Comparison of *Azolla mexicana* and N and P fertilization on paddy taro 
(*Colocasia esculenta*) yield

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The yields of taro intercropped with *Azolla* and under slowly flowing water (F) and taro intercropped with *Azolla* after incorporation of *Azolla* into mud (B) were compared with N and P fertilization and a control in Mangaia, The Cook Islands. Significantly, higher yields were obtained for treatments F and B than for the chemical fertilization treatment, which had a minimal effect on yield. The control produced 53.4 and 64.7% of yield of treatments F and B, respectively.

Keywords: Incorporation; Intercropped; Decomposition; Leaching; Fixation; Inoculation; Canopy

The importance of *Azolla mexicana* as a bio-fertilizer in paddy rice production in China, Vietnam, and Senegal is well documented. It also serves as fish food and animal fodder (Watanabe *et al.*, 1977; Lumpkin and Plucknett, 1980, 1982; IRRI, 1987; Ventura *et al.*, 1987; FAO, 1989). In the Philippines, a programme to meet 50% of the N requirement for paddy rice production through the application of *Azolla* as a green manure is in progress (IRRI, 1987).

Less attention has been given to the benefits of *Azolla* in paddy taro production. This trial was therefore undertaken to compare the effect of *Azolla* with chemical fertilization on the yields of paddy taro.

**Materials and Methods**

The soils of Mangaia are classified as Latosols, Lithosols, Alfisols, and Colluvium. Latosols are the most important group and are widely distributed throughout the island.

The experiment was carried out in a paddy taro field (31.9 m x 10.5 m). The soil is of volcanic origin, reddish-brown weathered from basalt. It has a strongly developed structure, friable, well drained, and deep with low water-holding capacity. The pH was 6.1. Available phosphate was low and cation-exchange capacity of the soil was medium.

The design was a randomised block (RBD) with six treatments and five replications. The treatments were (A) Control (no chemical fertilizer, no *Azolla*); (B) *Azolla* incorporated into mud at 20 t ha\(^{-1}\) and also applied to the soil surface at 0.5 kg m\(^{-2}\) at planting of taro; (C) 20 kg N ha\(^{-1}\) (ammonium sulphate); (D) 40 kg N ha\(^{-1}\) (ammonium sulphate); (E) *Azolla* applied to the soil surface at 0.5 kg m\(^{-2}\) plus 10 kg P ha\(^{-1}\) (triple superphosphate), and (F) *Azolla* intercropped and under slowly flowing water.

The land had been fallow for six years. At the time of clearing for the trial, it supported a mixture of tall grasses and shrubs. Water was drained from the field and the land was cleared with the help of bush knives (machetes). The seed bed was prepared by trampling (foot), use of a rotary hand-pushed plough, and bamboo sticks.

Taro sets, variety Niue (40–80 g in size), were planted on 23 January 1990. Inter-row and intra-row distances were 1.0 m and 0.7 m, respectively. At planting *Azolla* was incorporated and (or) applied to the surface, and chemical fertilizers were broadcasted at rates indicated above.

During the growing season and at harvest (on four marked plants from each plot) petiole length, leaf area, fresh weight of plant tops, corn fresh weight separated to mother corn and suckers, and economic value of corns were taken.
Results and Discussion

Plant growth in general
At its juvenile stage (30 days after planting) taro encountered cyclone 'Pani'; however, plant recovery was quick. Later, in the growing season, plots were infested with the notorious weed Ludwigia ascendens which had the capacity to depress Azolla. Hand weeding was performed twice. Throughout the growing period both height and leaf area were retarded. Harvest was performed 48 weeks after planting (WAP).

Petiole length
Petiole length increased slowly until 28 WAP and decreased thereafter for all treatments. Esumah and Plucknett (1977), Sivan (1980), and Wilson (1984a) reported the highest shoot growth for Colocasia at 16-24 WAP. In this trial differences in height among treatments became evident at 16 WAP. Thereafter treatment B produced significantly taller petioles than other treatments except treatment A (control).

Leaf area
Leaf area throughout the season was small. This might be due to the small (40-80 g) sett size used for planting, cyclone 'Pani', and weeds. According to Kagbo et al. (1979) the optimal sett size for Colocasia is 100-120 g.

From 20-40 WAP treatment B produced the highest leaf area. This was significantly higher than the other treatments apart from treatment A which experienced a larger flow of fresh water, the temperature of which might have been lower, and dissolved and eroded nutrients from uplands might have improved the fertility of the soil. Azolla absorbs its nutrients from the water in which it grows (Lumpkin and Plucknett, 1982). From about 30 WAP onwards, the new leaves were not as large as the earlier leaves.

Harvest data
Weight of total plant tops, mother corns, and total corns are presented in Table 1. There was a positive relationship between leaf production and corn yield. According to Enyi (1977) and Abit and Allerez (1980) leaf area is closely related to corn and cornel yield. For total corn fresh weight, treatment F produced a significantly higher yield than treatments A, C, D, and E.

Treatment A (control) which received greater quantities of freshwater than treatments B, C, D, and E produced significantly higher plant tops and corn yield than treatments C, D, and E. Because sets of 50-100 g and taro leaves can be sold for planting and for food preparation the production of higher plant tops by treatments A, B, and F has an economic advantage for the farmers.

The yield of treatment A (control) was 53.4% of the total corn fresh weight of treatment F and 64.7% of that of treatment B. This is in agreement with Lumpkin and Plucknett (1982) who reported yield in control plots that were 10-100% of the yield of plots treated with Azolla.

At harvest, corns were divided into marketable and nonmarketable corns. All mother corns were marketable while sucker corns for all treatments were unmarketable. Wilson (1984b) indicated that Colocasia under flooded conditions in Hawaii gave higher sucker yields. This might be due to the higher fertilizer application. Under upland conditions Colocasia does not produce marketable sucker corns.

Weights of marketable and unmarketable corns are presented in Table 2. The rank of both marketable and unmarketable corns were as follows: F > B > A > C > D > E. Therefore, treatments with Azolla produced higher sucker yield than without Azolla and treatments under chemical fertilizer.

Previous studies indicate that Azolla can produce more than 2 kg N ha⁻¹ day⁻¹, which is equivalent to more than 10 kg of ammonium sulphate (Lumpkin and Plucknett, 1982). IRRI (1987) reported Azolla production of 450 kg N ha⁻¹ yr⁻¹.

According to Lumpkin and Plucknett (1982) the range of nutrient composition of Azolla on a dry weight basis for N was 1.96-5.33%, P 0.16-0.59%, and K 0.31-5.97%. Comparable N (3.55%), P (0.20%), and K (2.85%) elemen-

Table 1 Total plant tops, mother corn fresh weight, and total corn fresh weight (kg ha⁻¹)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Total plant tops at harvest</th>
<th>Mother corn fresh wt</th>
<th>Total corn fresh wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2 623.7 a</td>
<td>4 415.8 ab</td>
<td>5 471.9 bc</td>
</tr>
<tr>
<td>B</td>
<td>2 514.2 ab</td>
<td>5 790.3 ab</td>
<td>8 465.7 ab</td>
</tr>
<tr>
<td>C</td>
<td>729.9 b</td>
<td>3 437.5 bc</td>
<td>4 178.4 c</td>
</tr>
<tr>
<td>D</td>
<td>823.8 b</td>
<td>3 036.8 bc</td>
<td>3 851.0 c</td>
</tr>
<tr>
<td>E</td>
<td>561.2 c</td>
<td>1 871.3 c</td>
<td>2 192.3 c</td>
</tr>
<tr>
<td>F</td>
<td>4 275.9 a</td>
<td>7 185.4 a</td>
<td>10 235.2 a</td>
</tr>
</tbody>
</table>

Means followed by the same letter do not differ significantly by LSD (P = 0.05).

Table 2 Weight of marketable and unmarketable corns at harvest (kg ha⁻¹)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Marketable</th>
<th>Nonmarketable</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4 415.8</td>
<td>1 056.1</td>
<td>5 472.0</td>
</tr>
<tr>
<td>B</td>
<td>5 790.3</td>
<td>2 655.4</td>
<td>8 445.7</td>
</tr>
<tr>
<td>C</td>
<td>3 437.3</td>
<td>740.5</td>
<td>4 178.4</td>
</tr>
<tr>
<td>D</td>
<td>3 036.8</td>
<td>614.2</td>
<td>3 651.0</td>
</tr>
<tr>
<td>E</td>
<td>1 871.3</td>
<td>230.9</td>
<td>2 102.3</td>
</tr>
<tr>
<td>F</td>
<td>7 185.4</td>
<td>3 049.8</td>
<td>10 235.2</td>
</tr>
</tbody>
</table>

Trop. Agric. (Trinidad) Vol. 72 No. 1 January 1995 71
tal composition was obtained from Azolla mexicana in Mangaia, The Cook Islands.

The N content of Azolla (3.5%) was higher than that of alfalfa (Medicago sativa; 2.8%) and soya bean (Glycine max; 2.9%) (Lumpkin and Plucknett, 1980). Azolla also contained high levels of K.

References


