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MAIZE VARIETY EVALUATION
IN THE HIGHLANDS OF PAPUA NEW GUINEA

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Food Crops Agronomist



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AFTSEMU

The Agricultural Field Trials, Studies, Extension and Monitoring Unit (AFTSEMU) was established as a component of the Southern Highlands Rural Development Project (SHRDP). Part of its work was to research the subsistence agricultural systems of the province so as to provide a better understanding of these systems and develop guidelines for their improvement.

The results of AFTSEMU's research are published as a series of Technical Reports, of which the following are complete or in press.

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(C.N. Floyd and E.J. D'Souza)

ABSTRACT

A series of experiments evaluating thirty varieties of maize (Zea mays) available within Papua New Guinea, and from DPI Kairi, Queensland, and twenty six open pollinated varieties from CIMMYT, Mexico, are reported.

Evaluation of the Papua New Guinea germplasm confirmed the current DPI recommendation of Piwa as an open pollinated variety, although improvements are necessary in certain variety characteristics. Recommendations for hybrid varieties are also made. The evaluation of germplasm from Kairi was limited but results indicate that further evaluation of Kairi germplasm should be carried out. Because of quarantine restrictions the evaluation of CIMMYT germplasm was also comparatively limited, however, four varieties were identified for further evaluation.

The incidence of Turcicum leaf blight (Helminthosporium turcicum) was severe in the trials and caused heavy yield losses in susceptible varieties. Local varieties were the most resistant to Turcicum leaf blight and much of the CIMMYT germplasm was particularly susceptible. Later maturing varieties were less susceptible. Results indicated that Turcicum leaf blight resistance should be an important criteria for variety selection for this environment and further study is required to elucidate the relationship found between variety maturity and disease susceptibility.

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1. INTRODUCTION

The climate of the highlands of Papua New Guinea, with its relatively high daytime temperature (25 - 30 deg C), cool night time temperatures (10 - 15 deg C) and high levels of solar radiation, is well suited to producing high yields of maize (Duncan, 1975). In similar environments elsewhere in the world, for example in South America and Central and South East Africa, maize is a staple crop. In the highlands of Papua New Guinea, despite the apparent suitability of the climate maize has remained only a supplementary crop.

In addition to its suitability to the environment, maize is also nutritionally appropriate as a supplementary food to the highland staple of sweet potato. Not only does green maize have the advantage of being an attractive, appetising food with a higher protein content (3 - 10 g protein per 100g edible portion (Martin, 1984; SPC, 1983; WHO, 1979) than sweet potato (1 - 1.9 g protein per 100g edible portion (Martin, 1984; SPC, 1983; WHO, 1979), but it also has an amino acid composition which complements that of sweet potato.

Thus, because of its potential as a food crop, AFTSEMU has focussed attention on maize, and specifically on variety identification and soil fertility problems. These factors were identified as being the greatest constraint to increased maize production, certainly in the Southern Highlands, and possibly throughout the highlands.

AFTSEMU's variety identification work on maize is reported here, while that on soil fertility is reported elsewhere in AFTSEMU Technical Reports.

The aims of the variety identification work were two-fold.

1. To provide a recommendation for maize open pollinated varieties and hybrid varieties for immediate use under highland conditions.
2. To identify suitable germplasm and germplasm sources as a basis for improving available open pollinated varieties and/or introducing improved open pollinated varieties for highland conditions.

During the variety identification programme, material from three sources was evaluated.

1. Germplasm, both hybrid and open pollinated varieties, available within Papua New Guinea.

2. Germplasm, both hybrid and open pollinated varieties, from Kairi Research Station (Queensland DPI), Atherton Tableland, Queensland, Australia.
3. Open pollinated varieties from the Centro Internacional de Maiz y Trigo (CIMMYT), Mexico.

Of the two trials reported here, the first (MZM 2 (1))* , evaluates material from Papua New Guinea and Kairi, and the second (MZM 2 (2))* , material from CIMMYT. Hereafter these trials are referred to as the PNG variety trial and the CIMMYT variety trial respectively. In this report each trial is reported separately in Parts 2 and 3 respectively. Part 4 discusses, as appropriate, the results of the trials taken together. Finally, Part 5 draws conclusions and makes recommendations for further work.

NOTE

* Experiment identity number from DPI Biometrics, Department of Primary Industry, Konedobu, N.C.D., Papua New Guinea. A set of experimental data for these trials is held by DPI Biometrics.

Table 1: Description of entries tested in PNG variety trial.

Entry	* Type	Origin	PNG Supplier	Grain type	Total height m	# Ear height % of total height	Locations of test site			
							HAC	HAES	Piwa	Kiburu
Piwa	OP	Unknown	DPI, Piwa, Tari	Yellow	2.6	46	X	X	X	X
Suwan	OP	Thailand	DPI, Bubia	Yellow	2.3	43	X	X	X	X
Metro	OP	Unknown	DPI, Laloki	Yellow	2.0	45	X	X	X	X
Q 12508	OP	Unknown	DPI, Kerevat	White	2.8	48	X	X	X	X
Tambul	OP	DPI, Tambul	DPI, Kuk	Yellow	2.2	38	X	X	X	X
Melbourne	OP	Melbourne Univ	DPI, Kuk	Yellow	2.1	41	X	X	X	X
Hycorn 9	HY	Pacific Seeds	South Pacific	Yellow	2.2	41	X	X	X	X
Hycorn 1	HY	Toowoomba	Machinery	Yellow	2.0	33	X	X	X	X
Minicorn	HY	Queensland	Boroko	Yellow	1.6	25	X	X	X	X
PX 49	HY	Northrop Kene	Farmset, Banz	Yellow	1.9	31	X	X	X	X
3591	HY	Pioneer	Yates Seeds	Yellow	1.9	21	X	X	X	X
3709	HY	"	New Zealand	Yellow	1.8	27	X	X	X	X
507	HY	"	"	White	2.3	39	X	X	X	X
6836	HY	"	"	Yellow	2.6	34	X	X	X	X
3901	HY	"	"	Yellow	1.9	29	X	X	X	X
5065A	HY	"	"	White	2.1	43			X	X
X 304C	HY	"	"	Yellow	2.1	38			X	X
AD1-CO	OP	Kairi	None	Yellow	1.9	32			X	X
AD2-CO	OP	DPI	"	Yellow	1.8	34			X	X
BB1-C2	OP	Queensland	"	Yellow	2.3	34			X	X
BB2-C2	OP	"	"	Yellow	2.2	34			X	X
KC1-CO	OP	"	"	Yellow	2.2	47			X	X
KS14-CO	OP	"	"	Yellow	2.2	38			X	X
XL 81	HY	"	"	Yellow	2.2	30			X	X
Sergeant	HY	"	"	Yellow	2.0	35			X	X
XL 94	HY	"	"	Yellow	2.1	38			X	X
GH 5004	HY	"	"	Yellow	2.1	34			X	X
QK 675	HY	"	"	Yellow	2.4	52			X	X
QK 394A	HY	"	"	Yellow	2.4	35			X	X

* OP - open pollinated variety,
At Kiburu.

HY - hybrid variety.

Table 2: Details of experimental sites for PNG variety trial.

Site	Location	Altitude m.a.m.s.l.	Soil type	Annual rainfall mm	Mean max temp deg C	Mean min temp deg C
HAC	Kagamuga Mt Hagen WHP	1630	Alluvial	2717	25.1	13.9
HAES	Tambul WHP	2240	Alluvial volcanic ash	2617	21.0	10.0
Piwa	Tari SHP	1620	Alluvial volcanic ash	2693	23.9	13.1
Kiburu	Mendi SHP	1670	Alluvial volcanic ash	2800	23.5	12.7

2. PNG VARIETY TRIAL

Evaluation of hybrid and open pollinated material from within Papua New Guinea and from Kairi Research Station, DPI, Queensland.

2.1. Method

Thirty varieties were evaluated in this trial. Fifteen varieties available in Papua New Guinea, both open pollinated and hybrid, were evaluated at four locations, Mendi (Kiburu) and Tari (Piwa) in the Southern Highlands, and Mt Hagen (HAC) and Tambul (HAES) in the Western Highlands. Three other varieties available in Papua New Guinea and twelve varieties from Kairi were also evaluated, but only at two sites, Kiburu and Piwa. Variety details and sites at which they were tested are given in Table 1. Details of the experimental sites are given in Table 2.

A completely randomised block design in two replications was used for evaluation at each site. At Kiburu and Piwa, where all thirty varieties were evaluated, the varieties being evaluated at all sites and the varieties being evaluated only at Kiburu and Piwa were grown in separate blocks. Plot size was 15m sq (four 5m rows 75cm apart) and at harvest all plants in the central two rows were used for yield determination. The experimental method at each site was the same but, due to the geographical separation of the sites, operations were carried out at slightly different times at each site. Before thinning operations were carried out within a week of each other. After thinning work was carried out in relation to the growth stage of the crop at each site.

At each site, primary and secondary cultivations were completed not more than ten days before planting. At this time the experimental site was marked out and basal dressings of fertilizer applied and incorporated using a pedestrian rotary cultivator. Levels of fertilizer application are given in Table 3. On the day of planting plots were lightly cultivated and levelled to provide an adequate seedbed. The crop was planted by hand at twice the target population of 53,333 pl/ha with one seed per station. After planting, 2kg a.i. Lindane/ha was applied to the soil surface above the crop rows to control insect damage to the germinating and emerging plant, primarily from cut worm (Agrotis epsilon). This dressing was repeated approximately ten days after planting when the emerged stand was gap filled.

Table 3: Fertilizer application (nutrients as elemental kg/ha) in PNG variety trial.

Site	Nutrient							Mg	Zn
	N			P	K				
	*	#		*	*	#		*	*
HAC	30	30	30**	100	30	30	30**	10	2
HAES	30	30	30##	750	30	30	30##	10	2
Piwa	30	30	30**	200	30	30	30**	10	2
Kiburu	30	30	30**	200	30	30	30**	10	2

* Basal dressing

** Top dressed approx 60 DAP

Top dressed at thinning 30 DAP

Top dressed approx 90 DAP

One month after planting, the stand was thinned to the target population, with one plant per station, and a side dressing of fertilizer applied. A subsequent side dressing of fertilizer was made at 60 or 90 days after planting, depending on the site (Table 3).

Fertilizers were applied in sufficient quantities to ensure that nutrient supply did not limit crop yield. The levels of phosphorus fertilizer applied were required to overcome the high levels of phosphate fixation found in the experimental soils, which were derived from volcanic ash.

The crop was kept weed free primarily by hand weeding. At all sites except Piwa, an attempt was made to control weeds by applying Atrazine (1.7kg a.i./ha in high volume) six weeks after planting. Although the contact effect of this application was good, the residual effect was poor and hand weeding was subsequently used.

The crop was visited regularly, in practice at least twice a month, and more frequently at flowering, and observations made on the crop. At the dry silks stage the incidence of disease was scored. In practice it was only possible to score for two diseases Turcicum leaf blight (Helminthosporium turcicum) and common rust (Puccinia sorghi). For scoring a scale of 0-5 was used; 0 represented no infection and 5 complete infection.

The crop was harvested dry according to the maturity period of the varieties and air dried in storage before shelling. Grain dry matter and test weight were determined after shelling.

Table 4: Grain yield and ranking of varieties tested at all sites in PNG variety trial.

Variety #	HAC		HAES		Piwa		Kiburu *		Mean of sites	
	yield t/ha	rank	yield t/ha	rank	yield t/ha	rank	yield t/ha	rank	yield t/ha	rank
Hycorn 9	10.9a	1	7.3a	1	6.5abc	1	4.7	2	7.7a	1
507	9.7b	2	5.9bc	3	4.7abc	4	3.5	4	6.3b	2
6836	8.8bc	4	6.1b	2	4.5abc	5	5.0	1	6.2b	3
Piwa	9.7b	2	5.7bc	4	3.8bc	6	3.4	5	6.0bc	4
Tambul	6.4efg	8	3.8efg	11	5.2abc	2	3.9	3	5.0cd	5
Metro	6.7def	7	3.6fg	14	4.9abc	3	3.3	6	4.8d	6
Hycorn 1	6.9de	6	4.8cdef	7	3.5bc	7	2.7	7	4.7d	7
Q 12508	7.7cd	5	3.8efg	11	3.2bcd	9	2.2	13	4.5d	8
Suwan	6.0efgh	9	3.9efg	11	2.9bcd	10	2.5	9	4.5d	8
3709	5.1hi	12	5.2bcd	5	2.8bcd	12	2.3	11	4.0de	10
PX 49	5.4ghi	10	3.9efg	10	3.4bc	8	2.5	9	4.0de	10
3901	5.3ghi	11	4.9bcde	6	2.8bcd	12	1.9	14	4.0de	10
3591	4.8hi	13	4.2defg	9	2.9bcd	10	2.3	11	3.9de	13
Melbourne	4.2i	14	3.4g	15	2.4cd	14	2.7	7	3.3ef	14
Minicorn	2.6j	15	4.3defg	8	0.6d	15	0.5	15	2.2f	15
Site mean yield t/ha	7.0		4.7		3.7		2.9		1.1	
LSD (5%)	1.1		1.1		2.3		NA		22.1	
CV %	7.3		10.9		28.1		NA			

* One replicate only, other sites two replicates.
 # Varieties ranked in descending order of mean yield across all sites.
 ** Duncans multiple range test - means followed by the same letter are not significantly different ($P < 0.05$) from one another.

2.2. Results

The results are presented separately for those varieties tested at all four sites and those tested at only Kiburu and Piwa.

2.2.1. Varieties tested at all sites

i) Yield

Mean yields for varieties at all sites are summarised in Table 4. For these varieties establishment was good and the target population was established in all plots. For Kiburu the result from one replicate was discarded because of water logging which occurred after heavy rain, and which appeared to affect yield and uniformity of the crop.

Yields were highest at HAC (site mean of 7.0 t grain dry matter/ha) followed by HAES, Piwa and then Kiburu (site means of 4.7, 3.7 and 2.9 t grain dry matter/ha respectively).

In Table 4, varieties are ranked in descending order of mean yield over all sites. Hycorn 9, a hybrid variety, gave the significantly highest mean yield over all sites, and did consistently well at the individual sites. Thus, at HAC, HAES and Piwa, Hycorn 9 was the highest yielding variety, and at both HAC and HAES its yield was significantly greater than the second highest yielding variety. At Kiburu, Hycorn 9 ranked second, yielding slightly less than 6836. This result detracts little from the performance of Hycorn 9 as it is based on a single replicate. Also 6836's performance at other sites is less consistent than that of Hycorn 9; ranking 2nd at HAES, 4th at HAC and 5th at Piwa.

There were no significant differences in mean yield (over all sites) between the next three highest yielding varieties, the Pioneer hybrids 507 and 6836, and Piwa which is the current DPI recommendation for the highlands. Of the other two DPI recommended varieties, Suwan and Metro, Suwan but not Metro yielded significantly less than Piwa.

The mean yield differences between varieties yielding less than Metro were small and generally not significant. The exceptions were Melbourne and Minicorn which gave a significantly lower yield than the other varieties.

An analysis was conducted to determine whether there was a significant interaction in the performance of varieties between the three sites HAC, HAES and Piwa, where two replicates were harvested. This interaction was significant ($P < 0.05$) and resulted from the relatively good performance of

the Pioneer hybrids 3709, 3901 and 3591, and Minicorn at the high altitude site HAES, as opposed to the lower altitude sites. The performance of other varieties was consistent across the three sites.

Table 5: Variety scores (0 - no infection to 5 - complete infection) for Turcicum leaf blight (*Helminthosporium turcicum*) and common rust (*Puccinia sorghi*) for varieties tested at all sites (PNG variety trial).

Variety *	Turcicum leaf blight					Common rust
	HAC	HAES	Piwa	Kiburu	Mean #	HAES
Piwa	1.5	1	1.5	1.5	1.4a	1.5
Suwan	2	1	2	2	1.8ab	2
Metro	2	1	2	2	1.8ab	2
Hycorn 9	2.5	1	2	2	1.9abc	1
3709	2.5	1.5	2	2	2.0bcd	1
Q 12508	2.5	2	2	2	2.1bcd	1.5
PX 49	3	1.5	2	2	2.1bcd	1
3591	2.5	2	2	2	2.1bcd	1.5
Tambul	3	1.5	2.5	2	2.3bcd	2
6836	3	2	2	2	2.3bcd	1.5
Hycorn 1	3	1	2.5	2.5	2.3bcd	1
507	2.5	1.5	3	2.5	2.4cd	1.5
3901	3	1	3	2.5	2.4cd	1.5
Melbourne	3	1.5	3	2.5	2.5d	1.5
Minicorn	4	2.5	4	3	3.4e	1
Site mean	2.7	1.5	2.4	2.2		1.4
LSD (5%)	1.0	1.0	0.9	NA	0.5	0.9

* Varieties ranked in increasing order of mean *H. turcicum* score.

Duncans multiple range test - means followed by the same letter are not significantly different ($P < 0.05$) from one another.

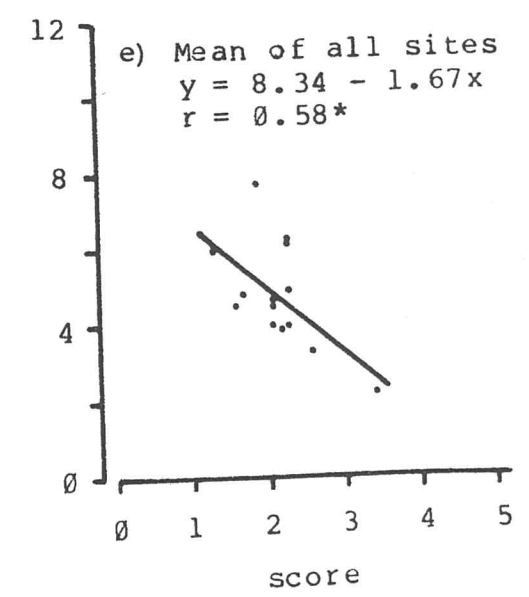
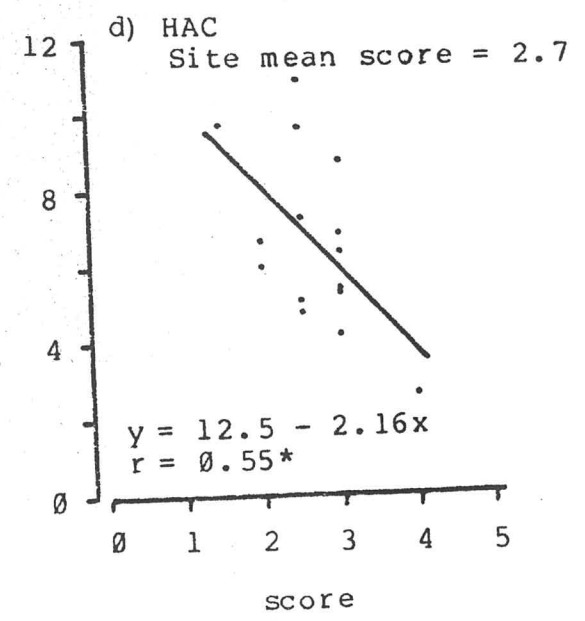
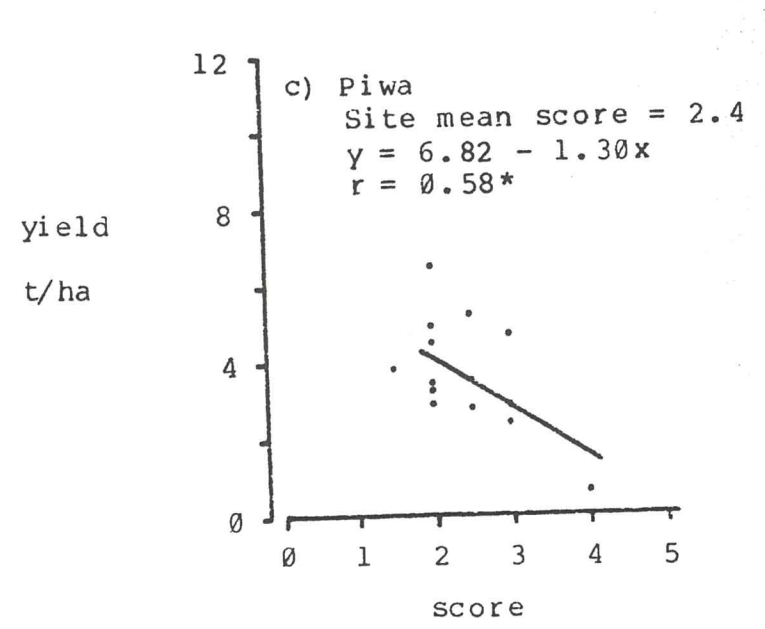
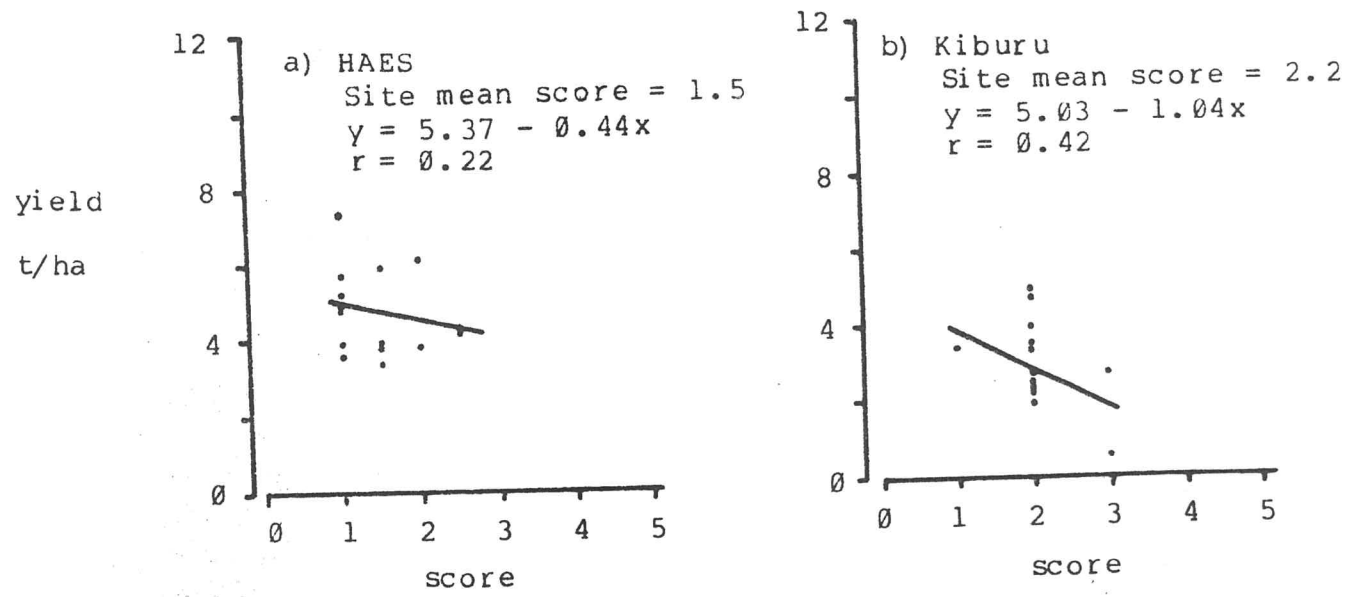


Figure: 1 The relationship between grain yield and mean Turcicum leaf blight score for 15 varieties at four sites (HAES, Kiburu, Piwa and HAC)

ii) Disease incidence

Turcicum leaf blight (Helminthosporium turcicum) was the most important disease at all sites, its mean scored incidence decreasing with altitude from 2.7 at HAC to 1.5 at HAES (Table 5). On average, Minicorn was the most susceptible variety and Piwa the least. The three DPI recommended varieties Piwa, Metro and Suwan, had the three lowest mean blight infection scores.

Field observation suggested that increased incidence of blight was associated with lower yields. This relationship was examined by regression analysis and the results are illustrated in Figure 1. At all sites grain yield decreased with increased level of blight infection, the rate of decrease increasing with the mean level of infection at each site. There was a significant correlation between yield and Turcicum blight infection score at two sites, Piwa and HAC (Figure 1, c and d), and for the mean effect over all sites (Figure 1 e).

The incidence of common rust (Puccinia sorghi) was only sufficiently high for scoring at HAES. This result is given in Table 5. The levels of rust were slight, there were no significant differences in scores between varieties and disease incidence was not related to yield.

iii) Insect damage

Insect damage to the crop was slight at all sites. The Lepidoptera spp., Heliothis armiger and Mythimna separata were the species most commonly found. However, their incidence was too low to make scoring practical.

Table 6: Yield and Turcicum leaf blight score for varieties classified by time to maturity (PNG variety trial).

Time to harvest (days)	Variety	Grain yield (t/ha)	Turcicum leaf blight score
130 - 140	Minicorn	2.1.	
	3901	3.8	3.4
	3709	3.9	2.4
	Mean	3.3	2.0
			2.6
140 - 150	Melbourne	3.4	
	Hycorn 1	4.6	2.5
	Tambul	5.1	2.3
	PX 49	3.9	2.3
	3591	3.6	2.1
	Mean	4.1	2.1
150 - 160	Hycorn 9	7.6	
	507	6.0	1.9
	Metro	4.8	2.4
	Q 12508	4.3	1.8
	Mean	5.7	2.1
160 - 170	Suwan	4.2	
	Piwa	5.8	1.8
	6836	6.3	1.4
	Mean	5.4	2.1
			1.8

* At Kiburu.
Mean over all sites.

iv) Maturity period

Results show that maturity period may be an important consideration in variety selection in this environment but it is difficult to determine the cause of this effect from the experimental data. In Table 6, varieties are grouped according to their maturity times into ten day intervals. Mean yields and blight scores are given for the varieties and groups. These results illustrate the generalised relationship between increased maturity, increased yield and decreasing incidence of blight.

For maize, the relationship of increased yield with increased time to maturity is to be expected (Duncan, 1975). However, for these varieties, the rate of grain dry matter accumulation per ha per day is lower (0.02t/ha/day) in varieties of a maturity period of less than 150 days, than in the varieties with a greater maturity period (0.03t/ha/day). This result suggests some benefit of increased time to maturity per se. In areas with a seasonal climate, maturity period in maize may be important as it enables the climate to be matched with the different environmental requirements of a maize variety during its growth period. At all the test sites climate is effectively aseasonal so it seems unlikely that such an effect operated here.

In this trial it was noted that, particularly amongst the earlier maturing varieties, senescence of the plant occurred before grain fill was complete. This effect was apparent only after the green cob stage and may explain the lower rates of grain dry matter accumulation in earlier maturing varieties. The incidence of Turcicum leaf blight may be involved in this effect; by reducing leaf area, blight attack would reduce the supply of assimilate and lead to premature senescence. The most extreme case of premature senescence and failure of grain fill was in Minicorn, which was both the earliest maturing and the most blight susceptible variety. At both HAC and Piwa, the sites with high incidence of leaf blight, stem collapse had occurred in Minicorn before the grain was mature. In contrast, at HAES, the site with the lowest incidence of Turcicum blight, the effect of premature senescence was minimal and Minicorn was the 8th highest yielding variety. At all other sites, Minicorn was the lowest yielding variety.

For reference purposes the approximate maturity times for Hycorn 9 and Piwa at the different sites are given in Table 7.

Table 7: Time to harvest (days) of Hycorn 9 and Piwa at the four test sites in PNG variety trial.

Site	Altitude m.a.m.s.l.	Variety	
		Hycorn 9	Piwa
HAC	1600	140-150	160-170
Piwa	1640	140-150	160-170
Kiburu	1685	150-160	160-170
HAES	2240	190-200	210-220

v) Other variables

Results from the other variables recorded are not given in detail. While this is partly because of the complexity of presentation for a large number of varieties at different sites, it is mainly because results have a limited impact on the criteria for variety selection, and because results, as would be expected, tend to follow grain yield. For example, the number of cobs per plant and grain test weight for a variety are positively correlated with grain yield. Thus in this section, only deviations from these generalisations are considered, particularly where they are considered relevant to variety selection criteria.

Although percent lodging was positively related to Turcicum leaf blight infection score, there was a deviation from the general trend in that lodging in the taller PNG varieties, Piwa and Q 12508, was higher than would be expected from their leaf blight scores. This was because these varieties, being tall, lodged easily in the wet and windy conditions that occurred before harvest, particularly at Piwa. Although in this trial, there was probably little yield loss associated with this lodging, the increased lodging in tall varieties does illustrate a particular disadvantage of such varieties under highland conditions. Lodging would be expected to lead to yield loss as a result of rat damage, increased ear rotting and germination in the ear, especially in the production of dry grain.

The DPI recommended varieties were tall, with Piwa (2.6m) and Q 12508 (2.8m) the two tallest varieties in the trial. Another characteristic of the DPI varieties was their relatively high ear position. Piwa and Q 12508 had the highest ear position, when expressed as a percentage of panicle height, 46% and 48%, respectively (Table 1).

Table 8: Grain yield and ranking of varieties tested only at two locations (Kiburu and Piwa) in PNG variety trial.

Variety	Type	Origin	Piwa, Tari		Kiburu, Mendi		Mean of sites	
			yield t/ha	rank	yield t/ha	rank	yield t/ha	rank
QK 675	HY	Kairi	9.3	1	6.0	2	8.2	1
GH 5004	HY	Kairi	NR		6.4	1	6.4*	2
QK 394A	HY	Kairi	8.3*	2	3.9	6	6.1	3
X 304C	HY	Yates	6.8	3	4.5	4	6.1	3
BB1-C2	OP	Kairi	7.1	4	3.8	9	6.0	5
XL 81	HY	Kairi	NR		5.3	3	5.3*	6
BB2-C2	OP	Kairi	5.5*	5	3.8	8	4.6	7
SERGEANT	HY	Kairi	NR		4.4	5	4.4*	8
XL 94	HY	Kairi	NR		3.9	6	3.9	9
5065A	HY	Yates	4.6	6	2.6	12	3.9	9
KC1-CO	OP	Kairi	4.3*	7	2.9	10	3.6	11
KS14-CO	OP	Kairi	NR		2.7	11	2.7*	12
AD2-CO	OP	Kairi	1.3*	8	0.8	14	1.1	13
AD1-CO	OP	Kairi	NR		0.9	13	0.9*	14

* One replicate only.

Table 9: Comparison of mean grain dry matter yields for all varieties tested at Kiburu and Piwa (PNG variety trial).

Variety	* Piwa, Tari		# Kiburu, Mendi		** Mean of sites	
	yield t/ha	rank	yield t/ha	rank	yield t/ha	rank
	##					
QK 675	9.3a	1	6.0	1	8.2a	1
X 304C	6.8abc	3	4.5	4	6.1b	2
BB1-C2	7.1ab	2	3.8	6	6.0b	3
Hycorn 9	6.5abc	4	4.7	3	5.9b	4
Tambul	5.2abc	5	3.9	5	4.8bc	5
6836	4.5bc	9	4.9	2	4.6bcd	6
Metro	4.9abc	6	3.3	9	4.4bcde	7
507	4.7bc	7	3.5	7	4.3bcdef	8
5065A	4.6bc	8	2.6	12	3.9cdef	9
Piwa	3.8b	10	3.4	7	3.7cdef	10
Hycorn 1	3.5bc	11	2.7	10	3.2cdef	11
PX 49	3.4bc	12	2.5	13	3.1cdef	12
Q 12508	3.2bc	13	2.2	17	2.9def	13
Suwan	2.9bc	14	2.5	13	2.8def	14
3591	2.9bc	15	2.3	15	2.7ef	15
3709	2.8bc	16	2.3	15	2.6ef	16
Melbourne	2.4bc	18	2.7	10	2.5f	17
3901	2.8bc	16	1.9	18	2.5f	17
Minicorn	0.6c	19	0.5	19	0.6g	19
LSD (5%)	4.0		na		1.59	
CV %	44.0		na		23.9	

* Mean of two replicates.

Data from one replicate.

** Mean of three replicates, two from Piwa and one from Kiburu.

Duncans multiple range test - means followed by the same letter are not significantly different ($P < 0.05$) from one another.

2.2.2. Varieties tested at two sites (Piwa and Kiburu)

The grain yield of varieties tested only at Piwa and Kiburu are listed in Table 8. Unfortunately, results for these varieties are limited because of the generally poor establishment of varieties from Kairi at both Piwa and Kiburu, and because one replicate was abandoned at Kiburu because of waterlogging. Of all the sites, Piwa had the lowest mean level of establishment. Results are only presented here for plots in which it was possible to establish a population of at least 41,666 pl/ha at thinning. Consequently, there is a paucity of yield information for the Kairi material.

Table 9 compares the yields of all the varieties grown at Kiburu and Piwa, both from the group tested only at Kiburu and Piwa, and the group tested at all sites. Results are only presented for varieties in which establishment was satisfactory in both replicates at Piwa. An analysis of variance was conducted on the mean results from the three replicates for the two sites.

Three of the varieties tested only at Piwa and Kiburu had a higher mean yield at these sites than Hycorn 9, the highest yielding variety from the group tested at all sites. However, only for the Kairi hybrid QK 675 was this difference significant (Table 9). Comparison of variety performance at only two sites changes the relative performance of the open pollinated varieties. A Kairi variety, BB1-C2, was the highest yielding open pollinated variety although this yield was not significantly greater than the next highest yielding open pollinated varieties, Tambul and Metro. The performance of Piwa at these two sites, in comparison to that over the four sites, was relatively poor.

The high yield of QK 675, X 304C and BB1-C2 at Kiburu and Piwa was not related to any marked reduction in blight infection in these varieties.

are not significantly different ($P < 0.05$) from one another.

Table 10: Varieties tested in CIMMYT variety trial.

Entry	Description	Source of seed
Across 7921	Full season tropical varieties	CIMMYT 1983 Elite variety trial 18A
Guaymas (1) 8022		
La Maquina 8022		
Poza Rica 8024		
Suwan 8027		
Pichilingue 7928		
Across 7929		
Across 7936		
Across 8043		
Across 7728		
Across 7729		
Yousafwala 8033	Full season sub-tropical varieties	CIMMYT 1983 Elite variety trial 20
Across 7934		
Antalya 8045		
Across 8045		
Tlaltizapan 8046		
Gemiza 8047		
Across 8047		
Quilamapu 7948		
Across 7948		
Across 7734		
Across 7748		
Suwan 1 (S) C9-F2	Downy mildew resistant varieties	CIMMYT Asian Regional Maize Programme
Suwan 2 (S) C7-F2		
Caripeno (S) C5-F2		
Takfa early-139 (S)C1-F1		
Suwan (PNG)	Local varieties	Department of Primary Industry Papua New Guinea
Piwa		

3. CIMMYT VARIETY TRIAL

Evaluation of open pollinated varieties from CIMMYT, Mexico.

3.1. Method

A total of twenty six open pollinated varieties supplied by CIMMYT were evaluated in this trial (Table 10). Twenty two of the varieties tested came from two elite variety trials, ELVT 18A (full season tropical varieties) and ELVT 20 (full season sub-tropical varieties), which were part of CIMMYT's International Maize Testing Programme for 1983. In addition, four of CIMMYT's downy mildew resistant varieties from the Asian Regional Maize Programme were also tested.

Papua New Guinea quarantine regulations restrict the import of maize seed from areas where Stewart's wilt (*Erwinia stewartii*) is known to exist. As a result there were considerable restrictions on the import of the CIMMYT material. The quarantine restrictions were as follows.

1. On receipt, seed was immersed in sodium hypochlorite solution with 3% available chlorine content for 10 minutes and subsequently air dried.
2. The evaluation trial was established in a quarantine area as best isolated from other maize growing areas as possible. Entry to the quarantine area was restricted to essential personnel and activities.
3. All plants in the trial were inspected regularly, at least twice weekly, by the agronomist conducting the trial, for the presence of pathological symptoms. No pathological symptoms which might have been related to the incidence of Stewart's wilt were observed.
4. A plant pathologist from DPI, Konedobu, inspected the trial eighty eight days after planting for the presence of Stewart's wilt. No pathological evidence of this disease was reported.
5. Only 200 seeds of each variety were released by quarantine for evaluation.

Material was evaluated at Kiburu Farm, one of the test sites for the PNG variety trial (Table 2).

A completely randomised block design in four replications was used for evaluation. Due to the restrictions on seed numbers available, plot size was one row, 5m long and 75cm wide. Each replicate consisted of two raised beds 12m by 5m. In each bed 16 rows of maize were planted, the outer

two rows being discard rows of a local variety which had not been included as a test variety in the trial. The inner fourteen rows contained the fourteen varieties allocated to that bed. At harvest, all plants in the plot were used for yield determination.

Table 11: Fertilizer application in CIMMYT variety trial (nutrients as elemental kg/ha).

Timing of application	Nutrient				
	N	P	K	Mg	Zn
Seedbed	30	200	30	10	2
21 DAP	30		30	5	
42 DAP	20		30	5	
84 DAP	20				

Primary and secondary cultivations were completed ten days before planting. At this time, the experimental site was marked out and basal dressings of fertilizer (Table 11) applied and incorporated using a pedestrian rotary cultivator. On the day of planting, plots were lightly cultivated and levelled to provide an adequate seedbed. The crop was planted by hand at twice the target population of 53,333 pl/ha with one seed per station. Immediately after planting 2kg a.i. Lindane/ha was applied to the soil surface above the crop rows to control cut worm (Agrotis epision) damage to the emerging plant. This dressing was repeated approximately ten days after planting, when the emerged stand was gap filled. Twenty one days after planting, the stand was thinned to the target population, with one plant per station, and a side dressing of fertilizer was applied. A subsequent side dressing of fertilizer was made at 42 and 84 days after planting (Table 11).

The crop was kept weed free by hand weeding and no plant protection measures other than those given above were taken. At the dry silks stage the crop was assessed for insect and disease incidence. The low levels of insect incidence precluded scoring.

Although the rusts, Puccinia polysora and P. sorghii were present in the crop, their incidence was slight and largely obscured by the widespread occurrence of Turcicum leaf blight. Because of this, scoring was only practical for the incidence of Turcicum leaf blight (Helminthosporium turcicum).

The crop was harvested according to the maturity of the varieties and dried in storage before shelling to determine grain yield. The dry matter and the test weight of the grain were determined after shelling. At harvest, other

experimental variables were recorded for which results are given in Tables 12 and 13; recording methods are self explanatory or have been described above (see 2.1). Plants were rated on their overall appearance immediately before harvest on a scale of 0 (bad) to 5 (good). A similar procedure was used to rate husked cobs at harvest.

Table 12: Variety means of selected experimental variables for CIMMYT variety trial
(continued on next page).

Variety *	Days to 50% flower	Panicle height (cm)	Ear Position as % of panicle height	Cob number per plant	Grain dry weight t/ha	Test wt g/100 seeds	Shelling %
					#		
Suwan 1	84	205	47	1.2	5.61a	25.8	74.4
Suwan 8027	86	190	56	1.2	5.13ab	22.9	77.4
Piwa	86	250	57	1.3	5.01ab	23.9	76.6
Caripeno	79	200	47	1.2	4.87abc	22.6	80.9
Across 7921	85	200	48	0.9	4.38bcd	22.5	74.7
Poza Rica	85	210	48	1.0	3.96cde	20.1	71.9
Gemiza	74	170	43	1.0	3.75def	23.1	77.7
Across 7929	86	190	50	1.0	3.50defg	19.5	76.5
Across 7729	87	200	47	1.0	3.44defg	20.8	74.3
Across 7936	84	200	50	1.1	3.42defg	21.6	76.7
Across 7728	84	200	53	1.1	3.40defg	20.9	77.6
Suwan (PNG)	83	205	55	1.2	3.31defgh	18.1	78.5
Guaymas	85	200	50	0.9	3.28defgh	19.6	77.5
Pichilingue	82	195	52	1.0	3.23efghi	18.4	77.5
Suwan 2	75	175	44	1.1	3.01efghi	19.5	77.4
Across 8043	89	210	48	0.9	2.79fghi	22.0	75.8
Across 7934	80	180	46	1.0	2.74fghi	19.3	75.1
La Maquina	85	185	46	0.9	2.45ghij	17.7	73.4
Across 7734	78	195	47	0.9	2.22hijk	20.0	74.9
Across 8045	73	165	52	1.0	2.16ijk	16.9	78.9
Across 8047	76	165	44	0.8	1.94jkl	18.1	74.8
Anatalya	73	160	42	1.0	1.65kl	17.2	72.6
Takfa early	70	150	42	1.0	1.05lm	18.2	73.4
Across 7748	64	175	39	0.7	0.51m	14.8	64.4
Yousafwala	68	135	45	0.6	0.43m	12.3	62.9
Across 7948	64	130	32	0.9	0.31m	13.9	59.7
Quilamapu	68	150	35	0.9	0.24m	12.8	50.6
Tlaltizapan	60	120	44	0.4	0.20m	12.8	51.6
LSD (5%)	4.3	29	9.8	0.3	0.95	3.6	10.6
CV %	3.9	11.4	14.9	19.7	24.4	13.2	10.4

* Ranked according to descending order of grain yield.

Duncans multiple range - means followed by same letter are not significantly different ($P < 0.05$) from one another.

** Variety names have been shortened - see Table 10 for full name.

Table 12: (Continued)

Variety*	% Root lodging	% Stalk lodging	% Rotten cobs	% Cobs with loose tips	Cob rating (0-5)	Plant rating (0-5)	Turcicum score (0-5)
Suwan 1	0	1	3	11	3.0	4.0	1.3
Suwan 8027	4	0	1	11	3.5	3.3	1.3
Piwa	8	0	1	3	3.3	4.0	1.3
Caripeno	2	1	7	8	3.3	2.8	1.5
Across 7921	3	0	3	4	2.3	3.8	1.5
Poza Rica	0	3	7	9	3.0	3.3	1.8
Gemiza	4	1	3	9	2.5	2.8	1.5
Across 7929	4	5	3	7	2.8	3.3	1.3
Across 7729	6	0	4	9	2.8	3.3	2.0
Across 7936	7	2	5	9	2.5	3.5	1.8
Across 7728	6	2	4	15	2.5	3.3	1.3
Suwan (PNG)	9	6	7	10	4.0	3.3	1.8
Guaymas	3	4	5	11	2.3	3.3	1.8
Pichilingue	2	1	6	9	2.8	3.0	2.0
Suwan 2	1	7	0	7	2.8	3.0	1.3
Across 8043	0	1	2	12	2.0	3.0	2.3
Across 7934	3	6	7	2	2.8	2.5	2.0
La Maquina	10	0	0	8	2.0	3.5	2.3
Across 7734	9	0	9	7	2.3	2.8	1.8
Across 8045	9	7	2	5	2.5	2.3	2.0
Across 8047	14	3	3	10	2.8	2.5	2.0
Antalya	13	4	2	9	2.8	2.0	2.0
Takfa early	5	20	0	2	2.8	2.3	2.5
Across 7748	1	22	2	0	1.8	1.8	2.8
Yousafwala	12	15	17	0	1.5	2.0	3.3
Across 7948	7	19	7	0	1.3	1.0	3.3
Quilamapu	1	26	2	2	1.8	1.3	3.0
Tlaltizapan	6	38	12	6	1.3	1.0	4.0
LSD (5%)	8	11	9	10	1.0	0.7	0.7
CV %	112	113	149	99	28.7	18.4	25.3

Table 13: Variety type means of experimental variables for CIMMYT variety trial.

Variety type	No of varieties	Days to 50% flower	Panicle height (cm)	Ear position % of panicle height	Cob No per plant	Grain dry wt t/ha	Test wt g/100 grains	Shelling %
Local	2	85	230	56	1.2	4.28	21.4	77.4
DMR *	4	77	180	45	1.1	3.68	21.7	76.4
Tropical	11	85	200	50	1.0	3.54	20.5	75.7
Sub-tropical	11	70	160	43	0.9	1.58	16.8	68.6

Variety type	% root lodging	% stalk lodging	% rotten cobs	% cobs with loose tips	Cob rating 0-5	Plant rating 0-5	Turcicum score 0-5
Local	9	3	4	6	3.1	3.6	1.5
DMR *	2	7	3	7	2.9	3.0	1.6
Tropical	4	2	4	10	2.6	3.3	1.7
Sub-tropical	7	13	6	4	2.1	2.0	2.5

* Downy mildew resistant variety.

3.2. Results

i) Yields

Mean effects of varieties on selected experimental variables are given in Table 12. There were no significant differences in the grain yield of three three highest yielding varieties, respectively Suwan 1 (downy mildew resistant), Suwan 8027 (tropical variety) and Piwa (local check). Piwa itself was not significantly higher yielding than Caripeno, a downy mildew resistant variety, and Across 7921, a tropical variety.

The mean effect on the same experimental variables of variety type classed as local, downy mildew resistant, tropical and sub-tropical varieties is given in Table 13. No standard errors are given in Table 13 because of the complexity of providing multiple standard errors to compare means from populations of different sizes. However, there were significant differences between groupings for all variables in Table 13 except percent rotten cobs. Table 13 demonstrates the relatively good performance of the local variety population in contrast to the intermediate performance of the downy mildew resistant and tropical populations, and the poor performance of the sub-tropical population.

ii) Disease incidence

Turcicum leaf blight (H. turcicum) was the most important disease present and tended to obscure the slight incidence of the rusts P. polysora and P. sorghii.

The effect of Turcicum leaf blight was severe, particularly among the lower yielding varieties, e.g. Across 7748, Yousafwala, Across 7948, Quilamapu and Tlaltizapan (Table 12) and sub-tropical varieties (Table 13). Scoring was done at the dry silks stage, and does not reflect the complete defoliation that had occurred in these varieties by maturity. Levels of Turcicum infection were significantly positively correlated with percent stalk lodging. The extent of this relationship was particularly notable for the six lowest yielding varieties (Table 12).

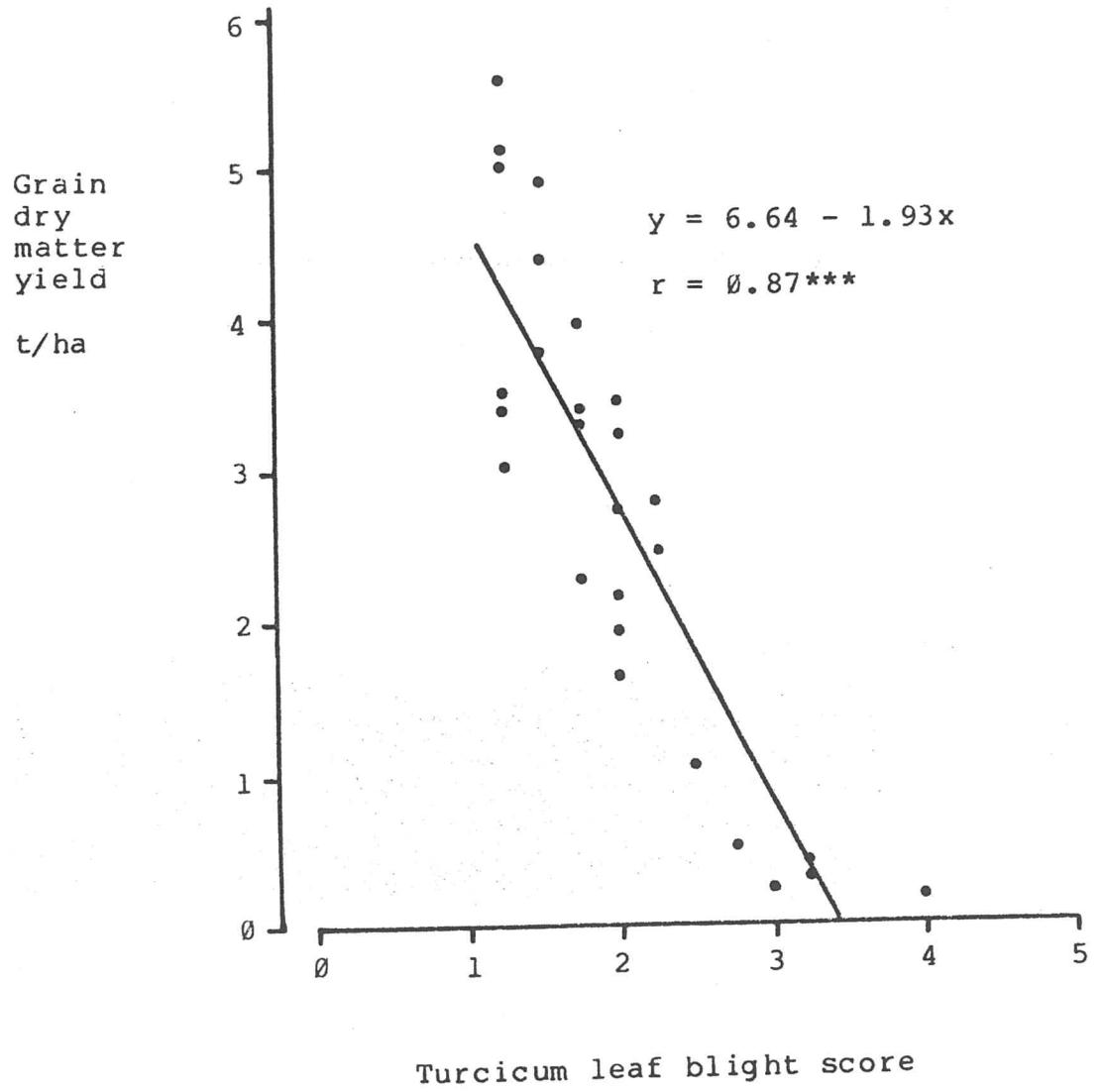


Figure 2: The relationship between grain yield and Turcicum leaf blight score for varieties in CIMMYT variety trial.

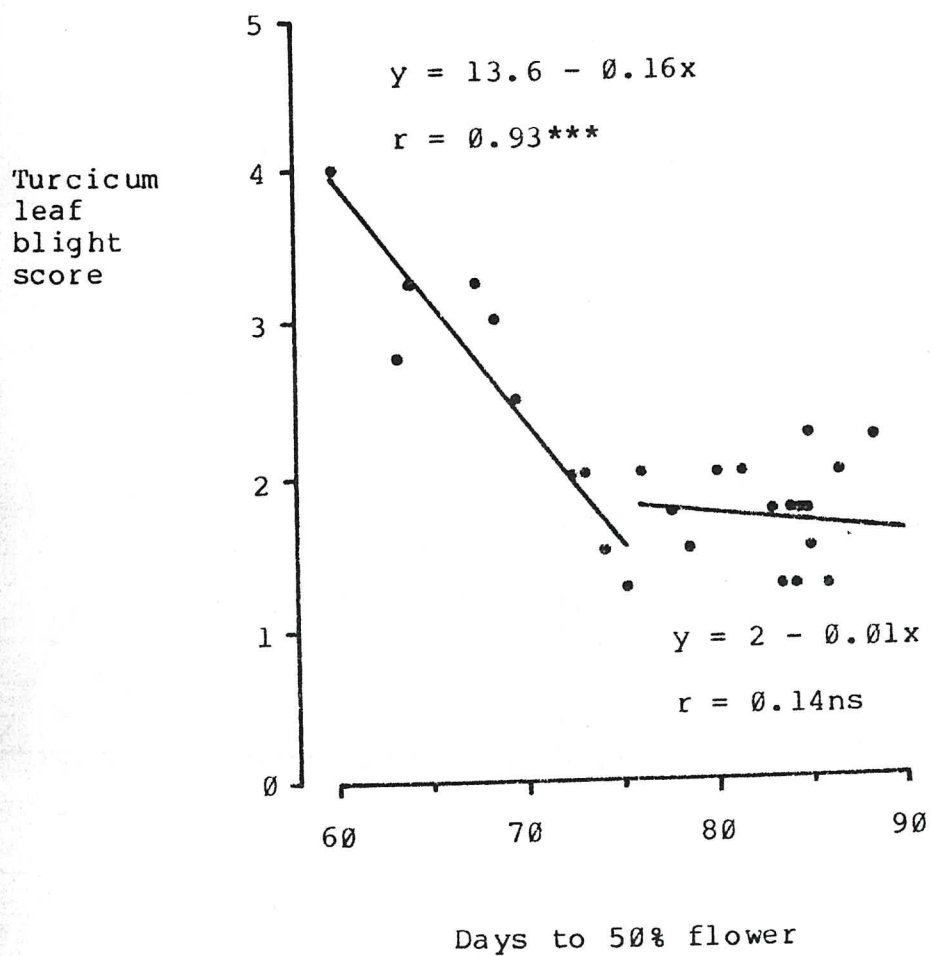


Figure: 3 The relationship between Turcicum leaf blight score and maturity (days to 50% flower) for varieties in CIMMYT variety trial. (Regression lines have been fitted to maturity groups of greater than, and less than, 75 days to 50% flower).

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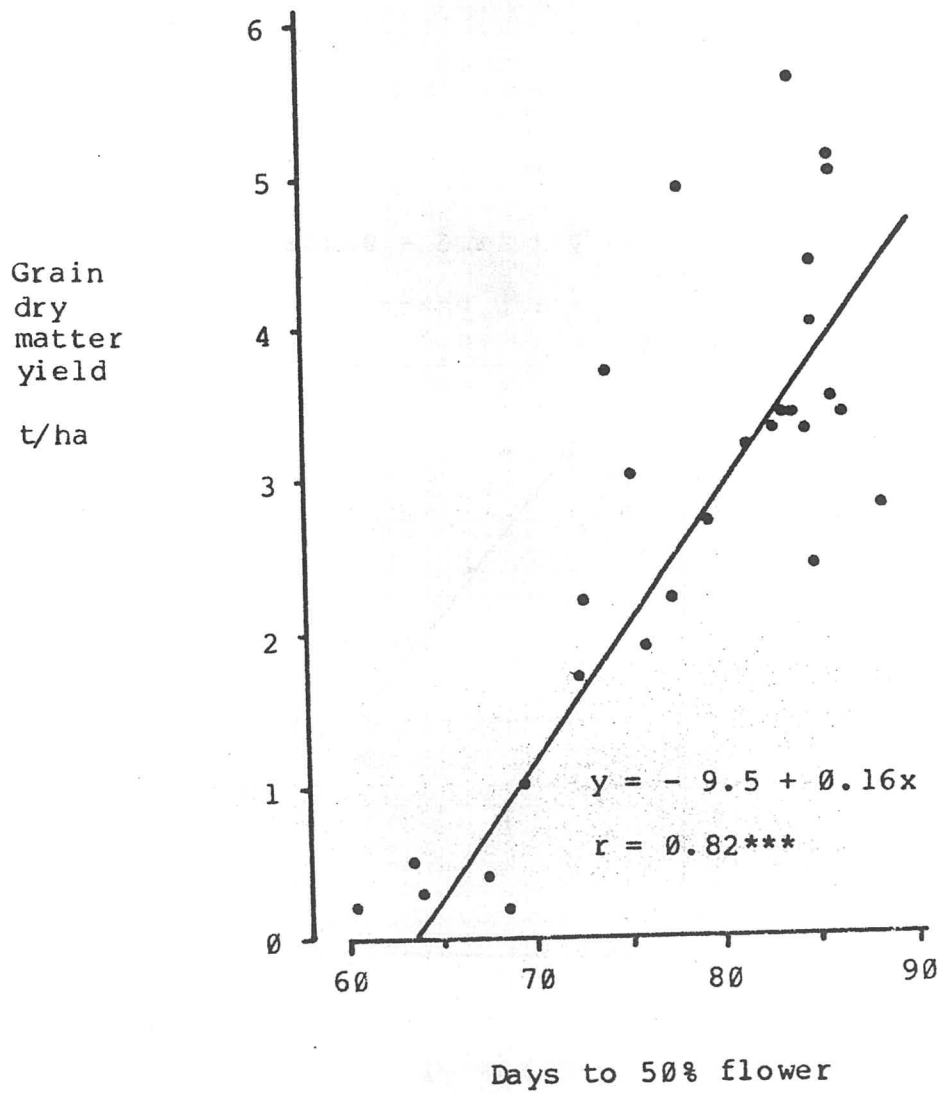


Figure: 4 The relationship between grain yield and maturity (days to 50% flower) for varieties in the CIMMYT variety trial.

There was a significant linear correlation between mean grain yield and mean Turcicum blight scores for the varieties tested. This relationship is illustrated in Figure 2.

The mean Turcicum leaf blight scores were also related to the maturity period of the varieties. In varieties of less than 75 days to 50% flower earlier maturity was associated with increased Turcicum infection. In varieties of greater than 75 days to 50% flower, there was no relationship between maturity period and Turcicum damage (Figure 3).

iii) Insect damage

Insect damage in this trial was minimal and was limited to the sporadic feeding by the Lepidoptera species, Heliothis armiger and Mythimna separata. Their low levels of incidence present precluded scoring.

iv) Maturity period

Grain yield increased with increased maturity period over all varieties tested and there was a significant correlation between the two variables (Figure 4).

v) Other variables

Although results from other variables are given in Table 12, they are not discussed in detail. This is largely because variables have a limited importance as criteria for variety selection. In addition, results, as expected, tend to follow grain yield results: for example, grain test weight, shelling percent and number of cobs per plant were significantly and positively correlated with grain yield. Although other significant correlations exist between variables, whether causal or not, the relationships are only discussed where they are of practical relevance.

Results from other variables may provide additional selection criteria between varieties. For example, although results were not significant, Suwan 1 and Suwan 8027 had a higher percentage of cobs with loose tips than did Piwa (Table 12). While the Suwan varieties gave a slightly higher yield than Piwa, the greater proportion of loose tips could confer a disadvantage in permitting a more rapid development of ear rots or possible invasion of Heliothis armiger. Under the trial conditions, there was little difference in the occurrence of ear rots between varieties (Table 12) but loose tips could be of greater importance under different conditions.

Except for four varieties, percentage root lodging was less than 10% but, of the top five yielding varieties, Piwa had at least twice the rate of root lodging.

As in the PNG variety trial, the local varieties tended to be tall and to have a high ear position. Piwa was the tallest variety (2.5m) and had the highest ear position (57%). Although shorter, the local Suwan (PNG) and Suwan 8027 had higher ear positions, but Suwan 1's ear position (47%) was relatively low (Table 12).

4. DISCUSSION

The results of both these trials were not entirely satisfactory; in the PNG variety trial, the Kairi material was poorly evaluated, and in the CIMMYT variety trial the limited plot size, necessitated by the limited quantity of seed, would have reduced the precision of results obtained. However, despite these limitations, the results do provide a basis for making recommendations and for establishing priorities for further work.

4.1. Recommendations

The current DPI recommendation of the open pollinated variety Piwa for the Highlands is endorsed. However, improvements are necessary to rectify Piwa's less desirable characteristics. These improvements are discussed below (4.7). Of the hybrid varieties tested, Hycorn 9 is recommended for use.

The trials did not permit conclusive rejection of alternative test varieties that performed, at some stage, as well as, or better, than Piwa. Major restrictions on the conclusiveness of results were: the loss of one replicate at Kiburu; the poor germination of Kairi material in the PNG variety trial; and the small plot size necessitated by the release of limited quantities of seed of the CIMMYT varieties, in conformity with quarantine regulations.

Further testing of other promising material is recommended; these recommendations are given below (4.6).

4.2. Disease incidence

These trials, particularly the CIMMYT variety trial, indicated the potential severity of Turcicum leaf blight in this environment. This severity is probably not fully appreciated because the local varieties have a degree of resistance to the disease and because maize is seldom grown as monocrop plantings on the scale of these trials. The poor yields of susceptible varieties and the significant relationship between yield and Turcicum leaf blight incidence in the CIMMYT variety trial, serve to illustrate that only Turcicum leaf blight resistant or tolerant material should be considered in any further evaluation.

4.3. Variety type

Results show that, in general, tropical as opposed to sub-tropical or temperate, varieties of maize appear more suitable for the highlands. In the CIMMYT variety trial,

sub-tropical varieties were less resistant to Turcicum leaf blight and this may largely explain why, as a group, they performed less well than tropical varieties.

In the PNG variety trial, there was also evidence from the performance of the Pioneer hybrids that tropical varieties were more suitable to lower altitudes and temperate varieties to higher altitudes. The temperate hybrids 3591, 3907 and 3901 performed relatively better at the high altitude site (HAES), while the sub-tropical hybrids 507 and 6836 and the tropical hybrids 5065A and X 304C performed relatively better at the lower altitude sites. Unfortunately, it was not possible to test all the Pioneer hybrids at all sites. However, the combined evidence from the two trials suggest that tropical, and in some cases sub-tropical, germplasm will perform best in the highlands.

Varieties from the Suwan population were extensively tested in these trials and this population appears a good source of germplasm for further evaluation. The Suwan population of maize, which was developed in Thailand, has the added advantage that it is also downy mildew resistant. Downy mildew of maize, although not commonly seen in the highlands, possibly because local varieties have some resistance, could become important in more intensive maize production systems.

4.4. Maturity period

In both these trials, varieties with a maturity period of greater than 75 days to 50% flower, which is equivalent to 150 days to physiological maturity in this environment, were more suitable for dry grain production. This suitability was related to the tendency for varieties with a shorter maturity period to be more susceptible to Turcicum leaf blight. From the data, it is not certain whether a causal relationship exists between maturity and Turcicum leaf blight resistance. However, results obtained show that, in this environment, the most suitable varieties will tend to have a maturity period of greater than 75 days to 50% flower.

4.5. Soil fertility

The yields of maize were good, particularly at HAC, and illustrate the potential for maize production in this environment. At all sites the limited availability of soil phosphorus is probably the major constraint to maize production. Low levels of available soil phosphorus are a major constraint to crop production on volcanic ash soils in this area (Radcliffe, 1983). These trial yields were achieved with the relatively large application (200-750kg P/ha)

phosphate fertilizer. Other experimental results (AFTSEMU unpublished data) show that, with the levels of fertilizer applied, it is unlikely that the supply of nutrients would have significantly limited yield at any of the sites. Further results (AFTSEMU unpublished data) also show that production of grain maize in the Highlands can be economic because of the high yields possible when soil fertility constraints to production are overcome, and because fertilizer placement can be used to reduce the levels of fertilizer application required.

Progress has been made in identifying rice varieties with a degree of tolerance to low levels of soil phosphorus but no such progress is reported for maize (Sanchez, 1976). Although research in this direction may be considered a high priority internationally, variety screening for varieties tolerant to low levels of soil available phosphorus in the highlands is of limited importance. The problem of phosphorus fixation is so severe in these soils that initially it would be more productive to overcome the fertility problems by agronomic methods, rather than by variety identification or breeding.

Maize variety identification should therefore aim to identify varieties capable of yield responses under conditions of improved soil fertility. The agronomic potential for overcoming soil fertility problems with regard to maize is discussed elsewhere in AFTSEMU Technical Reports.

4.6. Further testing

These trials did not identify a variety which could be recommended as a replacement for Piwa. However, results do indicate that further testing of some varieties is required to more clearly establish their performance relative to Piwa.

a) Open pollinated varieties

Four varieties, Suwan 1, Suwan 8027, Caripeno and Across 7921, which gave yields comparable to, and not significantly different from, Piwa in the CIMMYT variety trial should be further evaluated with a larger plot size and at a range of sites.

Suwan 1 is of particular interest as a replacement for Piwa. Besides giving a slightly higher yield than Piwa, Suwan 1 has a shorter more compact plant habit, lower ear position and reduced plant to plant variability.

In the PNG variety trial the performance of the Kairi open pollinated variety BB1-C2 suggests that adequate screening of Kairi open pollinated material is a priority.

b) Hybrid varieties

Despite the recommendation of Hycorn 9, a greater degree of resistance to Turcicum leaf blight than afforded by Hycorn 9 is desirable. This means that further testing is necessary to identify hybrid material of equivalent, or higher yield, but with a greater degree of resistance to Turcicum leaf blight. Thus early further testing of the Kairi Hybrid QK 675 and the Pioneer hybrid X 304C is recommended.

Although the demand for hybrid variety seed would not justify in-country multiplication, the availability of seed of suitable hybrid varieties is important in order to provide adequate seed to growers, particularly for cash earning enterprises. Thus limited continued testing of hybrid material is warranted.

4.7. Breeding

For a country with the limited agricultural research and development resources of Papua New Guinea, variety improvement is best achieved by variety identification rather than by variety development (breeding). Breeding, because of the relatively slow gains and high cost of the programme should be considered only after the possibilities for variety identification have been exhausted.

In Papua New Guinea two main factors militate against variety identification work being successful and suggest the need for undertaking some breeding work.

Firstly, because PNG is remarkably free of maize diseases, quarantine regulations must be strictly enforced. This restricts the extent of maize germplasm populations which can be sampled, particularly with the level of quarantine support services currently available.

Secondly, the limited occurrence of humid tropical highland environments world wide means that breeding of varieties for this environment may receive limited attention. This reduces the potential for identifying germplasm from other countries likely to be suitable for the highlands of Papua New Guinea.

Despite the continued recommendation of Piwa, some improvements are needed in this variety. Some of these are necessary to reverse the inbreeding decline which has occurred under the uncontrolled multiplication which has taken place. Some measures are needed to modify the following characteristics of Piwa.

- a) Vigour
Although Piwa is generally a vigorous variety, considerable variation in vigour exists within a population sample. A reduction in this variation could be effected by appropriate roguing in multiplication blocks.
- b) Ear height
The ear position in Piwa is relatively high and variable. Ear position needs to be lowered and the variation eliminated. This could be achieved by progressive roguing in multiplication plots.
- c) Variability
There is considerable plant to plant variation within the current populations of Piwa. Although some variability, particularly in flowering patterns, is desirable in an open pollinated variety, it would be beneficial to reduce the degree of general variability in Piwa. This could be achieved by progressive roguing in multiplication plots.
- d) Turcicum leaf blight resistance
In comparison to other entries in this trial, Piwa was resistant to Turcicum leaf blight. However, further increases in resistance would be desirable, particularly in large plantings, and could be achieved by incorporating disease resistance in an appropriate breeding programme.
- e) Plant habit
Piwa's tall and leafy plant habit is an undesirable characteristic where maize is planted as an intercrop, as it results in shading of lower growing crops. As intercropping is predominant in the highland subsistence system, it would be desirable for maize varieties to have a less competitive plant habit. A further disadvantage of a tall variety can be its propensity to lodge. For Piwa, this effect was seen in both trials and confirms the need to reduce Piwa's height, or, probably more practically, replace Piwa with a shorter variety of at least equivalent yield and disease resistance.

Of the above measures, the first three could be implemented relatively simply in DPI multiplication blocks. Other measures require slightly more sophisticated methods and planning, and the acquisition of germplasm with desirable characteristics. This type of programme, of which a good example is given by Darrah and Mukuru (1977), aims to improve a local variety and should be within the capabilities of a regionally based National DPI research team.

5. CONCLUSIONS

1. Piwa, the current DPI recommendation, continues to be recommended for highlands conditions, although it would be desirable to improve the uniformity of the population and rectify other characteristics, particularly the high ear position and general variability of the variety, and also improve resistance to Turcicum leaf blight.
2. Four CIMMYT open pollinated varieties, Suwan 1, Suwan 8027, Caripeno and Across 7921 gave yields which were not significantly different to that of Piwa. Because these varieties have more suitable plant characteristics, particularly habit, they should be further evaluated against Piwa at a range of sites.
3. Hycorn 9 is recommended as a hybrid variety despite the inadequacy of its resistance to Turcicum leaf blight in this environment. Further testing should be undertaken to identify equivalent or higher yielding hybrid varieties with a greater degree of Turcicum blight resistance.
4. Turcicum leaf blight was the major disease of maize in these trials and it would be beneficial to identify varieties suitable for the highlands that incorporate a higher degree of Turcicum blight resistance than current varieties. Turcicum leaf blight at the levels of incidence experienced probably would not have affected the yield of green cobs.
5. Results suggest that varieties with maturity periods in this environment of less than 150 days, i.e. 75 days to 50% flowering, may be unsuitable for producing dry grain. Further work on this effect is required. It is suggested that the greater incidence of Turcicum leaf blight in early maturing varieties may be implicated.
6. Germplasm from DPI Kairi, Queensland, was not well evaluated as a result of the poor establishment of the limited amount of seed available. It is recommended that further testing of Kairi material should take place. Initially, the hybrid variety QK 675 should be further tested and further sampling of open pollinated populations should be undertaken to establish those most appropriate for advancement.

7. There will be a continuing need to import maize germplasm into Papua New Guinea in order to maintain and improve the quality of available varieties. The need to maintain strict quarantine regulations in Papua New Guinea will be a major restriction on this importation. As maize germplasm may currently be imported without restriction from Australia and New Zealand it would seem important to foster a link with Kairi, DPI Queensland, despite the fact that they are not breeding maize specifically for the PNG highlands environment. A strengthening of national plant quarantine facilities will be necessary to allow the import for evaluation of germplasm from countries other than Australia and New Zealand.

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