The use of mulches to increase yields and improve the sustainability of Pacific Island cropping systems.

Utilisation des mulchs pour l'accroissement des rendements et l'amélioration de la durabilité des systèmes de culture des îles du Pacifique

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Introduction

The Tonga Archipelago consists of 171 islands which are scattered between latitudes 14 to 23°S and longitudes 173 to 177°W, covering a total area of 362,500 km². However, the total land area is only approximately 747 km² with a population of about 98,000 people. Along the eastern side of the archipelago, lies a series of coralline islands in a north-south alignment, with the Tonga Trench just to the east. Parallel in the western side of the archipelago lies a series of volcanic islands with several active terrestrial and submarine volcanoes.

Shifting cultivation system is still practised at large by Tongan farmers although various modified forms have evolved at different areas and crops. Basically it consists of rotation of fields of cultivation and bush fallowing. Land is cleared by slash and burn or fallow regrowth incorporated followed by a period of mixed cropping and crop rotation for 3-5 years before bush fallowing. Nutrient requirements in this system depend solely on the nutrients stored and regenerated in the vegetation biomass and soil during the fallow period.

In terms of area, coconut (C. nucifera) and guinea graa (P. maximum) are the dominant fallow species. This is due to a decreasing fallow period coupled with frequent burning which suppresses regrowth of the forest species. In a study of the volcanic ash soils of Tonga the cropping period was found to result in a marked decline in total soil C of from 77.0 mg/kg in forest to 31.6 mg/kg in cultivated soil. There was an approximate 70% reduction in labile C during the same period. This decline was associated with reduced soil fertility such that a 366% response to P was recorded in a soil at the end of the cropping cycle compared to a 27% response in an uncropped forest soil. A two-year-old guinea grass stand yields at least 20 t DM/ha, which is usually either burnt or plowed into the soil. Mulching in Tonga is mainly practised with the cultivation of vanilla with only a few farmers using mulch on yam cultivation. The organic material used depends on accessibility and amount, and includes coconut fronds, guinea grass, coconut husk etc..
Materials and Methods

Two field experiments were carried out at Vaini Research Station to investigate the effects of using thick organic mulch application on: first, growth and tuber yield of (*Dioscorea alata* L. cv Kahokaho) in 1994/95 and; second, growth and fruit yield on watermelon (*Citrullus lanatus* L. var Candy Red) in 1996. The first experiment consisted of four treatments: non-mulch control with staking; coconut sawdust mulch (20 cm thick); guinea grass mulch (20 cm thick); mature coconut fronds (20 cm thick). The treatments were arranged in a complete randomised block design with eight replications. The second experiment consisted of five treatments: non-mulch control; transparent plastic mulch; dry coconut frond mulch; guinea grass mulch, coconut sawdust mulch. The treatments were arranged in a complete randomised block design with six replications.

The site for both experiments was on a Vaini clay loam (*Typic Argiudoll*) and had been under root crop cultivation and guinea grass fallow. Soil samples were collected and analysed (Table 1). The soil pH is almost neutral, the plant available P is low and the high cation exchange capacity dominated by Ca and Mg.

### Table 1. Soil analysis of the trial site at Vaini Research Station.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>pH (1:2.5 H$_2$O)</th>
<th>Bondorf-P (µg/g)</th>
<th>Total N (g/100g)</th>
<th>Exchangeable cations (meq/100g) Ca</th>
<th>Mg</th>
<th>K</th>
<th>Na</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20</td>
<td>6.5</td>
<td>46</td>
<td>0.21</td>
<td>27.3</td>
<td>7.7</td>
<td>0.17</td>
<td>0.61</td>
</tr>
</tbody>
</table>

The guinea grass was plowed and replowed two months earlier before it was disced and ridged. For the yam experiment, the yam mounts were at a spacing of 1.5m x 1.5m. and there were 16 data plants in a 4x4 arrangement. Yam (*Dioscorea alata* L. cv Kahokaho) was planted with mini tuber set (800 g - 1400 g) in November 1994. The mulch application was applied afterwards. The trial was harvested in May 1995.

For the watermelon experiment, a blanket application of fertilizer (100 kgN/ha, 100 kgP/ha and 80 kg K/ha) was applied. A basal application of 30% of N and 70% of K and all of the P was mixed within the rows 10 days before planting. The remainder was sidedressed 40 days after planting. Watermelon (*Citrullus lanatus* L. var Candy Red) was direct seeded at 0.7m spacing between the rows. There were 40 data plants in two double rows, 1m between single rows and 3m between double rows. The mulch material was applied to the 3m space 7 days after germination to avoid slug damage.

Watermelons were harvested twice, at 104 days and 112 days after planting, and weighed. Data was statistically analysed with the SAS Statistical package.

Results and Discussion

**Yam experiment**

The climate was normal during the experiment but *Anthracnose* disease was severe towards the end as a result of continuous wet weather. The heaviest tuber was 23.5 kg which came from a coconut sawdust plot with a total tuber yield of 50.7 t/ha.. The yield in the non-mulch staking control was significantly lower than all the mulch treatments which did not differ from each other (Table 2). There was no significant treatment effect on the number of tubers per plant.
Table 2. Mean yam fresh tuber yield under different mulch treatments.

<table>
<thead>
<tr>
<th>Non-mulch (control)</th>
<th>Coconut sawdust (20 cm thick)</th>
<th>Guinea grass (20 cm thick)</th>
<th>Coconut fronds (20 cm thick)</th>
</tr>
</thead>
<tbody>
<tr>
<td>38.0 b</td>
<td>44.1 a</td>
<td>45.0 a</td>
<td>43.5 a</td>
</tr>
</tbody>
</table>

Total tuber yield (t/ha)¹

Mean number of tubers per plant¹

¹ Means followed by the same letter are not significantly different at P ≤ 0.05 according to Duncan’s multiple range test.

Watermelon experiment

The climate during the trial was the best in years for watermelon production, especially the rainfall distribution. The season was cool (18-25°C) and relatively dry (69-76% H). The excellent rainfall distribution resulted in 99.3% germination, vigorous vegetative growth, negligible first fruit set (normally pruned) and very few fruits with blossom-end rot. At the first harvest, fewer but heavier fruits (max 15.1 kg) were picked, whereas the second harvest yielded more but lighter fruits. The watermelon yield ranged from 58.6 to 69.2 t/ha (Table 3).

Table 3 Mean watermelon fruit yield for different mulch treatments.

<table>
<thead>
<tr>
<th>Non- mulch (control)</th>
<th>Transparent plastic</th>
<th>Coconut sawdust (20 cm thick)</th>
<th>Guinea grass (20 cm thick)</th>
<th>Coconut fronds (20 cm thick)</th>
</tr>
</thead>
<tbody>
<tr>
<td>58.6 c</td>
<td>62.9 b</td>
<td>69.2 c</td>
<td>68.0 a</td>
<td>63.6 a</td>
</tr>
</tbody>
</table>

Fruit yield (t/ha)¹

Mean number of fruit per plant¹

¹ Means followed by the same letter are not significantly different at P ≤ 0.05 according to Duncan’s multiple range test.

The results show that there is a significant positive effect of all mulch treatments on fruit yield (p<0.05). There was also a significant effect of sawdust and grass mulch on fruit relative to plastic and fronds mulch. The sawdust and the grass mulch treatment also had a significant effect on the number of fruits per plant. The significant increase in Watermelon fruit yield in the mulch treatments was mainly due to the increased number of fruits per plant, and not to the weight per fruit. The results generally correlate with the capability of the mulch to conserve soil moisture, ranking from lowest in the control, to highest in plastic treatment. However, plants under plastic mulch were affected by gummy stem blight disease resulting in lower yield.
The thick organic mulch layer is a simulation of the thick organic littler layer in an undisturbed tropical rainforest. A number of field trials with positive effects of mulch on different crops (maize, soybean, mungbean, cowpea, papaya) have been reported by Lal, 1978; Sekhon & Kaul, 1978; Simpson and Gumps, 1986; Gauer & Mukherjee, 1980; Wicks et al, 1994; Kamar, 1994; Mongia, 1991; Young and Plucknett, 1981. All these authors account for the positive effects of mulch as due to three factors namely conservation of soil moisture, reduction of soil temperature and weed control. These parameters were measured from December 1996 to May 1997. The temperature in all mulch treatments were at least 4°C lower except for the plastic mulch, which was 10°C higher (Table 4).

### Table 4. Mean difference between the air temperature and soil (2cm depth) under different treatments measured at 1400 hours with a Barnant 100 thermocouple thermometer.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Unmulched control</th>
<th>Plastic mulch</th>
<th>Sawdust mulch</th>
<th>Grass mulch</th>
<th>Frond mulch</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{\text{air}} - T_{\text{soil}}$ (°C)</td>
<td>-0.2 (2.2)</td>
<td>10.3 (3.7)</td>
<td>-4.0 (2.0)</td>
<td>-5.5 (1.7)</td>
<td>-5.9 (2.3)</td>
</tr>
</tbody>
</table>

$^1$ Numbers within parenthesis are equivalent to 1 standard deviation.

The soil moisture retention of the mulch treatment was highest for the plastic and coconut sawdust treatment and lowest for the unmulched control (Table 5). This implies that thick mulching significantly lowered the soil water evaporation rate.

### Table 5. Mean soil moisture at depths 10 cm and 20 cm for different treatments, measured at 1400 hours with Aquaterr model 200 moisture meter. Calibration with water = 100%.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Unmulched control</th>
<th>Plastic mulch</th>
<th>Sawdust mulch</th>
<th>Grass mulch</th>
<th>Frond mulch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil moisture 10 cm (%)</td>
<td>14.6 (5.0)</td>
<td>24.0 (5.6)</td>
<td>24.4 (6.0)</td>
<td>22.6 (4.6)</td>
<td>20.8 (5.9)</td>
</tr>
<tr>
<td>Soil moisture 20 cm (%)</td>
<td>30.0 (13.6)</td>
<td>51.4 (15.8)</td>
<td>51.4 (15.8)</td>
<td>47.5 (15.0)</td>
<td>45.6 (14.2)</td>
</tr>
</tbody>
</table>

$^1$ Numbers within parenthesis are equivalent to 1 standard deviation.

The weed growth in the unmulched control was much higher than all the mulch treatments (Table 6). This shows the suppression of weed growth by mulch application.
Table 6. Mean weed infestation scoring, ranking from 0 = weed free to 5 = extremely dense infestation.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Unmulched control</th>
<th>Plastic mulch</th>
<th>Sawdust mulch</th>
<th>Grass mulch</th>
<th>Frond mulch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed score</td>
<td>4.3 (0.7)</td>
<td>1.0 (1.3)</td>
<td>2.3 (0.8)</td>
<td>1.6 (0.4)</td>
<td>1.2 (0.6)</td>
</tr>
</tbody>
</table>

1 Numbers within parenthesis are equivalent to 1 standard deviation.

In the single crop experiments reported here the major effects of thick mulch application have been in lowering soil temperature, improving soil moisture and in the suppression of weed growth. Because of the slow release rate of nutrients from these organic mulch materials the effect of nutrient supply is not as significant as the other effects. The ready availability of guinea grass and coconut fronts as a sources of organic mulches in Tonga and their positive effects on crop yields makes them ideal candidates for further research.

References


Gauer, and Mukherjee (1980).


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Mots clés : mulches organiques, SOM, carbone labile