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## Harvest

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## HARVEST

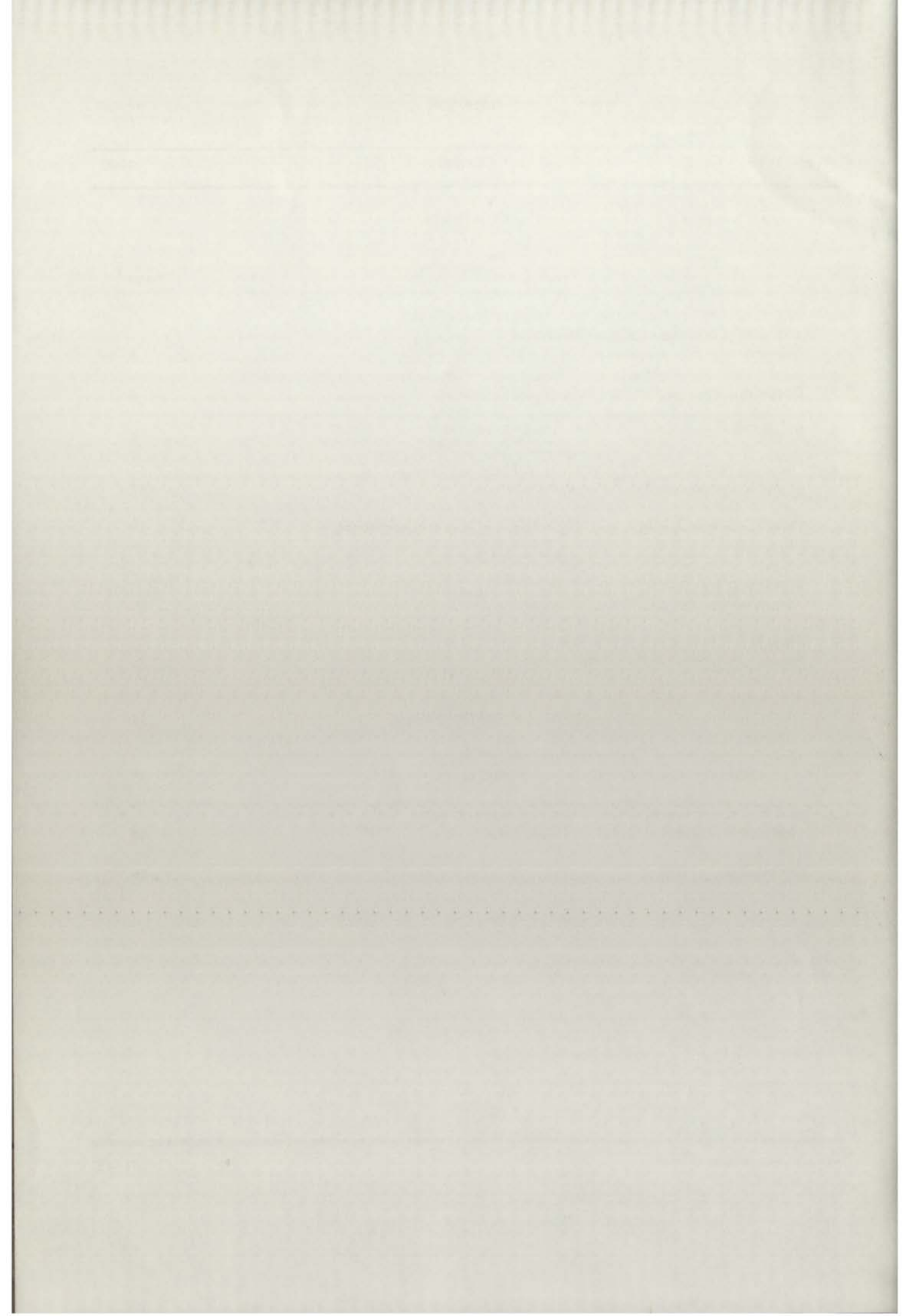
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# EFFECT OF DIFFERENT LEGUME SPECIES AS GREEN MANURE ON THE YIELD OF CHINESE CABBAGE (PAK-CHOI) (Revised version)

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## ABSTRACT

Seven different legume species VIZ: snake bean (SNB), gut pela cowpea (GTC), velvet bean (VEB), sunnhemp (SUN), common cowpea (CMC), sesbania (SES) and winged bean (WGB) were evaluated as green manure crops on the yields of pakchoi (Chinese Cabbage). Fresh organic matter yield (FOMY), in the same observation excluding WGB, showed CMC to be highest while the lowest was observed in SNB. The yield of succeeding pakchoi crop, when planted on these respective beds, showed VEB to be superior followed by SUN, SES, GTC, CMC, SNB and WGB respectively. Statistical analysis showed insignificant effect ( $P > 0.05$ ) between legume species, however, velvet bean seemed to be the best green manure crop in this observation. Although no soil tests were done to confirm the levels of nutrients, particularly nitrogen provided by the respective legumes, a good crop of pakchoi is an indication of the contribution of these legumes to soil fertility.

## INTRODUCTION

### Background

With the current energy crisis and the consequent increased cost of commercial fertilizers, many subsistence farmers in Papua New Guinea are finding it difficult to grow crops, particularly vegetables, without the use of fertilizers. Some farmers have appreciated the problem and have resorted to the use of organic fertilizers such as compost, and animal manures in vegetable production. However, most farmers find the former difficult to make due to either the lack of knowledge, or lack of necessary materials, or both, while having a negative attitude for the latter let alone touching it. The attitude to any type of animal manure is culturally negative and these are regarded by many as unhygienic and therefore should not be used in growing food crops.

During Community Agriculture Extension (CAGE) outreach effort in few villages and squatter settlements in and around Port Moresby, it was observed that brassicas (cabbage family) are among the most common vegetables grown by many backyard vegetable growers of which Chinese Cabbage (pakchoi) is most popular. It was also observed that few farmers are realizing the value of chicken manure and are therefore beginning to utilize this material in vegetable production while there are still others who insist on the use of commercial fertilizers despite the high cost.

### Green manuring

Green manuring is an ancient practice which is currently common among large commercial farmers while still unknown by many subsistence farmers in the developing countries. The practice involves digging back into the soil of green plants before reaching maturity stage. Green manure crops, particularly leguminous plants, have the greatest advantages in providing the soil with organic matter thereby increasing nutrient particularly of nitrogen, improved soil structure, aeration, nutrients and water holding capacities, soil pH, and the population of beneficial soil micro-organisms.

This report is an attempt to demonstrate that vegetables such as brassicas could be successfully grown (when followed by a green manure crop), without the use of commercial fertilizers. Among numerous tropical legume species that are often used either for green manuring or as a cover crop, the velvet bean (VEB) is very commonly used by subsistence farmers. As a cover crop the VEB has the potential of providing about 30t/ha of fresh organic matter and is capable of yielding an incredible solid cluster of dark-red active nodules each averaging 4 cm in diameter with a total weight of 500 kg/ha.

Subsistence corn growers in South America who commonly use VEB as a cover crop claim that this legume is able to contribute about 4 t/ha more corn when incorporated with commercial fertilizers. The

**Table 1 Mean Fresh Organic Matter Yield of different Legume Species**

Legume Species	Mean Number of plants (plants/m <sup>2</sup> )	FOMY*		Rank
		Kg/bed	t/ha	
Snake bean	5.33	1.96	3.3	6
Gutpela cowpea	19.00	2.6	4.3	3
Velvet bean	7.15	2.19	3.65	5
Common cowpea	28.33	3.21	5.35	1
Sunnhemp	39.00	3.15	5.25	2
Sesbania	265.33	2.42	4.03	4
Winged bean	3.00			

\* **Fresh Organic Matter Yield****Table 2 Mean Yield of Pakchoi in Green Manure Plots**

Legume Species	Yield		% Increase in Pakchoi Yield	Green Manure Ranking
	Kg/bed	t/ha		
SNB	12.65	21.08	8.84	6
GTC	18.07	30.12	55.49	3
VEB	22.31	37.18	91.94	1
CMC	15.40	25.67	32.52	5
SUN	20.00	33.33	72.07	2
SES	19.80	33.00	70.36	4
WGB	11.62	19.37	0.00	7

\* **Taking pakchoi yield in winged bean (WGB) plot as standard**

VEB is also known to be the best choice of legume species for the purpose of rehabilitating depleted land, and also for eliminating serious weeds such as the nut grass.

#### METHODOLOGY

Seeds were sown on 6 m x 1 m low-raised-bed in a completely randomized block design (CRBD), where each legume species was replicated 6 times. Four weeks after sowing, population count of the respective legume species were taken using 1 m x 0.5 m rectangular quadrant. The same quadrant was used 3 weeks later for fresh organic matter yield (FOMY) determination.

Eight weeks after sowing, the legumes were chopped with a "bush" knife and immediately dug back into the respective beds with digging fork. Three weeks after the digging back of the legumes, the beds were lightly tilled and 4-weeks-old pale pakchoi seedlings were planted at 0.4 m x 0.3 m (inter-row and intra-row) spacing.

The cabbages were harvested 4 weeks after planting and total and marketable crop yields per bed were recorded. From the data potential pakchoi yields per treatment were estimated.

From the sowing of the legume seeds until harvesting of pakchoi, weekly application of water was done using sprinkler irrigation. During the same period manual weeding was done twice for the legumes and once for the pakchoi. The control of small insects was carried out using an organic extract from ripe chilli-fruits with a dissolved sunlight soap mixture which was fortnightly sprayed before harvest.

#### RESULTS

Table 1 shows plant population of different legume species where sesbania (SES) had the highest mean number of plants per square metre followed by the common cowpea (CMC), while the winged bean (WGB) had the lowest due to its poor establishment.

Fresh organic matter yield data (Table 1) shows CMC to have the highest FOMY followed by the sunnhemp

(SUN), than gutpela cowpea (GTC), while the snake bean (SNB) yielded the lowest. No FOMY recording was obtained from WGB due to its poor establishment and growth.

When the pakchoi crop was grown on beds that were preceded by respective legume species, the yield was highest in velvet bean VEB followed by SUN and SES. Beds that were preceded by WGB yielded the poorest crop of pakchoi.

Table 2 shows that pakchoi yield is obviously not directly related to FOMY of the preceding legume species. The VEB which ranked fifth in FOMY contributed to the highest pakchoi yield, while the CMC and SUN which showed the first and second highest in FOMY, ranked fifth and second respectively in their contribution to pakchoi yield.

## DISCUSSION

Plant population in Table 1 shows SES as having the highest number of plants per square meter of land followed by SUN, CMC, GTC, VEB, SNB, and WGB respectively. There was no standard seed sowing rate as reflected in varying plant densities of respective legume species.

The CMC had the highest FOMY (Table 2) while the lowest was observed in SNB with the respective FOMY of 3.21 and 1.98 kg/ha. The establishment of WGB was very poor therefore no FOMY data were obtained from this species.

The SES although having the highest plant population didn't yield as much fresh organic matter, unlike the CMC. This was due to the slow growth rate of the former species wherein by the 8th week most of the plants were less than a meter high. Furthermore, high population of this species resulted in plants having weak thin stems with few leaves resulting in low FOMY. The latter species on the other hand reached flowering stage by the 8th week and the individual branches were up to a metre long. More branches meant higher leaf flush resulting in higher FOMY.

The SUN which scored the second highest FOMY also had the second highest plant population. Bulk of the FOMY may have been contributed by the woody part of the individual stems which was obvious during FOMY observation on the 8th week. The VEB, SNB and WGB had low populations and consequently yielded low amounts of fresh organic matter.

The highest mean pakchoi yields (Table 2) were obtained from the beds that were preceded by VEB. In order of superiority VEB is followed by SUN, SES, GTC, CMC, SNB, and WGB with the respective pakchoi yields of 22.31, 20.00, 19.80, 18.07, 15.40, 12.65 and 11.62 kg/bed.

Obviously pakchoi yield was not directly related to the amount of organic matter contributed by the preceding legume species. Most probably the difference in pakchoi yields could be attributed to the varying degrees of soil nitrogen contributed by respective legume species.

Preliminary results of this work showed that out of the seven legume species the velvet bean seemed to be the best green manure crop which contributed about 92% more benefit (Table 2), most probably due to soil nitrogen, in the yield of pakchoi.

No analysis was done for the soil samples on which the respective legumes were grown, therefore the real cause of the resultant increased pakchoi yields could not be confirmed.

However, pakchoi as belonging to brassica family, is known to have a high demand for nitrogen. Therefore with a good crop of pakchoi that was harvested from this work, nitrogen could be the most important soil nutrient that was contributed by respective legume species, of which velvet bean provided the most.

## FURTHER READING

Bunch, R. (1986). Notes on "Green Manure Crops for Small Farmers". *World Neighbours*, Apartado 278-C, Tegucigala, Honduras. Central America.

(NOTE: - The above article first published in vol. 1, 1993 had several important errors. Due to its importance to agriculturists in PNG, the article is reprinted as a revised and mistake free version - Editor).

## HORTICULTURE NOTE NO. 22

# COCOA PRUNING

C. Benton,

Cocoa Quality Improvement Project, P. O. Box 1637, Rabaul

### ABSTRACT

*Pruning is a management practice used by plantation tree-crop farmers through out the tropics. It is done to prevent a crop such as a cocoa tree growing very tall, by developing second and third storeys from the original jorquette of a young cocoa tree. Pruning allows a cocoa tree to attain a constant height throughout its productive period, helps in preventing the spread of pests and diseases, and allow the use of proper management practices.*

### INTRODUCTION

Pruning is one of the most controversial of all work performed on cocoa. Farmers have their own ways of pruning which they think is best, so one could argue for ever on the merits of each system. To avoid this, let us look at what we wish to achieve when we prune cocoa. Pruning is one of the most important operations, and it can affect the yield of cocoa for many months - even years after the pruning. It is imperative that all care be taken when pruning. There are three types of cocoa trees that have to be pruned.

# Hybrids

# Trinitarios

# Clones (Vegetatively propagated cocoa)

(This paper will deal only with *HYBRID* and *TRINITARIOS*).

### PRUNING HYBRIDS AND TRINITARIOS

1. Formation pruning
2. Chupon or Water Shooting Pruning
3. Sanitary Pruning
4. Structural Pruning

### PRUNING TOOLS

To prune cocoa properly you **MUST** have the proper tools. (See Figure 1) At all times these **MUST** be kept sharp.

N.B. A bushknife should never be used to prune cocoa.

### PRUNING HYBRIDS AND TRINITARIOS

#### 1. FORMATION PRUNING

Young cocoa, if left to its own devices, will jorquette at about 1.5 meters. It will then produce chupons that will grow past the original jorquette to form second and third storeys. If this is allowed to happen, the cocoa trees will become far too tall to manage correctly. To prevent this, the tree is pruned along the following lines to give the desired shape:-

#### 1.1. Remove Double Headers and Side Shoots

If a cocoa seedling is damaged mechanically and the growing point is destroyed, the seedling will throw up

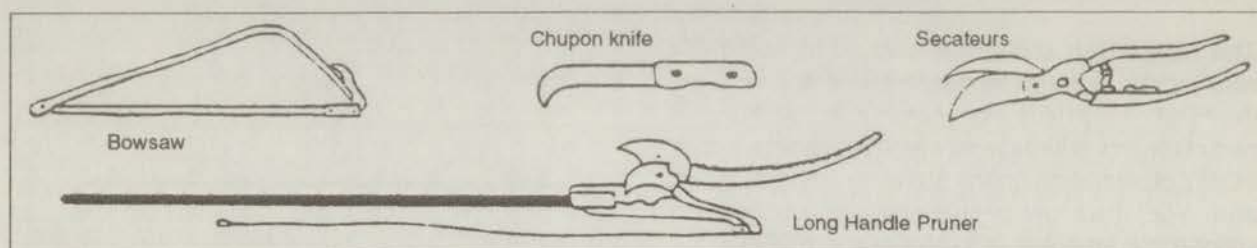


Figure 1. Pruning tools

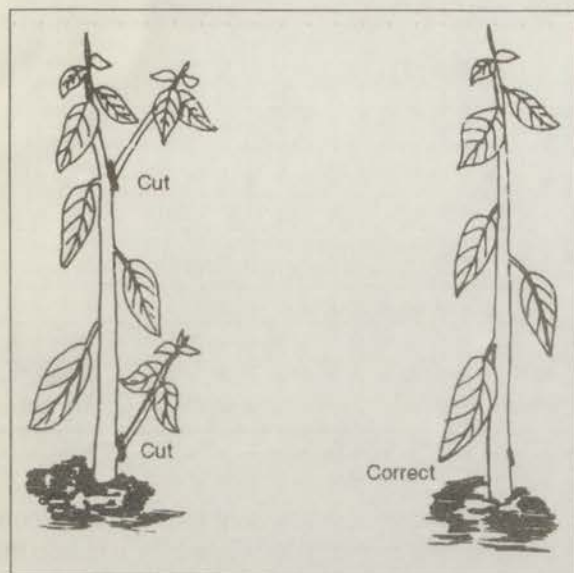


Figure 2.

a number of new shoots to replace the lost growing point. (See Figure 2.) This damage, often seen in cocoa, may be caused by falling nuts and fronds from coconuts, wind damage, hand-slashing, insect damage, or over-zealous use of herbicides. If left unpruned, the young seedling will be retarded - first from the mechanical damage, and then from the seedling trying to grow multiple stems. It is most important that these plants be pruned back to a single stem as soon as possible, to divert all energy into one stem. The chupon team doing the monthly rounds on the mature cocoa tree should also do monthly double - header and chupon rounds in new plantings.

### 1.2. Prune Trees to a Manageable Height

Cocoa seedlings, if mechanically damaged,

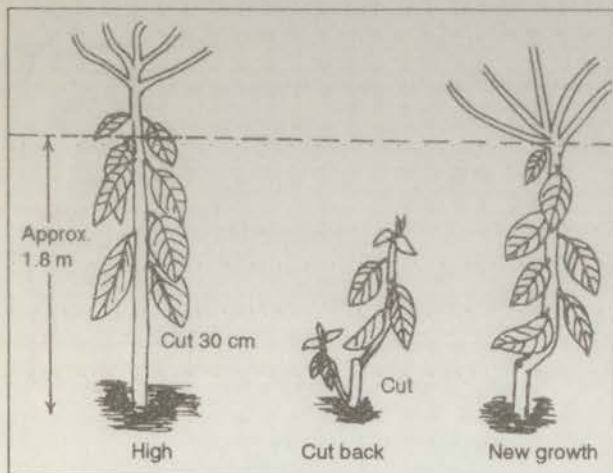


Figure 3.

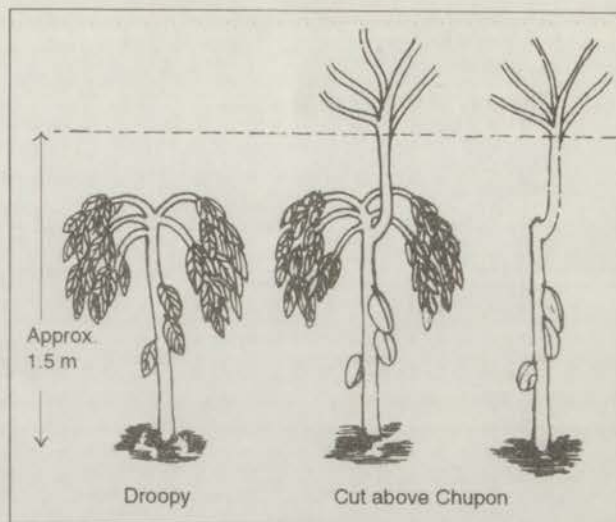


Figure 4.

overshaded, or genetically inclined, will often jorquette at a height that is too high for normal management practices. If cocoa seedlings jorquette above 1.8 metres, they should be stumped back at an angle to about 30 centimeters, and two new basal chupons should be allowed to grow. After about three months, the weaker of the two should be cut off and the stronger new shoot allowed to form a new tree. (See Figure 3). If the tree once again jorquettes too high, leave it, as nothing else can be done.

Other seedlings, especially the Kee 22 seedlings have a low jorquette and drooping habit which impedes access to the cocoa. These trees can be encouraged to jorquette higher by allowing an apical chupon to grow, and ramify at a higher point by allowing an apical chupon to grow up through the existing tree. Once it has ramified at the correct height, remove the old canopy. (See Figure 4).

### 1.3. Allow 5 Main Branches to Surround the Main Trunk

The natural ramification of branches from the trunk is five, so there is no need to change this. When pruning, aim for five strong branches evenly spaced around the trunk. When the majority of trees are formed a jorquette at about 9 months, you need to have a round of five-branches pruning. Pruners should carry a 60 centimeter stick and cut out all branches within this area. (See Figure 5.) If there are not enough branches to get five, extra branches can be created by allowing a main branch to divide into two. (See Figure 6.) Five-branch pruning rounds should be done every 4 to 6 weeks as part of a normal chupon round. They should not be stopped once the

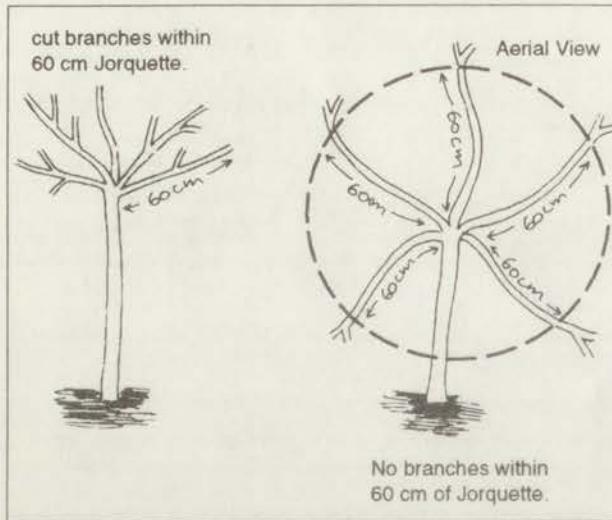


Figure 5.

tree has matured. The reason for this is that cocoa trees are constantly changing from mechanical damage, or bad management. It is, therefore, a constant job to keep trees with five strong lateral branches.

## 2. CHUPON AND WATER SHOOT PRUNING

If allowed to grow, chupons will grow up through the

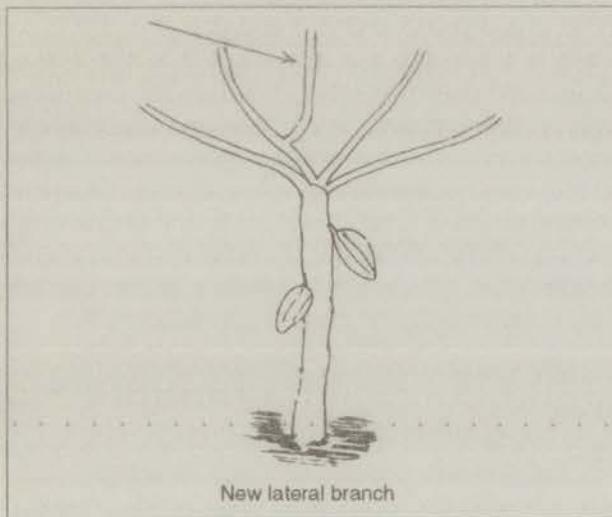


Figure 6.

present canopy and form a second storey. All chupons should be removed from the tree when they are soft and have not taken any energy out of the tree. To achieve this, chupons should be pruned off every 4 to 6 weeks. If chupons are pruned regularly, all that will be required for their removal is a sharp knife - NOT A BUSH KNIFE. It is important that the knife be kept sharp and that the chupon be cut as close to the trunk as possible. If "hat pegs" or cushions are left, the

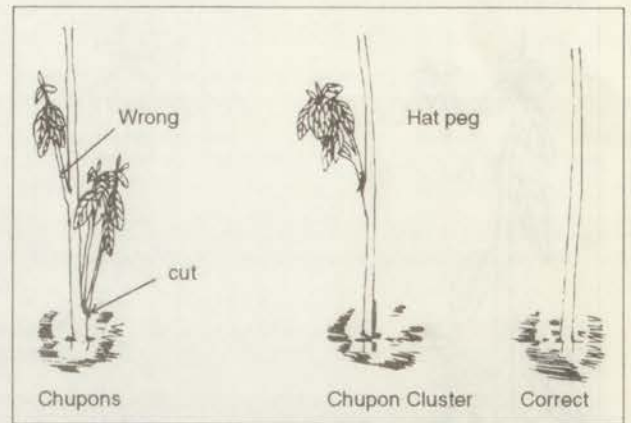


Figure 7.

chupons will regrow in thick clusters, requiring more work on the next round. (See Figure 7.) It is also the job of the chupon pruners to remove any coconut fronds, rubbish, etc from the tree. Chupon pruners should carry a pair of sharpe secateurs to cut off any diseased or damaged branches as a normal part of their round. They should carry a 60 centimeter stick, and cut out all branches within a 60 centimeter-radius of the jorquette, while all the time ensuring that the tree has five strong branches surrounding the trunk. (i.e. If a tree has only 4 branches, a young fan branch should be left to grow as a replacement for the lost branch.) Pruners should be taught the difference between chupons and fan branches to make sure the right ones are being cut off or retained. (See Figure 8.)

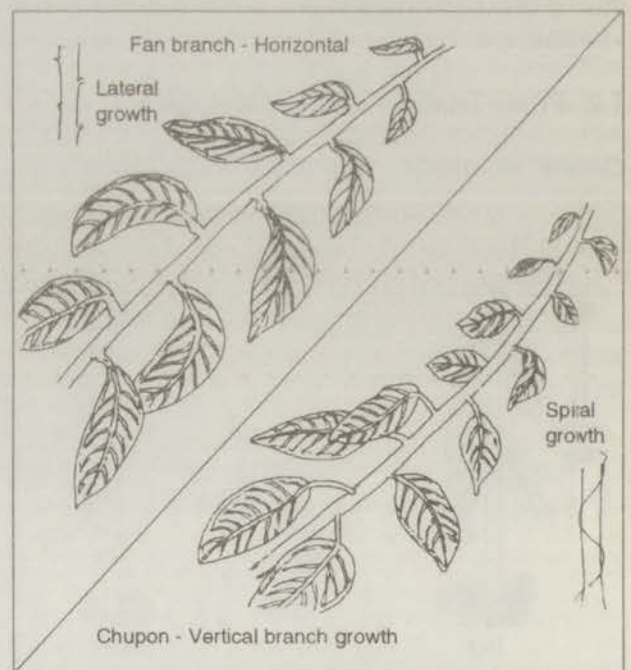


Figure 8.

### 3. SANITARY PRUNING

Sanitary pruning is pruning to remove diseased or damaged wood to help control the disease. The main

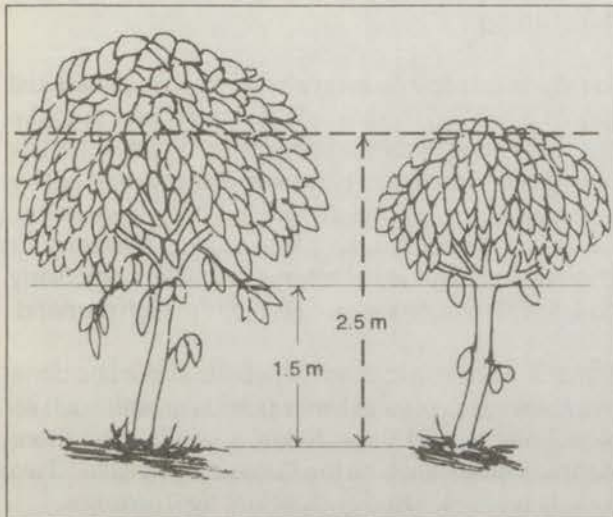


Figure 9.

diseases in PNG that require sanitary pruning are Pink Disease and Vascular Streak Dieback. (See CCRI Information Bulletin and Plant Pathology Notes). Sanitary pruning is combined with the normal structural pruning. (i.e. When pruning a tree, the sanitary pruning is done first, the tree is then evaluated,) and the structural pruning done to compensate for any loss of branches and foliage. However, in some cases where there are bad outbreaks of disease, special sanitary pruning rounds will be necessary, particularly with "Pink Disease" (*Corticium salmonicolor*) in young cocoa in the wetter areas of the country.

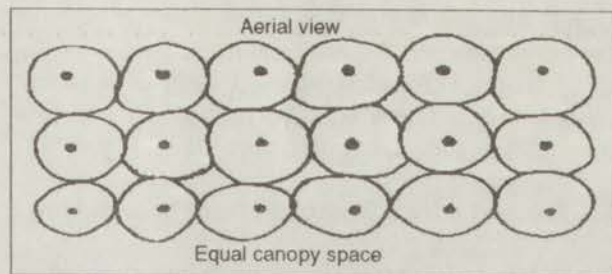


Figure 10.

### 4. STRUCTURAL PRUNING

#### 4.1. Remove Diseased or Damaged Branches

When you first start to prune a cocoa tree, the first task is to remove any diseased or damaged branches. Once this is done, the tree can be looked at as a whole, and decisions made on how it can best be pruned to make the best tree from what is left.

#### 4.2 Control Height of Trees

If cocoa was allowed to grow to its natural height, harvesting and disease control would be impossible. Sunlight would be restricted and air movement impeded. To allow all activities to be done with ease, the cocoa must be pruned to a height that is accessible to harvesters, fungicide spray teams and sanitation rounds. It is recommended that cocoa be kept to a height of about 3.5 meters. To do this, major branches should be allowed to grow up to 3.5 meters. Hence, major branches extending above 3.5 meter-mark, (i.e. those thicker than 40 millimeters.) Smaller branches can be left as they will curve down with gravity, if they don't they can be pruned off next

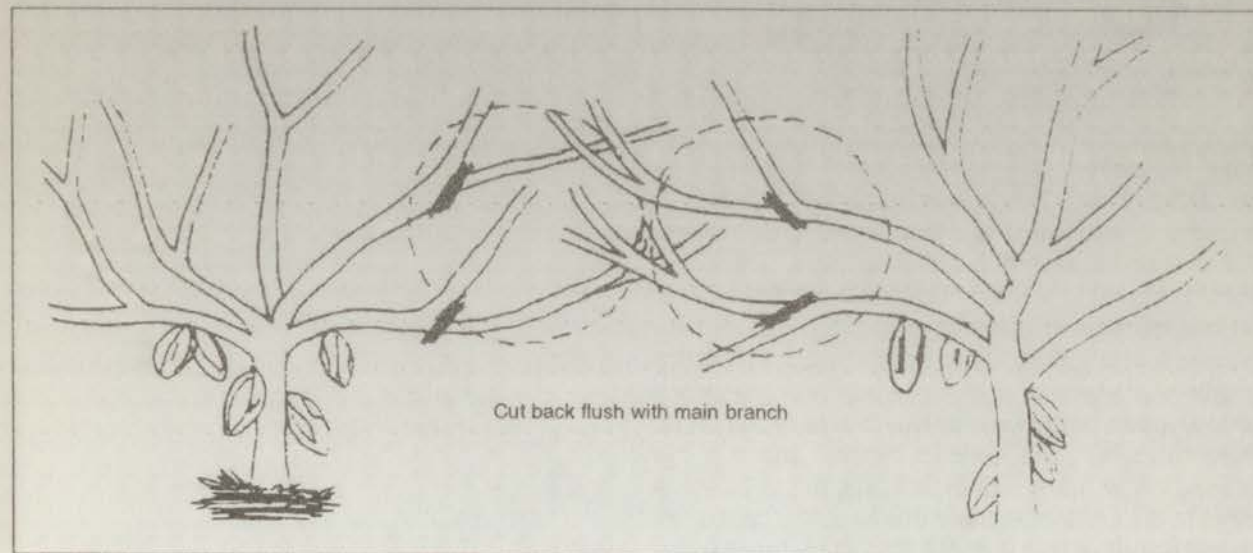


Figure 11.

round. All parts of the trees are then within range of the harvesters' hooks and extended lances of the spray teams. To allow easy access of workers, canopies should be lifted to 1.2 metres. This means cutting off any low-lying branches. (See Figure 9.)

#### 4.2 Prevent lateral Branches from Interlocking

Cocoa trees, if unpruned, will grow into each other laterally, forming a thick mat of foliage, which will impede light and air access. As well, the more vegetatively vigorous trees will dominate the less vigorous, which are usually the best producers as they are putting their energy into pods rather than vegetative growth. (See Figure 10.)

All lateral growth should be cut off when it touches the other tree. This should be done midway between the trees so that each tree has the same area to grow in, and the less vigorous trees are not overgrown by the vigorous ones. (See Figure 11). Nodal branches are cut to the nearest node.

#### 4.4 Canopy Allowing Air and Sunlight Penetration

Once the height and tipping are complete, the canopy

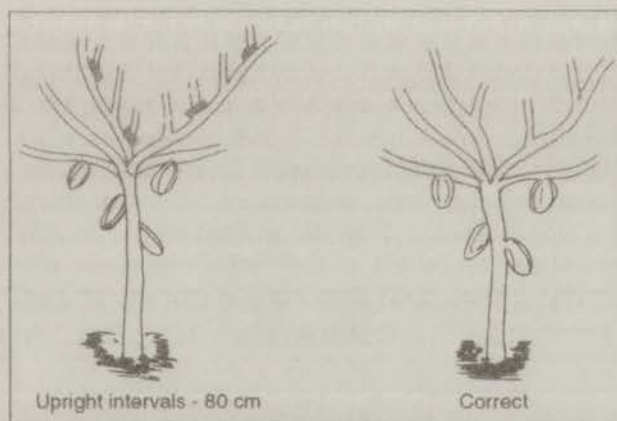


Figure 12.

must be looked at with the aim of allowing free circulation of air. This is most important in reducing humidity, which in turn helps to control fungal diseases. Penetration of sunlight is also important. Canopies should intercept the maximum amount of sunlight for photosynthesis, while leaving enough foliage to protect the tree from sunburn. The practice of cutting out the middle of the tree must be avoided. With the vigour of the hybrids, particularly with high density plantings, there tends to be a "witch's broom" effect in the canopy. After many pruning rounds, the trees strive to get to the sunlight. Where this happens, branches should be pruned out to about 30 centimeter intervals evenly along the main branches. (See Figure 12.)

Once again, this leaves branches evenly spaced to allow air and sunlight to penetrate. When completed, there should be a dappled sunlight effect on the ground. Care must be taken not to cut out too much material.

#### 4.5 Timing

Ideally, in-canopy pruning should be completed just before flowering to stimulate flowering and to make sure the young pods start off in an environment of low humidity and sunlight. However, there should not be any major pruning (height and tip) before flowering. No pruning should take place during flowering or cherrele set. This is not always possible, particularly on large plantations where labour is in high demand.

Structural pruning rounds for hybrids should be done twice yearly in areas of less vigorous growth such as New Ireland, and three times a year in the more vigorous areas such as the Gazelle Peninsula. Two rounds a year is usually sufficient for Trinitarios.

#### 5. CONCLUSION

Pruning is one of the most important and expensive cocoa management tasks, so it is vital that it is done carefully and correctly. Bad pruning can ruin a tree for life, or at the least affects production for many months.

Remember the main aims of pruning:-

**TO CREATE TREES OF THE CORRECT HEIGHT WITH AN OPEN CANOPY THAT ALLOWS AIR AND SUNLIGHT TO PENETRATE.**

## VEGETABLE GROWER SURVEY - 1993

**Geoff Wiles**

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### ABSTRACT

*The results of a survey of vegetable growers conducted in February to May 1993 in selected districts are presented. The information obtained reveals significant differences between districts in crops grown, technology adopted by farmers, pest and disease problems encountered and marketing practices. Growers also reported on the perceived problems affecting their production. While finance, marketing and transport are major constraints, technical constraints recognised by farmers include pest and disease problems and lack of irrigation.*

### INTRODUCTION

In order to assist Fresh Produce Development Company (FPDC) with establishment of a specialised extension service for vegetable growers a baseline survey was carried out in selected areas where it was planned to place extension officers. The areas were selected because of their reputation as being established producers of marketed vegetables. In each area approximately 40 growers were selected at random and asked questions about their vegetable production activities. The results of the survey provide an insight into farmer practices and problems in 8 vegetable growing districts in the highlands and Central Province.

The area surveyed only included gardens where vegetable crops were being grown for sale (Table 1). Some farmers had other gardens planted to traditional crops for subsistence use which were not included in the survey. The large gardens in the Tambul area included some significant commercial potato plantings. In Hiri district only a few farmers were surveyed; in this area only farmers with access to irrigation can engage in vegetable production. These farmers generally have larger areas under production. In Waghi district the large planted area was due to inclusion of a number of farmers engaged in commercial scale pineapple production.

*Table 1. Areas surveyed for vegetable growers*

District	Area surveyed (m <sup>2</sup> )	No. of farmers	Average area (m <sup>2</sup> )
Tambul	570,892	41	13,924
Hiri (Central)	79,705	9	8,856
Waghi	277,914	40	6,948
Goilala (CP)	205,010	38	5,395
Mendi (SHP)	73,307	40	1,832
Goroka (EHP)	59,807	40	1,495
Laiagam (Enga)	49,161	35	1,405
Gembogl (Simbu)	52,071	40	1,302

**Table 2. The most important crops grown in each surveyed district**

District (no of farmers)	Crop	No. of farmers (% of sample)	Crop	Area (m <sup>2</sup> ) (% of total)
Tambul (41)	Potato	37 (90)	Potato	386,168(67.6)
	Cabbage	34 (83)	Kaukau	93,240(16.3)
	Cauliflower	23 (56)	Cabbage	47,992 (8.4)
	Broccoli	23 (56)	Broccoli	25,986 (4.6)
	Kaukau	8 (44)	Cauliflower	11,025 (1.9)
	Carrots	1 (27)	Strawberry	5,007 (0.9)
Hiri (9)	Cucumber	7 (78)	Watermelon	4,464 (18.1)
	Corn (maize)	6 (67)	Corn (maize)	13,512 (17.0)
	Tomato	6 (67)	Pumpkin <sup>1</sup>	3,375 (16.8)
	Capsicum	5 (56)	Taro <sup>1</sup>	2,000 (15.1)
	Watermelon	4 (44)	Cucumber	6,605 (8.3)
	Bean	3 (33)	Capsicum <sup>1</sup>	2,056 (2.6)
	C/cabbage	3 (33)		
	Spring onion	3 (33)		
Waghi (40)	Kaukau	31 (78)	Kaukau	125,149(45.0)
	Cabbage	21 (53)	Pineapple	93,190(33.5)
	Spring onion	20 (50)	Cabbage	19,633 (7.1)
	Tomato	15 (38)	Tomato	7,590 (2.7)
	Lettuce	13 (33)	Corn (maize)	6,546 (2.4)
	Carrots	11 (28)	Spring onion	4,084 (1.5)
Goilala (38)	Kaukau	31 (82)	Kaukau	183,279(89.4)
	Cabbage	17 (45)	Peanut	6,870 (3.4)
	Spring onion	17 (45)	Potato	6,356 (3.1)
	Potato	15 (40)	Strawberry	2,169 (1.1)
	Peanut	9 (24)	Corn (maize)	2,047 (1.0)
	Tomato	9 (24)	Cabbage	1,532 (0.7)
Mendi (40)	Cabbage	32 (80)	Kaukau	39,608 (54.0)
	Kaukau	29 (73)	Potato <sup>1</sup>	9,820 (27.0)
	Potato	29 (73)	Cabbage	7,519 (10.3)
	Spring onion	3 (33)	Corn (maize)	1,478 (2.0)
	Corn (maize)	11 (28)	Lettuce	1,471 (2.0)
	Carrots	9 (23)	Taro	561 (0.8)
	Lettuce	9 (23)		
Goroka (40)	Carrots	24 (60)	Kaukau	20,379 (34.1)
	Cabbage	18 (45)	Carrot <sup>1</sup>	1,694 (19.6)
	Spring onion	6 (40)	Cabbage	6,729 (11.3)
	Potato	5 (38)	Potato	6,024 (10.1)
	Broccoli	2 (30)	Broccoli	3,183 (5.3)
	Tomato	1 (28)	Tomato	2,091 (3.5)

Table 2 (continued). The most important crops grown in each surveyed district

District (no of farmers)	Crop	No. of farmers (% of sample)	Crop	Area (m <sup>2</sup> ) (% of total)
Laiagam (37)	Potato	34 (92)	Potato	24,308 (49.4)
	Cabbage	12 (32)	Kaukau1	4,506 (29.5)
	Broccoli	10 (27)	Cabbage	4,490 (9.1)
	Carrots	10 (27)	Broccoli	2,814 (5.7)
	Kaukau	10 (27)	Cauliflower	805 (1.6)
	Spring onion	4 (11)	Spring onion	545 (1.1)
Gembogl (40)	Carrots	32 (80)	Cauliflower	4,964 (28.7)
	Cauliflower	32 (80)	Carrot	9,953 (19.1)
	Cabbage	26 (65)	Cabbage	5,970 (11.5)
	Broccoli	25 (63)	Kaukau	4,408 (8.5)
	Snowpeas	20 (50)	Broccoli	3,676 (7.1)
	Potato	19 (48)	Potato1	2,394 (4.6)
	Strawberry	19 (48)		

Table 2 shows the importance of different crops in each area surveyed. All survey areas except Hiri represent Highlands vegetable production areas. However these may be subdivided into high altitude areas (above the coffee limit of c. 1800 m) and coffee growing areas (1000 to 1800 m). In the high altitude areas brassicas and potatoes were the most important crops. In the coffee growing areas other crops such as lettuce, tomatoes and beans were also important. Goilala is somewhat different because of its remoteness and poor transport infrastructure. Here traditional crops still predominate, while peanuts appear to be the main cash crop. Hiri district is the only lowland area surveyed and is quite different from the other areas, with watermelon, pumpkin, corn and taro the most important crops. Capsicum, cucumber and tomato are also grown to a significant extent.

### FARMING PRACTICES

Farmers were asked questions about fertilizer use, pest and disease control practices and varieties of different crops planted. The answers revealed significant differences in farming practices and technology adoption between the areas surveyed.

### FERTILIZER USE

The number of farmers using fertilizer (Table 3) ranged from only 37% in Goilala to 100% in Laiagam, Tambul and Hiri districts. This is indicative of the less developed status of Goilala district, where obtaining fertilizer is difficult because of poor transport and lack

of suppliers.

The most widely used fertilizer is 12:12:17 NPK compound fertilizer (Table 4). Chicken manure is used where available; availability varies greatly from one district to another. Triple superphosphate (TSP) is important in Tambul district and is also used in Mendi and Laiagam in neighbouring provinces. Other fertilizers used include potato mix and urea. The latter is recognised to be beneficial for cabbage production. The use of compost does not appear to have been widely adopted.

### PEST AND DISEASE CONTROL

The percentage of farmers using chemical pest control varied from 23% (Laiagam) to 95% (Tambul) (Table 5). Both Laiagam and Goilala had a low level of sprayer ownership and chemical use. In some districts farmers who did not own a sprayer reported using chemicals for pest and disease control; presumably they borrow a sprayer when required.

The important pests and diseases as reported by farmers are shown in Table 6. Bacterial wilt was an important problem in most potato growing areas. In Goroka target spot was mentioned as a potato disease problem. Cutworm was reported as causing serious damage to potatoes. Cutworm was also a serious pest of brassicas. Brassicas were widely reported as being attacked by caterpillars. Both diamond back moth and cluster caterpillar were mentioned as being serious pests. In Gembogl snail damage was also

Table 3. Number of farmers using fertilizer (by district)

District	Farmers using fertilizer	Farmers not using fertilizer	Percentage using fertilizer
Laiagam	35	0	100
Tambul	41	0	100
Hiri	9	0	100
Mendi	36	4	90
Gembogl	33	7	83
Goroka	33	7	83
Wahgi	31	9	78
Goilala	14	24	37

Table 4. Type of fertilizer used (number of farmers)

District	Chicken Manure	Compost	12:12:17	TSP	Other
Laiagam	8	1	30	9	2
Tambul	1	0	37	35	4
Hiri	2	0	6	0	3
Mendi	21	6	15	5	6
Gembogl	8	3	21	0	12
Goroka	6	0	16	0	4
Wahgi	14	1	18	2	6
Goilala	2	3	2	0	4
<b>TOTAL</b>	<b>62</b>	<b>14</b>	<b>145</b>	<b>51</b>	<b>41</b>

Table 5. Number of farmers using chemicals for pest and disease control

District	Number owning a sprayer	Percent of sample	Number using chemicals	Percent of sample
Tambul	35	95	39	95
Hiri	8	89	8	89
Goroka	25	63	28	70
Mendi	33	83	28	70
Gembogl	15	38	24	60
Wahgi	26	65	21	53
Goilala	3	8	12	32
Laiagam	22	63	8	23

Table 6. Major pests and diseases reported by farmers

District	Crop	Major pest	Crop	Major disease
Tambul	Potato Brassicas Strawberry	Cutworm Caterpillars Cutworm Beetles	Potato Cabbage	Bacterial wilt Bacterial soft rot
Hiri	Tomato Cabbage	Caterpillar (fruit worm?) Diamond back moth		
Goroka	Cabbage Broccoli Tomato Spring onion	Diamond back moth Cluster Caterpillar Fruit worm Aphids	Potatoe	Target spot
Mendi	Potato Cabbage	Cutworm Cutworm Caterpillar	Potato	Bacterial wilt
Gembogl	Brassicas Strawberry	Caterpillar Diamond back moth Cutworm Snail Beetle	Potato Cauliflower	Bacterial wilt Bacterial soft rot
Waghi	Cabbage Tomato	Cutworm Cluster Caterpillar Fruit worm (borer)		
Goilala	Cabbage Strawberry	Cutworm Caterpillar Diamond back moth Beetle	Potato	Bacterial wilt
Laiagam	Brassicas	Cutworm	Potato	Bacterial wilt

reported. Bacterial soft rot was reported as attacking cabbage (Tambul) and cauliflower (Gembogl). In those districts where strawberries were being grown beetles were noted as pests requiring control. In tomato fruit worm (borer) was commonly reported as being troublesome.

### SEED SUPPLY AND VARIETIES

Farmers were asked the question: 'Is it easy to get seeds of the variety you want when you want it?' Answers are recorded below:

District	Yes	No	% yes
Hiri	8	1	89
Waghi	28	11	72
Tambul	27	12	69
Goroka	13	24	35
Gembogl	13	27	33
Laiagam	6	29	17
Goilala	6	32	16
Mendi	6	33	15

Those farmers close to Mt Hagen or Port Moresby had a good access to seed supply. Goroka appears to be much less well supplied. Availability of seed was poor in Goilala, Laiagam and Mendi.

The varieties used (combined data for all districts) are shown in Table 7. Many farmers however used any available variety. Sequoia is the predominant potato variety. Of the cabbages open pollinated varieties Golden Acre and Early Drumhead predominate. Green Coronet is the most widely planted hybrid. Only for

broccoli is hybrid seed generally used. Green Duke is by far the most popular.

Table 7. Preferred varieties of main vegetable crops (no. of farmers)

Broccoli	Green Duke	50
	Winter Harvest	16
Carrot	Manchester Table	31
	Topweight	26
	New Kuroda	7
Cauliflower	Snowball Y	28
	Phenomenal 4 month	19
Cabbage	Early Drumhead	39
	Golden Acre	34
	Sugarloaf	17
	Green Coronet	14
Lettuce	Great Lakes	22
Potato	Sequoia	95
	Kennebec	13
Strawberry	Redland Crimson	6
Tomato	Grosse Lisse	28
	Beefsteak	6

Farmers were asked where they marketed their produce. A separate response was obtained for each crop marketed. This information has been used to

Table 8. Relative importance of different market outlets (%)

	Own village	Road side	Trad. Market	Dealer/ depot	Retail store	Other
Gembogl	0.7	18.1	33.1	48.1	0.0	0.0
Goilala	15.0	0.0	44.0	17.0	17.0	7.0
Goroka	0.5	7.7	36.7	29.5	12.1	13.5
Hiri	0.0	3.6	45.2	22.6	15.5	13.1
Laiagam	16.4	36.8	26.9	12.9	2.9	4.1
Mendi	1.6	14.8	57.4	6.0	6.0	14.2
Tambul	0.5	14.5	63.8	17.4	1.4	2.4
Waghi	1.8	14.2	40.4	34.4	1.4	7.8
Average	4.6	13.7	43.4	23.5	7.0	7.8

Table 9. Major constraints to vegetable production reported by farmers

District	Constraint	No. of farmers (% of sample)
Gembogl	<b>Non-availability of other agricultural inputs</b>	<b>14 (35)</b>
	Pests	12 (30)
	Labour shortage and cost	9 (23)
	Marketing	8 (20)
	High price of agricultural inputs	7 (18)
	Lack of proper equipment	7 (18)
	Poor soil	7 (18)
	Tribal fighting & compensation	7 (18)
Goilala	<b>Transport, lack of or too expensive</b>	<b>27 (71)</b>
	Marketing	26 (68)
	Lack of irrigation	23 (61)
	Weather	22 (58)
	Pests	10 (26)
Goroka	<b>Finance</b>	<b>12 (30)</b>
	Pests	10 (25)
	Disease	9 (23)
	Lack of irrigation	8 (20)
	Labour shortage and cost	7 (18)
Hiri	<b>Finance</b>	<b>5 (56)</b>
	Land cultivation/ no tractor	3 (33)
	Labour shortage and cost	2 (22)
	Lack of irrigation	2 (22)
	Transport, lack of or too expensive	2 (22)
Laiagam	<b>Marketing</b>	<b>27 (77)</b>
	Transport, lack of or too expensive	18 (51)
	Labour shortage and cost	11 (31)
	Tribal fighting and compensation	8 (23)
	Finance	7 (20)
Mendi	<b>Finance</b>	<b>21 (53)</b>
	Marketing	20 (50)
	Pests	13 (33)
	Disease	12 (30)
	Transport, lack of or too expensive	11 (28)
Tambul	<b>Marketing</b>	<b>38 (93)</b>
	Transport, lack of or too expensive	26 (63)
	Finance	24 (59)
	Labour shortage and cost	12 (29)
	No extension officer advice	11 (27)
	Non-availability of seed	11 (27)
Waghi	<b>Labour shortage and cost</b>	<b>20 (50)</b>
	Transport, lack of or too expensive	18 (45)
	Pests	17 (43)
	Disease	13 (33)
	Finance	13 (33)

prepare Table 8 which gives the relative importance of different markets to farmers in each district. The traditional open market remains the most important outlet for growers in most districts. However sales to dealers predominate in Gembogl (Simbu) and are important in Goroka and Waghi districts. In Laiagam district roadside sales are particularly important (probably produce sales to vehicles travelling from Wabag to Porgera). Only in Central Province and Goroka do sales to retail stores exceed 10% of reported outlets. In Central Province sales to stores in Port Moresby are significant. Growers in Goroka are known to drive to Lae to sell their produce to stores.

### CONSTRAINTS TO PRODUCTION

Farmers were asked to list the major problems affecting their production. The five most important constraints in each district are listed in Table 9.

Many of these constraints were not due to technical factors, but were of a more general economic or social nature. Finance available to growers was listed as the major constraint in Goroka, Mendi and Hiri districts and was also considered important in Laiagam, Tambul and Waghi. Marketing was listed as the most

important constraint in Laiagam and Tambul, and was a major constraint in Gembogl, Goilala and Mendi districts. Transport was the major constraint in Goilala (a district with very poor road access), but was also listed as an important constraint in five other districts. Tribal fighting was regarded as a constraint in Gembogl and Laiagam districts.

A number of technical constraints were mentioned. The importance of these constraints varied from district to district. Pests were a problem in Gembogl, Goilala, Goroka, Mendi and Waghi; diseases were regarded as important in Goroka, Mendi and Waghi. Lack of irrigation was, not surprisingly, considered a serious problem in Hiri district, but was also mentioned as a constraint in Goilala and Goroka. These highland areas tend to have a pronounced dry season.

### ACKNOWLEDGEMENTS

This survey was conducted by Rural Statistics Section of DAL. The enthusiastic involvement of Kapera Miaea in conducting the survey is gratefully acknowledged. PVESP officers in the various districts collected most of the farm level data. Without their cooperation and the support provided by Fresh Produce Development Company this survey could not have been completed.

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**PLANT PATHOLOGY NOTE NO. 38**
**DISEASES OF CITRUS**  
**PART 1: BACTERIAL AND FUNGAL DISEASES**

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**ABSTRACT**

*Bacterial and fungal diseases of citrus are abundantly increasing and many are not yet found in Papua New Guinea. Few economically important diseases are currently on the rise and have become too common in citrus orchards. Diseases commonly found here are discussed.*

**INTRODUCTION**

Citrus contains many species and varieties belonging to the Rutaceae family. It is a crop that grows and thrives in almost any condition provided there is sufficient moisture and nutrient in the soil. Soils that are too dry cause poor plant growth and fruit quality and excessive moisture cause general foliage chlorosis (leaf yellowing). In either case death may result.

It is worth mentioning here that not all symptoms or abnormal signs that appear on citrus plants leading to death or loss in yield are caused by diseases. Notable symptoms that may be difficult to differentiate (able to see and tell symptom difference one from the other) are basically on the foliage including general foliage chlorosis, veinal and interveinal chlorosis, leaf twisting and curling either upwards or downwards and leaf mottling. Such symptoms may be related to either excess or deficiency in moisture and nutrients or diseases.

Discussed here are some of the more economically and common diseases found in PNG. Other undesirable alien diseases including economically and lesser important ones are contained in the checklist.

**DISEASES OF CITRUS**

There are several economically important diseases affecting citrus plants. In PNG three very common diseases are bacterial canker, pink disease and scab. In 1991 survey for virus diseases of citrus in PNG, 5 different virus diseases were detected and other diseases including 3 mentioned above were obviously present.

**BACTERIAL CANKER**

Bacterial canker is known to occur in almost all continents worldwide including Africa, Asia, Australasia and North and South America. It is a disease caused by bacterium *Xanthomonas campestris* pv. *citri* and attacks most commercial citrus varieties and many relatives. Among the commercial varieties susceptible to bacterial canker are grapefruit, trifoliate orange\*, key lime sweet orange, lemon, Satsuma, mandarin, calamondia, citron and kumquat. The disease is common mainly in the tropics and semitemperate regions. High humidity in particular favours the spread and development of this disease.

**SYMPTOMS**

The distinctive and obvious feature of bacterial canker is the scab-like lesion (spot) that develops on fruits, leaves, twigs (branches) and roots. On fruits the canker first appears as a small, round, slightly raised spot which grows and develops into irregular, sunken, tan-coloured scab. On leaves, twigs, branches and roots lesion often appears as a small, raised, translucent spot, usually darker green in colour than the surrounding tissue. The epidermis (outer skin layer) over the spot on fully developed canker turns yellowish or whitish and ruptures exposing the crater like line with tan-coloured spongy tissue. On leaves alone canker lesion often appears on both sides of the leaf. Individual lesions may coalesce to form scurfy patches. Infection on midribs and petioles may cause leaf drop or leaf to fall.

**CONTROL**

In areas where canker is not present strict quarantine measures against introduction should be mounted.



Figure 1. Bacterial canker on leaf. Notice the chlorosis or yellowing margins surrounding the necrotic or dead tissue of canker disease.

resistant species and varieties may be grown. A measure partly effective in prevention is spraying with Bordeaux mixture having an excess of lime during the early first three months after fruit is formed. Infected trees areas should be immediately removed and burned.

#### PINK DISEASE

Pink disease is caused by a fungus, *Phanerochaete salmonicolor* (Syn. *Corticium salmonicolor*). It attacks many woody plants and among these are some of the very economically important crops such as citrus, tea, coffee, cocoa and rubber. It is present in Africa, Asia, Australasia and South America but more common in the eastern hemisphere. Plant parts mainly affected are the twigs and limbs (trunks) and affected trees are often killed by its girdling effect. The pink disease affects all citrus species and relatives.

#### SYMPTOMS

Infection often starts in sap pockets on either the trunks or twigs and the first symptoms are the drying, hardening and cracking of the bark and secretion of gum. Following this, the affected area is then covered with a thin mass of pinkish orange fungal mycelium with a white advancing margin that spreads over the

outside of the bark. This may only be visible during rainy season. During dry weather and with age the velvety surface of affected area cracks and a dirty white hard coating over the bark. The fungus then enters the bark and sometimes the wood and affects the conducting tissues. The tissues become brown in colour and both water and nutrient up-take ceases, resulting in girdling effect. This is characterised by the rapid yellowing and drying of leaves, which eventually leads to die-back condition.

#### CONTROL

Affected twigs, branches and trunks should be removed by pruning and burned. Pruning should be done well below or away from sites of obvious infection. Disinfect the pruned parts immediately by spraying with copper fungicide or lime-sulfur mixture. For effective control spraying should be done before and during the rainy season. Ensure all individual trees or the orchard be kept clean from source of infections.

#### SCAB

Scab disease is caused by a fungal pathogen called *Elsinoe fawcettii*. It is quite common in some parts of PNG and attacks almost all parts of citrus plant including leaf, fruit, twig and small limbs. Citrus



Figure 2. Bacterial canker on twig of citrus plant.



Figure 4. Scab disease on leaf and twig of citrus. Notice that marginal chlorosis surrounding the scab spot is absent while stentation (curling and twisting) of leaf is a typical symptom of this disease.



Figure 3. Pink disease affecting the stem of citrus plant. Notice the white to pinkish colour of the fungus growing over the affected stem surface.

species that are susceptible to scab disease are sour orange, lemon, tangelo, grapefruit and mandarin varieties.

#### SYMPTOMS

The disease first appears as small translucent (clear) lesions or spots. These spots are raised above surface levels and are variously coloured, mainly dull yellow, but at times colours such as red, orange, or bright yellow may be seen. Well developed spots are often olive-drab or dull, yellowish brown in colour with a well defined warts or scab on the surface of infected part. On fruits the scab may consist of either corky projections (tough solid substance protruding onto surfaces) or irregular raised pustules without distortion as a grapefruit. Lesions on leaves are mainly semitranslucent (slightly clear) dots with well defined margins and with either flat or depressed at the centre of the spots. The leaves become crinkled, distorted and stunted while the fruits become deformed. Fruits with such features are often not marketable due to their ugly and unsightly appearances. On young and succulent twigs lesions are of the same features as those on leaves.

Checklist of some economically important Bacterial and Fungal Diseases of Citrus (diseases marked with an asterisk (\*) have been recorded in PNG)

DISEASES	CAUSAL AGENT	ATTACKS	SPREAD BY
BACTERIAL DISEASES			
* Canker	<i>Xanthomonas citri</i>	Leaves, twigs, roots, fruits	Water splash, infected nursery stock, contaminated body parts and equipment
Blast and black	<i>Pseudomonas syringe</i>	Leaves, twigs, fruits,	Infected buds and rootstock injuries pit to plant parts.
FUNGAL DISEASES			
* Foot rot	<i>Phytophthora parasitica</i>	Trunks	Rains splash, wind, insect, soil
* Melanose	<i>Diaporthe citri</i>	Twigs, leaves, fruits	Rain, wind, contact with diseased plant parts.
Black spot	<i>Homa citricarpa</i>	Fruits, leaves, twigs	Rain, wind, contact with diseased plant parts.
* Scab	<i>Elsinoe fawcettii</i>	Leaves, fruits, twigs	Wind, insect, dew, rain.
* Anthracnose	<i>Colletotrichum gloeosporiodes</i>	leaves, twigs, Fruits	Rain, dew, contact with diseased plants parts.
* Pink disease	<i>Corticium salmonicolor</i>	Trunks, branches	Rain, insect
* Blue mould	<i>Penicillium italicum</i>	Fruits	Contact with diseased fruits.
* Green mould	<i>Penicillium digitatum</i>	Fruits	Contact with diseased fruits
* Bark rot	<i>Diplodia natalensis</i>	Trunks	Rain splash.
Seedling blight	<i>Phytophthora palmivora</i>	Young seedlings, young growing shoots	Rain, wind.
Gummosis	<i>Diplodia natalensis</i> <i>Fusarium</i> sp. <i>Phytophthora</i> sp.	Trunks, stems, fruits	Rain, winds.
* Damping-off	<i>Rhizoctonia solani</i> <i>Sclerotium rolfsii</i> <i>Fusarium</i> sp.	Seedling, young growing shoots	Poor management water splash, contaminated soil.
* Dry root rot	<i>Fusarium</i> sp.,	Roots	Overwatering, injuries to roots by heavy application of fertilizer and herbicides or mechanical injuries.
Fomes root rot	<i>Fomes lamavensis</i>	Roots	trunks overwatering, contact with infected parts.
* Collar and root rot.	<i>Phelinus noxius</i>	Trunks, roots	As Fomes root rot.
Armillaria root rot.	<i>Armillaria mellea</i>	Trunks, roots	Root contact, infected soil.
* Leaf spots	<i>Colletotrichum</i> <i>Gloeosporolodes</i> <i>Ascochyta citri</i> <i>Glomerella cingulata</i> <i>Phomopsis</i> sp. <i>Phoma tracheiphila</i>	Leaves	Rain splash, wind, dew, contact with diseased parts.
* Twig die back	<i>Dothiorella</i> sp. <i>Diplodia</i> sp. <i>Tryblidiella rufula</i>	Twigs	Rain, contact with infected parts.
* Stem blight	<i>Rhizoctonia</i> sp.	Stem	Rain, contact with infected parts.

are of the same features as those on leaves.

## CONTROL

Control and prevention of scab in orchards may consist of spraying with Bordeaux or Bordeaux-oil emulsion or Copper oxychloride. Spraying should be just before growth starts and when at least all of the blossoms have fallen. Severe infection spraying may be applied at pre-bloom and after petal fall. Always follow manufacture's dosage. In nursery stock plants can be prevented by frequent spraying Bordeaux mixture. Reducing light intensity through increasing shading in the nursery also protects plants from infection.

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(The following correction on p. 19 was pointed out to us too late to be corrected. "under fig 4 Stenation should read enation" - Editor)

## THE CURRENT STATUS OF FRUIT FLIES (TEPHRITIDAE) IN PAPUA NEW GUINEA

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### ABSTRACT

An account of the present economic status of pest species of fruitflies (Tephritidae) in PNG is given. The species covered in the paper all belong to the Genus *Bactrocera*. The paucity of information on natural enemies and non-chemical control measures is highlighted.

### INTRODUCTION

Papua New Guinea (PNG) has a large fruit fly fauna compared with other South Pacific Island countries and Australia. Over one hundred and sixty fruit fly species (Tephritidae: Dacinae) have been described (Drew, 1989). This list is incomplete and many more species remain to be determined. This is due to the fact that the survey conducted in the 1970's did not cover all provinces and as well, collections were made largely from male attractant traps (Methyl eugenol, Cue-lure and Willison's lure), to which some species do not respond at all.

Beside the introduced melon fly, *Bactrocera cucurbitae* Coquillett, which is widespread in the country, two other exotic species are recorded as present. They are the Queensland fruit fly, *Bactrocera tryoni* (Froggatt), three specimens of which were recorded from the Western Province (Drew, 1989) and *Bactrocera dorsalis* (Hendel), which was recently collected from male traps by the North Australian Quarantine Service (NAQS) from locations along the border of PNG and Irian Jaya. It is reported that the species of *dorsalis* complex collected from the border is the same as that recorded in Malaysia and Indonesia (Hancock-pers. comm. 1992). We assume that it is *Bactrocera* Taxon B species. Drew (1989) expressed doubts as to whether *B. tryoni* is an integral part of PNG's fruit fly fauna as no other recording has been made since at the sites nor from elsewhere in PNG.

The current work programme on the Collection and Handling of Infested Fruit for Host Records started two years ago. It involves collecting wild and cultivated fruits to determine species of fruit flies, host ranges, seasonal abundance, species of parasitoids and parasitism rates. Because of the scarcity of funds and manpower much of the activities are restricted to sites within the Central Province. Attempts are also

made to initiate laboratory colonies of the mango fruit fly, *Bactrocera frauenfeldi* (Schiner) and the banana fruit fly, *Bactrocera musae* (Tryon), for host tests.

### Pest Species of Economic Significance in Papua New Guinea

A large number of fruit fly species have been collected over the two years. Many of these have been identified while others within certain complex groupings remain to be sent overseas for expert identification. A number of species have been identified as pests (Ismay, 1982; Drew, 1989) which pose a potential threat to the future of the fruit and vegetable export industry. These species are listed in Table 1.

The additional information gathered and provided on host range is based on the work done at Laloki. Therefore it does not reflect fully the status at national level.

*Bactrocera frauenfeldi* (Schiner) is abundant and widespread in PNG. So far the survey has recorded the species from fruits and nuts of eleven different plant families. Because it is polyphagous it poses serious threats to fruits with potential export status. Within the Port Moresby environs, guava appears to be a favourite host and any fruit which is not covered is vulnerable to attack. It attacks bananas, though not as abundantly as *B. musae*. It also attacks papaya, sapodilla (*Manilkara achras*), egg fruit (*Lucuma* sp.), star apple (*Chrysophyllum cainito*), bread fruit (*Artocarpus altilis*) and beetle nut (*Areca catechu*). It has been reared from the outer flesh of nuts of *Terminalia catappa*, *T. okari*, *Inocarpus edulis* and the fleshy apple fruit of cashew nut, *Anacardium occidentale*. Investigations are continuing to establish the species status on mango. Although it attacks clean, undamaged fruit at ripening stage, anecdotal evidence indicates that female oviposits readily on

Table 1. Some Fruit Fly Species of Economic Importance in Papua New Guinea.

Fruit Fly Species	Fruit or Vegetable Attacked
<i>Bactrocera</i> ( <i>Bactrocera</i> ) <i>frauenfeldi</i> (Schiner)	Guava, Banana, Papaya, Egg fruit ( <i>Lucuma</i> sp.), Sapodilla ( <i>Manilkara acharas</i> ), Bread fruit, <i>Terminalia catappa</i> , <i>T. okari</i> , <i>Inocarpus edulis</i> , <i>Eugenia</i> species, beetle nut ( <i>Careca catechu</i> ).
<i>Bactrocera</i> ( <i>Bactrocera</i> ) <i>musae</i> (Tryon)	Banana, Papaya
<i>Bactrocera</i> ( <i>Zeugodacus</i> ) <i>cucurbitae</i> (Coquillett)	Melon, Cucumber, Zucchini, Other cucrbits
<i>Bactrocera</i> ( <i>Paratridacus</i> ) <i>atrisetosa</i> (Perkins)	Tomato, Cucumber, Zucchini.
<i>Bactrocera</i> ( <i>Bactrocera</i> ) <i>bryoniae</i> (Tryon)	Birds eye chillie ( <i>Capsicum minimum</i> ), Snake bean ( <i>Phaseolus unguiculata</i> ), Capsicum ( <i>Capsicum annum</i> ), Kongakongo ( <i>Bryonopsis affinis</i> ).
<i>Bactrocera</i> ( <i>Bactrocera</i> ) <i>moluccensis</i> Perkins	Aela or Tahitian chestnut ( <i>Inocarpus edulis</i> )
<i>Bactrocera</i> ( <i>Bactrocera</i> ) <i>trivialis</i> Drew	Guava, <i>Capsicum frutescens</i> , grapefruit ( <i>Citrus paradisi</i> ), <i>Eugenia</i> sp.
<i>Bactrocera</i> ( <i>Paradacus</i> ) <i>decipiens</i> (Drew)	Pumpkin
<i>Bactrocera</i> ( <i>Bactrocera</i> ) <i>umbrosa</i> (Fabricius)	Bread fruit
<i>Bactrocera dorsalis</i> complex	A wide range of fruits are attacked in Malaysia and Indonesia
<i>Tryoni</i> complex (? <i>Bactrocera neohumeralis</i> ) (Hardy)	Guava; Documentation of hosts range continues
<i>Bactrocera</i> ( <i>Bactrocera</i> ) ( <i>tryoni</i> ) (Froggatt)	Attacks a wide range of wild and commerical hosts in Eastern Australia

developing and mature fruits previously attacked by red banded caterpillar, *Noorda albizonalis* (Lepidoptera: Pyralidae). Female fruit fly oviposits either into a hole of *Noorda* caterpillars or adjacent to the hole if the surrounding tissues have softened and display premature ripening even though the rest of the fruit may still remain green.

*Bactrocera musae* (Tryon), the banana fruit fly, is a major pest of banana throughout PNG. It attacks all banana cultivars, wild, cooking and ripe bananas,

with oviposition occurring on green fully mature banana fruits (Smith, 1977). In the subsistence gardens the pest status of *B. musae* is minimized due to the traditional cultural practice of wrapping the banana bunch during the developing stage which prevents female fruit fly access to oviposition sites. *B. musae* has been reared once from papaya at Laloki but not from other fruits.

*Bactrocera cucurbitae* (Coquillett), the introduced melon fly, is widespread in the lowlands and highlands

region and infests all cucurbits, wild and cultivated. Infestation of fruits can occur at the early fruiting stage as well as at the mature stage.

*Bactrocera atrisetosa* (Perkins) attacks tomato, cucumber and zucchini at Laloki. Drew (1989) reported the species attacking tomato and cucurbits at higher altitudes, (1200 m - 1650 m a.s.l.) in Oro Province. Observations show that attack on zucchini occurs at the early stage of fruit development, while tomato and cucumber fruits are attacked at mature and ripe stages.

*Bactrocera bryoniae* (Tryon) is continuously reared in large numbers from the birds eye chillie (*Capsicum minimum*). It also attacks snake bean, *Phaseolus unguiculata*. The female oviposits on fully mature green bean pod which is about to change colour, much similar attack as on chillies. *B. bryoniae* was recently reared from fruits of kongakongo, (*Bryonopsis affinis*) (Cucurbitaceae), collected from the Gazelle Peninsula, East New Britain. We have yet to rear the species from bananas as Smith (1976) did at Popondetta.

*Bactrocera umbrosa* (Fabricius) is widespread in the lowlands and Islands. It infests breadfruit, *Artocarpus altilis*. Females have been observed to attempt oviposition on developing fruits, causing premature ripening and falling of fruits.

*Bactrocera moluccensis* (Perkins) infests Aela or Tahitian chestnut, *Inocarpus edulis*. The larva feeds on the fibrous tissue as well as the kernel compared to *B. frauenfeldi* larva which feeds only on the fleshy tissue of the nut.

*Bactrocera trivialis* (Drew) has been recorded from guava fruit at Laloki. Other host records from PNG include *Capsicum frutescens* from Sogeri and grapefruit, *Citrus paradisi* at Mt. Hagen (Dew 1989).

*Bactrocera diciptiens* (Drew) was recorded infesting pumpkin at Keravat, East New Britain (Ismay, 1982; Hooper and Drew, 1989).

A number of specimens of *Bactrocera dorsalis* complex were recorded from male traps at locations along the border of PNG and Indonesia in 1992 by NAQS. The species is reported to be a serious pest of a wide range of fruits in Malaysia (Drew, 1992). It is a new record for PNG. At this stage it is not known whether the *dorsalis* complex is a recent incursion from across the border or whether it is endemic to the border areas. Only time and an intensive trapping system

coupled with a broad survey programme will confirm the status of the species.

A species of fruit fly of the *tryoni* complex and similar to *Bactrocera neohumeralis* (Hardy) attacks guava fruit.

*Bactrocera tryoni* (Froggatt) has been recorded from Western Province (Drew, 1989). Despite the doubts expressed by Drew (1989), it may not be established in PNG, *B. tryoni* will remain included in the list because it has been detected in PNG and further more, because of its economic importance in Australia as a serious pest of a wide range of fruits.

### ECONOMIC SIGNIFICANCE

While little is known of the fruit fly fauna of PNG, in particular the number of endemic economic species and their hosts range, the prospects of negotiating a successful bid for fruit export at this stage will be difficult.

PNG's geographical location and sharing of the same land mass with a Southeast Asian country will be a continuing concern with regard to introduction of exotic species. The fruit fly problem has been magnified with the incursion of two species, *B. cucurbitae* and *B. dorsalis* complex species. *B. cucurbitae* is now extensively present in large populations in the highlands, lowlands and islands. There appears to be no plan in place within the system to monitor the spread of *B. dorsalis* complex from the border areas into the other parts of the country. Also the proximity of Australia's Torres Strait Islands to the Western Province poses similar risk through the occasional incursion of *B. tryoni* into PNG.

With regard to bananas, two species of fruit fly, *B. musae* and *B. frauenfeldi* are considered important with the former the more dominant pest of the two. Although there are other *musae* complex species in existence, *B. prolixa* and *B. bancroftii* (Tryon) in the Western Province and Torres Strait (Australia) respectively, only *B. musae* is recorded to attack bananas (Drew, 1989). *B. frauenfeldi* is reared frequently from field collected ripe cooking and eating bananas.

### NATURAL ENEMIES

A number of species of parasitoids have been reared from fruit flies. Parasitism rates are low and their prospect as beneficial biological control agents do not

appear promising. There are other natural enemies including birds, fruit bats, rodents and wild pigs which feed on infested fruits and indirectly kill fruit fly larvae. It is not known what degree of control these have on the fruit fly fauna overall. Other biological control agents that have been recorded are earwigs (*Chelisoches morio*), commonly found on banana (Ismay, 1982).

## CONTROL

Ismay (1982) discussed some remedial control measures that can be adopted in order to reduce fruit fly infestation. The recommendations are general and advised on the different control techniques that can be applied to minimise fruit fly infestation at preharvest stage. The chemical insecticides recommended for prophylactic sprays are to be replaced with those less hazardous to beneficial species. As well, spraying technique and the use of protein bait spray which have been adopted in some parts of the Pacific and Asias will be investigated and tested under Papua New Guinea conditions.

At this stage it is important to highlight that, traditionally, subsistence farmers in most parts of PNG have practiced physical and cultural control measures against pests in general on commodities such as bananas, by wrapping banana fruits with leaves at the early stage of fruit development, which is very effective against *B. musae* and *B. frauenfeldi*. In the Central Province it has become a necessity to bag or cover guava fruits with paper or plastic bags in order to stop fruit fly infestation.

## CONCLUSION

It will be necessary to update information on the status of fruit fly as the survey is extended to the other parts of the country and as further details become available. The most urgent requirement now is to provide a complete and comprehensive list of the range of hosts of cultivated and non cultivated plants.

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**HORTICULTURE NOTE NO. 23****DESIGNING A VEGETABLE FARM**

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**ABSTRACT**

*Commercial vegetable farms should be designed properly for good crop management during the growing season. Fertilizers, insecticides, fungicides, herbicides and irrigation can be effectively applied to obtain good quality produce. The land can be better managed for sustained vegetable production.*

**INTRODUCTION**

For commercial vegetable production, it is important to design and layout the plots in the farm for effective application of irrigation, fertilizers, pesticides and to exercise good post harvest handling of bulk vegetables harvested from field plots. The farmer or farm manager will be able to plan for the next seasons crop by rotating crops between plots in the field to minimize build-up of root diseases and nematodes. With good farm layout, the land will be better utilized for sustainable vegetable production.

This horticulture note is intended for commercial vegetable farmers in the Central Province as particular reference is made to the Vegetable Extension Programme being coordinated by DAL Food Management Division and the Taiwanese (ROC) Agriculture Technical Mission to Papua New Guinea in the Tubuseriea area. However, some basic information provided can be modified to suit specific conditions for vegetable production throughout the country.

**LAND PREPARATION**

After clearing virgin or old farmland, it is advisable to plough the land and leave for up to one month depending on the weather condition. During the wet season the period may be less than a month before actual field preparation for growing vegetables. The practice of ploughing and exposing the land for some time helps to destroy unwanted soil organisms such as the cutworms (*Agrotis ipsilon*) by starvation. Cutworms chew off young seedlings at or just below soil level.

Fresh chicken manure and basic fertilizer can either be applied on the land before ploughing or applied

after the land has been ploughed and harrowed, then mix into the soil by a rotovator or small tiller. But more chicken manure and fertilizer may be required for both these methods. The third method is to apply fresh chicken manure and basic fertilizer onto the beds and add water to ferment the fertilizers. After about three days this should be mixed using a power tiller before transplanting or direct sowing. For effective utilization of the inorganic fertilizer (NPK) it is recommended that this be applied into the planting holes only.

The field must be prepared to a fine finish using tractor drawn implements such as plough, harrow and rotovator. A ridger should be used to form beds and a plough to form watermelon beds at recommended spacings.

**DESIGNING A FURROW IRRIGATION SYSTEM**

Designing a furrow irrigation system for vegetables enables an efficient application of water between crops planted in rows. This is achieved by releasing an equal amount of water down each furrow from a slightly elevated canal or supply ditch at the end of the field. A recent development is the use of PVC pipes with small controlled outlets fitted to supply field plots through a small supply ditch. The system has been tested by the Taiwanese (ROC) Vegetable Extension Team and is very useful in the Central Province.

**Furrow Shapes and Sizes**

Many different shapes of furrows are used for different crops. The furrows can be spaced farther apart in soils which allow easy lateral movement of water, such as in light or layered soils. Soils which take water slowly require larger furrows so that there is a large area of watered soil. Shallow-rooting crops will

need shallow furrows at close spacing; deep-rooting crops will need deeper furrows and can be far apart. Flat-bottomed or round-bottomed furrows are better than V-shaped furrows.

In Central Province bed sizes were mechanically constructed to suit the types of vegetables that were grown. A standard size bed to use for most vegetables except watermelons, and wax gourd should be 1.25 metres wide. Furrows should be made between beds to allow water to flow through freely. Watermelon beds are spaced 7 or 8 metres during the dry and wet season respectively. One row of watermelon is planted on either side of the beds. The growing vines are guided into the centre.

### Length of Furrow

The best length for furrows will depend on the soil type and slope. If the furrow is too long the top end gets water-logged, but if it is too short this means more supply ditches and more interference with mechanization. If the gradient is very flat the water does not move quickly enough down the furrow and if it is too steep there is danger of soil erosion. Therefore in both these cases the length should be shorter than in the case of an ideal slope which is about 0.3 percent. Soils with high infiltration need short furrows because the water would sink in before reaching the far end of the furrow.

### Grade of Furrow

Furrow irrigation is most efficient on gentle uniform slopes where precise furrow grades can be obtained without too much leveling. The optimum furrow gradient is from 0.15 to 0.3 percent on heavy soils, and 0.3 to 2.0 percent on medium textured soils. Furrows can be used on grades up to 5 or 6 percent but will promote soil erosion.

It is important to test the irrigation system to make sure water is flowing and filling up the furrows properly before planting.

### Advantages of Furrow Irrigation

1. Large areas of the vegetable farm can be irrigated quickly compared to other systems such as sprinkle irrigation.
2. Water can be controlled by temporary earth bunds or by using stoppers if PVC pipes are used.
3. Evaporation is less than when the whole surface is

flooded.

4. Unnecessary weed establishment is minimized.
5. Flowering of vegetables such as tomato, watermelon and capsicum is not affected. Sprinkle irrigation is likely to disturb flowering and fruit set of these vegetables.
6. The installation cost is reduced. Compared to sprinkle or drip irrigation systems where pipes and sprinklers have to be purchased or replaced if not looked after properly.
7. There is less danger of puddling in heavy soils.
8. The method is suitable for a wide range of soils and slopes.

### Possible Disadvantages

1. Not suitable under saline soils and/or where saline water is used for furrow irrigation.
2. High labour requirement if not mechanized.

After transplanting, the young seedlings should be watered from the furrows by using empty containers. Once plants have been established, irrigation through the furrows is sufficient. Irrigation is required 1 to 2 times a week. It is necessary to make drains around the farm to remove excess water. Too much water will affect plant root development and may also promote diseases.

### Recommended Bed Size

The recommended bed size for most vegetables using furrow irrigation is 1.25 metres.

Watermelon beds should be 7 to 8 metres wide during the dry and wet season respectively. For pumpkin and wax gourd the bed size should be doubled that of watermelon.

### Recommended Plant Spacing

During the dry season and in poor soils use the lower range spacing and the high range during the wet season and on fertile land. The spacing given in the table is recommended under Central Province conditions and may be adjusted for other areas in the country depending on the soil and climatic condition.

Head lettuce and cabbage should be raised in a

nursery tray or other temporary field nursery bed, then transplanted into nursery pots before field planting. This increases the survival rate of the plants in the field. Cucumber, yard long bean, watermelon and wax gourd should be thinned to one healthy seedling after field establishment.

The best time to transplant is in the evening. Water the young seedlings from the furrows using small containers. Irrigation should be provided 2 times for the first two weeks. After seedling have established, irrigation is required 1 or 2 times a week depending on the soil structure and weather condition.

Temporary shade maybe required for the first week after transplanting but is usually not necessary.

The table below outlines some recommendations for vegetables and the spacings available to us.

Crop	Spacing	Type of Planting
Tomato	75-90 cm	Transplanted
Capsicum	75-90 cm	Transplanted
Head Lettuce	75 cm	Transplanted
Head cabbage	75 cm	Transplanted
Eggplant	75-90 cm	Transplanted
Yard Long		
Bean	1 m	Direct planting
Cucumber	1 m	Direct planting
Wax Gourd	1.5 m	Direct planting
Watermelon	1.5 m	Direct or transplanted

Grass mulch should be used to cover the soil around the base of the plants to control weeds and reduce soil moisture loss.

#### PEST AND DISEASE CONTROL

Protective application of insecticides and fungicides may be required during the early stages of crop establishment. Young plants should be sprayed weekly. After about four weeks, spray only when necessary.

The cucurbits (watermelon, pumpkin, wax gourd and cucumber) are affected by the cucurbit leaf beetle. If not controlled the beetle will destroy the leaves of the young plants. For effective chemical control Carbaryl or Orthene are recommended for use. If wire net is available this should be used to protect the young seedlings from the cucurbit beetle. Remove the net once the plants have established.

For capsicum, tomato, eggplant and watermelon, chemicals such as Karate or Furadan should be applied around the planting holes to protect young plants from cutworm or cricket damage. Furadan is available as granules, soluble powder or in liquid form. A bait made from 100 ml Malathion 50% EC to 1kg layers' mash and mixed with enough water can be used to control crickets where severe damage occurs. The paste is applied around the seedlings late in the afternoon after transplanting.

Cultural control of cutworms can be achieved by ploughing and exposing the land for some time before final land preparations.

#### ACKNOWLEDGEMENT

Thanks are due to Professor Lin and the Taiwanese (ROC) Agriculture Technical Team for providing some of the information and for Field demonstrations at the Vegetable Extension Farms in Tubusereia, Central Province.

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**HORTICULTURE NOTE NO. 24**
**HOW TO ESTABLISH A VEGETABLE NURSERY**

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**ABSTRACT**

*Most introduced vegetables need proper care and attention especially during nursery establishment. Usually small vegetable seeds have to be raised carefully in the nursery to obtain healthy seedlings before transplanting. This can be achieved through the use of proper nursery techniques which most vegetable farmers should acquire. The basic principles are outlined in this horticulture note and should provide a useful guide for commercial and backyard vegetable farmers, educationists and food crops extension workers serving throughout Papua New Guinea.*

**NURSERY ESTABLISHMENT**

The key to successful vegetable farming is for the farmer to be able to raise healthy seedlings in a nursery before transplanting. Remember that a healthy plant has a better chance of surviving adverse environmental factors such as moisture stress, pests and diseases.

Vegetables grown from seeds can either be direct seeded or transplanted into the field. Usually vegetables with small seeds such as tomato and eggplant have to be raised in the nursery and transplanted to the field. Watermelon and pumpkin for example can either be planted direct or transplanted.

**POTTING MIX**

Most soils, for example in Central Province contain large proportion of clay. This is obvious because when the soil is wet it is very sticky and becomes very hard when dry. Therefore to prepare a good potting mix, a first hand rule to follow is to mix 3 parts soil to 1 part fine sand. If pure chicken manure is available mix 1 part chicken manure to 20 parts soil/sand mix. Chicken manure should be fermented before using in the potting mix. This can be done by putting fresh chicken manure into a heap, then add some water and cover with leaves or empty bags and leave for 1 week. If chicken manure is not available than use garbage ash. Sandy loam soils are suitable for use as potting mix, remember also to add fermented chicken manure or ash.

The soil can be sterilized by steaming in a half 44

gallon drum split lengthwise. Fill the drum with potting mix, put some water to make the soil moist. Light a fire underneath and the soil should be ready within 2 hours. To be sure if the soil has been sterilized properly, put some sweet potato tubers into the soil before lighting the fire. The soil has been sufficiently sterilized once the tubers are cooked. This method is used to kill unwanted organisms, fungal spores and weed seeds.

However, seedlings have been raised successfully without sterilizing the soil in Central Province by farmers in the Tubusereia area. The soil was collected from virgin land.

**GERMINATING SEEDS**

Single jiffy pots, plastic pots or vegetable nursery trays can be used to germinate seeds. Seed boxes can be used also but one disadvantage is that if seedlings are pulled incorrectly from the seed box during transplanting, roots may be damaged and seedlings are likely to suffer transplanting shock and may not grow well. A pot enables the seedling to be tipped with the soil intact, therefore minimizing root damage during transplanting. Before sowing, soak the seeds overnight in water and plant the next day. For most transplanted vegetables, plant only one seed per pot or in a single spot in vegetable nursery trays. Recognized seed companies have guaranteed germination percentage (>80%) for most vegetables but three seeds may be required per pot for some vegetables such as tomatoes. Thin two seedlings and leave the healthy looking one if all three seeds germinate. After sowing keep the potting mix moist by watering once every day in the afternoon. The

seeds should germinate within 2 to 4 days after sowing depending on the type of vegetables.

### **NURSERY SHADE**

A simple nursery shade can be constructed using available bush materials. Farmers who can afford nursery shade cloth should use a light type (40%) to protect young seedlings from excessive heat and dehydration. If heavy shade cloth (50-75%) is used, seedlings may have to be hardened for one week before transplanting. Hardening is the process by which young seedlings are gradually exposed to the sun by removing the shade cloth or putting the seedlings out in the sun during the day. The process prepares the young seedlings to adopt to field conditions after transplanting.

### **WATERING**

A watering-can should be used to water seedlings, usually once every day in the afternoon. However, the frequency of watering will depend on the type of soil used in the potting mix. Too much water can cause "damping-off", a soil born fungal disease of young seedlings. Stop watering two days before

transplanting. By doing this the young seedlings are temporarily deprived of water so that once water is made available after transplanting, more roots will grow and the seedlings will establish quickly in the field.

### **WHEN ARE SEEDLINGS READY FOR TRANSPLANTING**

As a common rule, most vegetable seedlings should be ready for transplanting after five full leaves have developed, usually between 15 to 30 days after sowing depending on the type of vegetable. A temporary shade of coconut fronds or other material may be required to protect the seedlings after transplanting from excessive heat and dehydration for the first few days, but this is usually not necessary.

### **PEST AND DISEASE CONTROL**

Spraying with broadbase insecticides and fungicides may be required to protect young seedlings against pests and diseases while in the nursery. This may be applied once or twice depending on the situation during nursery establishment.

## HORTICULTURE NOTE NO. 25

### VEGETABLE CROP: GARLIC

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#### WHAT THE PLANT LOOKS LIKE

Garlic belongs to the onion and leek family but it is different from the common onion in several ways:

- The leaves are flat and folded lengthways, not round and hollow.
- The mature bulb is made up of many small bulbs known as cloves.

#### HOW IT IS USED

Because of the strong flavour and smell, garlic is mainly used as a flavoring for other foodstuffs.

The cloves are also used for planting.

#### WHERE IT GROWS

Garlic needs moist conditions for establishment, warm and moist conditions for growth, as are found in the **highlands**, and warm dry conditions at maturity for proper curing\*.

Garlic has been grown in the lowlands of Indonesia but performs better in the highlands in the cooler conditions. Poor bulbing occurs when temperatures get above 20°C late in the season.

Garlic in the lowlands grows slowly and suffers from early death resulting in low yields with too small bulbs.

For successful lowlands production a heat-tolerant variety must be used.

#### SOILS AND FERTILIZERS

The best soils for garlic growing are well drained, of high fertility and with a pH of about 6.5.

Heavy soils may cause mis-shapen bulbs. Lime can improve the structure of clay soils as well as reducing soil acidity which is common in PNG.

\* Curing: Drying the garlic bulbs after harvest to reduce further water loss and entry of disease.



Garlic bulb



Garlic cloves



Garlic clove

The amount of fertilizer used will depend on soil type, previous cropping and present soil fertility. Trials in PNG (Gunther 1992) have shown that fertilizer application rate can be a major factor in increasing bulb size.

On virgin volcanic soils Triple Super Phosphate (TSP) may be the only requirement applied as a base dressing at or before planting at 250 - 750 kgs/ha (1/2 - 1 1/2 large tin fish per 10m<sup>2</sup>).

Soil analysis will indicate if nitrogen or potassium is required.

As a general guide for other soil types a base fertilizer recommendation of 500 kgs/ha 12:12:17 (1 large tin fish per 10 m<sup>2</sup>).

Soils known to be low in phosphorus should have TSP added in the base dressing.

A trial at Aiyura used both 500 kgs/ha 12:12:17 and 250 kgs/ha TSP (1.5 large fish tins of 2:1 mix per 10 m<sup>2</sup>) and got a mean bulb size of 17.2 grams compared with 1.9 grams for garlic with no fertilizer. Higher rates of fertilizer gave even higher mean bulb sizes (Gunther 1992).

A side-dressing of 150 kgs/ha urea (1 large fish tin per 25 m<sup>2</sup>) may be required at **initial bulbing**. Urea (nitrogen) **should not be applied** late in the growing season as it may increase rots.

## VARIETIES

Australian varieties form bulbs with the lengthening of days and the increasing of temperatures.

As daylength does not change significantly throughout the year in PNG we must use short-day or day-neutral varieties which will bulb in PNG conditions. As previously stated, temperature also affects the formation of bulbs.

Two main cultivars (varieties) are grown.

One is a white-skinned type of mild pungency. the other has pink skin and is highly pungent. General demand is for **LARGE GARLIC** and this must always be kept in mind.

Existing local garlic has the advantage that it has proven that it will bulb here and you know whether it has any disease.

**DO NOT PLANT** imported garlic purchased in the stores as it probably will not bulb and you may introduce serious diseases such as white rot (*Sclerotium cepivora*) to your garden.

DAL are investigating the import of disease free, short-day, large-bulbed varieties.

## HOW IT IS GROWN

Planting is done with cloves saved from the previous crop. Small cloves are not desirable as planting stock as they will produce small bulbs. As a guide, the cloves should be bigger than your smallest finger nail.

Cloves should be planted with the shoot-end upward (root-end down), to a depth such that the top end is just below the soil surface.

To plant a hectare you will require approximately 10,000 bulbs at 25 g each which is 250kgs of garlic.

This will depend on the number of cloves per bulb which will vary.

## Preparing for Planting

Separate the garlic bulbs into cloves just before planting, as whole bulbs store better than single cloves. Discard small cloves.

## Plant spacing

Plant the cloves with rows 20 - 40 cms apart and the cloves 5 - 10 cms apart in the row.

## Weeding and watering

The crop should be kept free from weeds. Garlic is shallow rooted so pull the weeds carefully so as not to disturb the roots.

If dry weather occurs, the crop will need watering, particularly during the period of bulb growth. Do not add water close to maturity as it will prevent proper curing.

## PESTS AND DISEASES

### Insect Pests

**Onion thrips** (*Thrips tabaci*) - feed on the leaf surfaces, causing the damaged areas to lose colour. Early signs of thrips feeding are indicated by white spots which run together to form large silvery areas down the leaf.

### Control

Spray Malathion 50 (45 mls in 15 litres of water). Add a wetting agent and do not harvest for 7 days after spraying.

### Diseases

**Downy mildew** (*Peronospora destructor*) can destroy large sections of leaf, causing losses of yield. The early symptom is a furry, violet covering on the leaf. Overcast days with high humidity favour the spread of the disease. Wet foliage will also encourage its spread.

### Control

Chemical control produces variable results. Sunny breezy weather will help reduce the disease. Copper oxychloride, Dithane or Ridomil will help in the control

of the disease.

**Copper oxychloride** (75 grams in 15 litres of water) at 7 -10 day intervals. The withholding period is one day and wetting agent should be added.

**Dithane** (30 grams in 15 litres water) at 7-10 day intervals. The withholding period is 7 days and a wetting agent should be used.

**Ridomill** (40 grams in 15 litres water) A maximum of 3 applications at 10 day intervals when plant is actively growing and humidity is high.

#### **Purple blotch** (*Alternaria porri*)

A serious problem in onions and is wide-spread in PNG. First symptoms are sunken spots on the leaves which enlarge and turn purple surrounded by a pale area.

#### **Control**

Dithane M45 (30g per 15 litres water) (see Downy Mildew for details)

#### **Harvesting**

The crop should be harvested when the tops have gone down but are still slightly green. Pull up the bulbs and leave to dry on racks or in open mesh onion bags. Place the tops uppermost to protect the bulbs from the sun. Leave the tops on until thoroughly dry. Then, remove the tops and roots leaving 2.5 cms of top and less than 1 cm of root.

Garlic is prone to damage from both rain and hot sun so move to storage area as soon as possible.

#### **Storage**

The storage area must be dry and well ventilated so that air can circulate between the bulbs. An open-sided shed, as used for onions, will allow for this ventilation.

**NEVER** store garlic in plastic bags as they will soon go mouldy.

Optimum conditions are 60% relative humidity and 0°C. Storing garlic at higher temperatures of 15 - 30°C is satisfactory apart from the loss due to shrinkage.

### **BUDGET FOR GARLIC (1 Ha)**

#### **Income**

1 m beds 3 rows/bed, = 300,000 plants/Ha	
10 cms between cloves	
Average bulb weight	25g
Potential Yield	7,500Kgs
Field Factor (70%)	
<b>Actual Yield</b>	<b>5,250 kgs</b>
Price Depot	K2.00/kg
Market	K4.00/Kg
<b>Total Income</b> 5,250kgs x K2.00 =	<b>K10,500</b>

#### **Production Costs**

Land Preparation (Tractor Hire) =	240.00
Seed 300,000 cloves	
@ 30 cloves / bulbs = 10,000 bulbs	
10,000 X K0.20/bulb =	2,000

#### **Fertilizer**

500 Kgs NPK 12:12:17	
@ K26.00/bag =	260.00
250 Kgs TSP @ K26.00/bag =	130.00
150 Kgs Urea @ K25.00/bag =	75.00

#### **Pesticide**

8 sprays X 800g Dithane =	50.00
2 sprays X 140g Malathion =	10.00

Total (Excluding Labour and Harvesting) = 2,765.00

**Miscellaneous costs (10%)** = 276.00

Bags (350 X 20 Kg onion bags @ K0.40 each) =	140.00
Labour (600 person days @ K4.80 each) =	2,880.00
Transport to depot/market	160.00

**Production cost (Delivered to depot)** = 6,221.00

**GROSS RETURN PER HECTARE** = 4,279.00

### Production Costs and Marketing

It is difficult to estimate the demand for garlic as, at present, it is of poor quality and very expensive. It is likely that if the quality could be improved (size) and the price came down there would be a high demand for the crop.

Current outlets include local markets (K4.00/kg) and wholesalers (K2.00/kg) but growers are likely to get higher prices by selling direct to retail stores or hotels.

With estimated yields in the area of 5 tonnes per hectare a grower could expect K10,000 from one hectare and, with costs at K6,000 and profit of K4,000.

### FURTHER READING

Victorian Ag Notes - Garlic Growing,  
Gunther (1992). Garlic Fertilizer Trial Report

### FURTHER INFORMATION

For further information and advice on garlic, contact your Regional Horticulturist.

#### Southern Region

Food Management Division  
PO Box 417,  
Konedobu

#### Mamose Region-

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P O BOX 1984  
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#### Highlands Region

D.A.L.  
PO Box 1075  
Goroka

#### New Guinea Islands Region

Lowland Agricultural Experiment Station  
P O Keravat,  
E.N.B.P

or contact:

Principal Horticulturist  
Food Management Division  
P O Box 417  
Konedobu

Derek Sparkes  
Fresh Produce Development Company  
PO BOX 1290  
Mt Hagen.

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## BIO GAS PRODUCTION AT HIGHLANDS AGRICULTURAL COLLEGE

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\*Lecturer, Livestock, \*\*Japanese Volunteer,  
Highlands Agricultural College, Mt. Hagen.

### ABSTRACT

The purpose of this project was to develop a Bio-Gas system which is cost effective and feasible for a village situation in PNG. People, who live in town or city, have electricity and gas, but most of the people, who live in villages, do not have electricity supply and gas. These village people are using kerosene or firewood for cooking and lighting in their houses. Bio-gas system can be another very effective technology in a PNG village. The reasons for developing a Bio-Gas system at H.A.C. (Highlands Agricultural College) are based on the following four factors:

1. Pig is a very valuable animal in the society of PNG and the people have many pigs in their villages. The resource of bio-Gas system is excreta from pigs and it is easy for village people to get these resources.
2. PNG is located in Tropical Zone, and the climate is suitable for fermenting excreta to produce methane gas.
3. Structure of Bio-Gas system is very simple, and the maintenance is easy.
4. Introduce Bio-Gas Production as a course component of Agricultural Machinery at H.A.C.

### INTRODUCTION

Manure is a valuable product. It contains a lot of nutrients for plants and can therefore be used as fertilizer. Manure is not seen as a waste in every country. Some see it as a valuable by-product of the pig industry. Apart from providing plant nutrients it can also be utilized in other areas.

Our neighbours in the South East Asian Countries collect and store the manure especially from pigs to produce bio gas for cooking. In commercial as well as in other pig production systems it is necessary to maintain a good waste management program. This is very important in preventing the spread of diseases and in maintaining the overall hygiene and sanitation in the farm. Pig manure can be used to produce an odourless and highly inflammable gas when organic matter (pig manure) decomposes in the absence of oxygen. It is a mixture of methane, carbon dioxide, water vapour and traces of other gases.

This article outlines the work we have done on bio gas

at Highlands Agricultural College with the help of Mr Tutomu Day (Japanese Overseas Cooperation Volunteer) from Japan.

### PRINCIPLES

#### a) Bio-Gas

Bio-Gas is a System of producing gas from fermented excreta of livestock such as pigs, poultry and cows.

#### b) Amount of produced Gas;

One Kilogram (1kg) resources of Bio-Gas can produce 500 m<sup>3</sup> of methane gas in a temperature range of 20-25 °C for two months.

#### c) Volume of fermentation tank.

The volume of fermentation tank can be decided as follows:

1. Necessary volume of Bio-Gas.

The necessary volume of Bio-Gas is  $1\text{ m}^3$  to generate for cooking, and  $2.2\text{ m}^3$  to generate electricity in a day.

## 2. Necessary amount of resource.

The necessary amount of resource is 2 kg excreta from livestock to produce  $1\text{ m}^3$  of bio-gas in a day.

## 3. Necessary volume of fermentation tank.

The fermentation tank within a  $1\text{ m}^3$  volume can produce  $0.5\text{ m}^3$  of methane gas.

## d) Utilization of Bio-gas

A Bio-Gas System can be used in applications requiring cooking or lighting, electrical input of generator and to produce liquid fertilizer.

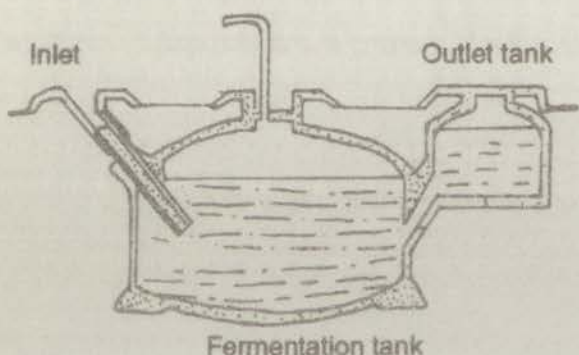


Figure 1. A typical Bio-Gas tank

## e) Construction of Bio-Gas system

A common design of Bio-Gas System is shown in figure 1.

The Inlet and Outlet are connected to the fermentation tank with pipes. Inspect the construction of the Bio-Gas plant for the following:

1. Check the gap for leaking excreta from fermentation tank and outlet tank.
2. Check the gap from gas escaping from the upper part of the fermentation tank.

## PROJECT IMPLEMENTATION

Bio-Gas system was constructed at H.A.C. during May to August 1993.

### 1. Materials

#### List of Materials

- . Block - 144
- . Iron Pole - 4 mm x 20 m
- . Iron Pipe - 20 mm x 0.3 m
- . Iron net -  $8\text{ m}^2$
- . Stop cock - 1
- . Vinyl chloride pipe - 150 mm x 3 m
- . Cement - 20 kg X 25
- . Sand -  $1\text{ m}^3$
- . Gravel -  $1\text{ m}^3$
- . Inlet (ceramic ware)
- . Timber (to make foundation)

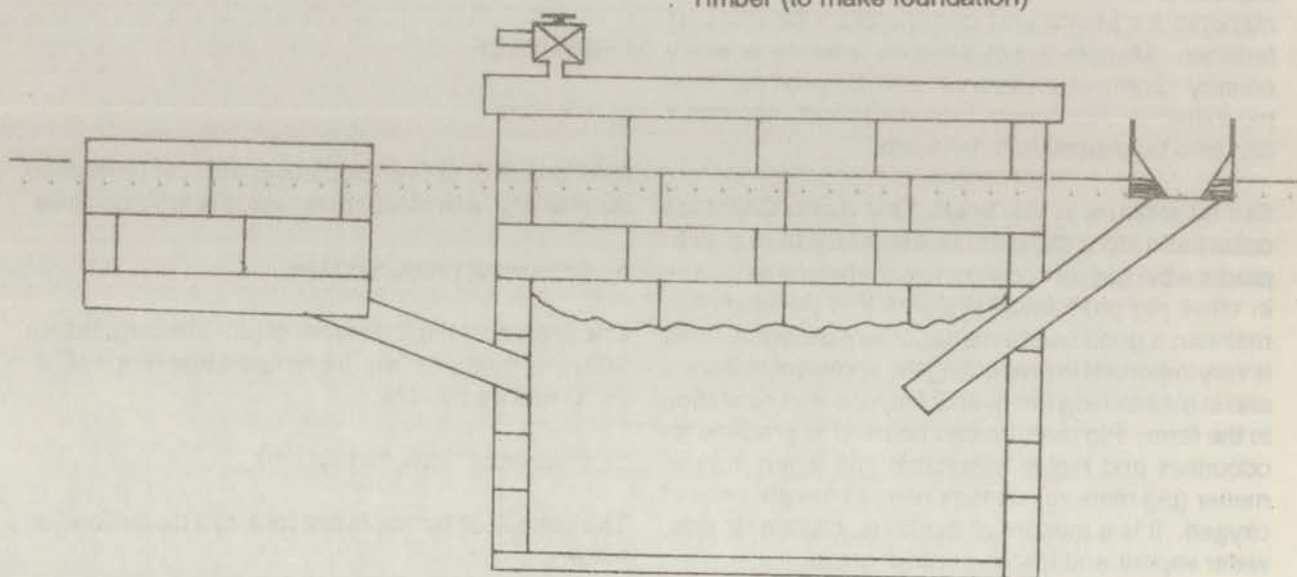


Figure 2. Bio-Gas System, Constructed at H. A. C.

## 2. Design

### Fermentation tank:

Volume of fermentation tank was decided as follows: (refer principle-c)

- The purpose of this project was to produce methane gas for cooking and lighting, therefore necessary volume of produced Bio-gas is 1.5 m<sup>3</sup>.
- Piggery of H.A.C. has around 25 pigs, therefore there is no problem with the resources of Bio-gas system.
- Temperature of H.A.C. is around 10 - 25 °C every day. Therefore, the volume of gas produced from 1 m<sup>3</sup> fermentation tank is expected to be around 0.4 m<sup>3</sup>.

In these circumstances, the volume of fermentation

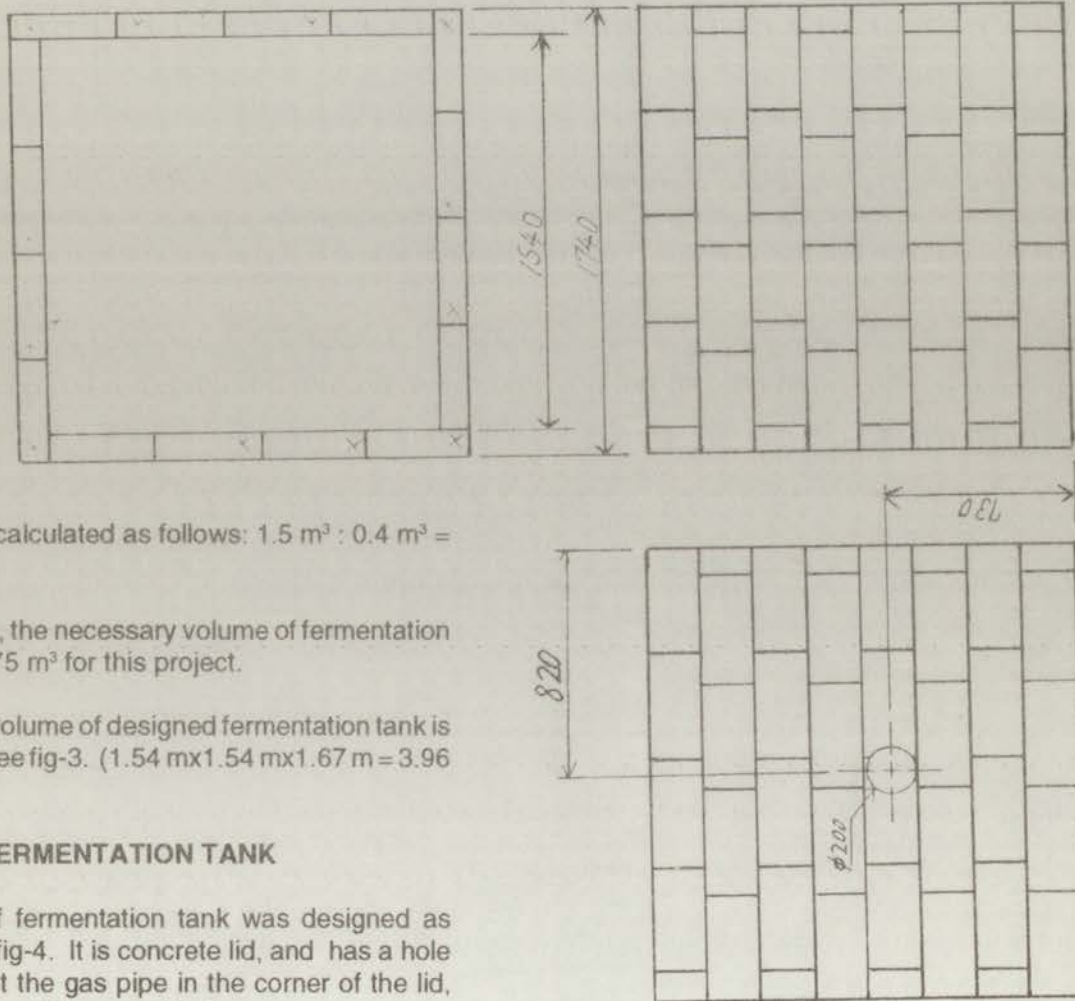


Figure 3. Fermentation tank

tank was calculated as follows:  $1.5 \text{ m}^3 : 0.4 \text{ m}^3 = 3.75 \text{ m}^3$

Therefore, the necessary volume of fermentation tank is 3.75 m<sup>3</sup> for this project.

The final volume of designed fermentation tank is 3.96 m<sup>3</sup>, see fig-3. (1.54 mx1.54 mx1.67 m = 3.96 m<sup>3</sup>).

### LID OF FERMENTATION TANK

The lid of fermentation tank was designed as shown in fig-4. It is concrete lid, and has a hole to connect the gas pipe in the corner of the lid, which has a thickness of 15 cm.

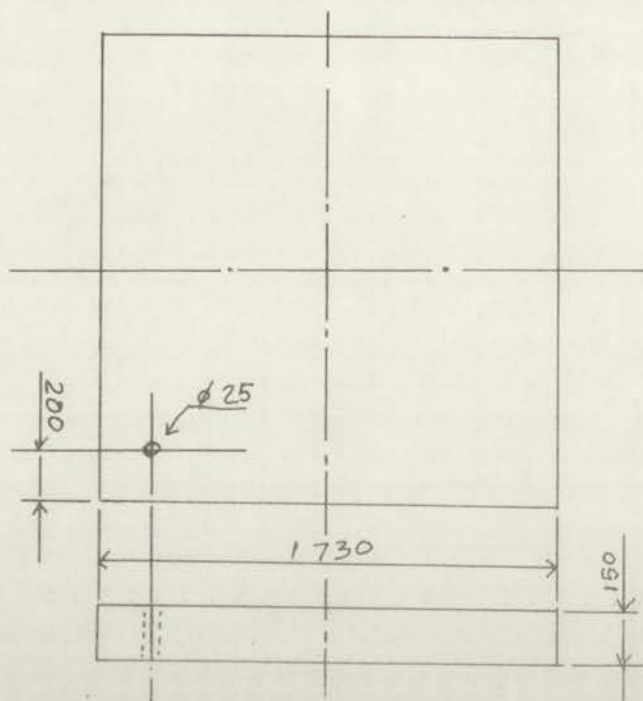


Figure 4. Lid of Fermentation tank

**Outlet tank**

The outlet tank is made of blocks, and has concrete lid. See fig-5 and fig-6.

**3) Location:**

The bio-gas system at H.A.C. is located near the piggery. The location is very good for the management of this system, because it is close to the source of excreta, the waste can easily be disposed and it gets a lot of sunshine.

The position of the fermentation tank, outlet tank and inlet was decided according to the following plan. See figs. 8 - 9.

**4) The process of making Bio-gas system:**

1st, 2nd, 3rd day (18th, 19th May, 3rd June)

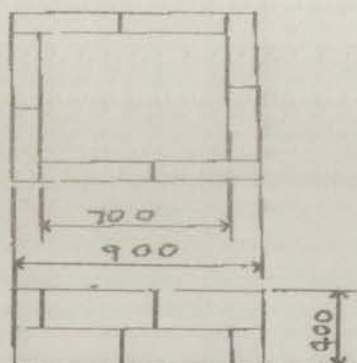


Figure 5. Outlet tank

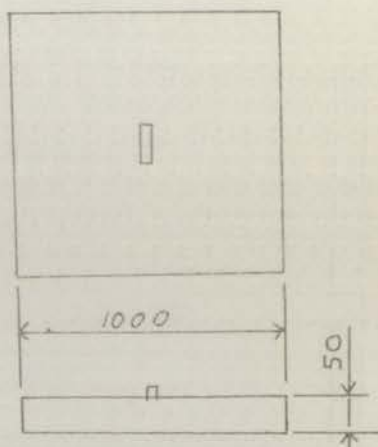


Figure 6. Lid of the Outlet tank

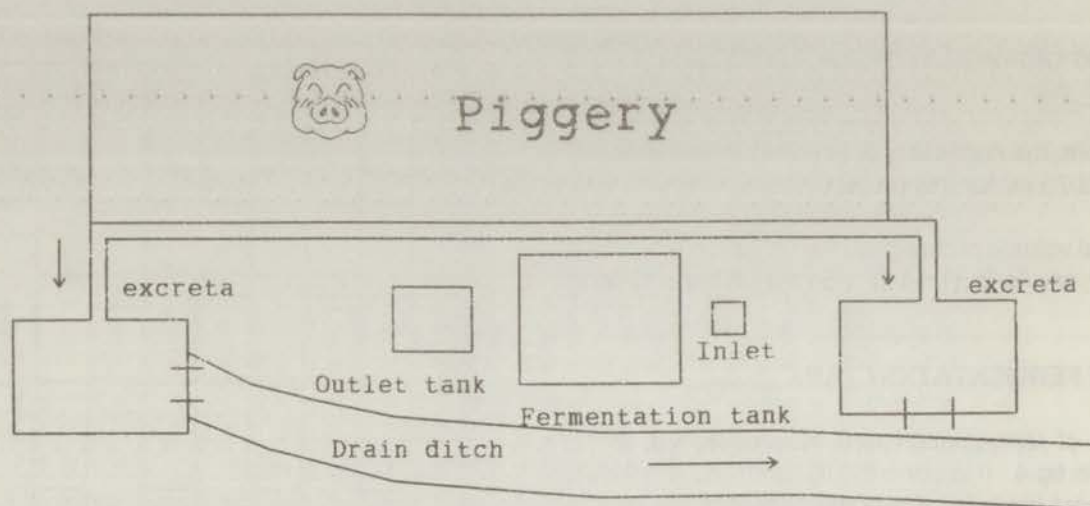


Figure 7. Location of Fermentation, Outlet in relation to the Piggery at H. A. C.

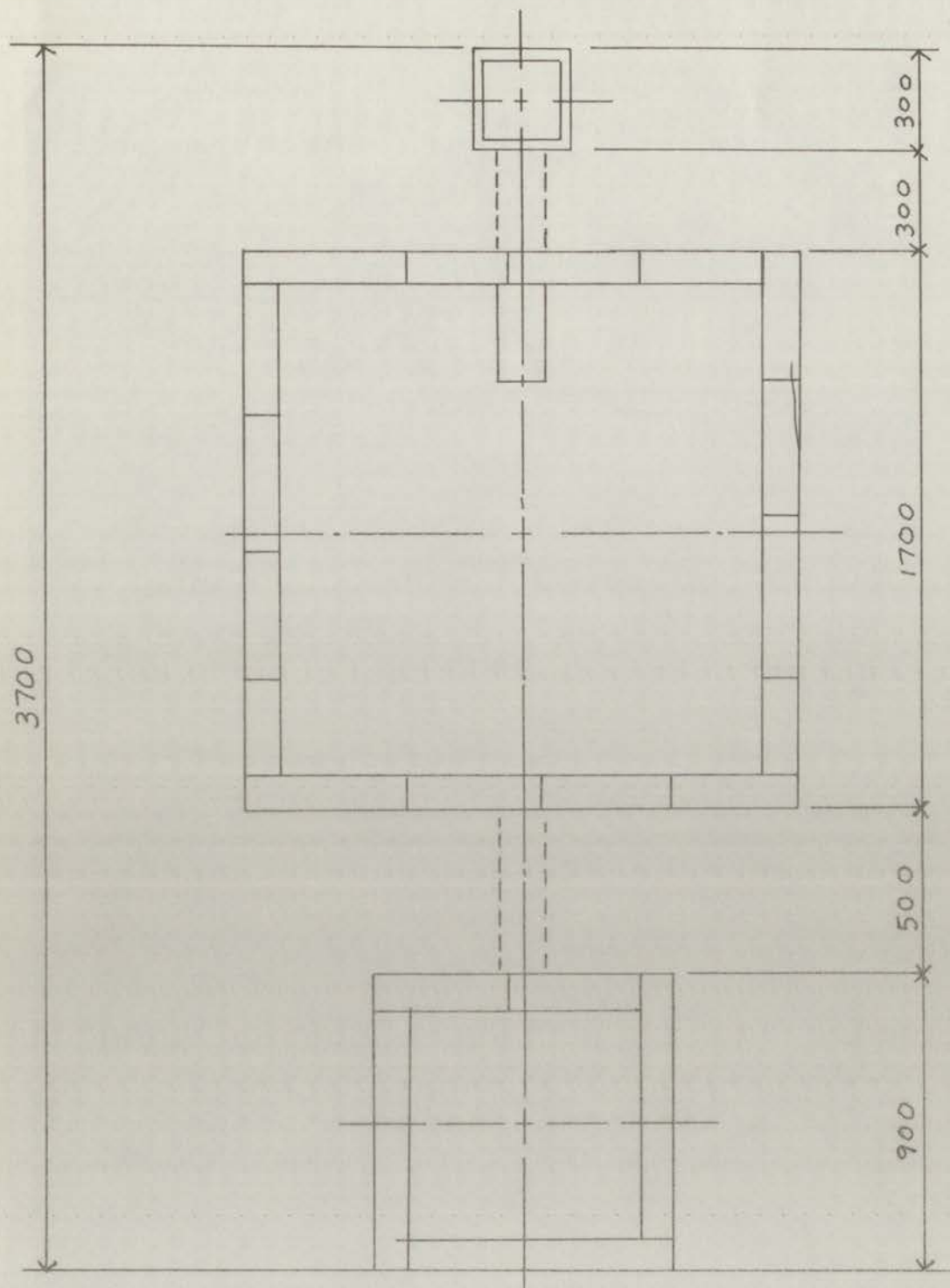


Figure 8. Longitudinal section of the Bio-Gas system at H. A. C.

Dug a hole in the ground, that shape is referred to in figure 6, figure 7.

**4th day (8th June)**

Laid the foundation of a fermentation tank.

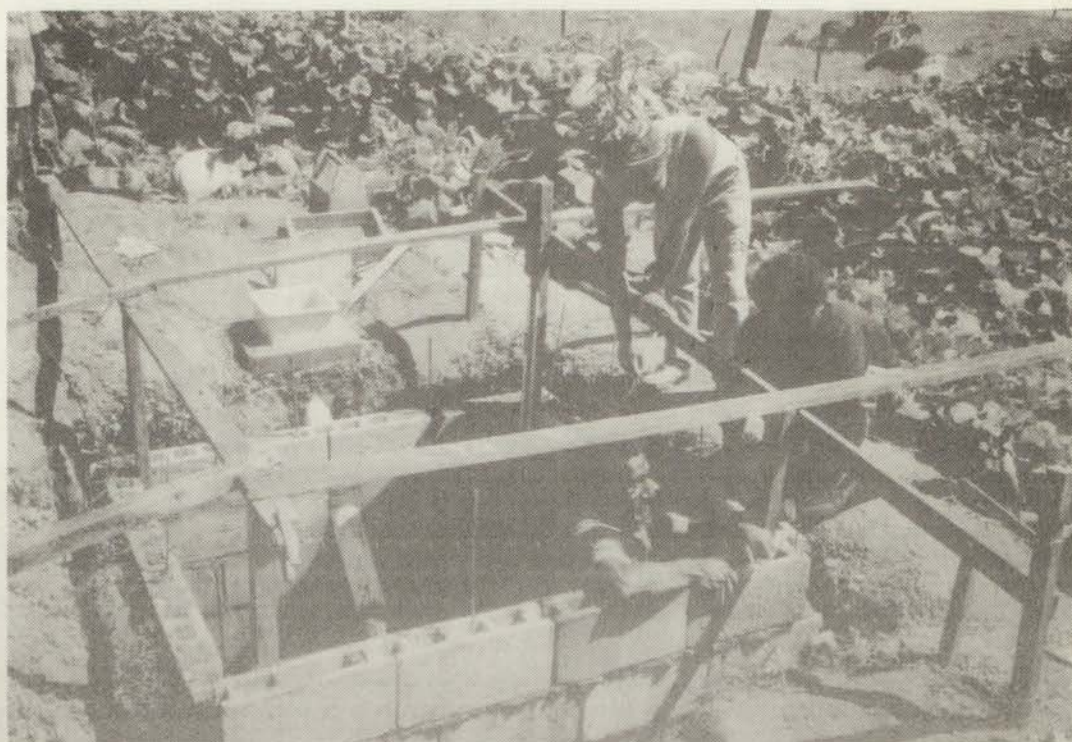
- (1) Made a frame to fit into the inside diameter of the fermentation tank.

(2) Put the frame in place, and cemented the outside of the frame.

**5th, 6th day (9th, 10th June)**

Built the wall of fermentation tank.

- (1) Laid the blocks on the foundation level.
- (2) Cemented the blocks.



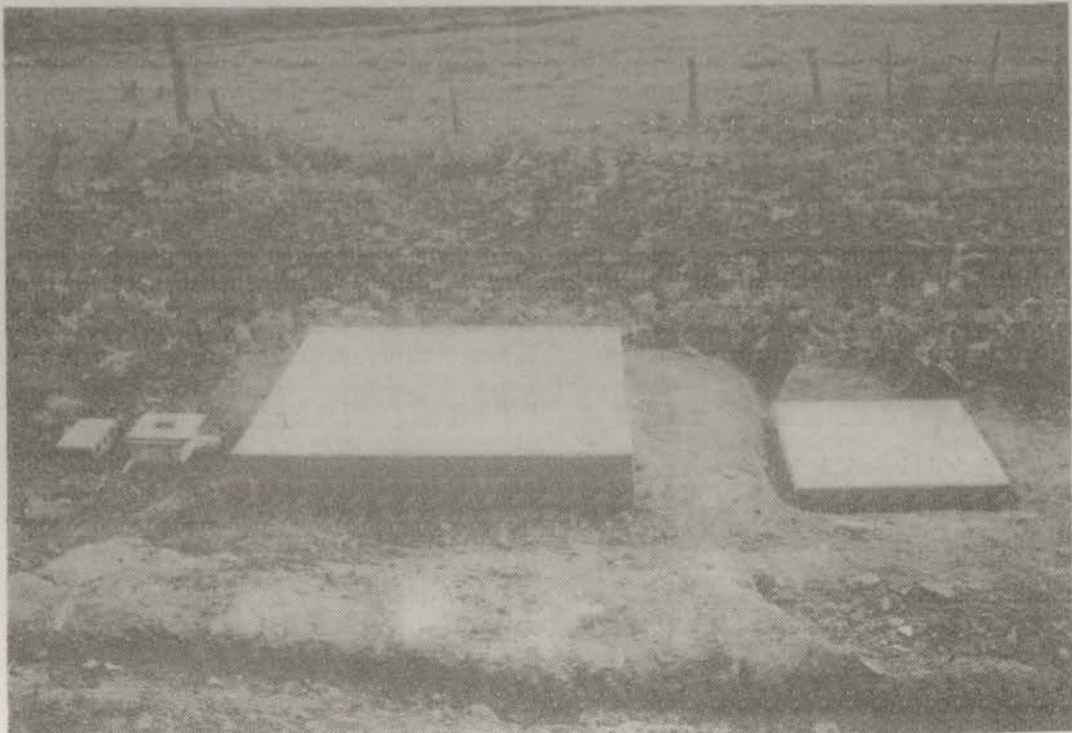
Laying of the layers of blocks



Cementing of the floor of fermentation tank



Putting of iron rods into the holes of the blocks



Completed Bio-Gas Plant (top view)

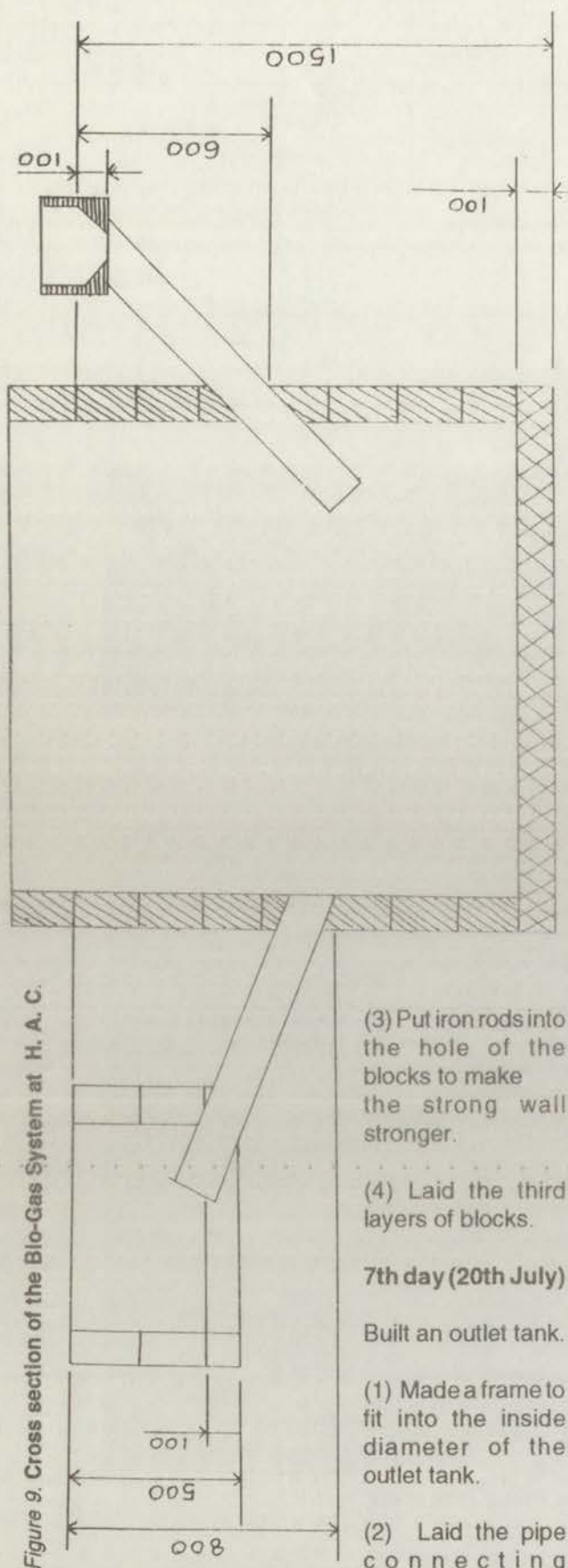


Figure 9. Cross section of the Bio-Gas System at H. A. C.

- (3) Put iron rods into the hole of the blocks to make the strong wall stronger.
- (4) Laid the third layers of blocks.
- 7th day (20th July)**  
Built an outlet tank.
- (1) Made a frame to fit into the inside diameter of the outlet tank.
- (2) Laid the pipe connecting

- fermentation tank and the outlet tank.
- (3) Placed the frame on the top of the outlet tank, and cemented the outside of the frame.
- (4) Laid the blocks on the foundation level.
- (5) Cemented the blocks.
- (6) Put iron rods in between the blocks.
- (7) laid the second layer of blocks.

**8th day (21st July)**

Placed fourth layer of blocks for the fermentation tank and made an inlet.

- (1) Laid the fourth layer of blocks.
- (2) Made a foundation frame for the inlet and fixed a pipe connecting fermentation place and inlet.
- (3) Placed inlet in the foundation frame. Inlet is the ceramic vessel.
- (4) Cemented the inside of frame.

**9th day (22nd July)**

Laid the 5th and 6th layer of blocks.

**10th day (27th July)**

Laid the 7th and 8th layer of blocks.

**11th day (28th July)**

Plastered the wall, and around the connecting pipe.

**12th day (29th July)**

Cemented the floor of the outlet tank.  
Cemented the wall of the fermentation tank.

**13th day (16th August)**

Cemented the floor of the fermentation tank.

**14th day (17th August)**

Made a lid for fermentation tank.

- (1) Built a frame on the fermentation tank
- (2) Put the bords in the frame, and put iron rods and fence on the bords.
- (3) Made a hole of gas valve on the bords.
- (4) Put a gas valve.
- (5) Cemented the inside of frame.

**15th day (18th August)**

Made a lid of outlet tank.

- (1) Made a frame, and placed on the vinyl seat.
- (2) Placed the iron fence in the frame.
- (3) Cemented the inside of frame.

## CONCLUSION

The negative attitude towards pig manure in PNG is forcing farmers to adopt ad hoc solutions often without the necessary guidance and know how.

Existing technology on pig manure is mainly based on transferring the problem to another site rather than treating the problem on site. This is not a long term solution. Pig manure should not be a problem at all in PNG. As stated earlier it used to be a perfect fertilizer and still is.

We have got to think positive and realize that pig manure is a part and parcel of our pig production

system. The production of bio-gas using pig manure is inexpensive and can be easily tried elsewhere in PNG.

## REFERENCES

Lee, W. J., (1989), Utilizing manure is better than disposing of waste, Misset International, Netherlands, pp. 11-13.

Thornton, K., (1989), What to do with manure? Misset International, Netherland, pp. 8-9.

**(Note:- The authors of the above article were unavailable to read the proofs. The material from the text is however, faithfully reproduced above. - Editor)**

## D.A.L. ENTOMOLOGY BULLETINS, PLANT PATHOLOGY NOTES, HORTICULTURE NOTES AND LIVESTOCK DEVELOPMENT NOTES

All Entomology Bulletins, Plant Pathology Notes and Horticulture Notes which have appeared in Harvest are available as reprints. They can be obtained by writing to: The Distribution Officer, Publications Section, Training Division, Department of Agriculture and Livestock, P O Box 417, Konedobu, Papua New Guinea. (Telephone: 258191).

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2. Control of termites in cocoa
3. Pests of cocoa - Trunk longicorns
4. Pests of cocoa - Use of crazy ants for control of pantorhytes
5. pests of cocoa - Pantorhytes
6. How to send insects for identification
7. Protection of seedlings from cutworm damage
8. Control of diamond-back moths in brassicas
9. Safe handling and use of pesticides - a code of practice
10. The cardamon mirid and its control
11. Sexava: a pest of coconut and oilpalm
12. The screw-worm fly
13. The giant African snail
14. House flies
15. The sorghum midge
16. Nezara - the green vegetable bug
17. The sweet potato weevil
18. Occasional pests of sweet potato
19. Fruit flies
20. Insect pests of winged bean
  1. Leucoptera - leaf miner
21. African army worms
22. Bed bugs
23. Pests of cocoa - Mirids
24. Pests of cocoa - Grey weevils
25. pests of cocoa - Leaf eating insects
26. Pests of cocoa - Mealybugs
27. A code of practice for hygiene in registered cocoa stores
28. The beanfly
29. Taro beetles
30. Oribus weevils
31. Pests of coconut palm - The Asiatic rhinoceros beetle
32. Pests of coconut palm - The New Guinea rhinoceros beetle
33. Green scale: A pest of coffee
34. Heliothis caterpillars
35. Heliothis caterpillars - a pest of sorghum
36. Pests of coconut palm - The black palm weevil
37. White wax scale - A pest of citrus
38. Buffalo fly
40. Pests of cucurbits - 1. Pumpkin beetle
41. Pests of cucurbits - 2. Black leaf-footed bug
42. Pests of cucurbits - 3. Minor pests of cucurbits
43. Psyllid pest of leucaena
44. Human lice
45. Forest insect pest of Papua New Guinea -1. Under bark borers of Kamarere and Terminalias - Agrilus
46. Forest insect pests of Papua New Guinea -2. Pin hole borer (shot hole borers) attack on logs, lumber and living trees
47. Forest insect pest of Papua New Guinea -3. White ants (termites) attack on Plantation trees
48. Forest insect pests of Papua New Guinea -4. Defoliators of Pinus (Pines) in the highlands
49. Control of cabbage cluster caterpillars in brassicas
50. Pests of Cocoa - Longicorn Tip Borer
51. Pests of Cocoa - Coffee Stem Borer
52. Pests of Sweet Potato - Sweet Potato Weevil
53. Locusts and Grasshoppers of the Markham Valley
54. Banana Scab Moth
55. A potential biological control agent for *Mimosa invisa* weed in Papua New Guinea

### PLANT PATHOLOGY NOTES

1. Blister smut of maize
2. Coffee rust disease
3. Collar rot
4. Rhizobium supply service
5. Root knot nematode
6. Black pod disease of cocoa
7. South American leaf blight of rubber
8. Sweet potato little leaf
9. Taro blight
10. Fiji disease of sugar cane and its vector
11. A new treatment of bark canker on cocoa

12. The importance of quarantine against coffee rust in PNG
13. Virus diseases of taro
14. Ridomil tolerance
15. Bacterial wilt
16. Fungal diseases of tomato
17. Sweet potato leaf scab
18. Bacterial soft rot of vegetables
19. Citrus canker
20. Bark canker of cocoa
21. Vascular Steak die-back disease of cocoa
22. Seedling blight of cocoa
23. Brown eye spot disease of coffee
24. Bacterial head rot of banana
25. Rice blast
26. Nematodes - treat to crop yield
27. Collar rot of aibika
28. Black rot and leaf scald of crucifers
29. Early and late leaf spots of peanut
30. *Radopholus similis* - the burrowing nematode of banana
31. Recommendation of control of coffee leaf rust on arabica coffee in Papua New Guinea
32. A virus disease of peanut
33. Bacterial wilt of peanut
34. How to send diseased plant specimens for identification
35. Role of quarantine in the introduction of new planting materials into Papua New Guinea
36. Rhizome and root rot of cardamon
37. Pesticides
38. Diseases of Citrus. Part1: Bacterial and fungal diseases
16. Mango Field Management; Planting and Care of Young Trees
17. Mango - Flowering to Market; Management of Bearing Trees
18. Silverbeet
19. Seed yam production
20. Aibika
21. How to ripen bananas quickly
22. Cocoa pruning
23. Designing a vegetable farm
24. How to establish a vegetable nursery
25. Vegetable Crop: Garlic

#### LIVESTOCK DEVELOPMENT NOTES

1. Artificial Insemination and Embryo Transfer Techniques.
2. Biogas production at Highlands Agricultural College

#### HORTICULTURE NOTES

1. Capsicums
2. Tomatoes
3. Cabbage
4. Yams
5. Chinese cabbage and pak choi
6. The giant Vietnam guava
7. Vegetable variety recommendations for the Port Moresby Lowlands
8. Cassava
9. Vegetable variety recommendations for Highlands of Papua New Guinea
10. Carrots
11. Cauliflower
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14. Production of Bulb Onions
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If there is any work going on in your area which you think would interest other **HARVEST** readers, we would be pleased to hear about it.

**2 TYPE OF ARTICLE** - Articles can be about a single topic or project, the work of a group of people, or the primary industry of a particular area.

**3 PRESENTATION** - Articles should be double-spaced through with wide margins on both sides. They should be presented simply and normally run into about 3000 words, or 6-7 typed pages.

Good black and white photographs give the best results but colour prints or slides are also acceptable. Assistance can be provided to redraw line drawings.

Captions to plates and figures must be typed on a separate sheet. All pages of typing including references, appendices, captions and tables should be numbered consecutively.

**4 ABSTRACT** - An informative abstract suitable for use by abstracting services should precede the introductory paragraph. Because it is not part of the paper, an abstract should be intelligible on its own and should summarise the contents and conclusions of the paper. It should be written as simply as possible to assist people who are not specialists. The abstract should not exceed 2% of the total extent of the contribution; maximum 300 words.

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**6 HEADINGS** - In experimental papers the general order of headings is: Abstract, Introduction, materials and Methods, Results, Discussion, Acknowledgements, References, Appendix. In descriptive, or other types of papers, as far as possible a similar format should be followed.

No headings should be underlined.

**7 TEXT** - Papers should be concise. Extensive introductions referring to the work of earlier authors should be avoided. Lengthy discussions and detailed descriptions should be reduced by the use of tables and diagrams. The text should not repeat in detail what is apparent from a table or diagram. Names of countries or organisations may be abbreviated to capitals without full stops but must be given in full at the first mention.

All scientific names of animals and plants must be underlined to indicate that they should be set in italic type. The authority should be cited in full on the first occasion a scientific name is used. Where the same name is used repeatedly, the genus may be abbreviated to a capital letter after the first citation. For example, use *Homo sapiens* Linnaeus on the first occasion and *H. sapiens* thereafter.

Common or local names may be used but the scientific name should be quoted on the first occasion. An agricultural chemical must be referred to by its genetic or common name when it is first quoted.

**8 TABLES** - Numerical results should be displayed as means with relevant standard errors rather than as detailed data. Standard errors should be given to one place of decimals more than the means to which they refer and the number of degrees of freedom should also be quoted. Tables should be complete in themselves so that they can be understood without reference to accompanying text. Each table should have a brief and self explanatory title. The presentation of the same data in tabular and graphic form is not permitted.

**9 FIGURES AND PHOTOGRAPHS** - Line drawings should be drawn in black water-proof on smooth tough paper. Labelling should be clear and always produced with stencils using black water-proof ink and should be legible when reduced. No alternations or additions to artwork can be made by the editors. Figures should be no larger than an A3 page, and no smaller than final published size. Photographs should be glossy prints of good quality and must make a definite contribution to the value of the paper. Indicate the top of figures and photographs on the back. Also indicate clearly on the back; the

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"Moran and Brown (1956) showed" or "Various workers" (Miller and Smith 1956; Adams *et al.* 1960; Wilson 1978, 1979a;) found...." The term *et al.* should be used when there are more than two authors. The letters a,b,c, should be used to distinguish several papers by the same author in one year.

All references in the bibliography should be given in full and in alphabetical order. For a journal the reference should include surname and initials of all authors, (year), title of paper, full title of the journal, volume, (part) and full page numbers. For a book the reference should include author's surname and initials, (year), title of chapter and page numbers if appropriate, full title of book, publisher and city and total page number. Conference proceedings should include the year and place of the conference. The title of the journal or book is underlined to be printed in italics. Examples are:

BOWETT, C.M. and SMITH, L.N. (1950). Measurement of phosphorus. p. 1-10. In *Methods of Soil analysis*. Ed. C.A. Lack. Department of Primary Industry, Port Moresby, 400 pp.

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g	- gram
kg	- kilogram
t	- tonne
l	- litre
ml	- millilitre
ha	- hectare
mm	- millimetre
m	- metre
a.s.l	- above sea level
yr	- year
wk	- week
h	- hour
min	- minute
s	- second
K	- kina
n.a	- not applicable or not available
n.r.	- not recorded
var	- variance

sd	- standard deviation
s.e.m	- standard error of mean
s.e.d.	- standard error of difference
d.f.	- degrees of freedom

Levels of significant:

n.s.	- not significant
*	- $0.05 \leq p < 0.05$
**	- $0.01 \leq p < 0.01$
***	- $p < 0.001$

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