THE CONTROL OF BACTERIAL WILT (*Ralstonia solanacearum*) OF POTATO BY CROP ROTATION IN THE HIGHLANDS OF PNG

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ABSTRACT

*A trial was conducted to compare the effect of rotation with different crops or fallow treatments and for different durations on the level of bacterial wilt infection in subsequent potato crops. Land severely infected with bacterial wilt (*Ralstonia solanacearum *biovar 2, race 3) at Tambul, Western Highlands Province, was selected for the trial. Potato crops were rotated with maize, sweet potato, bare fallow or weed fallow. Yield and wilt infection in subsequent potato crops were then observed.*

After one break crop, wilt infection remained high in all treatments. Two or three break crops of maize or bare fallow were effective in reducing wilt incidence. Alternating potato with maize over five crops was just as effective. Sweet potato breaks alone were ineffective in controlling wilt. Weed fallow breaks did not reduce the level of wilting and actually reduced yield of subsequent potato crops. This suggests that weed fallows permit the survival of the pathogen, and raises the possibility that a weed host of R. solanacearum *may be present.*

Potato yields were significantly higher ($P < 0.01$) after two or three maize crops or bare fallows than after continuous potato or potato following two or three weed fallows. Alternating potato with maize showed similar improvements. Potato crops interspersed with one maize and one sweet potato crop (in either order) also out-yielded continuous potato, but the incidence of wilting was still high.

Keywords: Bacterial wilt, Potato, fallow, weed, sweet potato, maize.

INTRODUCTION

Bacterial wilt (BW) caused by *Ralstonia solanacearum* (Smith) (biovar 2/race 3) causes significant yield losses in potato (*Solanum tuberosum*) in Papua New Guinea (PNG) (Tomlinson and Gunther 1985). Chemical control of this bacterial disease is not a practical option. The bacteria remain dormant in the soil for many years and under PNG conditions this effectively prevents replanting potato on any land which has been infected. Seed tubers can also carry the disease in a latent phase and thereby clean fields can be infected unknowingly.

Two approaches to control bacterial wilt have been studied by researchers in PNG; screening of introduced potato clones for field resistance to BW (Gunther 1992) and control of BW by crop rotation (Bang and Wiles 1994). This paper reports a trial, which was aimed at finding a crop rotation appropriate to the PNG highlands, which can reduce the persistence of *R. solanacearum* to subsequent potato plantings.

MATERIALS AND METHODS

A field was selected at Tambul, Western Highlands Province (5°53'S; 143° 57'E; 2320 meters above sea level). The previous potato crop was heavily infected by BW. The trial was planned to cover a five-crop cycle and lasted for approximately 30 months. There were 14 treatments (Table 1) assigned in a randomized complete block design with four replications. The treatments were selected to compare continuous potato (variety-*Sequoia*) production with potato rotated with maize (variety-*QK hybrid*), sweet potato (variety-*Wanmun*), bare fallow or weed fallow. There were one, two or three break crops of maize, and one or two break crops of sweet potato. Fallow treatments of duration equivalent to one, two or three potato crops were also tested. The other breaks were either sweet potato followed by maize or vice versa.

Each treatment plot was 8 m long and 3 m wide. Potato and sweet potato were spaced 75 cm x 40 cm apart, while maize was spaced at 75 cm x 25 cm between plants. There were 4 rows per plot of

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Table 1. **Crop rotation treatments used in the bacterial wilt control trial.**

Treatment	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5
1	Potato	Potato	Potato	Potato	Potato
2	Potato	Bare fallow	Potato	Bare fallow	Potato
3	Potato	Bare fallow	Bare fallow	Potato	
4	Potato	Bare fallow	Bare fallow	Bare fallow	Potato
5	Potato	Maize	Potato	Maize	Potato
6	Potato	Maize	Maize	Potato	
7	Potato	Maize	Maize	Maize	Potato
8	Potato	Sweet potato*		Potato	
9	Potato	Sweet potato **		Sweet potato	Potato
10	Potato	Weed fallow	Potato	Weed fallow	Potato
11	Potato	Weed fallow	Weed fallow	Potato	
12	Potato	Weed fallow	Weed fallow	Weed fallow	Potato
13	Potato	Maize	Sweet potato*	Sweet Potato	Potato
14	Potato	Sweet potato*		Maize	Potato

* one twelve-month crop
** two nine-month crops

each crop. However only the two center rows of each plot were used for collection of wilt incidence and yield data. All volunteer potato plants and tubers in the weed fallow were uprooted and removed. The dominant grass in the weed fallow was Kikuyu grass (*Pennisetum clandestinum*) (Henty 1969). Fertilizer was applied at 750 kg NPK + Mg (12:12:17+2) and 250 kg triple superphosphate per hectare before planting all crops. This amounted to 90 kg N, 90 kg P and 105 kg K per hectare. No fertilizer was applied to fallow treatments. Weekly applications of acephate (Orthene) and mancozeb (Dithane) were made from crop emergence to senescence for control of pests and diseases.

The first crop (potato in all treatments) was planted in December 1991 and inoculated on 28 January 1992 with local strains of BW to ensure even distribution of infection on the trial site. After harvest, infected tubers were evenly spread on all plots and dug in to produce a uniform level of infection. The dates of planting, harvesting and seed source of all 5 crops are given in Table 2. From Crop 2 to Crop 5, the following records were taken:

Number of plants emerged per plot.
Number of plants with visual BW infection.
Total and marketable yield.
Number of infected tubers at harvest; tubers showing weeping eyes (oozing) were counted as having BW infection. Upon cutting the tubers, browning and oozing of the vascular tissue were observed.

Crop residues were carefully removed from the plots away from trial area. After the weed fallows, all weeds were removed and the land was prepared one week before planting of the next crop. Weeds from all plots were discarded from trial area. Drains 0.75 m wide and 0.50 m deep were dug between each plot to minimize disease spread. Soil samples after crop 5 were taken for nutrient analysis of the ten treatments with potato as the final crop. The samples were a subset of soils collected at random from each plot from a depth of 30 cm.

The trial area was fenced off and access strictly limited to those involved in the trial. All workers were required to wash hands, legs and all tools in a sterilizing (5%) solution of formalin before and after working on each plot, to prevent transmission of BW from one plot to another.

Table 2. **The planting and harvesting dates and seed source of potato crops planted.**

Crop	Planting Date	Harvesting Date	Seed Source
1	December 1991	April 1992	Certified ex Australia
2	15/07/92	21/12/92	Certified ex Australia
3	18/02/93	11/06/93	Tsinsibai – Clean seed
4	18/08/93	29/12/93	Tsinsibai – Clean seed
5	08/03/94	20/07/94	Tsinsibai – Clean seed

In this report the following abbreviations have been used to describe treatments: P = potato; M = maize; SP = sweet potato; BF = bare fallow; WF = weed fallow.

RESULTS

Results are presented on subsequent performance of potato crops after one, two or three break crops. Thus results are compared against the third, fourth or fifth potato crop in the continuous potato treatment.

Crop 3

In crop 3 the percentage of wilted potato plants at 45 and 90 days after planting (DAP) was significantly less (P<0.05) after the bare fallow (P-BF-P) and maize (P-M-P) than in continuous potato (P-P-P) (Table 3). However there were no significant differences in total tuber yield and percentage of marketable tubers (Table 4). In all rotation treatments, a large proportion (>50%) of tubers showed signs of BW infection and marketable yields were reduced accordingly. Although tuber yield was lower in continuous potato and P-WF-P plots, differences were not statistically significant.

***Table 3.* Percentage of wilting potato plants at 45 and 90 DAP in Crop 3 for treatments with one break crop.**

Treatment	45 days	90 days
1. P-P-P	9.8	32.8
2. P-BF-P	0.8	5.0
5. P-M-P	0.0	7.8
10. P-WF-P	9.0	30.5
L.S.D. (5%)	8.4	20.5

***Table 4.* Tuber yield and percentage of marketable tubers in Crop 3 for treatments with one break crop.**

Treatment	Total yield (t/ha)	Percentage marketable (by weight)
1. P-P-P	17.5	29.7
2. P-BF-P	22.7	25.9
5. P-M-P	21.9	28.3
10. P-WF-P	13.6	13.8
L.S.D. (5%)	NS	NS

Crop 4

In Crop 4 the percentage of wilting plants was significantly less (P <0.01) after the maize and bare fallow (Table 5). Yield was significantly higher after the maize rotation compared to continuous potato. The lowest yield and tuber number per plant occurred for potato following weed fallow. The percentage of rotten tubers was also lower after maize than in other rotations, though the difference was not significant at P<0.05.

Crop 5

Total yields in potato crop 5 were much lower than in earlier potato crops. This was probably because of the very small potato seed used for planting this crop. Therefore only total yields are presented in Table 6, as marketable yields were extremely low. In crop 5, emergence was significantly (P<0.01) lower in treatments following weed fallow breaks (P-WF-P-WF-P and P-WF-WF-WF-P) than in continuous potato (P-P-P-P-P). The percentage of wilting plants at 60 DAP was significantly higher (P<0.01) under continuous potato and after interspersed potato crops with weed fallow. The lowest wilting percentage was in potato crops following maize or bare fallow.

Yield was significantly higher (P <0.01) in treatments with maize or sweet potato as a break crop and where potato crops were interspersed with bare fallow than in treatments with continuous potato and where potato crops were interspersed with weed fallows. When maize and sweet potato were used in combination (P-M-SP-P and P-SP-M-P), the yield was significantly increased. While differences in tuber rotting were not significant, the smallest percentage of rots again occurred following the maize break treatment.

In order to assess whether the effect of crop rotations on yield was due to bacterial wilt or to changes in soil fertility, a soil analysis was carried out after the final potato crop (Crop 5). The soil analysis results are shown in Table 7. Following weed fallow, nitrogen levels were depleted and the carbon/nitrogen ratio was extremely high. After maize (and weed fallow), base saturation was improved slightly from a low level. However, cation exchange capacity decreased following maize. Phosphorous levels were similar in all treatments.

Table 5. **The effect of rotation with two break crops on BW and tuber yield of potato Crop 4.**

Treatment	% wilting plants 60 DAP	Tuber number per plant	Marketable yield (t/ha)	Total tuber yield (t/ha)	% rotten tubers by weight
1. P-P-P-P	73.4	11.0	6.2	15.8	32.3
3. P-BF-BF-P	11.0	16.9	6.2	17.6	35.7
6. P-M-M-P	1.4	13.7	17.9	29.0	16.8
8. P-SP-P	32.9	15.8	8.0	18.9	28.3
11. P-WF-WF-P	74.0	6.2	4.1	10.7	42.7
L.S.D. (5%)	15.9	3.8	3.6	4.6	NS

Table 6. **The effect of rotation with three break crops on emergence, BW and tuber yield of potato Crop 5.**

Rotation Treatment	Emergence (plants per plot)	% wilting plants 60 DAP	Tuber number per plant	Total yield (t/ha)	% rotten tubers (by wt)
1. P-P-P-P-P	35.0	28.8	4.1	4.57	32.3
2. P-BF-P-BF-P	33.2	2.2	4.4	4.96	33.8
4. P-BF-BF-BF-P	31.5	4.8	7.1	6.75	38.3
5. P-M-P-M-P	33.2	1.6	5.1	7.54	22.8
7. P-M-M-M-P	32.7	2.4	5.3	8.63	12.7
9. P-SP-SP-P	32.0	31.1	4.1	6.75	24.1
10.P-WF-P-WF-P	28.5	31.0	2.4	2.38	34.2
12. P-WF-WF-WF-P	26.7	14.5	1.7	2.29	44.7
13. P-M-SP-P	32.0	15.5	4.7	9.41	27.6
14. P-SP-M-P	31.0	14.7	5.1	9.12	20.1
L.S.D. (5%)	1.7	10.9	0.9	1.50	NS

Duration of break crop or fallow

In an attempt to assess the effect of the duration of the break crop or fallow on reduction in BW and performance of subsequent potato crops, the relative performance of potato after various break crops has been expressed as a percentage of continuous potato (Table 8).

A maize crop break resulted in the greatest yield increase over continuous potato. Potato yields stabilized at about 180% of continuous potato after two crops of maize. Weed fallow resulted in decreased yield and the percentage decrease in yield was greater with a longer weed fallow. Interspersing potato crops with sweet potato or bare fallow resulted in a smaller yield increase than with a maize crop break.

Maize and bare fallow reduced wilting incidence relative to continuous potato. After two or more maize crops, wilting in the subsequent potato crop was less than 10% of that in continuous potato. Sweet potato or weed fallow breaks failed to consistently reduce incidence of wilting.

The maize crop break was the only treatment, which gave a reduction in tuber rots. The reduction was greater after two or three maize crops than after only one crop. After a weed fallow, the incidence of tuber rots actually increased. However treatment differences in tuber rots were not statistically significant at $P < 0.05$.

Table 7. **Analysis of soil sampled from the five break crop treatments following the 5th (final) crop of potato.**

(a) Extractable bases

Treatment	Rotation	Extractable bases *					CEC	Base
		pH	Ca	Mg	K	Na	me %	Sat %
1	P	4.5	0.9	0.23	0.30	0.01	40.7	3
4	BF	4.5	0.9	0.31	0.23	0.01	42.9	3
7	M	4.7	1.7	0.45	0.34	0.03	24.0	10
9	SP	4.8	1.1	0.22	0.30	0.01	43.5	3
12	WF	4.6	1.5	0.46	0.35	0.04	37.0	6

(b) Carbon, phosphorus and nitrogen

Treatment	Rotation	P ** Mg/kg	Organic Carbon %	Total N %	C/N Ratio
1	P	11.2	14.0	1.03	14
4	BF	8.2	12.8	1.03	12
7	M	11.6	14.6	1.09	13
9	SP	9.4	14.5	1.10	13
12	WF	13.3	12.5	0.74	17

* me %
** Olsen's P method

Table 8. Total yield, percentage wilting and percentage of rotten tubers expressed as a percentage of continuous potato after varying durations of break crops or fallow treatments.

	Total yield (percentage of continuous potato)	% wilting	% rotten tubers
Maize break			
1 cycle	148.7	30.1	98.5
2 cycles	183.8	1.4	57.1
3 cycles	195.4	8.4	39.1
Sweet potato break			
2 cycles	120.9	46.4	89.8
3 cycles	150.5	97.4	77.1
Bare fallow break			
1 cycle	148.1	21.9	98.1
2 cycles	112.2	21.3	117.6
3 cycles	151.2	15.5	119.3
Weed fallow break			
1 cycle	84.3	95.6	125.3
2 cycles	68.7	108.7	137.1
3 cycles	49.5	66.0	129.1
L.S.D. (5%)	60.0	61.0	NS

DISCUSSION

In this trial, BW in potato was reduced following rotation with maize or bare fallow. Maize rotation has also been shown to reduce bacterial wilt in potato in other locations (CIP, 1990; Elphinstone and Aley 1992). In the Philippines (CIP, 1990), *R. solanacearum* Race 1 was the causal organism involved. In the present study, Race 2 is believed to be the causal organism (Tomlinson and Gunther 1985). The fact that maize was more effective than even bare fallow, as evidenced by the reduction in rotten tubers (Table 8) suggests that maize may be antagonistic to *R. solanacearum* present in the soil. In South America, Elphinstone and Aley (1992) found that *R. cepacia* in the maize rhizosphere increased at the expense of *R. solanacearum*. It is possible that a similar response is involved here.

After weed fallow, BW incidence was as high as in continuous potato. Thus BW appears to persist in weed fallow. It raises the question as to whether a weed host of *R. solanacearum* is present at Tambul.

The number of rotten tubers remained quite high even after three break crops. Rots were only examined visually and not all rotten tubers were necessarily affected with BW. Tuber rotting actually appeared to increase following weed fallow. It is probable that some other tuber rotting organisms were present in addition to *R. solanacearum*.

The changes in yield observed were not necessarily due to the level of BW infection. After a weed fallow, reduced crop emergence was also a factor in Crop 5. The reason for reduced emergence is not clear, but it may have been related to weed competition. Soil analysis also suggests that low nitrogen and a high C/N ratio may have depressed yields following a weed fallow.

A break of two maize crops was more effective than one crop in bringing bacterial wilt under control (Table 8). However there was no significant improvement following a third maize crop.

This trial was designed to establish how to bring BW under control from an initial high level of infestation. None of the treatments was able to eliminate BW infestation over the duration of this experiment. However there are implications for the current recommendations for potato seed production (Hughes *et al*, 1989) that a four-year break should be allowed between potato crops. Firstly, if this break is to be achieved by weed fallow, there is no evidence from this experiment that it will have the desired effect of ensuring freedom from BW. Secondly, if maize is used as a break crop it may be possible to shorten the rotation as there was no evidence in this experiment of additional benefit when more than two crops of maize followed potato.

Unfortunately sweet potato, which is the traditional staple food crop in the Tambul area, was less effective than maize in reducing BW infection in soils. It is not clear whether farmers will be willing to adopt maize rotation as a strategy for BW control as it is not a common practice to plant maize as a sole crop. There may be a need to examine maize / sweet potato intercrops and their effect on BW persistence in highlands soils.

CONCLUSION

Based on the experimental results described above, it is recommended that maize should be planted following potato crops, which have shown a high level of BW infection, to reduce it to tolerable levels. Where infection is severe, at least two cropping cycles are required before potato is planted again.

ACKNOWLEDGEMENTS

The Highlands Regional Horticulturist (M. Hughes) initially set up the trial with the assistance of the Seed Potato Coordinator (G. Liripu) and Seed Inspector (P. Siwie). The Research Technician (A. Pinzen) supervised the execution of trial work.

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