Papua New Guinea

A STUDY OF SITE X VARIETY INTERACTIONS FOR SWEET POTATO IN THE HIGHLANDS OF PAPUA NEW GUINEA

M.B. Kanua and C.N. Floyd

Agricultural Field Trials, Studies, Extension
and Monitoring Unit (AFTSEMU),
Southern Highlands Rural Development Project,
P.O.Box 98, Mendi
Southern Highlands Province

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Department of Primary Industry
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Food Crops Agronomists

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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.

1. The Management of Andisols in Southern Highlands Province, Papua New Guinea.
   (D.J. Radcliffe)

2. Land Evaluation for Food Crop Production in Papua New Guinea.
   (D.J. Radcliffe)

3. The Land Resources of Pomiorine Experimental Farm.
   (D.J. Radcliffe)

4. A Study of Gardening Activity and Bodyweight in the Southern Highlands of Papua New Guinea.
   (R. Crittenden, C.N. Floyd, R.D.B. Lefroy and R.A. Urben - Editors)

5. The Land Resources of Kiburu Experimental Farm.
   (D.J. Radcliffe)

6. The Land Resources of Piwa Experimental Farm.
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7. The Land Resources of Kuma Experimental Farm.
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9. Maize Variety Evaluation in the Highlands of Papua New Guinea.
   (C.N. Floyd)

10. Evaluation of Introduced Vegetable Varieties on Volcanic Ash Soils in the Southern Highlands of Papua New Guinea.
    (M.B. Kanua and E.J. D'Souza)

11. Groundnut Variety Evaluation in the Southern Highlands of Papua New Guinea.
    (C.N. Floyd and E.J. D'Souza)

12. Composting and Crop Production on Volcanic Ash Soils in the Southern Highlands of Papua New Guinea. (C.N. Floyd, R.D.B. Lefroy and E.J. D'Souza)

ABSTRACT

A feature of subsistence production of sweet potato (Ipomoea batatas) in the highlands of Papua New Guinea is the number and diversity of cultivars used. One possible reason for this is the apparent suitability of varieties to specific environments. Such effects have important implications for the design of sweet potato variety evaluation trials, and for the reliability of existing variety recommendations. Thus, an experiment was conducted to investigate site x variety interactions for sweet potato in the Southern Highlands, and also to evaluate introduced sweet potato varieties and develop variety recommendations.

Nine contrasting sweet potato varieties were evaluated at six sites which covered a range of climate and soil conditions. Although results were not unequivocal analysis showed that site x variety interactions were of limited importance. There were, however, important differences between varieties in their response to site differences in yield potential, and in their ability to yield at sites with poor yield potential. Established varieties gave lower yields and a smaller variation in yield across sites than introduced varieties. Although of a reduced yield potential established varieties had the ability to give some yield at poor sites, a characteristic shared by only some of the introduced varieties.

The incidence of sweet potato leaf scab (Elsinoe batatas) and insect damage were assesssed but results offered no explanation of yield differences between varieties. Although leaf scab incidence was high in the crop it appears to be a minor constraint to yield at present. The possible involvement of viruses in the expression of variety yield effects are discussed and variety recommendations made.

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1. INTRODUCTION

A feature of subsistence production of sweet potato (Ipomoea batatas) in the highlands of Papua New Guinea is the number and diversity of the cultivars available to, and used, by growers. The summary by Bourke (1985:97) shows that an average of thirty four sweet potato cultivars are grown by groups in the highlands. In the Tari basin of the Southern Highlands, Wood (1984) found that, of the approximately thirty cultivars available, six of them accounted for more than 90% of the plantings. Normally mixed variety plantings are used, but extensive single variety plantings may be found in specific environmental zones.

The reasons for the diversity of varieties are undoubtedly complex but probably include; the adoption of new cultivars derived from the spontaneous germination of seeds in what is normally a vegetatively propagated crop; the cultural isolation of growers; taste preferences of the growers; the need to produce sweet potato for both people and pigs; and an apparent suitability of varieties to specific environments.

While some cultivars are grown throughout the Southern Highlands, each locality will have certain varieties which, it is claimed, do particularly well in that locality. Although recommendations of sweet potato varieties for the highlands are given by Akus (1982), there is little information on the suitability of varieties to specific environments, and to the Southern Highlands in particular. Furthermore, there appears to be no reported investigation of site x variety interactions for sweet potato in the highlands. Such interactions have important implications for the design of sweet potato variety evaluation trials and also for the reliabilty of existing recommendations.

Thus, the experiment reported here was conducted with the following objectives.

1. To investigate site x variety interactions for sweet potato in the Southern Highlands.

2. To evaluate introduced sweet potato varieties against existing varieties and develop improved variety recommendations.

Table 1. Soil, climatic and environmental description of experimental sites.

Site	Pomiorine	Egari	Karil	Kugu	Wabia	Piwa
	Pangia	(Mendi V)	(Mendi V)	(Tari)	(Tari)	(Tari)
Grid reference (54M)	AN816941	ZJ004318	ZU019324	YU187534	YU213479	YU182518
Altitude (m.a.s.l)	1560	2170	2170	1650	1600	1620
Mean annual rainfall of DHQ (mm) *	4864	2887	2887	2542	2542	2542
Cropping history of site	*Miscanthus floridulus* and *Imperata cylindrica* fallow > 10yrs.	Old sweet potato garden over grown with grass > 2yrs.	I. *cylindrica* and M. *floridulus* fallow > 5yrs.	I. *cylindrica* fallow > 3yrs.	Mixed shrub and *Ischaemum polystachyum* grass fallow > 5yrs.	I. *polystachyum* grass fallow > 3yrs.
Soil parent material	airfall a) tephra	airfall c) tephra	airfall c) tephra	airfall tephra	mudflow	alluvium b)
USDA Soil Taxonomy class	Typic Hydrandept	Typic Hydrandept	Typic Hydrandept	Hydic Dystrandept	NR	(Aquic) Entic Eutrandept
Mean temp. Max* (°C) Min*	24.4** 15.0**	21.6** 11.0**	21.6 11.0	23.9 13.1	23.9 13.1	25.1 14.1
Planting dates	31 Oct. 1984	17 Oct. 1984	17 Oct. 1984	19 Sept. 1984	5 Oct. 1984	5 Oct. 1984
Days to harvest	180	245	245	212	192	192

Sources: * - Mac-Alpine, Keig and Short, 1975
** - AFTSEMU unpublished data.
a) - Radcliffe, 1983

2. MATERIALS AND METHODS

a) Sites

Varieties were evaluated at the six sites for which descriptions are given in Table 1. Sites were in three districts of the Southern Highlands Province; one site (Pomiorine) was in the Pangia district, two (Egari and Karil) were in the Mendi district, and three (Kugu, Wabia and Piwa) were in the Tari district. The Mendi districts sites were at a higher altitude (2170m) than the other sites (1560-1650m). Four of the sites (Pomiorine, Egari, Karil and Kugu) were airfall volcanic ash soils, while the Wabia site was on a mudflow soil and the Piwa site on an alluvial soil. Sites also differed in cropping history and climate (Table 1). Two sites, Pomiorine and Piwa were on land managed by Division of Primary Industry, and the remaining sites were in village subsistence gardens.

Soil physical and chemical analyses for the site soils are given in Table 2.

b) Varieties

Nine varieties were evaluated at all sites and can be classified into four groups as follows:

i) Local varieties
One popular local variety from each of the districts (Goroka from Pangia, Kariap from Mendi, and Mamme from Tari), and one popular variety (Wanmun) common to all the three districts, were evaluated.

ii) DPI recommended varieties
Two DPI recommended varieties, Markham and NG 7570, were included. Markham is a variety originally collected in Papua New Guinea (see Akus, 1982), and NG 7570 a variety selected from germplasm imported from Nigeria.

iii) Polycross nursery progeny
Two varieties, K1 and K6, were varieties selected in a sweet potato polycross seed nursery at Kiburu Farm, Mendi, for improved yield, resistance to sweet potato leaf scab (*Elsinoe batatas*) and high dry matter contents. K1 and K6 were maternal half sibs of Mamme and Markham respectively, i.e. the mother of K1 was Mamme, and that of K6 was Markham.

Table 2. Soil physical and chemical analysis for soils of experimental sites

			Sites					
			Pomiorine	Egari	Karil	Kugu	Wabia	Piwa
$pH(H_2O)$			5.2	5.2	5.0	5.4	5.2	5.0
Bulk density		g/cc	0.66	0.57	0.53	0.57	0.64	0.63
Organic matter		%	19.3	20.0	19.8	19.5	12.1	12.5
Extr.phosphorus		ug/me	3	4	3	2	6	7
P retention		%	96	98	99	97	88	97
Extractable Cations	K	me/100g	0.6	0.14	0.43	0.18	0.16	0.52
	Ca	me/100g	2.1	4.8	1.2	3.9	4.4	5.5
	Mg	me/100g	0.83	1.12	0.51	1.30	1.04	1.96
	Na	me/100g	0.05	0.06	0.07	0.06	0.05	0.06
	Al	me/100g	0.83	0.32	0.70	0.23	0.52	0.83
	ECEC	me/100g	4.49	6.44	2.91	5.67	6.12	8.87
	CEC	me/100g	22	27	25	25	22	27
Base Saturation as % of ECEC	K	%	15.14	2.17	14.78	3.17	2.61	5.86
	Ca	%	46.77	74.53	41.24	68.78	71.90	62.01
	Mg	%	18.49	17.30	17.53	22.93	16.99	22.10
	Na	%	1.10	0.93	2.41	1.06	0.82	0.68
	Total	%	81.51	95.03	75.95	95.94	91.50	90.64
Sulphate Sulphur		ug/g	65	12	14	70	3	56

iv) Introduced highland variety
The remaining variety evaluated was Munduwana, a variety recently introduced to the Southern Highlands from elsewhere in the Highlands, probably originally from Simbu province.

c) Experimental design

At all sites a randomised complete block design in four replications was used to evaluate the varieties. At all sites the plot size was 2.5m x 2.5m (6.25m sq), on which a single variety of sweet potato was grown on one mound made in the traditional manner (see Waddell, 1972).

d) Cultivation

Before marking out, the experimental areas were cleared and cultivated by hand to produce a suitable tilth for subsequent operations.

An application of 30t fresh wt/ha of *Ischaemum polystachyum* grass was used as compost at all sites. For the Pangia and Tari District sites grass for composting was cut at a site adjacent to that of the experiment and immediately weighed into bundles suitable for application to one plot. For the Mendi District sites grass was cut at a central site near Mendi and transported to the experiments.

The fresh compost was placed on the plots and allowed to decompose and dry out under prevailing weather conditions for approximately one month. After this time one mound was made per plot to incorporate the compost following traditional practice. To do this the compost was removed from the plot and a slight depression dug in the centre of the plot. The composting material was then heaped up in this depression and the mound made over the compost. Soil from the whole of the plot was used to make the mound which had a final diameter of approximately two metres. The compost supplied approximately 123kg N/ha, 15kg P/ha and 123kg K/ha, as well as other macro, and micro, nutrients.

Immediately after mounding sweet potato cuttings, approximately 30cm in length, of the respective varieties were planted on the mounds at a plant population of 38,400 pl/ha. For each mound this population represented twenty four cuttings which were planted in eight stations evenly distributed over the upper surface of the mound, with three cuttings per station. At each site the mounding and planting operations were completed in one day.

During growth no plant protection measures were taken other than keeping the crop relatively weed free.

In order to maximise the uniformity of cuttings for each variety across sites two central nurseries were used. One at Kiburu Farm, Mendi, served the Pomiorine, Egari and Karil sites, and one at Piwa Farm, Tari, served the other three sites. To establish the nurseries, cuttings for each variety were collected from one source and divided between the central nurseries. Cuttings to plant the experiments were taken from the nurseries approximately four months after the nurseries were planted. For each site, cuttings were taken from the respective nursery and planted in the experiment on the same day.

All experiments were conducted at approximately the same time during 1984 and 1985. The planting dates and days to harvest for each experiment are given in Table 1. Harvest was later at Egari and Karil, than at other sites to account for the increased time to maturity of the crop with higher altitude.

An assessment of sweet potato leaf scab incidence and insect damage in the crop was made monthly after planting for each experiment. For leaf scab incidence, the number of plants per mound affected by leaf scab were counted. For insect damage, each mound was scored for the proportion of leaves having some insect damage on a scale of 0-5. On this scale 0 represented no leaves damaged, and 5 represented all leaves having some damage.

At harvest mounds were broken up and the yields as fresh weight of vines, stockfeed tubers (i.e. tubers <100g) and marketable tubers (>100g) were recorded for each mound. Numbers of vines, and numbers of both stockfeed and marketable tubers were also recorded.

Limitations of drying facilities and the extent of sub-sampling necessary limited the accuracy with which yields could be expressed as dry weights across the range of sites used. The dry matter of mature tubers for the varieties in the Kiburu nursery were as follows.

Variety	% dry matter
Wanmun	30.2
Kariap	27.7
Mamme	23.7
Goroka	30.4
NG 7570	23.7
Markham	28.1
Munduwana	31.5
K1	34.0
K6	33.2

AFTSEMU (unpublished) data has shown that the dry matter content of a variety is relatively stable over a range of maturity and sites. Thus, the dry matter contents given above can be taken as a reliable indication of values that are likely to attain over all sites. Fresh sweet potato vines are approximately 14% dry matter.

e) Root-knot rating

At planting a composite sample of soil was taken from each site. Some of this soil was used for soil analysis (Table 2) and some was used in an assessment of the level of root-knot (Meliodogyne spp.) nematode infestation of the site soil.

To assess nematode infestation enough soil to fill a 20l polythene growing bag was sieved and mixed with an application of NPK compound fertilizer and triple superphosphate, equivalent to 40 kg N/ha, 151 kg P/ha and 47 kg K/ha. For each site one bag was filled with this soil and six seeds of tomato (var. Grosse Lisse) were sown. After establishment the seedlings were thinned to three per bag and these plants were grown for two months in an unheated greenhouse.

After this time the soil was washed from the roots of the plants and the occurrence of root-knots scored with a root-knot rating chart (Bridge and Page, 1980) on a scale of 0 to 10, where 0 represented no knotting and 10 severe knotting.

f) Statistical analysis

The results for each experiment were analysed initially by analysis of variance. At two sites, Pomiorine and Karil, there was significant ($P<0.05$) heterogeneity of variance for yield variables. Results of Bartlett's and Levene's tests for heterogeneity of variance for the fresh weight yield of tubers are given in Appendix I. At other sites there was also an appreciable degree of heterogeneity of variance for these variables even though effects were not statistically significant ($P<0.05$). Heterogeneity of variance was associated with low yields and concomitantly coefficients of variation were high.

In order to reduce heterogeneity of variance the original yield data was transformed to the log of X + 1. This log transformation reduced the heterogeneity of variance and the coefficients of variation (Appendix I). Results, unless otherwise stated, are presented as untransformed yields but the yield rankings and the mean separations given for the untransformed yields are those obtained from the means and analyses of variance of the log transformed data. Unless otherwise stated all further references to statistical significance refer to significance at the $P<0.05$ level of probability.

A combined analysis of variance was also conducted on the totals of the log transformed yield data and leaf scab incidence data for all sites, in order to examine the significance of site x variety effects, using the method of Cochran and Cox (1957:545-561).

Table 3: Variety marketable tuber dry weight yield (t/ha) and yield ranking for six sites and mean of all sites.

Variety	Pomiorine		Egari		Karil		Kugu		Wabia		Piwa		Mean of sites	
	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Yield
Munduwana	1	0.76 a	1	5.95 a	3	2.08 abc	4	2.77 bcd	2	5.71 a	1	5.07 a	1	3.72 a
NG 7570	2	0.54 ab	4	3.30 bc	2	2.64 ab	1	4.32 a	5	4.60 ab	2	4.35 ab	2	3.29 ab
Markham	8	0.12 c	3	4.05 b	1	3.31 a	2	3.40 ab	3	5.05 ab	5	3.16 bcd	3	3.18 ab
K6	6	0.21 bc	2	4.40 ab	5	1.36 bcde	3	3.05 bc	4	5.05 ab	3	4.08 abc	4	3.03 bc
Kariap	3	0.43 abc	7	2.17 cd	4	1.59 bcd	6	2.33 cd	7	3.32 bc	7	2.34 de	5	2.03 cd
K1	7	0.19 bc	9	1.34 e	9	0.45 e	5	2.54 bcd	1	5.67 a	4	3.23 bcd	6	2.24 de
Mamme	9	0.07 c	6	2.57 cd	8	0.78 de	7	2.09 d	6	3.95 ab	6	2.93 bcd	7	2.06 de
Wanmun	4	0.35 abc	8	2.13 d	7	0.84 cde	9	1.40 e	8	2.14 cd	8	2.14 de	8	1.50 e
Goroka	5	0.30 abc	5	3.18 bcd	6	0.90 cde	8	1.44 e	9	1.58 d	9	1.40 e	9	1.46 e
CV%		70		15		36		11		16		14		

Notes

1. Yields are actual mean yields.
2. Rankings of varieties and Duncan multiple range mean separations are those obtained from the analysis of log transformed data.
3. CV% is from the analysis of variance of the log transformed data.

3. RESULTS

As all sweet potato produced in the subsistence system is consumed by either people or pigs, both total and marketable tuber yields are relevant indicators of variety performance. However, in this report results will concentrate on marketable tuber yield because of the relevance of this parameter to human nutrition.

Ideally comparisons between varieties, in terms of human nutrition, should be made when dry matter, protein and carbohydrate contents of the varieties are known. In this experiment it was not possible to collect data on protein and carbohydrate contents, but inter-site, and inter-variety, variation in these factors may exist (Bradbury at al., 1985). In this experiment dry weight yield was considered the most appropriate criteria for establishing variety recommendations. However, in examining the site x variety effects, fresh weight yields will be used as the dry matter contents of the varieties were not determined at each site.

a) Yields

Varieties are ranked in descending order of mean marketable tuber dry weight yield over all sites in Table 3. The same results for total tuber yield are given in Appendix II. When meaned over all sites, Munduwana was the highest yielding variety although there was no significant difference between the yield of Munduwana and that of NG 7570 and Markham, the next two highest yielding varieties (Table 3).

The mean yield advantages over all sites, of Munduwana, NG 7570 and Markham were reflected in their relative yields at individual sites. Thus Munduwana was either the highest yielding variety, or its yield was not significantly different from the highest yielding variety, at all sites except Kugu. Similarly NG 7570 only gave a yield that was significantly lower than the highest yielding variety at Egari. The yields of Markham were lower; it gave a significantly lower yield than the highest yielding variety at three sites, Pomiorine, Egari and Piwa.

The yield advantage of Munduwana, NG 7570 and Markham at individual sites, in comparison to the local variety, at that site, were limited. Munduwana and NG 7570 gave a significantly higher yield than the local variety only at two sites; Egari and Piwa for Munduwana, and Karil and Kugu for NG 7570. The yield of Markham was significantly higher than the local variety at three sites, Egari, Karil and Kugu.

The mean marketable tuber dry weight yields over all sites of the polycross progeny, K6 and K1, maternal half sibs of Markham and Mamme respectively, were not signficantly different from that of their parent. Only at two sites was there a significant difference between the yield of parent and progeny; at Egari the yield of Mamme was significantly higher than that of K1, and at Karil the yield of Markham was significantly higher than that of K6. Thus, results show no yield advantage to the polycross progeny in comparison to their known parents.

While the district local varieties Kariap, Mamme and Goroka, tended to do well at the other sites within their districts they also did well at some sites outside their district. For example Goroka, the Pangia district local variety, gave its highest yield relative to other varieties at Pomiorine, its local site, but also had the same yield ranking at Egari. Such effects were, however, small.

b) Site x variety effects

The combined analysis of variance for log transformed marketable tuber fresh weight yield, for the nine varieties at the six sites, is given in Table 4.

Table 4: Combined analysis of variance for sites and varieties.

Source of variation	df	SS	MS	F	required F 5% best	required F 5% worst
Sites(S)	5	19.103	3.821			
Varieties(V)	8	3.903	0.488	6.85*	2.18	6.61
S x V	40	2.846	0.071	23.93***	1.48	2.36
Pooled error	144	2.606	0.018			

In the combined analysis of variance the mean of the variances of the six individual site analyses of variance was used as the pooled error. The pooled error was then used to test the significance of the site x variety interaction. Similarly, the significance of the variety effect was tested using the site x variety mean square. Because of significant heterogeneity, according to Bartlett's test, amongst the individual site variances which were combined to give the pooled error mean square , and evidence of a significant site x variety effects in the combined analysis (Table 4), care is required in assessing the significance of the calculated F ratios. Of particular concern is that the distribution of the calculated F ratios is distorted and declares too many significant effects.

Cochran and Cox (1957) suggest that, to allow for this distortion, a best and worst required F should be used in testing the significance of the F ratios in a combined analysis of variance. These required F ratios are given in Table 4. The best (lower limit) required F is based on the degrees of freedom given in Table 4. The worst (upper limit) required F is based on modified degrees of freedom which account for the worst distortion of the F distribution that is likely to occur. The modified degrees of freedom used for testing the interaction effect are (t-1) and n', where t is the number of treatments (varieties) an n' is the number of error degrees of freedom at an individual site; here 8 and 24 degrees of freedom respectively (Cochran and Cox, 1957:554). The modified degrees of freedom for testing the significance of the treatment (variety) effect are 1 and (p-1), where p is the number of sites; here 1 and 5 degrees of freedom respectively (Cochran and Cox, 1957:551).

In the combined analysis of variance (Table 4) both the site x variety effect and the variety effect were significant using the worst required F. The analysis therefore indicates that there are real differences in variety yields from site to site, and that there are also differences in variety yield which are consistent across sites.

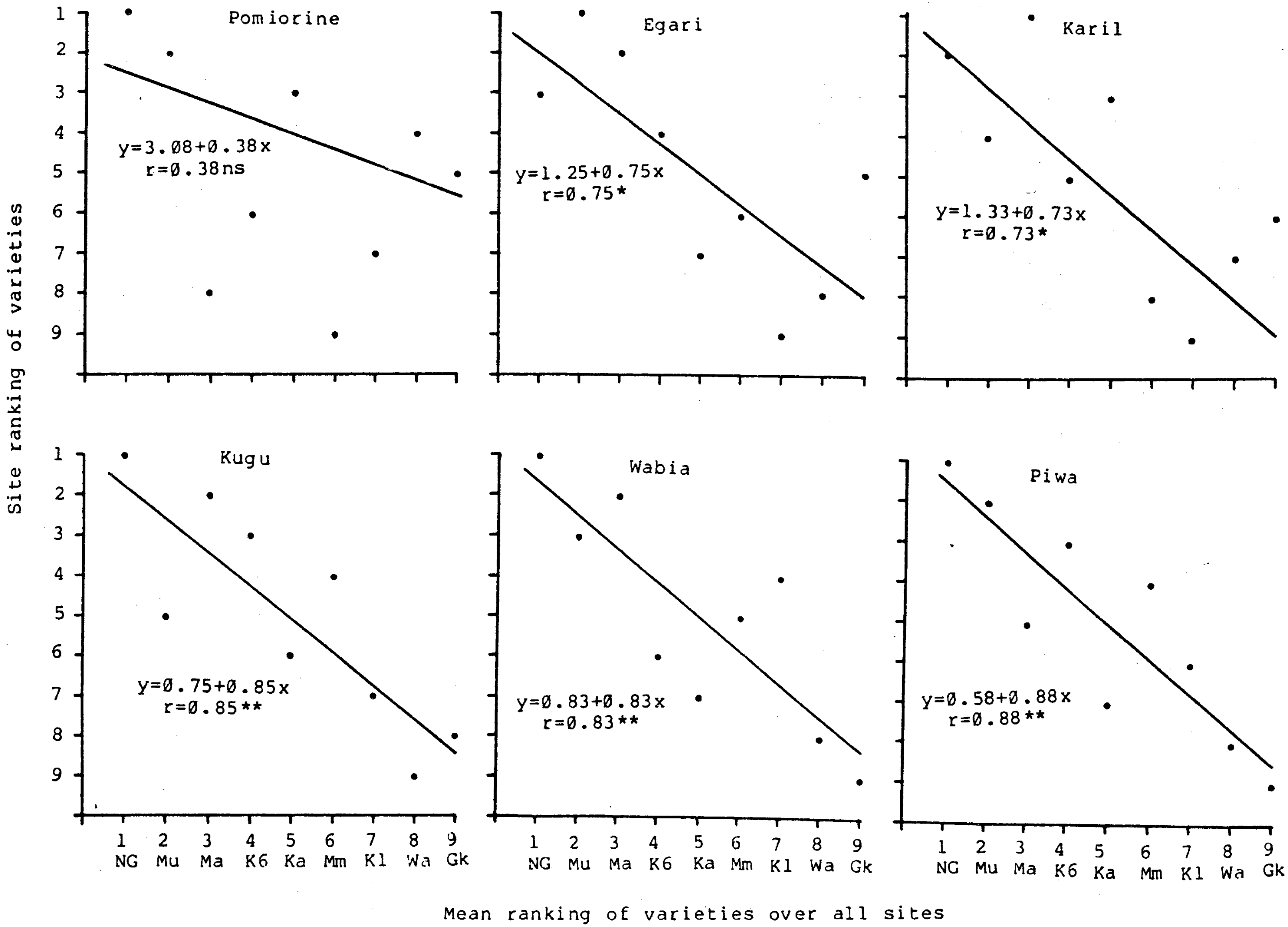
These variety differences, across and between sites, are further examined in two ways. Firstly by comparing ranking of variety mean yields at individual sites against the rankings for variety mean yields across all sites. Secondly, by a method, after Finlay and Wilkinson (1963), which examined the relationship between variety yield at the experimental sites and the mean yields of all varieties at those sites.

i) Comparison of rankings

For each site, the ranking of the mean yields of the nine varieties is compared with the ranking of the mean yield of varieties over all sites (Figure 1). In Figure 1 linear regressions have been fitted to the data to illustrate the extent to which the ranking of varieties at individual sites are related to their ranking over all sites.

At all sites, except Pomiorine, there was a significant ($P<0.05$) linear correlation between the ranking of varieties at that site and the ranking of varieties over all sites. The poor relationship between site and mean rankings at Pomiorine is of limited practical importance as yields were lowest at this site (mean site yield of 1.1 t fresh weight marketable tubers/ha).

sites and the ranking of variety mean yields over all sites.



Varieties: NG = NG 7570; Mu = Munduwana; Ma = Markham; Ka = Kariap;
Mm = Mamme; Wa = Wanmun; Gk = Goroka; Kl = Kl; K6 = K6.

The results in Figure 1 indicate that varieties which had the higher mean rankings over all sites in these experiments can reasonably be expected to do well at other sites within the environmental range covered by the experimental sites.

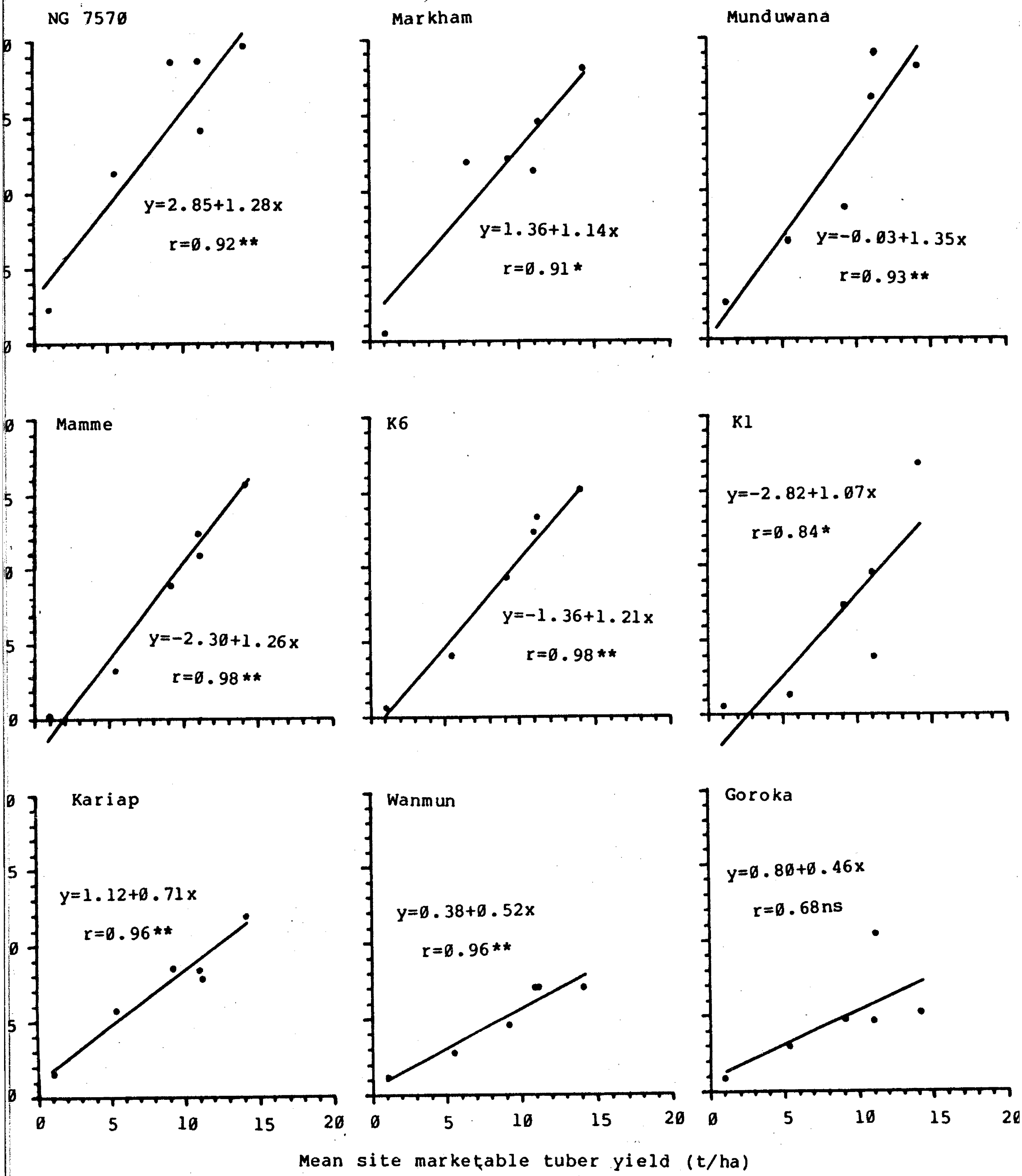
ii) Finlay-Wilkinson analysis

A method after Finlay and Wilkinson (1963) was used to examine the variation in yield of the nine varieties across all sites (Figure 2). In Figure 2, for each variety, the mean yield of the variety at each of the sites is plotted against the mean yield of all varieties at those sites. The mean yield of all varieties at a site estimates the yield potential of a site and the regression lines fitted to the data for each variety quantify the response of varieties to differences in yield potential between sites.

For all varieties, mean yield at a site increased with site yield and, with the exception of Goroka, there was a significant positive linear correlation between these two variables. The lack of significant correlation for Goroka, and the lower level of significance of the correlation for K1, than for the other varieties, was caused primarily by variety yields at Egari. At Egari, Goroka gave an unusually high yield, and K1 an unusually low yield, compared to that which would be predicated from the yields of these varieties at the other sites.

The slopes and the elevations of the regression lines fitted in Figure 2 have practical significance. The slopes, or regression coefficients, indicate how the varieties respond to differences in yield potential between sites. This response is a measure of the vigour of a variety, a greater slope indicating greater vigour. In general terms, the elevations of the lines indicate the relative yield potential of the varieties, and the relative ability of a variety to yield at sites with poor yield potential. Positive intercepts indicate that some yield at poor sites is likely, whereas negative intercepts indicate that it is not. Deviations from the individual variety regressions, here linear models, are an estimate of the stability of the response of a variety to differences between sites. Reduced deviation indicates increased stability.

Figure 2: The relationship between variety marketable tuber yield at a site and the mean yield of all varieties at that site.



Differences between the regression lines for all varieties were compared using the method of Snedecor and Cochran (1972:432). Details of these comparisons are given in Appendix III. There was no significant difference between the slopes of the individual regression lines for all the varieties (Appendix IIIa). This result is surprising in view of the extent of significant correlations for the regressions and the range of regression coefficients amongst the varieties (Figure 2). The lack of significant differences between regression coefficients appears to be primarily due to the significant heterogeneity, according to Bartlett's test, of the residual variances amongst the individual variety regression lines.

Despite the lack of significant differences between regression coefficients, varieties can be classified into two groups on the basis of these coefficients. One group, comprising NG 757Ø, Markham, Munduwana, Mamme, K6 and K1 have regression coefficients in the range of 1.1 to 1.4. The other group, comprising the remaining varieties, Kariap, Wanmun and Goroka, have regression coefficients in the range of Ø.5 to Ø.7. Differences between the regression lines for the varieties within these two groupings are compared in Appendix IIIb and IIIc. For both groupings, the F ratios for the difference amongst regression coefficients within the groupings were less than unity. The ratios were Ø.92 and Ø.52 for the NG 757Ø group (Appendix IIIb) and the Kariap group (Appendix IIIc) respectively. This result suggests that there are two definite groupings of varieties; a high coefficient, or high vigour group, i.e. the NG 757Ø group, and a low coefficient, or low vigour group, i.e. the Kariap group.

Differentiation of varieties into these groups was further examined by comparing the pooled regression coefficient for varieties NG 757Ø, Markham, Munduwana, Mamme, K1 and K6 (Appendix IIIb) with that for the varieties Kariap, Wanmun and Goroka (Appendix IIIc). The comparison of the regression coefficients, using a t test, is given in Appendix IIId. There was a significant ($P<0.001$) difference between the pooled regression coefficients for the two variety groupings.

Differences in the elevations, or intercepts, between the individual regressions for all varieties were also significant (Appendix IIIa). However, the practical implications of these differences is limited by the relatively large differences in slopes that exist between the lines. In general terms, a higher elevation means that a variety will give a higher yield at all sites. Conversely negative elevations mean that a variety will give little or no yield at sites with poor yield potential.

Table 5. Number of plants per mound affected by leaf scab for varieties at all sites.

Variety	Pomiorine		Egari		Karel		Kugu		Wabia		Piwa		Mean of sites	
	Rank	#	Rank	#	Rank	#	Rank	#	Rank	#	Rank	#	Rank	#
Wanmun*	1**	8.0 a***	1	12.3 a	1	7.5 a	2	23.3 a	2	23.3 a	1	23.8 a	1	16.4 a
NG 7570	3	4.5 ab	3	4.7 bc	6	2.8 bcd	1	24.0 a	1	24.0 a	2	22.5 ab	2	13.8 b
Goroka	6	2.3 ab	6	1.7 bc	2	5.3 ab	3	20.3 b	3	21.8 ab	4	19.0 bc	3	11.7 c
Markham	6	2.3 ab	5	2.3 bc	4	4.3 bc	4	15.8 c	4	21.3 ab	3	20.0 abc	4	11.0 cd
Mamme	4	3.3 ab	2	6.0 b	5	3.8 bcd	6	10.8 d	5	18.5 bc	5	18.8 bcd	5	10.2 d
Munduwana	2	6.0 ab	4	4.3 bc	3	4.8 ab	7	7.0 ef	7	12.3 d	6	17.8 cd	6	8.7 e
K1	8	1.0 b	7	0.5 c	8	0.8 d	5	12.8 cd	6	14.5 cd	7	16.8 cd	7	7.7 f
Kariap	9	0.8 b	8	0.0 c	8	0.8 d	8	4.3 fg	9	7.3 f	8	15.3 cd	8	4.8 g
K6	5	3.0 ab	8	0.0 c	7	1.5 cd	9	2.3 g	8	7.8 ef	9	14.0 d	9	4.7 g
Site mean		3.5		3.5		3.5		13.4		16.8		18.7		
LSD		6.2		4.6		3.0		2.8		4.0		4.5		
CV%		109.5		54.9		42.7		12.0		14.2		14.5		

* Varieties are ranked in descending order of mean leaf scab damages over all sites.

** Varieties are ranked in descending order of mean leaf scab damages at individual sites.

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

Of the more vigorous varieties, three varieties (NG 7570, Markham and Munduwana) have high elevations, while the other three (Mamme, K6 and K1) have low elevations. This indicates that, although the vigour of the varieties is similar, NG 7570, Markham and Munduwana will give yield at poor sites and that Mamme, K6 and K1 will not. In contrast, the less vigorous varieties, Kariap, Wanmun and Goroka, while less able to respond to improved site conditions, do give some yield at poor sites.

c) Leaf scab incidence

Results for leaf scab incidence of the varieties at all sites, and when meaned over all sites, are given in Table 5. Leaf scab was worst in the Tari district with site means of 13.4, 16.8 and 18.7 infected plants per mound for Kugu, Wabia and Piwa respectively. Leaf scab incidence was lower, and the same (3.5 infected plants per mound), at the other sites.

On average, Wanmun and NG 7570 were significantly the most affected of the varieties. The four least affected varieties were Munduwana, K1, Kariap and K6. The remaining varieties had intermediate levels of infection.

The site x variety interactions for leaf scab incidence were examined by a combined analysis of variance in the same way as for yields (see Table 4). The effects of variety, and the site x variety interaction, were both significant. These effects were further investigated by examining the relationships between variety infection at a site and mean infection at that site, and the relationship between yield and leaf scab incidence.

For all varieties, leaf scab infection increased with increased level of site infection and there was a significant positive linear correlation between the variables for all varieties (Figure 3). In general, variety susceptibility, i.e. slope of lines in Figure 3, increased with mean level of variety infection. Thus Wanmun, NG 7570 and Goroka not only are the most susceptible varieties, but are also more likely to become more heavily infected at heavily infected sites. The reverse is true of K1, Kariap and K6, the least susceptible varieties.

There was no relationship between leaf scab incidence of a variety and its yield at individual sites, or across all sites.

Figure 3: The relationship between variety leaf scab incidence at a site and leaf scab incidence of all varieties at that site.

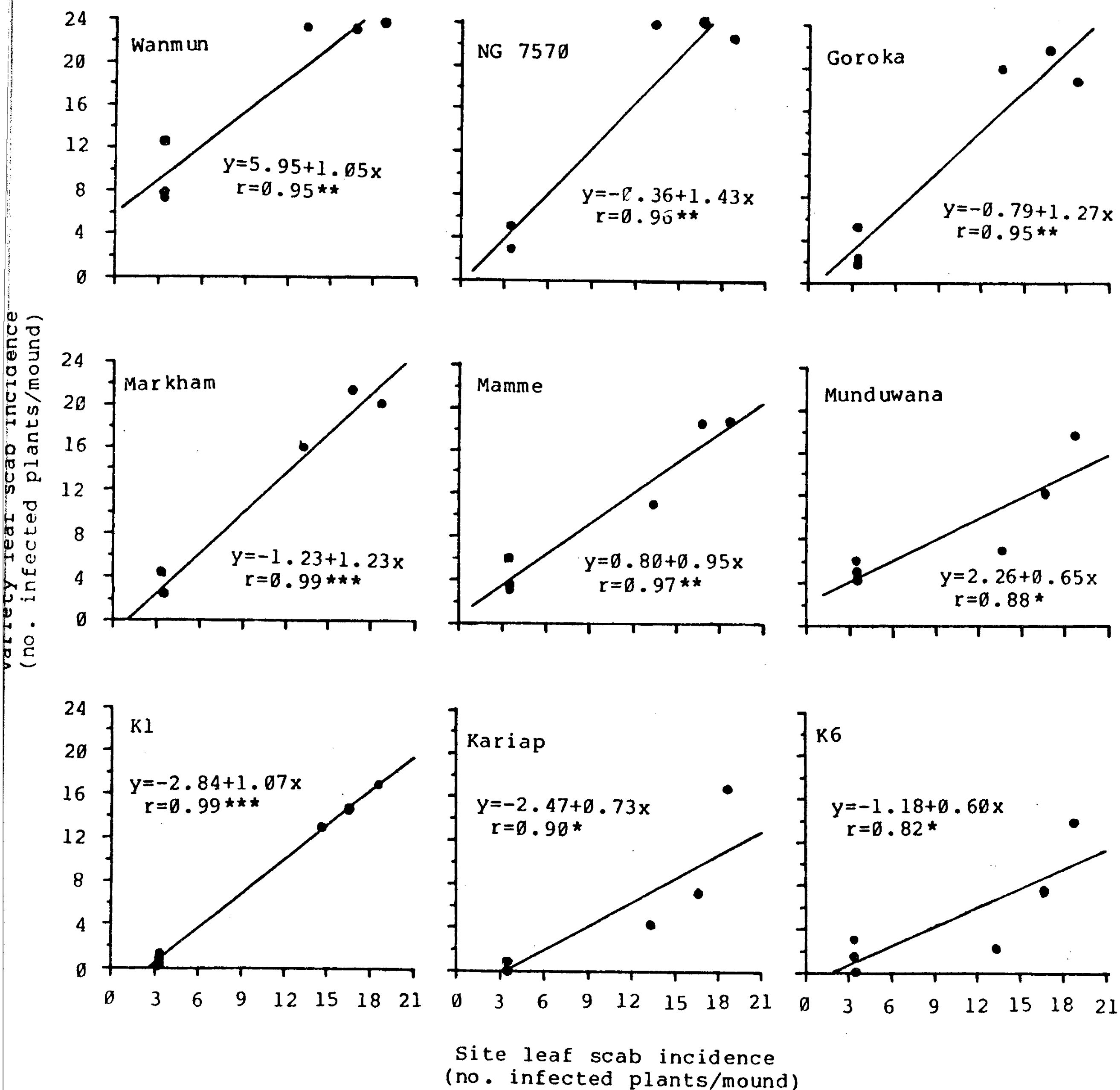


Table 6. Rating of insect damage on the leaves of nine sweet potato varieties at six sites.

Variety	Pomiorine	Egari	Karil	Kugu	Wabia	Piwa	Mean of sites
Wanmun*	2.60 a**	1.55 a	2.30 abc	2.25 ab	1.92 ab	2.58 ab	2.20 a
K1	2.05 a	1.15 a	2.00 abc	2.75 a	2.75 a	2.33 ab	2.17 a
Goroka	1.90 a	1.07 a	2.10 abc	2.58 a	2.25 ab	2.33 ab	2.04 a
K6	2.55 a	1.40 a	2.20 abc	2.67 a	1.67 b	1.75 ab	2.04 a
NG 7570	2.20 a	1.60 a	1.45 bc	3.00 a	1.83 ab	2.00 ab	2.01 a
Markham	2.05 a	1.05 a	1.35 c	2.25 ab	1.50 b	1.67 ab	1.88 a
Mamme	2.70 a	1.32 a	2.45 a	2.25 ab	1.50 b	1.67 ab	1.88 a
Munduwana	1.85 a	1.20 a	2.35 ab	2.00 ab	1.50 b	1.83 ab	1.79 a
Kariap	1.75 a	1.00 a	2.05 abc	1.33 b	1.50 b	1.17 b	1.47 a
Site Mean	2.07	1.26	2.03	2.34	1.87	2.07	
LSD	1.04	0.69	0.95	1.13	0.98	1.51	1.05
CV%	33	36	28	35	34	49	

* Varieties are ranked in descending order of mean insect damage over all sites.

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

The incidence of leaf scab in the polycross nursery progeny was low, but in particular was lower than for their parents (Table 5). Mean leaf scab incidence over all sites was significantly lower in the maternal half sibs, K1 and K6, than in their parents.

d) Insect damage

There were no significant differences in insect damage to the crop between varieties at any site, or in the mean variety effect over all sites. Neither was there any relationship between insect damage and yield at any site or when effects were meaned over sites (Table 6). Insect damage was uniform and low at all sites, with the mean insect damage score at each site ranging from 1.3 to 2.3. Thus, on average some 40% of the leaves of sweet potato had some damage on them.

e) Root-knot rating

The results of the root-knot rating are given in Table 7.

Table 7: Root-knot rating for experimental sites.

Site	Root-knot rating
Pomiorine	0
Egari	2
Karil	1
Kugu	0
Wabia	1
Piwa	1

4. DISCUSSION

a) Variety recommendations

Munduwana, NG 7570 and Markham gave the highest mean dry weight yields of marketable tubers over all sites. Although these yield advantages were consistent across sites, few of the yield advantages over the local variety were significant at individual sites.

Munduwana and Markham, although having a higher mean dry weight yield of marketable tubers over all sites, only gave yields which were significantly greater than the local variety at two and three sites respectively. Despite the limited extent of significant yield increases, the yield of Munduwana was higher than the local variety at all sites and the yield of Markham was higher than the local variety at all sites except Pomiorine. These yield increases, coupled with the Papua New Guinea origin of Munduwana and Markham, and thus likely taste acceptability, may mean that these varieties are more readily accepted than NG 7570. High tuber dry matter contents tend to be the local taste preference and Munduwana and Markham have a higher dry matter than NG 7570. Despite the limited significant yield advantages in comparison to local varieties, Munduwana and Markham are recommended for distribution throughout the province.

cf D'Souza & Bourke (1983)!

The yield of NG 7570 was higher than the site local variety at all sites except Pomiorine, but these effects were only significant at Kugu. Again, despite the limited significance of yield increases, NG 7570 is initially recommended for general distribution throughout the province. However, as taste appears to be an important criteria in local variety choice NG 7570 may not be widely accepted, despite its high yield, because of its different taste and texture to that of the local varieties, partly as a result of its relatively low tuber dry matter content.

An additional factor to be considered in variety recommendations relates to the differences in vigour detected between varieties. More vigorous varieties will be better able to respond to high yielding sites and to agronomic methods that increase yield potential. For example, other AFTSEMU research (Floyd *et al.*, 1985) has shown that sweet potato yield can be markedly increased by increasing the rates of traditional composting. Should such methods be adopted, then vigorous varieties would better utilise the potential increases in yield. Thus, on higher fertility sites or where methods likely to markedly increase yield are used, Munduwana, NG 7570 and Markham are particularly recommended.

The results for the polycross nursery progeny, K6 and K1, respectively maternal half sibs of Markham and Mamme, were disappointing. The only significant difference at any site between the yields of the half sibs and their parents occurred when the parent gave a higher yield than the progeny. Therefore, despite the reduced leaf scab susceptibility of K1 and K6 (Table 5) and relatively high dry matter contents, in the absence of further evidence, for example in increased protein or carbohydrate contents, K1 and K6 are not recommended for distribution.

In general terms, particularly because of the complexity of factors involved in the acceptance of new varieties, the possibility of specific site effects, and the problems of equating varieties in terms of their nutritional yield, (i.e. as dry matter, carbohydrate or protein yield), the variety recommendations above should be interpreted with caution. It is suggested that new varieties are best promoted by simple yield demonstrations against local varieties, combined with increasing availability of planting material at DPI stations within the province. In this way, other selection criteria, particularly taste, can be accounted for if the growers themselves are encouraged to evaluate the varieties under their own conditions.

b) Site x variety effects

The results of combined analysis of variance showed that there were consistent differences in the relative performance of varieties from site to site. The significance of the site x variety interaction showed that there were important deviations from this pattern.

The consistent nature of these effects was illustrated in two ways, firstly, by a comparison of variety yield ranking at individual sites in relation to the ranking of variety yields over all sites (Figure 1), and secondly, by a modified Finlay-Wilkinson analysis (Figure 2). The Finlay-Wilkinson analysis demonstrates that, with the exception of Goroka, and to an extent K1, variety yield at a site is well correlated with site yield, and that the main difference between varieties is in their ability to respond to site conditions that result in yield differences.

The evidence of the deviation from the general variety rankings, i.e. the specific suitability of a variety to a site, was more limited. The clearest example of specific site suitability of a variety was in the case of the relatively poor yield of K1 and relatively high yield of Goroka at Egari. No explanation of this effect can be offered from the experimental data. In particular, the result does not appear to have been caused by experimental error. An identical experiment is being repeated at Egari, using the same methods, to confirm the discrepancy of this result.

In order to examine the extent to which the yields of Goroka and K1 at Egari contributed to the significance of the site x variety interaction, the combined analysis of variance of the log transformed marketable tuber yield data (Table 4) was reworked excluding the yields of Goroka and K1 at Egari. In this analysis the F ratio for the site x variety effect was reduced to 2.76 and the F ratio for the variety effect increased to 16.4. Thus, the site x variety effect was only significant at $P<0.05$ (a worst required F of 2.36), and the significance of the variety effect increased to $P<0.01$. This analysis confirms that the significant site x variety interactions in this experiment were limited primarily to the relative yields of Goroka and K1 at Egari in comparison to the other sites.

With the reservation of the lack of statistical proof, the result of the comparison between regression lines developed in the Finlay-Wilkinson analysis, indicates the existence of two groups of varieties. The first group, comprising recently introduced, or bred, varieties, NG 7570, Markham, Munduwana, Mamme, K6 and K1, was vigorous and responsive to differences between sites that led to increased yield. The second group, comprising the established varieties, Kariap, Wanmun and Goroka, were less vigorous and were less responsive to improved site conditions.

Two explanations of the difference in vigour between these groups are suggested, however, neither can be substantiated by experimental data and thus further work is required. The first explanation is that the established varieties have been subjected to unconscious selection by the farmers themselves, as well as to natural selection pressure of the ecosystem. This selection results in varieties giving a similar yield over a range of sites, albeit at a low level. This characteristic was illustrated in the Finlay-Wilkinson analysis where the established varieties had lower regression coefficients, i.e. less variation in yield across sites, and had higher regression intercepts, i.e. an ability to give some yield at poor sites. It is also possible that vegetative propagation tends to select for vegetative rather than tuber yield. In summary, the yield of varieties may tend to be reduced by mechanisms inherent to the system of cultivation.

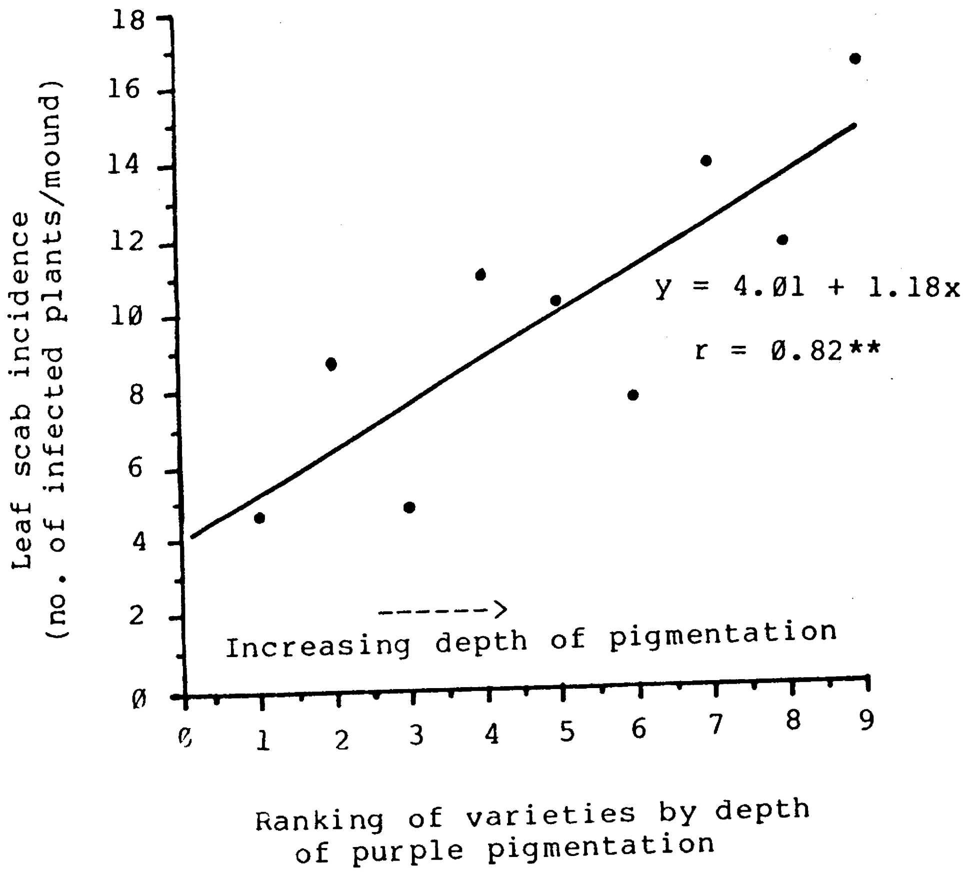
The second explanation relates to the presence of viruses in the sweet potato crop in this area (Waller, 1985). As a result of vegetative propagation, viruses may have accumulated to a greater level in the established varieties, Kariap, Wanmun and Goroka, and this may account for their lower vigour. Further work is required to examine differences in virus accumulation between varieties to confirm this suggestion.

Site x variety interactions and yield stability, and the methods of their analysis have been discussed by Finlay and Wilkinson (1963) and subsequent workers. In this investigation, an analysis after Finlay and Wilkinson (1963) was used but the discussion of results, particularly in terms of variety stability, has been restricted. This is primarily because of the small data set, but also because such discussion is of limited relevance to the aims of the experiment. In this experiment the importance of the Finlay-Wilkinson approach lies in the illustration of the extent of the site x variety interaction (Figure 2).

In this experiment the comparison of variety stability as measured by deviations from the regression models is restricted by the small data set. However, in these terms, all varieties, with the exception of Goroka and K1, had a similar yield stabilty.

The analysis used here emphasised the concept of vigour as indicated by the value of the regression coefficients, and the ability of the variety to give yield at sites of low yield potential as indicated by the regression intercept. An ideal variety would be one which was both vigourous, i.e. had a high regression coefficient, and gave some yield at low yield potential sites, i.e. had a positive regression intercept. Amongst the varieties tested, the local ones had reduced vigour, thus similar yields across sites, but an ability to give some yield at poor sites. Although the introduced varieties were comparatively vigorous, only three, Munduwana, NG 757Ø and Markham, combined this vigour with an ability to give some yield at sites with poor yield potential.

Figure 4: The relationship between leaf scab incidence and depth of purple pigmentation in the leaves of nine varieties.



c) Leaf scab incidence

Leaf scab is the most prevalent and obvious disease of sweet potato in the Southern Highlands (Waller, 1985:4). In these experiments incidence was high (Table 5), with over half the plants in the most susceptible varieties being affected by the disease. Although Goodbody (1983) found that leaf scab reduced sweet potato tuber yield by 26%, there was no relationship in these experiments between variety yield and leaf scab incidence at any, or across all sites. Results for NG 7570 and Wanmun illustrate the lack of any relationship. When averaged over all sites, Wanmun and NG 7570 were the varieties most affected by leaf scab, but they had the second lowest and second highest yields of marketable tubers respectively.

This result probably indicates, not so much that leaf scab does not cause yield loss, and thus resistance is desirable, but that varieties may show tolerance to the disease. In conjunction, or possibly alternately, it indicates that there are more important differences between varieties in other factors that constrain yield. For example, differences in environmental adaptation or, possibly differences in the level of virus accumulation between varieties. In the latter case, virus accumulation would be expected to be greater in Wanmun, an established variety, than in NG 7570, an introduced variety (Waller 1985:6), and may account for yield differences between the two varieties.

The suggestion by Waller (1985:4) that leaf scab incidence is lower in varieties lacking purple pigment in their leaves was examined using the results presented here. Leaf samples of the nine varieties taken from the Kiburu nursery were ranked on the depth of purple pigmentation in their leaves. This ranking was then related to the mean variety leaf scab incidence (Table 5). The result (Figure 4) shows a significant ($P<0.01$) linear correlation between increasing depth of purple pigmentation in leaves and variety susceptibility to leaf scab.

One of the criteria for progeny selection in the polycross seed nursery, from which K1 and K6 were selected, was reduced susceptibility to leaf scab. The reduced incidence of leaf scab in the polycross progeny (Table 5) confirms the effectiveness of this selection.

Although significant site x variety interactions in leaf scab incidence were indicated by a combined analysis of variance, there was limited evidence of this in the subsequent analysis (Figure 3). This discrepancy may be related to the fact that mean site leaf scab incidence was the same at three sites and that the other three sites had a higher incidence but at levels which were similar to one another. Thus, small differences in leaf scab infection between varieties across sites may be more readily detected as a site x variety interaction.

c) Insect damage

The low levels of insect damage experienced in these experiments, and the lack of significant differences between varieties, are consistent with the finding that insect damage is a minor constraint to the yield of sweet potato in the Southern Highlands (Thistleton and Masandur, 1985).

d) Root-knot rating

The low level of root knot rating scores reflect the cropping histories of the experimental sites (Table 1), in which grass fallows predominated. The highest root-knot rating was at Egari, the site with the most recent and intense sweet potato cultivation. However, a root-knot rating of 2 does not represent a serious level of infestation (Bridge and Page, 1980).

Other AFTSEMU (unpublished) results show that sweet potato varieties differ in their susceptibility to root-knot nematodes. Of the varieties tested here Markham is a susceptible variety and Wanmun a resistant variety. In this experiment the low levels of root-knot nematode infestation experienced would probably preclude the expression of varietal differences in yield related to differences in susceptibility to root-knot nematodes.

5. CONCLUSIONS

1. The investigation of site x variety interactions for sweet potato was not unequivocal but the balance of the evidence suggested that such interactions are of limited importance. In general, the yield response of a variety to differences in yield potential between sites was predictable. There were, however, important differences between varieties in their vigour, i.e. in the extent of this response.

2. Recently introduced, or bred, varieties were not only higher yielding than the established local varieties, but were more vigorous, and are therefore particularly suitable for use on high yield potential sites and with improved agronomic practices.

3. It is suggested that a greater accumulation of viruses in established varieties, and selection pressure inherent in the cultivation system, may be implicated in the differences in vigour. Further study of the implications of the presence of viruses for sweet potato yield, and for differences in vigour between varieties, is a priority.

4. Varieties differed in their ability to yield on poor yield potential sites. While local varieties gave such yield they also had reduced vigour. However, three of the introduced varieties combined increased vigour with an ability to give some yield at poor sites.

5. Planting material of the varieties Munduwana, NG 7570 and Markham should be made available to growers throughout areas of the Southern Highlands within the altitudinal range of 1500 to 2200m. This recommendation is tentatively extended to other areas of the province.

6. Because of the complexity of factors involved in the acceptance of new varieties, and the possibility of specific site effects, new varieties should be promoted in such a way as to encourage growers to evaluate the varieties for themselves under their own conditions.

7. Differences between the yield of the polycross selected progeny and their known parents were limited. The progeny were, however, less susceptible to leaf scab (<u>Elsinoe batatas</u>), and had a higher dry matter content than their known parents. Reduced leaf scab susceptibilty, and higher dry matter contents, were criteria used in progeny selection and the experimental results confirm the effectiveness of this selection.

8. Because of the potential inter-variety, and inter-site, variation in tuber dry matter and carbohydrate and protein contents, variety evaluation should take these factors into account. This necessity requires a greater commitment of experimental resources but is essential if varieties are to be realistically evaluated in terms of human nutrition.

9. The incidence of sweet potato leaf scab (Elsinoe batatas) was widespread in these experiments but while there were large differences in disease susceptibility between varieties, these differences were not related to the yield differences between varieties. Thus, although tolerance or resistance to leaf scab is a desirable varietal characteristic, leaf scab appears to be a minor constraint to yield at present. Results showed that susceptibility to leaf scab was lower in varieties with reduced purple pigmentation in their leaves.

10. Levels of insect damage experienced in these experiments was low and did not affect yield.

11. The existence of significant site x variety interactions has important implications for variety evaluation and development. The methods used here to examine the site x variety effects provide a basis for further, more extensive, testing to clearly establish the importance of such effects.

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coefficients of variation, for original and log transformed data of fresh weight yields of tubers.

Variables		Pomiorine	Egari	Karil	Kugu	Piwa	Wabia
		Experimental Sites					
Total	Bartlett (F)	0.0078 **	0.5746 NS	0.0000 ***	0.434 NS	0.2774 NS	0.1513 NS
Marketable	Levene (F)	0.0233 *	0.0801 NS	0.0015 ***	0.3403 NS	0.2596 NS	0.0828 NS
Tuber Wt.	Mean yield	1.14	11.2	5.54	9.18	11.14	14.28
	EMS	9.5569	9.7008	15.31	2.9738	7.83	19.73
	CV%	84.9	27.8	70.6	18.7	25.1	31.1
Log of	Bartlett (F)	0.4049 NS	0.8730 NS	0.0815 NS	0.2369 NS	0.4575 NS	0.7017 NS
Total	Levene (F)	0.3340 NS	0.1850 NS	0.0060 **	0.2615 NS	0.5922 NS	0.4276 NS
Marketable	Mean yield	0.284	1.04	0.706	0.968	1.048	1.14
Tuber Wt. + 1	EMS	0.0249	0.0117	0.03699	0.00679	0.01121	0.0687
	CV%	55.6	10.4	27.2	8.5	10.1	11.4
Total	Bartlett (F)	0.3994 NS	0.3411 NS	0.0009 ***	0.947 NS	0.1971 NS	0.2608 NS
Tuber Wt.	Levene (F)	0.0308 *	0.1458 NS	0.0032 **	0.7508 NS	0.1210 NS	0.1661 NS
	Mean Yield	4.26	13.7	8.40	11.45	13.53	16.7
	EMS	1.23607	9.0194	12.762	3.102	6.767	18.1299
	CV%	26.1	21.9	42.7	15.4	19.2	25.5
Log of	Bartlett (F)	0.5643 NS	0.8283 NS	0.2461 NS	0.9083 NS	0.8143 NS	0.7477 NS
Total	Levene (F)	0.1148 NS	0.5905 NS	0.1075 NS	0.7626 NS	0.7402 NS	0.5743 NS
Tuber Wt. + 1	Mean yield	0.705	1.14	0.938	1.064	1.14	1.21
	EMS	0.0085	0.00662	0.0130	0.0039	0.0052	0.01162
	CV%	13.1	7.1	12.2	5.8	6.3	8.9

* $P<0.05$

** $P<0.01$

*** $P<0.001$

Appendix II. Variety mean total tuber fresh weight (t/ha) and yield ranking for six sites and when meaned of all sites.

Variety	Pomiorine		Egari		Karil		Kugu		Wabia		Piwa		Mean across all sites	
	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Yield	Rank	Yield
NG7570*	1	6.0 a**	2	17.7 ab	2	15.1 ab	1	20.9 a	1	22.9 a	1	21.0 a	1	17.3 a
Markham	7	3.8 bcd	3	17.3 abc	1	15.0 a	2	13.8 b	3	18.9 ab	5	13.2 cd	2	13.8 ab
Munduwana	2	5.3 ab	1	20.8 a	3	9.3 bc	7	10.2 c	4	19.6 ab	2	18.2 ab	3	13.9 abc
Mamme	4	4.9 ab	5	14.8 bc	6	7.3 cd	3	12.6 bc	5	19.2 ab	3	15.4 bc	4	12.4 bcd
K6	5	4.1 bc	4	15.5 bc	4	7.8 cd	4	11.5 bc	6	17.6 ab	4	14.0 bcd	5	11.8 bcd
K1	3	4.9 ab	9	6.8 d	8	5.4 d	5	10.8 bc	2	20.8 a	6	13.2 cd	6	10.3 cde
Kariap	8	3.0 cd	7	8.9 d	5	7.3 cd	6	10.4 c	7	14.0 bc	7	10.7 d	7	9.1 def
Wanmun	6	3.8 bc	8	8.5 d	7	5.6 d	8	7.3 d	8	9.9 cd	8	10.5 d	8	7.6 ef
Goroka	9	2.7 d	6	13.0 c	9	4.7 d	9	5.4 e	9	6.4 d	9	5.6 e	9	6.3 f
Site means		4.3		13.7		8.6		11.4		16.6		13.5		
CV%		26.1		21.9		41.4		15.4		25.5		19.2		6.4
LSD		1.6		4.4		5.2		2.6		6.2		3.8		4.0

* Varieties are ranked in descending order of mean yield across all sites.

** Duncan's multiple range mean separation, yields in any column followed by the same letter are not significantly different ($P < 0.05$) from one another.

Note: Ranking and mean separation of varieties presented in this table are based on analysis of a log transformed data for total tuber yield.

Appendix III

Comparison of regression lines in Figure 2 after method of Snedecor and Cochran (1972:432).

(a) Regressions for all varieties.

	df	$\sum x2$	$\sum xy$	$\sum y^2$	Reg. Coef	Regression deviations df	SS	MS	F
Within									
NG 7570	5	110.70	142.18	217.37	1.28	4	34.77	8.69	
Markham	5	110.70	126.09	137.55	1.14	4	29.89	7.47	
Munduwana	5	110.70	149.65	233.55	1.35	4	31.24	7.81	
Mamme	5	110.70	139.46	181.46	1.26	4	5.75	1.44	
K6	5	110.70	132.30	161.91	1.21	4	3.78	0.95	
K1	5	110.70	119.38	182.26	1.07	4	53.47	13.37	
Kariap	5	110.70	78.84	59.94	0.71	4	3.78	0.95	
Wanmun	5	110.70	57.97	32.99	0.52	4	2.64	0.66	
Goroka	5	110.70	50.51	50.21	0.46	4	27.14	6.79	
						36	192.46	5.35	
Pooled, W	45	996.30	996.38	1257.24	1.00	44	260.78	5.93	
		Difference between slopes				8	68.32	8.54	1.60 NS
Combined						52	782.29		
		Between adjusted means				8	521.51	65.19	11.0***

(b) Regressions for NG 7570, Markham, Munduwana, Mamme, K1 and K6.

	df	$\sum x^2$	$\sum xy$	$\sum y^2$	Reg. Coef.	Regression deviations df	SS	MS	F
Within									
NG 7570	5	110.70	142.18	217.37	1.28	4	34.77	8.69	
Markham	5	110.70	126.09	137.55	1.14	4	29.89	7.47	
Munduwana	5	110.70	149.65	233.55	1.35	4	31.24	7.81	
Mamme	5	110.70	139.46	181.46	1.26	4	5.75	1.44	
K6	5	110.70	132.30	161.91	1.21	4	3.78	0.95	
K1	5	110.70	119.38	182.26	1.07	4	53.47	13.37	
						24	158.90	6.62	
Pooled	30	664.20	809.06	1114.10	1.22	29	128.59	4.43	
						5	30.31	6.06	0.92 NS
Combined						34	376.35		
		Between adjusted means				5	247.76	49.55	11.2***

(2) Regressions for Kariap, Wanmun and Goroka.

	df	$\sum x^2$	$\sum xy$	$\sum y^2$	Reg. Coef.	Regression deviations df	SS	MS	F
Within									
	5	110.70	78.84	59.94	0.71	4	3.78	0.95	
	5	110.70	57.97	32.99	0.52	4	2.64	0.66	
	5	110.70	50.51	50.21	0.46	4	27.14	6.79	
						12	33.56	2.80	
Pooled	15	332.10	187.32	143.14	0.56	14	36.48	2.61	
						2	2.92	1.46	0.52 NS
Combined						16	61.59	3.85	
	Between adjusted means					2	25.11	12.56	4.81*

(d) Comparison of pooled regressions from (b) and (c).

i) For NG 7570, Markham, Munduwana, Mamme, K1 and K6.
Variance of regression coefficient $S^2_{b_1} = \frac{4.43}{664.2} = 0.0067$ with 29 df.

so regression coefficient = 1.22 ± 0.167

ii) For Kariap, Wanmun and Goroka.
Variance of regression coefficient $S^2_{b_2} = \frac{2.61}{332.10} = 0.0079$ with 14 df.

so regression coefficient = 0.56 ± 0.1902.

iii) Pooled variance = 0.0071 with 43 df.

iv) Standard error of difference $= \sqrt{0.0071 \left(\frac{45}{450}\right)} = 0.0266$

and = 0.66/0.0266 = 24.812***

NOTE: Formala used in (iv) above $= \sqrt{S^2 \times \frac{n_1 + n_2}{n_1 \times n_2}}$