plant area affected (PLAA) by maize rust, maize streak virus disease (MSVD) and Turcicum leaf blight (TLB) on five pioneer hybrids and four elite Ugandan maize varieties grown at Kabanyolo during the first and second seasons of 1993.

Variety	Rust		MSVD				Turcicum Leaf blight			
	First	Second	First	Second	First	Second	First	Second	First	Second
	— — — — — AUDPC	— — — — — —	— — — —	— — —	F.sev	F.sev	— AUDPC PLAA	— — —		AUDPC LN
YIF64W	1.26±0.30	0.93±0.68	0.0	0.22±0.10	0.00	0.02	4.31± 0.71	0.93±0.17	1.11±0.94	0.78±0.11
PHB3424	1.59±0.44	0.82±0.00	0.13±0.01	0.08±0.08	0.10	0.17	4.02± 2.70	0.17±0.04	1.31±0.61	2.30±0.34
PHB3407	1.52±0.45	0.92±0.06	0.0	0.01±0.14	0.00	0.06	2.44± 0.47	1.08±0.66	0.88±0.07	1.70±0.20
PHB3253	1.15±0.10	0.84±0.16	0.19±0.11	0.13±0.07	0.03	0.80	0.57± 0.23	0.98±0.32	0.39±0.16	0.80±0.33
PHB3453	1.20±0.16	0.87±0.01	0.99±5.70	0.30±0.30	0.07	0.08	1.65± 0.30	0.40±0.20	0.96±0.30	0.07±0.32
Topcross	1.40±0.24	0.03±0.02	0.1±0.60	0.48±0.05	0.00	0.00	2.20± 1.30	0.48±0.17	0.73±0.32	1.09±0.13
Singlecross	1.50±0.49	0.63±0.32	0.12±0.70	0	0.17	0.16	2.90± 1.10	0.72±0.39	1.03±0.38	1.12±0.14
Longe 1	1.47±0.49	0.87±0.20	0.11±0.10	0.13±0.1	0.07	0.16	3.53±1.10	1.08±0.66	1.04±0.20	1.84±0.81
KWCA-SR	1.19±0.20	0.93±0.06	0.23±0.02	0.09±0.30	0.20	0.03	2.56± 1.23	0.17±0.62	1.08±0.38	1.84±0.20
Mean	1.36	0.87	1.36	0.16	0.07	o.15	2.66	0.66	0.94	1.35
LSD (0.05)	0.62	0.38	0.23	0.39	0.02	0.04	NS	0.38	0.77	0.90

[1] AUDPC standardised by dividing by the total number of days in the epidemic (Campbell and Madden, 1990). PLAA and LN are Plant leaf area affected
[2] and Lesion numbers, respectively
[3] F.sev = Final severity recorded 77 days after planting.
[4] Numbers in parenthesis are standard errors of the means.
Data are means of three replicates

Table 4. Intercept (Y_0^*), slope (r), and final severity of plant area affected by maize rust Puccinia polysora and Exserohilum turcicum on five Pioneer maize hybrids and elite Ugandan maize varieties grown at Kabanyolo during the first and second season of 1993.

Variety	Rust						Turcicum leaf blight					
	First rains			Second rains			Second rains			Second rains		
	[1]Y_0^*	[1]r	[3]F.sev	[1]Y_0^*	[1]r	[3]F.sev	[2]Y_0^*	[2]r	[1]F.sev	[2]Y_0^*	[2]r	[1]F.sev
YIF64W	-2.78	0.43	1.19	-0.04	0.03	0.79	-14.01	0.41	2.61	-5.52	-0.20	0.21
PHB3424	-4.78	0.01	1.12	-0.06	0.44	0.92	-13.54	0.15	2.66	-5.32	0.16	0.54
PHB3407	-6.46	0.11	1.38	-0.06	0.35	0.96	-11.43	0.07	1.63	-4.95	0.003	0.50
PHB3253	-0.02	0.02	1.40	-0.06	0.99	0.80	-3.79	0.04	2.00	-4.73	0.002	0.50
PHB3453	-0.72	0.72	1.16	-0.04	0.42	0.95	-9.01	0.07	1.13	-3.61	0.04	0.48
Topcross	-0.10	0.01	1.37	-0.10	0.42	0.67	-11.80	0.01	1.42	-3.49	-0.04	0.64
Singlecross	-0.42	0.42	1.39	0.06	0.27	0.81	-9.32	0.08	2.08	-4.59	-0.03	0.73
Longe 1	-0.79	0.76	1.36	-0-05	0.77	0.77	-12.02	0.09	1.64	-5.03	-0.26	0.81
KWCA-SR	-0.79	0.02	1.17	-0.08	0.85	0.91	-2.94	0.02	1.69	-9.24	-0.01	0.91
Means	-1.74	0.28	1.28	-0.06	2.08	0.17	-9.81	0.04	1.87	-5.14	0.03	0.80
LSD (0.05)	-6.89	1.15	0.20	0.17	13.24	0.22	-8.48	0.13	0.88	NS	NS	0.40

1 Slope and intercept calculated using the linearised exponential model (Campbell and Madden,1990)
2 Slope and intercept calculated using the linearised logistic model (Campbell and Madden,1990)
3 F.sev = Final severity recorded 77 days after planting.
4 Data are means of three replicates.

Table 5. Slope (r), area under disease progress curve (AUDPC), final severity (Yf) of plant leaf area affected by turcicum leaf blight and yield of nine Ugandan maize varieties during the first season of 1993 at Kabanyolo.

Variety	r^d	AUDPC[a]	AUDPC[b]	Y_f^{**}	Yield (t/ ha)
Longe 1	0.02	5.4	8.2	7.40	1.24
Babungo 3	0.10	4.5	6.6	7.50	1.38
KWCA-SR	0.11	5.2	9.1	9.32	1.34
Pop 42	0.10	3.5	4.3	4.6	1.20
Pop28	0.11	15.1	13.1	18.0	1.14
Pop29	0.08	5.2	6.7	10.9	1.20
Gusau	0.03	5.6	6.3	9.4	1.98

the lowest r values (Table 4). The initial amount of inoculum or intercept (Yo*) followed the same trend as the apparent rate of infection being higher on the hybrids that exhibited high disease progress than on those with low disease progress but not significant among genotypes. In general, the elite Ugandan varieties had lower disease levels and the resultant epidemiological parameters were thus lower than for the Pioneer hybrids (Table 4). The hybrid, PHB3253 was found most resistant and YIF64W most susceptible (Table 4).

The second study also experienced low disease levels during the first rains with final severity ratings ranging from 4.6% to 18% PLAA (Table 5). This probably accounted for the non-significant differences in final severity ($P \geq 0.05$) observed among the eight varieties studied. Highest disease levels were however, recorded on the susceptible check (Pop. 28) and the least on Babungo 3, a resistant check. The AUDPC values calculated from the weekly severity ratings followed a similar trend to the final severity ratings; and there was a high correlation between the two disease indices ($r = 0.95$; $P \leq 0.05$). Generally, apparent infection rate followed the same trend as AUDPC (Table 5). The wilt type lesions (Hilu and Hooker, 1963), low r and non significant Yo* values are indicative of rate-reducing resistance (Parlevliet, 1979) present in resistant elite Ugandan varieties. This corroborates earlier findings by Adipala *et al.* (1993a), who reported that Ugandan cultivars possessed polygenic resistance.

Linear regression of TLB final severity (percent leaf area blighted) on maize yield revealed a significant relationship (R^2 0.5, $P = 0.01$) between the two parameters during the wetter first season of 1993. Similar results were reported by earlier workers (Ullstrup and Miles, 1957; Bowen and Perdesen, 1972; Adipala *et al.*, 1993c). But, unlike in the earlier reported cases TLB accounted for up to 50% of observed variation in yield signifying its importance as a foliar maize pathogen.

Conclusion

These studies show that elite Ugandan varieties were more resistant than exotic Pioneer hybrids. However, the Pioneer hybrids were superior in grain yield and other desirable agronomic characteristics (data not shown). This would imply cautious release of introductions into new agro-ecologies particularly where some major diseases are endemic. These elite lines also showed multiple resistance to the three inportant foliar diseases studied, but a repeat of studies in particular for MSVD resistance is desirable.

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