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INCREASING MAIZE YIELDS IN AFRICA THROUGH THE USE OF MAIZE STREAK VIRUS RESISTANT HYBRIDS

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ABSTRACT

PAN 6099, a long season, white-grained, semi-flint maize streak virus (MSV)-resistant hybrid has been grown on a limited scale in South Africa and Swaziland, and has out-yielded other hybrids where MSV has been prevalent. Another hybrid, PAN 6195 (long season, white grained, semi-flint) has recently been tested extensively in several countries in Sub-Saharan Africa, and has shown excellent resistance to MSV in these regions. The results from these yield trials are presented and discussed.

Key Words : **Maize streak virus, yield**

RÉSUMÉ

PAN 6099, un hybride à saison longue, aux graines blanches en forme de "semi-flint" et résistant à la mosaïque en tirets a été cultivé en petite échelle en Afrique de Sud et au Swaziland. Là où la mosaïque en tirets était présente, il donnait une productivité supérieure aux autres hybrides. Un autre hybride, PAN 6195 (saison longue, graines blanches en forme de "semi-flint") a récemment été testé d'une manière approfondie dans plusieurs pays de l'Afrique sub-Saharienne, et a montré une résistance excellente à la mosaïque en tirets dans ces régions. Les résultats de ces essais sont présentés et discutés.

Mots Clés: **Mosaïque en tirets, vendement**

INTRODUCTION

In Eastern and Southern African countries, the maize area covers 12% (Madagascar) to 94% (Malawi) with an average of 42% of the total area under cereal. The preference for maize as a food crop in this region is far greater than in western and central Africa where this crop occupies 17% of the land area under cereal (CIMMYT, 1992). With the increase in population growth in eastern and southern Africa there is an increasing demand for maize as a food substance. Occasionally this increase in demand is met with an increase in production, but of the 16 countries surveyed by CIMMYT over the period 1989–1990, only five were net exporters of maize. The other 11 could not, for various reasons, produce sufficient maize to meet the needs of their countries.

One of the reasons for low yields in many countries is the prevalence of Maize Streak Virus (MSV). MSV seriously limits maize yields in sub-Saharan Africa and several Indian Ocean Islands. It occurs in the lowland humid and Savanna areas, as well as in the mid-altitude ecological zones

(1000–1800 m) (Anonymous,1982a and b). The virus is spread by a leafhopper, *Cicadulina mbila* Naude. The virus causes longitudinal chlorotic streaks along the leaf veins, with a concomitant reduction in photosynthesis, growth and yield (Kirby *et al.*, 1988; Barrow, 1992; Roca de Doyle and Autrey, 1992). Control of MSV has relied on costly, highly toxic chemicals or, more recently, on the use of maize cultivars resistant to the virus (Barrow, 1992). The development of maize germplasm that is resistant to MSV has therefore been the goal of several breeding programmes in Africa (Goodman, 1981), and several researchers have developed and released resistant populations and inbreds (Anonymous, 1982a, and b, 1984a and b, Kim *et al.*, 1982, 1987 and 1989; Barrow, 1992). In 1992, a long season, white-grained, semi-flint hybrid, PAN 6099, was released in South Africa by Pannar (Pty) and is limited for commercial sale in South Africa and Swaziland. The resistance of this hybrid to MSV in areas where the disease is endemic has enabled farmers to reap crops where previously severe reductions in yield occurred. Another hybrid, PAN 6195, has recently been released, and has also performed exceptionally well in areas where MSV occurs. The data presented in this paper illustrate the benefit to farmers of planting MSV-resistant hybrids in areas where the disease is endemic.

MATERIALS AND METHODS

The data presented were obtained from two different types of yield trials planted in 1990, 1991 and 1992: at Greytown, South Africa (Pannar) and Harare, Zimbabwe (CIMMYT).The

TABLE 1. Mean ratings of 20 maize hybrids to Maize Streak Virus infection at various sites during 1991

Rank	Mean Over Hybrid	Sites	South Africa		Zimbabwe	Mozambique	Zaire	Ivory Coast	Kenya
			Greytown	Tho'dou	Harare	Lionde	Lubumbashi	Bouake	Meru
1	PAN 6195***	1.04	1.0	1.0	1.3	0.3	2.0	1.0	0.7
2	PAN 6099***	1.28	1.7	1.0	1.3	0.7	1.7	1.3	1.3
3	PAN 6193***	1.38	1.3	1.0	1.3	0.7	1.7	2.0	1.7
4	EXP 725	1.42	1.7	1.3	1.7	1.0	1.3	1.7	1.3
5	EXP 701	1.52	0.7	1.3	2.3	1.0	2.0	1.7	1.7
6	PAN 6191***	2.04	2.0	2.3	2.3	1.7	2.0	2.0	2.0
7	EXP 101	2.47	2.3	2.0	2.3	3.0	3.0	2.0	2.7
8	EXP 157	2.85	2.3	2.7	3.7	2.3	3.0	3.3	2.7
9	EXP 195	3.37	3.0	3.3	3.7	3.3	3.7	3.3	3.3
10	EXP 755	3.67	3.3	3.7	4.0	3.3	3.7	3.7	4.0
11	EXP 167	3.80	3.0	4.0	3.0	4.0	4.3	4.0	4.3
12	LOCAL-1**	3.81	5.0	4.7	5.0	1.3	2.0	3.7	5.0
13	EXP 143	3.83	4.0	3.7	3.7	3.7	3.7	4.0	4.0
14	EXP 221	4.18	4.3	4.0	4.7	4.3	4.3	4.0	3.7
15	EXP 109	4.62	5.0	4.7	4.7	4.7	5.0	4.3	4.0
16	EXP 103	4.67	4.7	5.0	4.0	4.3	5.0	4.7	5.0
17	EXP 189	4.75	5.0	5.0	4.7	4.3	5.0	4.3	5.0
18	LOCAL-2**	4.78	5.0	5.0	5.0	4.5	4.0	5.0	5.0
19	PAN 6549*	4.92	5.0	4.7	5.0	5.0	5.0	4.7	5.0
20	PAN 6363*	4.96	4.7	5.0	5.0	5.0	5.0	5.0	5.0

* = Commercial Hybrids (Susceptible checks)

*** = MSV-Resistant Commercial Hybrids

** = Local Varieties

	LOCAL-1	LOCAL-2	
Greytown	PAN 6479	PAN 6481	(Commercial hybrids)
Thohoyandou	PAN 6479	PAN 6481	(Commercial hybrids)
Harare	PAN 6479	PAN 6481	(Commercial hybrids)
Lionde	MATUBA	MANICA	(Commercial vareities)
Lubumbashi	BABUNGO	SHABA-1	(Local varieties; open pollinated)
Bouake	IRAT 83	CJB 110	(Commercial varieties)
Meru	kh 625	kh 512	(Commercial hybrids)

Pannar trials had leafhoppers in small plastic vials clipped onto the plants for 24 hr (Barrow, 1992), and the CIMMYT trials had leafhoppers released e*n masse* onto the plants (Short, CIMMYT, pers. comm.). At Thohoyandou (S. Africa), Lionde (Mozambique), Lubumbashi (Zaire), Bouak (Ivory Coast) and Meru (Kenya) MSV infection was natural. The methodology of leafhopper rearing, infection method, source of MSV, and symptom rating were as described by Barrow (1992). Briefly, experimental plants at the 2–3 leaf stage are artificially infected with MSV by attaching a small plastic vial (20 mm diam. x 40 mm) with 2–3 leafhoppers enclosed onto the youngest leaf for 24 hr. The MSV symptoms are rated when the plants are at any height between 1 and 1.5 m on a 0-5 scale (0 = no symptoms; 5 = severe symptoms). Each row of 20 plants was given a rating, and a figure was obtained for each hybrid as a mean over three replicates.

Several authors (Mzira, 1984; Barrow, 1992, Roca de Doyle and Autrey, 1992) have recorded large differences in yields between MSV-infected and uninfected plants of the same hybrid. Barrow (1992) reported losses as high as 94.2% for a susceptible hybrid and as low as 5.6% for the most resistant hybrid. In areas where MSV is endemic, severe yield losses occur, and great benefit would be gained by farmers planting resistant cultivars. However, during years when no MSV occurs, it is

TABLE 2. Mean yield expressed as a percentage of the trial mean of 20 maize hybrids infected with Maize Streak Virus (MSV) at several sites in the 1990/91 season

		% Mean Rel.	Mean MSV	South Africa		Kenya	Zimba-bwe	Mocam-bique	Zaire	Ivory Coast
Rank	Hybrid	yield	Rating	Greytown	Tho'dou	Meru	Harare	Lionde	Lubumbashi	Bouake
	PAN 6195***	189.1	1.04	178.9	187.2	193.9	187.5	188.5	182.6	205.3
2	PAN 6099***	178.4	1.28	164.4	194.9	166.6	188.4	165.4	179.3	189.5
3	EXP 725	176.3	1.42	162.0	176.9	172.7	181.2	184.6	178.2	178.9
4	EXP 701	173.1	1.52	188.6	182.0	157.5	184.4	176.9	169.5	152.6
5	PAN 6193***	167.4	1.38	169.3	166.7	151.5	190.6	173.1	178.3	142.1
6	PAN 6191***	155.9	2.04	154.7	151.2	139.4	178.1	146.1	169.6	152.6
7	EXP 157	124.7	2.85	137.8	138.5	127.3	00.0	146.1	113.0	110.5
8	EXP 101	122.7	2.47	145.1	140.2	127.3	15.6	100.0	104.3	126.3
9	EXP 167	80.8	3.80	113.7	90.4	72.7	96.8	57.6	60.9	73.7
10	EXP 755	80.5	3.67	101.2	100.0	75.7	50.0	65.4	86.9	84.2
11	EXP 195	78.4	3.37	74.8	80.7	74.2	75.0	80.7	86.9	76.5
12	EXP 143	78.0	3.83	87.1	79.5	78.8	71.8	76.9	78.3	73.7
13	LOCAL-1**	74.7	3.81	29.0	25.6	45.4	56.2	142.3	134.7	89.5
14	EXP 109	54.0	4.62	50.8	58.9	66.7	43.7	61.5	39.1	57.8
15	LOCAL-2**	53.1	4.78	24.2	30.7	45.4	40.6	92.3	91.3	47.4
16	EXP 221	48.7	4.18	45.9	53.8	72.7	31.2	53.8	52.2	31.5
17	EXP 103	44.1	4.67	43.5	33.3	63.6	62.5	34.6	34.7	36.8
18	EXP 189	36.3	4.75	33.8	35.9	36.4	31.2	23.1	30.4	63.2
19	PAN 6549*	34.5	4.92	26.6	33.3	45.5	43.7	34.6	26.1	31.5
20	PAN 6363*	30.1	4.96	24.2	28.2	42.4	37.5	30.7	21.7	26.3
	Mean yield (t ha^{-1})			4.1	3.9	3.3	3.2	2.6	2.3	1.9
	C.V.(%)			18.6	24.7	21.7	29.1	30.7	31.4	24.6

= Commercial Hybrids (Susceptible checks);
** = MSV Resistant Commercial Hybrids
* = Local Varieties

	LOCAL-1	LOCAL-2	
Greytown	PAN 6479	PAN 6481	(Commercial hybrids)
Thohoyandou	PAN 6479	PAN 6481	(Commercial hybrids)
Harare	PAN 6479	PAN 6481	(Commercial hybrids)
Lionde	MATUBA	MANICA	(Commercial vareities)
Lubumbashi	BABUNGO	SHABA-1	(Local varieties; open-ollinated)
Bouake	IRAT 83	CJB 110	(Commercial varieties)
Meru	kh 625	kh 512	(Commercial hybrids)

essential that the resistant hybrid yields satisfactorily, as farmers would be averse to planting an MSV-resistant but low yielding hybrid. Trials were therefore planted at various sites in Africa to assess the yields of various hybrids under both MSV and MSV-free conditions. The trials used 20 hybrids (experimental and commercial) in a triple lattice design with three replications. The data were analysed with a Pannar in-house developed programme, written in Pascal, on a Unisys 5000–30 computer. Analysis of variance for a triple lattice design was utilised and results were compared at the 5% level of significance.

RESULTS AND DISCUSSION

Many isolates or strains of MSV occur in different localities, with some being more virulent than others (Bock *et al.*, 1974; Bock, 1982; Kirby *et al.* 1988; Pinner *et al.*,1988; Rybicki, 1988; Rybicki *et al.*, 1988, and Clarke *et al.*, 1989). However, it is evident from Table 1 that the resistance of PAN 6099 and PAN 6195 remained effective over the various sites. The local check in Mozambique (Matuba) has been specifically developed for MSV resistance and is sold in areas where MSV occurs. Babungo (Zaire) is a local open-pollinated variety that shows good resistance to MSV in Shaba province. The resistance level of PAN 6099 and PAN 6195 were higher or similar to those of Matuba and Babungo. The commercial cultivars grown in Ivory Coast and Kenya were severely affected by MSV and produced low yields (Table 2).

It is inevitable that trials under MSV pressure would show high coefficients of variation (CV). These should not, however, invalidate the usefulness of the results. The two MSV-resistant hybrids PAN 6195 and PAN 6099 considerably out-yielded the local commercial cultivars, coming overall first and second, respectively. The mean relative yields (MRY) over all sites ranged from 189.1% of the mean for PAN 6195 to 30.1% for PAN 6363. In some instances, local varieties performed fairly well under MSV: in Mozambique

TABLE 3. Mean yields expressed as a percentage of the trial mean of 20 maize hybrids planted at several (maize streak virus free) sites in Nigeria in the 1991/92 season

Rank	Hybrid[a]	% Mean Relative yield	Nigeria		
			Kidandan	Ibadan	Kudu
1	PAN 6195***	117.3	14.7	126.3	109.7
2	PAN 6193***	114.5	12.5	128.5	102.7
3	PAN 6566*	113.2	18.6	102.1	119.2
4	EXP 109	109.9	10.0	94.0	126.1
5	PAN 6363*	109.1	99.4	100.0	128.1
6	PAN 6099***	105.8	11.6	99.7	106.2
7	PAN 6481*	105.4	10.4	105.2	100.7
8	PAN 6579*	104.1	14.0	101.9	96.7
9	EXP 109	101.0	16.0	87.7	99.5
10	EXP 387	100.9	96.0	100.7	106.5
11	EXP 105	100.3	92.0	94.2	115.1
12	EXP 115	99.0	04.3	92.8	100.1
13	PAN 6480*	97.2	107.1	91.6	93.1
14	PAN 6549*	96.5	98.6	100.9	90.2
15	PAN 6057*	95.9	98.4	105.7	93.7
16	EXP 157	95.7	87.6	98.5	101.2
17	PAN 6033*	90.8	82.9	83.6	106.2
18	OBA SUPER-1**	84.3	76.1	102.1	74.7
19	AG ILORIN**	81.2	74.1	89.4	80.1
20	OBA SUPER-2**	77.4	76.1	94.2	62.6
	Mean yield (t ha^{-1})	5.8	4.2	4.0	
	C.V.	14.7	18.9	16.8	

* = Commercial hybrids (susceptible);
*** = MSV resistant commercial hybrids; and
** = Local commercial varieties

TABLE 4. Mean yields, expressed as a percentage of the trial mean, of PAN 6195 and KH 511, planted over three years at several sites in Kenya.

	Mean yield	1990 10.5T	1990 7.0T	1990 4.4T	1991 9.6T	1991 8.3T	1991 5.4T	1991 3.8T	1992 4.5T
	%	Kitale	Mombasa	Embu	Nakuru	Kitale	Nairobi	MERU[a]	Embu
PAN 6195	122.1	107.3	109.9	121.4	125.4	112.1	117.4	172.1	111.4
KH 511	89.8	100.2	80.3	94.1	84.9	107.5	120.1	44.1	87.8

[a]MSV infection present

TABLE 5. Mean yields, expressed as a percentage of the trial mean, of 20 maize hybrids planted at severe Maize Streak Virus sites in Southern Africa during 1990/91 season[a].

			Swaziland	South Africa	South Africa	Zimbabwe
Rank	Hybrid	Mean rel yield	Big Bend	Greytown	Venda	Harare
1	PAN 6479*	117.9	127.6	115.9	111.4	116.7
2	PAN 6482*	112.3	114.6	108.7	116.2	109.7
3	EXP. 701	111.4	115.3	112.3	107.8	110.2
4	EXP. 725	110.5	113.6	106.3	112.4	109.7
5	PAN 6363*	106.5	109.7	114.6	104.2	97.6
6	PAN 6549*	103.6	106.4	103.6	105.7	98.7
7	EXP 157	102.9	99.8	104.6	102.3	104.9
8	PAN 6099**	101.6	101.4	94.6	116.7	93.6
9	PAN 6195***	99.4	104.7	99.7	101.0	92.1
10	PAN 6191**	98.0	86.4	104.6	102.3	98.7
11	EXP 109	97.9	93.2	99.9	100.2	98.6
12	EXP 143	97.8	94.7	96.7	98.8	101.2
13	EXP 101	97.7	89.6	101.4	100.4	99.8
14	PAN 6193**	97.4	84.2	106.4	104.6	94.2
15	EXP 195	94.9	99.6	94.6	94.5	90.9
16	EXP 147	93.1	99.8	90.5	92.6	89.7
17	EXP 755	92.9	95.7	100.0	86.7	89.5
18	EXP 221	91.4	84.3	101.4	100.4	79.4
19	EXP 167	87.2	78.4	86.1	94.2	90.3
20	EXP 189	84.3	76.4	86.7	94.3	79.9
	Mean yield (t ha^{-1})		6.4	6.2	6.0	5.5
	C.V.		19.6	18.4	24.7	19.3

a* = Commercial hybrids; ** = local commercial varieties;
*** = MSV resistant commercial hybrids; mean rel yield = mean relative yield

(Matuba = 142.3% MRY) and Zaire (Babungo = 134.7% MRY).

There was very little MSV infection at the trial sites during the 1991/92 season, possibly due to the severe drought experienced at many sites. The results from the few sites that were harvested, however, show the yield potentials of the hybrids when there is no MSV pressure (Tables 3 and 4).

Nigeria. With no MSV pressure, for example in Nigeria (Table 3), PAN 6195 still out-yielded other hybrids, in particular the locally sold varieties. PAN 6099 did not perform as well in these trials as it had in other MSV-infected sites, and ranked 6th. PAN 6195 was also tested in various trials in Kenya over several seasons (Table 4). No MSV occurred at all sites except at Meru. PAN 6195 performed most satisfactorally at all sites. Therefore, in areas where MSV is a regular occurrence, farmers planting PAN 6195 would be assured of a good yield irrespective of whether MSV occurred or not. The performance of PAN 6195 has been far better in Central and Eastern African countries than in Southern Africa, where it has been out-yielded by commercial hybrids (Table 5). Where MSV is not endemic, it would

obviously be better to plant susceptible, but higher yielding commercial hybrids. Apart from the excellent MSV resistance exhibited by PAN 6195, it has good husk cover, excellent prolificacy and very good resistance to Southern rust, *Puccinia polysora*. In addition, it has a semi-flint grain, a favourable characteristic in Africa where poundability and protection from weevils during long term storage, especially in Malawi, are important. It is, however, very susceptible to common rust (*P. schwein*), which precludes its use in the high elevation maize production areas, such as Kitale in Kenya.

In many areas farmers grow locally adapted open-pollinated varieties that have developed over generations to reflect the pressures of the endemic disease spectrum. In some areas, like Lubumbashi and Mocambique, the cultivars have good resistance to MSV, but have poor yielding potential. It is hoped that PAN 6195 and other high yielding resistant hybrids will alleviate the plight of farmers who repeatedly suffer extensive losses due to this widespread disease.

REFERENCES

Anonymous. 1982a. First international trial with streak resistant maize varieties. *IITA Research Highlights*, 11–13.

Anonymous. 1982b. Disease resistant maize varieties for mid-altitude ecologies in Africa. *IITA Research Highlights*, 14–16

Anonymous. 1984a. Maize varieties with combined resistance to downy mildew and streak diseases. *IITA Research Highlights*, 35–37.

Anonymous. 1984b. Early maturing, streak resistant maize for African cropping systems. *IITA Research Highlights*, 38–40.

Barrow, M.R. 1992. Development of maize hybrids resistant to maize streak virus. *Crop Protection* 11: 267–271.

Bock, K.R. 1982. Geminivirus diseases in tropical crops. *Plant Disease* 66: 266–270.

Bock, K.R., Guthrie, E.J., and Woods, R.D. 1974. Purification of maize streak virus and its relationship to viruses associated with streak diseases of sugarcane and *Panicum maximum*. *Annals of Applied Biology* 77: 289–296.

Clarke, B.A., Rybicki, E.P., Hughes, F.L., Kirby, R. and von Wechmar, M.B. 1989. Characterization of Southern African isolates of maize streak virus : typing of three isolates by restriction mapping. *Intervirology* 30: 86–95.

Goodman, R.M. 1981. Geminiviruses. In : *Handbook of Plant Virus Infections*. E. Kuistak (ed.), pp 819–910. *Elsevier / North Holland Biomedical Press, Amsterdam.*

Kim, S.K., Singh, J., Fajemisin, J. and Bjarnason, M. 1982. Development of two early-maturing, streak-resistant maize populations for Africa. *IITA Briefs* 3 (2): 5–6.

Kim, S.K., Efron, Y., Khadr, F., Fajemisin, J.M., and Lee, M.H. 1987. Registration of 16 maize streak virus resistant tropical maize parental inbred lines. *Crop Science* 27: 824–825.

Kim, S.K., Efron, Y., Fajemisin, J.M., and Buddenhagen, I.W. 1989. Mode of gene action for resistance in maize to maize streak virus. *Crop Science* 29: 890–894.

Kirby, R., Clarke, B.A., and Rybicki, E.P., 1988. Evolutionary relationship of three Southern African streak virus isolates. *Intervirology* 26: 195–200.

Mzira, C.N. 1984. Assessment of effects of maize streak virus on yield of maize. *Zimbabwe Journal of Agricultural Research* 22: 141–149.

Pinner, M.S., Markham, P.G., Markham, R.H. and Dekker, E.L. 1988. Characterization of maize streak virus : descriptions of strains; symptoms. *Plant Pathology* 37: 74–87

Roca de Doyle, M.M., and Autrey, L.J.C. 1992. Assessment of yield losses as a result of co-infection by maize streak virus and maize stripe virus in Mauritius. *Annals of Applied Biology* 120: 443–450.

Rybicki, E.P. 1988. Maize streak virus : an African pathogen come home? *South African Journal of Science* 84: 30–32

Rybicki, E.P., Hughes, F.L., Clarke, B.A. and von Wechmar, N.B. 1988. Detection and differentiation of isolates of maize streak virus by use of cloned DNA hybridisation probes. *Proceedings 8th South African Maize Breeding Symposium. pp.* 27–32

Soto, P.E., Buddenhagen, I.W. and Asnani, V.L. 1982. Development of streak virus resistant maize population through improved challenge and selection methods. *Ann. Appl. Biol.* 100: 536–539