INTENSIFICATION OF SUBSISTENCE AGRICULTURE ON THE NEMBI PLATEAU, PAPUA NEW GUINEA
3. SWEET POTATO CULTIVAR TRIALS; CROP ROTATION TRIALS; AND CROP INTRODUCTIONS

E. D'Souza*†, R. Michael Bourke*†† and W.L. Akus*

ABSTRACT

*Three sweet potato (*Ipomoea batatas*) cultivar trials were conducted in village gardens on the Nembi Plateau. Local cultivars were compared with selections from Aiyura. The Aiyura selection, Markham 1, had the highest yield in all three trials. Its taste is acceptable to the villagers and its use should be promoted on the Plateau. In one of the cultivar trials plots were split for nematicide application as root knot nematode (*Meloidogyne *sp.) had been previously identified from sweet potato stems. No response to the chemical was obtained.*

*A second series of trials evaluated a number of species for use as rotation or fallow crops in sweet potato gardens. Five grain legumes were compared. These were cowpea (*Vigna unguiculata unguiculata*), *peanut *(*Arachis hypogaea*), rice bean (*Vigna umbellata*), soyabean (*Glycine max*) and winged bean (*Psophocarpus tetragonolobus*). Peanuts gave the highest yield and are acceptable as a supplementary food. Three rotation trials were then conducted to compare a sweet potato/peanut rotation with continuous planting of sweet potato. No beneficial effect was recorded for sweet potato crops that followed peanuts.*

*Three food crops that are presently not much used on the Plateau were evaluated. Potatoes (*Solanum tuberosum*) gave a mean tuber yield of 8.1 t/ha when grown in a trial that compared three micro environments. No significant difference between environments was found. Potatoes have potential as a food crop. Cassava (*Manihot esculenta*) plots planted on poor soils in sweet potato gardens yielded 2.2 t/ha. No potential is seen for cassava on these soils. Pigeon pea was grown in mixed garden soils and yielded reasonably well. It may have a role as a vegetable crop grown in mixed vegetable gardens.*

INTRODUCTION

This is the third paper in a series which deals with crop intensification techniques for subsistence agriculture on the Nembi Plateau. The experiments described in this paper are: Series A, Sweet potato (*Ipomoea batatas* (L.) Lam.) cultivar trials; Series B, Crop rotation trials; Series C, Crop introductions and evaluation.

* Highlands Agricultural Experiment Station, D.P.I., Aiyura, P.O. Box 384, Kainantu, E.H.P., Papua New Guinea.

† Present address: 92 St. Stephens, Hounslow, TW3 2BN, England.

†† Present address: Department of Human Geography, Australian National University, Canberra, Australia.

SERIES A. SWEET POTATO CULTIVAR TRIALS

Introduction

Introduction of new cultivars of a staple crop that are high yielding, of acceptable taste to the people and have other desirable characteristics, is one of the best ways to improve subsistence agriculture. Two experiments were conducted to compare high yielding cultivars from the Highlands Agricultural Experiment Station at Aiyura with popular local cultivars. Members of the Puit clan on the Plateau grow 25 cultivars of sweet potato (Bourke 1984a), but only six of these cultivars account for 93 per cent of cuttings planted. These six cultivars were evaluated in Cultivar Trial 1 against six cultivars selected at Aiyura. In the second cultivar trial, another six introduced cultivars were compared with three of the more promising cultivars from Trial 1.

A crop of sweet potato that followed a winged bean (*Psophocarpus tetragonolobus* (L.) A.P. de Candolle) time-of-planting trial, was shown to be damaged by root knot nematode. Root knot nematodes (*Meloidogyne* sp.) were recorded from the basal parts of vines, prior to tuber formation. Consequently, in the third sweet potato cultivar trial which compared nine cultivars previously tested, plots were split for a nematicide treatment.

Materials and methods

In Trials 1 and 2, replicates were located in various farmers' fields (Mukerjee 1963). In Trial 3 the replicates were located next to each other. All blocks were located in typical sweet potato gardens. A randomized block design was used for Trials 1 and 2. A split plot design was used in Trial 3. There were 13 replicates in Trial 1, 10 replicates in Trial 2 and 4 replicates in Trial 3. Because of losses caused by pig damage and stealing of vines and tubers, only six replicates were used for analysis for Trials 1 and 2. A plot size of 5 m^2 was used in Trials 1 and 2, and 9 m^2 in Trial 3. The cultivars evaluated are given in *Tables 1, 2* and *3*. Terminal cuttings 30 cm long were used as planting material. Planting densities were 24,000 cuttings/ha in Trials 1 and 2 and 27,000 cuttings/ha in Trial 3. Traditional techniques of land preparation and mounding were used for all trials.

In Trial 3 each plot was split for a nematicide treatment and a control. The trial was located at a site that was infested with root knot nematode. The nematicide carbofuran was applied to the treated plots prior to planting at a rate of 3 kg a.i./ha.

Two harvests were made in Trials 1 and 2. The first was at 26 weeks after planting and the second was at 38 weeks. In Trial 3, a single harvest was made at 28 weeks. Total tuber yield was recorded in all trials and top growth yield in Trial 2. Tubers and vines were collected from Trial 3 at harvest to check for nematode infestation.

Results

Statistically significant differences between cultivars were obtained in all three trials (*Tables 1, 2* and *3*). The cultivar Markham 1 from Aiyura yielded the highest in all three trials. No statistically significant yield response was found to nematicide application and material collected from control plots was not infested with nematodes (D.P.I. Plant Pathology Section, pers. comm.).

Discussion

These results indicate that Markham 1 is high yielding and displays a stable yielding pattern. It has good cooking and eating qualities. Following its introduction to the Plateau for these trials, planting material came into great demand by the villagers who recognized its value. Planting material and tubers were selectively stolen from our trials. Further information on this cultivar and other releases from Aiyura is given by Akus (1982). An immediate programme of distribution

Table 1.–**Sweet potato cultivar Trial 1. Origin of cultivars and tuber yields**

Cultivar	Origin	Tuber yields (t/ha) 1st harvest	2nd harvest	Total yield
Markham 1	H.A.E.S., Aiyura	11.3	2.2	13.6
Sokol	Nembi Plateau	10.5	2.3	12.8
Sumbil	Nembi Plateau	9.9	2.7	12.6
Ma'alua	H.A.E.S., Aiyura	9.1	2.8	11.9
Goroka	Nembi Plateau	9.2	2.3	11.4
Naveto	H.A.E.S., Aiyura	8.0	3.3	11.3
Kiko	Nembi Plateau	7.5	1.2	8.7
Merikan	H.A.E.S., Aiyura	7.7	0.8	8.5
Peripam	Nembi Plateau	6.2	1.7	7.9
Wanmun Kabiufa	H.A.E.S., Aiyura	5.9	0.6	6.5
Gonime	Nembi Plateau	3.8	1.6	5.4
Serenta (large leaf type)	H.A.E.S., Aiyura	1.5	0.2	1.6
Level of significance		**	*	**
L.S.D. (0.05)		4.41	1.84	5.35
C.V. (%)		51	89	50

Table 2.–**Sweet potato cultivar Trial 2. Origin of cultivars, tuber and top growth yields**

Cultivar	Origin	Tuber yields (t/ha) 1st harvest	2nd harvest	Total yield	Top growth yield (t/ha)
Markham 1	Aiyura	11.1	5.1	16.2	8.6
Tumun	Mt Hagen	6.5	3.2	9.7	10.8
Merenge	Aiyura	2.8	6.8	9.6	21.7
Mata	Aiyura	6.3	2.2	8.5	8.5
Sokol	Nembi	4.9	3.4	8.3	27.5
Serenta (small leaf)	Aiyura	5.4	2.6	8.0	7.1
Naveto	Aiyura	4.0	1.9	5.9	20.2
Deka	Aiyura	1.0	4.1	5.1	21.5
Kani	Aiyura	3.1	1.3	4.4	3.3
Level of significance		**	n.s.	*	***
L.S.D. (0.05)		4.40	4.30	6.90	9.50
C.V. (%)		74	107	70	59

of planting material of this cultivar should be initiated on the Plateau.

The local cultivar Sokol is the most popular on the Plateau (Bourke 1984a) and accounts for some 38 per cent of all cuttings planted. This cultivar performed unevenly in the trials with a rank of second, fifth and seventh in the three trials respectively. The Nembi cultivar Sumbil was the third highest yielding in Trial 1 and the fourth highest in Trial 3. A number of the cultivars tested matured later than the others, as shown by the higher yields in the second harvest relative to the first. This applied to Merenge and Deka.

None of the other introduced cultivars yielded consistently well. Those

Table 3.–**Sweet potato cultivar Trial 3. Tuber yields (t/ha)**

Cultivar	Tuber yield
Markham 1	12.6
Naveto	8.6
Goroka	8.4
Sumbil	7.3
Merenge	6.3
Ma'alua	6.1
Wanmun Kabiufa	5.9
Sokol	4.9
Gonime	3.0
Level of significance	***
L.S.D. (0.05)	3.2
C.V. (%)	37

that performed reasonably well such as Tumun, Naveto and Merenge should be tested further. The later maturity of Merenge would spread tuber production over a longer period, an advantage in a mixed cultivar situation. Tumun was introduced to the Plateau by students of the Highands Agricultural College in 1976. Some of the other introduced cultivars that performed reasonably well were already present on the Plateau under different names. This applies to Mata and Ma'alua which are known as Erave and Balus respectively.

SERIES B. ROTATION TRIALS

A number of grain legumes were evaluated for suitability as rotation/fallow crops in the sweet potato gardens. Peanuts were identified as the most suitable species. The effectiveness of a peanut/sweet potato rotation in increasing sweet potato yields was then tested.

GRAIN LEGUME EVALUATION

Materials and methods

The following grain legumes were tested as potential rotation crops with sweet potato: cowpea (*Vigna unguiculata* (L.) Walpers var. *unguiculata*), peanut (*Arachis hypogaea* L.), rice bean (*Vigna umbellata* (Thunberg) Ohwi and Ohashi), soyabean (*Glycine max* (L.) Merrill), and winged bean (*Psophocarpus tetragonolobus*). Four to eight plots (5 m^2 in area) of each species of grain legume were planted in existing sweet potato enclosures. Planting densities were 111,000 seeds/ha for peanut; 250,000 seeds/ha for cowpea, rice bean and winged bean; and 333,000 seeds/ha for soyabean. Cultivars used are given in *Table 4*. Observations were made on pest and disease problems. Grain weight was recorded on an air-dry weight basis at crop maturity.

Results and discussion

Peanuts clearly out-yielded other species tested (*Table 4*). The yields obtained (1100–1200 kg/ha) are reasonably high. Kimber (1974) has shown that the cultivar used, Virginia Bunch, out-yields White Spanish in the highlands. Peanuts are also a very popular food amongst the people on the Plateau although they are only grown infrequently at present.

The following pest and disease problems were identified: root knot nematode (*Meloidogyne* sp.) on winged bean; the fungi *Phyllosticta* sp. and *Cercospora* sp. on cowpea; and a minor infestation of *Colletotrichum* sp. on peanuts. Symptoms of bean fly (*Ophiomyia phaseoli* Tryon) damage were identified on cowpea and winged bean. Winged beans were also damaged extensively by an unidentifiable leaf miner. We have no data on how these organisms affected yield.

PEANUT/SWEET POTATO ROTATION TRIALS

Peanuts and winged beans are widely used as rotational crops with sweet potato in parts of the Eastern Highlands and Western Highlands Provinces. In the Aiyura Valley of the Eastern Highlands, for example, the village gardeners insist that peanuts restore sweet potato yields when the two crops are grown in a rotation. Having identified peanuts as the most suitable grain legume for the Plateau, the effectiveness of a peanut/sweet potato rotation was then examined in a series of trials.

Materials and methods

Trial sites were located in typical Nembi Plateau sweet potato gardens. The trials followed crops of sweet potato in all cases. Treatments were:

1. *Control.* Sweet potato crop followed by sweet potato. This is the traditional practice in the area.
2. *Rotation treatment.* Peanut crop followed by sweet potato.

Three trials were conducted over one rotation. The experimental design was a randomized block design with ten replicates in Trials 1 and 2 and five replicates in Trial 3. Plot size was 5 m^2 for each trial. Peanut cultivar Virginia Bunch Upright was planted at 120,000 seeds/ha in the first cycle. Sweet potato cultivar Sokol was planted at a density of 24,000 cuttings/ha.

On completion of the first crop, peanuts and sweet potato were harvested simultaneously. In Trial 1 the trash was removed, the plots reworked and immediately planted with sweet potato. In Trial 2 the trash was returned to plots from which it was taken at the end of the first crop. In Trial 3 all trash was returned and potash fertilizer was applied to all plots at a rate of 100 kg K/ha because the first sweet potato crop displayed typical potash deficiency symptoms and failed to yield a crop.

Results and discussion

No statistical difference in yield between the two treatments was found in any of the trials (*Table 5*), which suggests that a peanut/sweet potato rotation does not improve sweet potato yields on the Nembi Plateau. The environments in the Eastern and Western Highlands where a peanut/sweet potato rotation is widely used are drier than the Nembi Plateau, which may be significant in explaining the contrast between these results and growers' experience elsewhere in the highlands.

Despite these results, peanuts should be recommended for planting within the sweet potato gardens. It is likely that protein as well as energy is deficient in the villagers' diet and both protein and calorie intake must be increased to improve nutritional status (Heywood and Nakikus 1982; P. Heywood, pers. comm.). Peanuts are a popular food and are high in protein. Planting of small crops of peanuts between successive sweet potato crops is not likely to reduce sweet potato, and hence calorie, production greatly, particularly if the peanuts replace a sweet potato cover rather than a producing crop.

SERIES C. CROP INTRODUCTIONS

A number of crops that are rarely grown on the Plateau were introduced and evaluated. The species selected were potato (*Solanum tuberosum* L.), cassava (*Manihot esculenta* Crantz), and pigeon pea (*Cajanus cajan* (L.)

Table 4.–**Yields of five species of grain legumes in grain legume evaluation plots and grain legume minor elements fertilizer trial**

Legume species	Cultivar used	Yield of air dry grain (kg/ha) Grain legume trial	Fertilizer trial (1)
Peanuts (2)	Virginia bunch	1230	1120
Rice bean	Local	450	–
Cowpea	Gutpela	280	470
Soyabean	Yellow	260	–
Winged bean (3)	Local/UPS122	40	110

Notes: 1 After D'Souza and Bourke (1986a)
2 Peanut yields are recorded as shelled nuts
3 A local Nembi cultivar of winged bean was used in the grain legume yield trial and UPS122 was used in the fertilizer trial. In the fertilizer trial, winged bean also yielded 1530 kg/ha of edible tubers.

Table 5.–**Sweet potato rotation Trials 1, 2, 3. Tuber and top growth yields**

Treatment	Total tuber yield (t/ha) Trial 1	Trial 2	Trial 3	Top growth yield (t/ha) Trial 1	Trial 2	Trial 3
After sweet potato	0.86	4.9	5.3	4.5	8.0	20.3
After peanuts	0.91	5.8	4.8	4.5	6.9	18.4
Level of significance	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
L.S.D. (0.05)	0.31	1.51	2.66	0.58	1.47	4.11
C.V. (%)	34	28	30	13	20	12

Millspaugh). Potato and cassava are of interest because potato is quick-maturing and cassava does not have a fixed maturity period and tubers can be stored in the ground. Both crops may have a role in reducing the effect of variability in sweet potato supply. Cassava could be used as pig feed when the supply of sweet potato is inadequate. Pigeon pea produces a high protein bean and pulse.

POTATOES

Materials and methods

A trial was planted with various locations serving as treatments. The locations were:

1. Upper slopes of hillside sweet potato gardens;
2. Middle slopes of hillside sweet potato gardens;
3. Doline floors planted to mixed garden or under fallow.

A randomized block design was used with five replicates. Plots were 8 m^2 in area. Setts of the recommended D.P.I. cultivar, Sequoia (Nitschke and Nitschke 1982), were planted at a density of 25,000 setts/ha.

Results and discussion

The crop matured in 12 weeks. Yields for the three treatments were 7.5, 8.4 and 8.4 t/ha respectively. Differences between treatments were not statistically significant. Three of the five replicates were affected by bacterial wilt (*Pseudomonas solanacearum* (Smith) Smith). Affected tubers were not included in yield assessments. Minor incidence of target spot, caused by the fungus *Alternaria solani* Sorauer, also occurred.

The failure of plots planted on the doline floor to out-yield plots in sweet potato slope gardens was unexpected. Soil fertility is higher on the doline floors (Wood 1984) but this result may have occurred because soil nitrogen was unavailable in these soils as the crop followed immediately after a grass fallow.

The mean yield of 8.1 t/ha is reasonably high for an unfertilized crop when the low fertility of the soils is considered. A potato yield of 8 t/ha in 12 weeks is better than sweet potato yields of 6–7 t/ha from 23–28 weeks, but bacterial wilt may be a serious constraint. Potatoes have a role in farming systems on the Plateau as a quick maturing root crop that could supply food when sweet potato is in short supply.

CASSAVA

Four plots of cassava each 30 to 50 m² in area were planted in sweet potato gardens at a density of 10,000 setts/ha. The plots were located at the top of gardens on the poorest soils. The variety was a popular yellow-fleshed one from the Eastern Highlands.

An unidentified fungal infection caused severe dieback and defoliation during very wet conditions. Consequently the crop was harvested at ten months after planting. The mean tuber yield of 2.2 t/ha was very poor. The plots were located at an altitude of 1700 m. The altitudinal limit of cassava in Papua New Guinea is 1800 m (Bourke *et al.* 1984). Yield is likely to have been depressed by low temperatures as the altitudinal limit of all crops in the Southern Highlands tends to be lower than elsewhere in the highlands (Bourke 1984b). The very low yields obtained suggest that cassava has no potential as a crop grown on very poor soils in sweet potato gardens. It may, however, have a place on better soils in mixed vegetable gardens.

PIGEON PEA

An observation plot of pigeon pea was planted in a traditional mixed vegetable garden on an alluvial soil. Observations were made on growth and flowering. Maximum crop growth was achieved by seven months after planting. Flowering also occurred at this time. Short term crops in the garden, such as amaranthus, common bean, winged bean, *Nasturtium schlecteri* O.E. Schulz and hyacinth bean, had been harvested prior to maximum growth of the pigeon pea. Crops in the garden that were still growing were sugarcane, bananas, highland 'pitpit' (*Setaria palmifolia* (Koenig) Stapf), taro (*Colocasia esculenta* (D.) Schott) and *Rungia klossii* S. Moore. Only the last three crops would be expected to suffer from light competition from the pigeon pea grown in a mixed vegetable garden. Rungia and taro are shade tolerant.

Hence pigeon pea may have a role as a vegetable crop grown in the mixed vegetable gardens. It was first introduced to the Plateau for distribution to the villagers in 1978 by Mr. J. Tompkins of Adult Education in Mendi. Since then it has gained limited acceptance as a green bean crop. It should be promoted further.

CONCLUSIONS

Three sweet potato cultivar trials showed that the Aiyura release Markham 1 yields well under Nembi conditions and is acceptable to the villagers. It should be widely promoted on the Plateau. No response to nematicide was recorded in a sweet potato nematicide trial. Further work is needed to define the effect of nematodes on sweet potato yield.

Evaluation of five grain legume species showed that peanuts are the most suitable species in terms of yield and acceptability. The average yield of peanuts from a fertilizer trial, a grain legume evaluation and a rotation trial was 1100 kg/ha of air dried seed. Three rotation trials that evaluated a peanut/sweet potato rotation did not indicate any significant increase in sweet potato yield from the use of this rotation. Preliminary evaluation of potatoes, cassava and pigeon pea as food crops suggests that potatoes and pigeon pea have some potential for further expansion.

Results of some of the research reported in this series of papers are preliminary only and require further evaluation. Other results could be applied immediately, including the greater use of compost in sweet potato mounds, the use of pig manure and coffee pulp as fertilizer for sweet potato, and the cultivation of sweet potato cultivar Markham 1, potatoes and pigeon pea. These techniques are discussed in detail in two extension articles (D'Souza and Bourke 1982; 1983). Application of these technical solutions alone is not likely to solve the problems of low crop yields on the Nembi Plateau. However, their application, in conjunction with programmes to assist villagers to seek solutions to their problems, has the potential to have an impact on subsistence agriculture.

REFERENCES

AKUS, W.L. (1982). Sweet potato releases from Aiyura. *Harvest* **8**(2): 63–66.

ALLEN, B.J. (1984). Agricultural and nutritional studies on the Nembi Plateau, Southern Highlands. *Department of Geography Occasional Paper* No. 4. University of Papua New Guinea and Southern Highlands Rural Development Project.

BOURKE, R.M. (1984a). Systems of agriculture. In Allen (1984), pp. 55–67.

BOURKE, R.M. (1984b). The altitudinal range of coffee and some associated shade crops in Papua New Guinea. *Coffee Industry Board Research Newsletter* **3**(1): 7–12. Coffee Industry Board, Goroka.

BOURKE, R.M., EVENSON, J.P. and KEATING, B.A. (1984). Relationship between the altitudinal limit of cassava and soil temperature in Papua New Guinea. *Tropical Agriculture* (Trinidad) **61**(4): 315–316.

BOURKE, R.M. and KESAVAN, V. (1982) (Eds). *Proceedings of the Second Papua New Guinea Food Crops Conference*. Department of Primary Industry, Port Moresby.

D'SOUZA, E. and BOURKE, R.M. (1982). Compost increases sweet potato yields in the highlands. *Harvest* **8**(4): 171–175.

D'SOUZA, E. and BOURKE, R.M. (1983). Improving subsistence agriculture on the Nembi Plateau. *Harvest* **9**(2): 84–92.

D'SOUZA, E. and BOURKE, R.M. (1986a). Intensification of subsistence agriculture on the Nembi Plateau, Papua New Guinea. 1. General introduction and inorganic fertilizer trials. *Papua New Guinea Journal of Agriculture, Forestry and Fisheries*, **34**: 19–28.

D'SOUZA, E. and BOURKE, R.M. (1986b). Intensification of subsistence agriculture on the Nembi Plateau, Papua New Guinea. 2. Organic fertilizer trials. *Papua New Guinea Journal of Agriculture, Forestry and Fisheries*, **34**: 29–39.

HEYWOOD, P. and NAKIKUS, M. (1982). Protein, energy and nutrition in Papua New Guinea. In Bourke and Kesavan (1982), pp. 303–324.

KIMBER, A.J. (1974). Crop rotations, legumes and more productive arable farming in the highlands of Papua New Guinea. *Science in New Guinea* **2**(1): 70–79.

MUKERJEE, H.N. (1963). Determination of nutrient needs of tropical soils. *Soil Science* **95**: 276–280.

NITSCHKE, R.A. and NITSCHKE, L.G. (1982). Potatoes in Papua New Guinea: problems and progress. In Bourke and Kesavan (1982), pp. 178–183.

WOOD, A.W. (1984). Soils. In Allen (1984), pp. 35–54.