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BREEDING ALOCASIA MACRORRHIZA (L.) SCHOTT IN WESTERN SAMOA

Sélection de Alocasia macrorrhiza (L.) aux Samoa Occidentales

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SUMMARY

Although *Alocasia macrorrhiza* is considered a minor edible aroid in the Pacific as a whole, it is a staple food in Western Samoa and a program to improve production has been initiated. As baseline information for a genetic improvement program, present cultural methods practiced by Samoan farmers have been described and a technique to estimate yield without harvesting, by estimating stem weight from circumference and length measurements, has been developed and used to estimate yields in a large number of farmer's fields.

RESUME

Bien que Alocasia macrorrhiza *soit considéré dans l'ensemble du Pacifique comme une aroidée comestible mineure, c'est un aliment de base à Tonga et aux Samoa occidentales, et un programme d'amélioration de sa production est commencé. Au titre d'information de base pour un programme d'amélioration génétique, les pratiques culturales actuelles des Samoans ont été décrites et une technique d'estimation du rendement sans récolte (par estimation du poids de la tige par sa circonférence et sa longueur) a été mise au point et utilisée sur un grand nombre de culture d'exploitants. Pour développer les techniques nécessaires au programme d'amélioration génétique, la pratique de la floraison par l'acide gibbérellique a été étudiée et les résultats sont discutés.*

Alocasia macrorrhiza (giant taro, ta'mu, kape) is distributed throughout the islands of the Pacific but it is extensively cultivated only in Western Samoa, Tonga, Wallis and Futuna, the Lau Group of Fidji where there has historically been considerable Tongan influence, and parts of Vanuatu. Throughout the remainder of the region, very acrid, weedy types may be collected and eaten during times of food shortages.

Greater use of *Alocasia* is limited by a number of factors. Even cultivated types are more acrid than other edible aroids and careful peeling and thorough cooking is needed before eating. Time from planting to harvest is generally 12 to 24 months compared to 6 to 9 months required for *Colocasia* taro and with many cultivars, time of harvest must be carefully selected to avoid periods when eating quality is poor.

However, *Alocasia* also has a number of positive attributes. It is a hardy crop, resistant to many of the diseases which attack *Colocasia* taro. Since the main edible portion is an aboveground stem, it can be grown in stony, shallow soils which are less suitable for *Colocasia*, and some cultivars yield well under lower rainfall and lower soil fertility. *Alocasia* can be field stored for up to four or five years and, therefore, serves as a long-term emergency crop. After harvest, it can be stored under ambient conditions for several months. Plants have erect leaves and this vertical leaf display is advantageous when *Alocasia* is grown in high density monoculture systems or is the dominant crop in inter-cropping situations (Wilson, 1984).

Alocasia could have increased use in the future, especially as farmers expand into marginal growing areas, if improved cultivars are bred which combine these positive attributes with lower acridity, less fluctuation in eating quality and a shorter time to harvest. A critical first step in attuning the breeding program to farmer's needs and avoiding the development of inappropriate cultivars is to appraise current *Alocasia* production methods and identify key constraints as well as opportunities for exploiting resources. From this appraisal, breeding goals and selection criterial can be defined.

To actually carry out a breeding program to reach these breeding goals, techniques must be developed to : a) control flowering so that it occurs early in the growth cycle and is abundant and predictable, b) control pollination and produce large quantities of seeds, c) rear seedlings, d) screen breeding populations for desirable characteristics and e) develop methods of rapid clonal multiplication.

This paper will focus on the first of these steps, the reconnaissance survey aimed at providing the information needed to define the selection criteria to be used in the western Samoan *Alocasia* breeding program. To date only general comments concerning *Alocasia* production have been published and no yield estimates for Western Samoa have been reported.

MATERIALS AND METHODS

A description of *Alocasia* production methods, present yields and constraints was pieced together from information obtained by single visit interviews of farmers, direct field and market observations and measurements over longer periods of time and review of the limited literature.

Production Methods

All major *Alocasia* growing areas on the two large island of Western Samoa, Upolu and Savaii, were visited. Thirty-six farmers were interviewed and 37 fields chosen for description and estimation of yields (Hermans, 1984 ; de Groot, 1985). The sample of farmers and fields was not selected at random but rather purposely chosen and therefore biased by accessibility. However, the results provide a sufficient general picture for the purpose of defining breeding goals.

Estimated yields

Because farmers harvest *Alocasia* haphazardly as needed for home consumption or marketing, it was not practical to be present at harvesting time to weight stems. Therefore, to determine yields in farmer's fields, it was necessary to devise a non-destructive technique to estimate yields before harvest, while plants were still standing in the field. To do this, 109 stems of cultivar (cv) Toga and 101 stems of cv Niu Kini offered for sale at the local market were measured and weighed and for each cultivar a correlation between stem dimensions and stem weight determined (Hermans, 1984; de Groot, 1985). Dimension measurements were taken as follows (Figure 1) : length of the stem (L), defined as the distance between the upper most leafscar and the soil line, and diameter in three places, near the upper most leaf scar (C1), at half the length (C2) and at the soil line (C3). These values were used to calculate the estimated stem volume using the following formulae :

for cv Toga : $$V = L \times \frac{1}{4}\pi \times \frac{1}{6}\,(C1^2 + 4\,C2^2 + C3^2) \quad (1)$$

for cv Niu kini : $$V = L \times \frac{1}{4}\pi \times \frac{1}{6}\,(C1^2 + 3\,C2^2 + 2C3^2) \quad (2)$$

Formulae (1) and (2) were choosen out of several formulae with different multiplying factors for C1, C2 and C3 because, after regression, they showed the highest correlation coefficient and lowest average deviation from actual weight. Cv Toga has a cylindrical stem whereas the stem of cv Niu Kini is wider at the soil line (Figure 2) and this difference

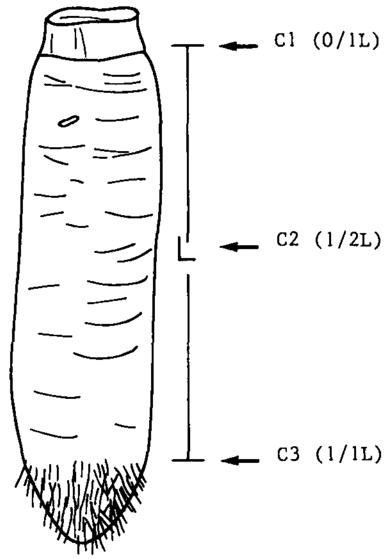

Fig.1 : Measurements used to calculate the estimated stem volume of Alocasia

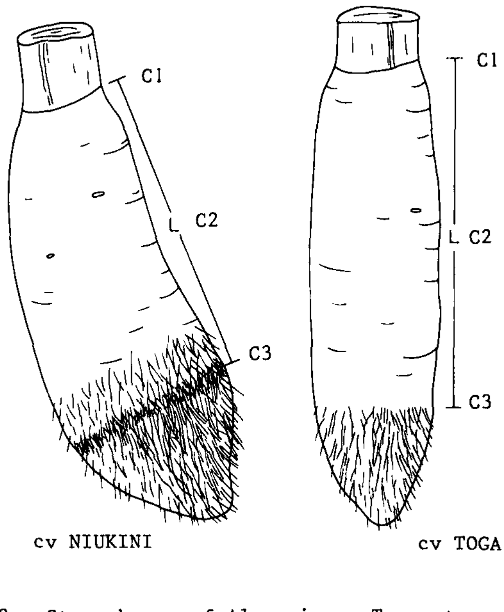

Fig.2 : Stem shapes of Alocasia cv Toga et cv Niukini

in shape is reflected in the formulae.

To determine the regression functions necessary for estimating yields in the field, estimated volumes were regressed on the actual weight (W_{act}), using a linear regression function.

for cv Toga :

$$W_{est} = 0.000880 V + 0.91 \quad (4)$$

average deviation $\pm$ 6.5%

W_{est} = estimated weight in kg

v = volume in cm^3

for cv Niu Kini :

$$W_{est} = 0.001137 V + 0.91 \quad (3)$$

average deviation $\pm$ 7.3%

In each of the 37 fields, a representative subsample of 20 to 25 plants was chosen and the lengths and circumferences of each stem measured (Figure 1). These measurements were used in formulae (1) to (4) to estimate stem weights. Estimated yields expressed in t/ha/yr were calculated based on field spacing and the age of the crop as determined from the farmer.

To check if the estimated yield calculated from the regression functions is a good estimate of the actual yield, stems were measured before harvest and weighed after harvest in 5 fields.

Soils samples were taken from subplots and later analyzed for nitrogen, phosphorus and organic carbon.

RESULTS AND DISCUSSIONS

Production Methods

Alocasia is grown in locations with a variety of climatic conditions ranging from those with a moderate to strong dry season and a mean annual rainfall of 2100 mm to locations with no well defined dry season and more than 4000 mm rainfall annually. Similarly, analysis of soils taken from 25 of the subplots incated that the crop is being grown on soils with a range of fertilities. (de Groot, 1985).

Alocasia is grown on small plots near houses in coastal villages as well as in larger fields in the inland foothills.

Plots near houses are grown for family consumption whereas distant fields are harvested for both home consumption and cash income. In general, plots near houses are better maintained than inland fields since weeding is more regularly carried out and grass cutting and other organic debries are often used to fertilize these plots. Inland fields generally contain only one or two cultivars whereas village plots contain a mixture of more cultivars.

On inland fields, *Alocasia* may be grown as the first crop after clearing fallow or after one to several crops of *Colocasia*. *Alocasia* is more often planted on low fertility soils than is *Colocasia* and it appears that a higher percentage of *Alocasia* is grown on stony soils because unlike *Colocasia* it does not require a large planting hole. However, this tendency to use stony soil for *Alocasia* was not as clear cut as expected since, surprisingly, *Colocasia* also is often planted on very stony soils.

There appears to be no fixed planting time for *Alocasia*. Farmers did not mention any and they often did not remember which month they planted a certain field. Planting is done with a planting stick in a 'hand deep' (10-15 cm) hole. In those fields measured, plant spacing ranged from 1.0 m x 1.0 m to 2.1 m x 2.1 m with an average of 2.2 m^2/plant. Spacing in monocrops is slightly closer than in intercropped fields.

For planting material, headsetts and suckers are used, with suckers preferred. When stems are harvested, the small underground cormels remain in the soil and the small plants emerging from them may be used for planting material, but this appears to be uncommon since none of the farmers interveiwed mentioned using this type of planting material. Suckers are infrequently sold on the Apia market (WS$10.00 for 100 suckers in 1984 and 1985).

Alocasia is grown as a monocrop or intercropped with a variety of companion crops, the most common being *Colocasia* taro. Other intercrops noted were bananas, papayas, pineapple, passionfruit, young coconut, young cocoa, kava, coffee, breadfruit and vegetables. Village plots are more often intercropped than inland fields and village plots generally contain a greater variety of companion crops. Frequently, *Alocasia* is found marking boundaries of fields or in ornamental gardens (especially the cultivar Fiasega) or as scattered single plants in a multiple crop planting.

Apart from plots near houses which are sometimes manured with organic debris, none of the farmers interviewed used fertilizers or pesticides on *Alocasia*. Maintenance of *Alocasia* fields is generally limited to weeding. The number of weedings varies from no weeding to six times each year with an average of 3 times each year. Weeding is most often done manually but the herbicide paraquat (Gramoxone) is sometimes used for weeding as well as for clearing fields before planting.

In Western Samoa, *Alocasia* is generally a hardy plant. Stems may be uprooted by pigs or damaged by rats or 'manuali'i' birds (*Porphyrio porphyrio*). Armyworms *Spodoptera litura*) occasionally reduce leaf area. Symptoms of Dasheen Mosaic Virus are frequently observed and peppery leafspot, (*Mycosphaerella allocasiae*) occurs ubiquitously but is not considered economically important (W.Gerlach, personal communication)Extensive damage bywhich causes the underground stem to rot was observed in one field.

Alocasia requires 12 to 24 months to produce a stem large enough to harvest. It may be harvested at that time or field stored for several years until needed, a characteristic which is much appreciated by farmers. To determine which stems to harvest, farmers may use the length of the stem, the fact that the stem is begining to bend over to flower, the decreasing diameter of the stem apex, a reduction in leaves to 3 or less (probably associated with flowering) or the age of the plant. Time of harvest is determined differently for different cultivars. Cv Niu Kini does not flower naturally and 70 per cent of the farmers interviewed said that this cultivar could be eaten at all stages in this growth cycle, with the time of harvest determined by stem size. In contrast, according to 77 per cent of the farmers, cv Toga must first flower before it is good for eating, although 50 percent of the farmers interviewed said that cv Toga can be eaten when it is older than 1½-3 years or when the stem has reached a certain size. Most, but not all, stems of cv Toga observed on the market throughout the year were flowering when harvested.

Most farmers responded that there is no special month of the year for harvesting *Alocasia* apparently not recognizing that naturel flowering in cultivars such as Toga is most frequent during November-January. A few farmers mentioned that cvs Toga, Lauo'o and Laufola should not be harvested during the rainy season unless they are flowering, probably because during wet periods the flesh becomes too watery, especially in the top part of the stem. In contrast, this does not appear to be true for cv Niu Kini. For marketing, time of harvesting is often dictated by the need for cash (school fees, ceremonies, church contributions), anticipated demand and supply on the market and availability of the other starches such as *Colocasia*, and breadfruit, rather than on the age or growth stage of the plant.

Harvesting is done by cutting the roots with a bush knife or spade and pulling up the stem by hand. The leaves are cut off and at least 3 to 4 petiole bases removed. Roots remaining on the stem are carefully cut off, taking care not to damage the stem. Cable (1981) mentioned that *Alocasia* requires less work to harvest than but this is probably true only on a per weight basis, not on a per plant basis.- Infrequently, a ratoon crop is harvested from suckers left in the field after the first harvest. Stem are marketed with petiole bases and corm apex attached, in contract to *Colocasia* corms from which they are removed before marketing locally. In Tonga *Alocasia* is stored for several months after harvesting, but in Western Samoa it is not purposefully stored. Farmers do recognize that it has a longer market shelf life than *Colocasia* but they prefer to cook the stems immediately after harvest.

Cv Niu Kini is marketed more frequently and in larger quantities than cv Toga. Other cultivars are seldomly found on the market. *Alocasia* is sold by the stem, with the price based on the size of stem and the cultivar, with cv Niu Kini demanding a higher price than cv Toga, e.g. during July/August 1984 cv Niu Kini averaged WS$ 0.44/kg compared to WS$ 0.21/kg for cv Toga.

During interviews, farmers gave several reasons for growing *Alocasia* which indicate the perceived value of the crop. It is a long-term, emergency crop which can be field stored for up to four years and harvested when needed for home consumption when other foods are in short supply or for marketing when cash is needed. It can be planted on soils which are too exhausted to support another crop of *Colocasia* or on soil types which are less suitable for *Colocasia* e.g. sandy or stony soils. It is a dual purpose crop used for both subsistence and for cash generation, and one farmer mentioned that it is useful as a shade crop for cocoa seedlings (de Groot, 1985)

Both the aboveground and underground stem of *Alocasia* are eaten, although the latter is less preferred because it is higher in acridity. Stems are prepared carefully peeling off 2-2.5 cm of skin and outer flesh which are high in acridity, cutting the stem into pieces and baking it in the traditional stone oven ('umu') or boiling it in water and adding salted, coconut cream. Traditionally *Alocasia* peeling is restricted to the men of the household. The status of *Alocasia* in the Samoan diet is lower than*Colocasia* and *Dioscorea* yam but it is generally preferred to green banana and breadfruit.

At present, the *Alocasia* germplasm collection maintained at the University of the South Pacific, Alafua, contains 17 accessions, but in the fields sampled only 8 differents cultivars were recorded : Niu Kini, Toga, Fui, Laufola, Fiasega, Sasa'uli and Faitama. Of these Niu Kini and Toga are the most frequently grown and they are the only two cultivars which are regularly marketed. Cv Niu kini is less acrid than cv Toga. When cooked, the flesh of Niu Kini is also firmer than cv Toga and this firm texture is preferred by Samoans. Similarly, the mean specific density of the uncooked flesh of cv Niu Kini averaged 0.93g/cm and was

Table 1. Estimated yields of Alocasia on farmers' fields in Western Samoa.

Location (Island)	Spacing (m^2/plant)	Plant Age (Months)	Yield (t/ha/yr) cv Toga	cv Niu Kini	cv Lauo'o	cv Laufol.
Alafua (Upolu)	2.2	18	11.0			
Alafua (Upolu) a[1]	2.5	12	16.6			
Alafua (Upolu) b[1]	2.5	12			9.9	
Alafua (Upolu)	3.0	31	8.1			
Alafua (Upolu)	2.1	12	15.8			
Aleisa (Upolu) a	2.5	12	16.6			
Aleisa (Upolu) b	4.4	17		8.7		
Aleisa (Upolu) a	2.5	8	21.8			
Aleisa (Upolu) b	2.5	10		13.0		
Aleisa (Upolu)	2.5	24	12.6[2]	14.7		
Moamoa (Upolu)	2.2	12	23.0			
Tahata (Upolu)	1.3	11		31.9		
Tanumalala (Upolu) a	2.1	28	7.3			10.3
Tanumalala (Upolu) b	2.8	28				
Sa'anapu (Upolu)	2.5	18	17.2			
Matautu (Upolu) a[3]	2.9	11	(40.9	22.2)[5]		
Matautu (Upolu) b[3]	1.3	8	(42.6	50.7)[5]		
Taga (Savaii)	2.6	20	10.0			
Taga (Savaii)	1.8	24		25.2		
Fai'aai (Savaii)	1.9	15			26.5	
Neiafu (Savaii)	2.4	14		26.6		
Neiafu (Savaii)	1.8	13		22.7		
Falealupo (Savaii)	2.1	14		19.9		
Vaisala (Savaii)	2.0	12		17.0		
Tufutafoe (Savaii)	1.2	11		25.1		
Tufutafoe (Savaii)	1.8	11	26.1	30.4		
Auala (Savaii)	1.3	18	15.0			
Fagamalu (Savaii)	1.9	12	26.4			
A'opo (Savaii)	2.5	11		23.0		
A'opo (Savaii)	1.9	10.5		24.1		
A'opo (Savaii)	2.5	14	12.8	8.9		
Puapua (Savaii)	2.3	15	7.4	9.1	13.0	
Vaiaai (Savaii)	2.1	14	21.7			
Lefagaoalii (Savaii)	2.6	24	6.7			
Saleaula (Savaii)	1.9	36	7.3			
Fagatuli (Savaii)[4]	2.3	11		(44.3)[5]		
			14.9	20.0		
			(6.7-26.4)	(8.7-31.9)		

1 a and b following a location indicate 2 fields grown by the same farmer.

2 Cultivars grown together in the same sample plot

3 Age of crop probably underestimated

4 Ratoon crop

5 Not included in means and ranges

significantly higher than cv Toga which averaged 0.86 g/cm (de Groot, 1985).

Although, cv Niu Kini is preferred, cv Toga and other cultivars are more frequently grown in some locations because they will tolerate lower soil fertility than Niu Kini.

Estimated Yields

The estimated yields for cv Toga ranged from 6.7 - 26.4 t/ha/yr with a mean of 14.9 t/ha/yr. Yields of cv Niu Kini were significantly higher, ranging from 8.7 - 31.9 t/ha/yr (Table 1). Yields were similar if a cultivar was grown alone or in mixture with other cultivars.

In two fields in Matautu, yields for cv Tonga were estimated as 40.9 and 42.6 t/ha/yr and for Niu Kini as 22.2 and 50.7 t/ha/yr, but these exceptionally high yields were probably due to underestimation of crop age and were, therefore, not included in the calculation of means and ranges. Farmers often found it difficult to recall the month and sometimes the year during which a specific field of *Alocasia* was planted and this reduces the accuracy of the estimated yield/year.

Using data from the five fields measured before harvest and weighed after harvest, estimated yields were compared with actual yields (Table 2).

Table 2 Comparison of actual yield (W_{act}) with estimated yield (W_{est}) of Alocasia to determine percentage error

no. of stems used in field-check	cv Toga			cv Niu Kini		
	W_{est} (kg)	W_{act} (kg)	$\frac{W_{est}-W_{act}}{W_{act}} \times 100$	W_{est} (kg)	W_{act} (kg)	$\frac{W_{est}-W_{act}}{W_{act}} \times 100$
5	24.7	24.0	+2.9%			
9	44.8	50.6	-11.5%			
50				473.9	410.4	+15.5%
3				28.1	30.1	- 7.2%
9	30.1	45.6	-30.9%	33.4	37.5	-10.9%
			-13.2%			- 0.9%

The percentage error for cv Toga ranged from +2.9% (overestimate to -30.9 per cent (underestimate) with a mean of -13.2 per cent and for cv Niu Kini ranged from +15.5 per cent to -10.9 per cent with a mean of -0.9 per cent. This error can be attributed to several factors. Before marketing, farmers remove several petiole bases from each stem so that the stem length measured in market is longer than in the field, resulting in an underestimation of yield. Similarly cv Niu Kini produces roots above as well as below the soil line, making it difficult to accurately determine the aboveground stem length in the market. The size of the underground stem varies with planting depth. Deeper than average planting depth will result in underestimation of stem yield, whereas shallower than average planting will result in overestimation of yield.

If the estimated yields in Table 1 are corrected using the mean percentage errors of -13.2 per cent for cv Toga and -0.9 per cent for cv Niu Kini, the estimated yield/ha/yr for cv Toga ranges from 7.6 to 29.5 with a mean of 16.9 and for cv Niu Kini ranges from 8.8 to 32.2 with a mean of 20.9 and there is no significant difference between yields of the two cultivars. These estimated yields are similar to the 12.5 - 20.0 t/ha reported for *Colocasia* on newly cleared bushland (Wilson, et al., 1984).

Although estimated yields differ somewhat from actual yields, they are still accurate enough to be used as baseline information for the *Alocasia* breeding program. Also, this non-destructive technique of estimating yields should prove useful for progressively determining yields in breeding populations and monitoring performance of improved cultivars in farmers' fields.

CONCLUSIONS

Bases on our present understanding of the *Alocasia* production system in Western Samoa, improved cultivars produced in the breeding program should have the following characteristics : 1) a level of acridity equal to or less than cv Niu Kini, firm flesh similar to cv Niu Kini, 3) flexible harvest time so that the stems can be harvested year round and field stored for 4 or 5 years, 4) reliable yields in a range of climatic zones, 5) reliable yields on less fertile and stony soils, with no or minimum inputs or fertilizer and pesticides, 6) rapid, early stem growth to permit harvesting after less than one year, 7) yields which average greater than 20 t/ha/yr., 8) levels of resistance to Dasheen Mosaic Virus, *Mycosphaerella* and *Sclerotium* equal to or higher than present cultivars, 9) 2 - 3 large suckers/plant for propagation, 10) erect leaves suitable for intercropping and close spacing.

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