WILD TARO (*Colocasia esculenta* (L.) Schott.) POPULATIONS IN PAPUA NEW GUINEA.

A. Ivancic, A. Simin, E. Ososo and T. Okpul [1]

ABSTRACT

Wild taro (Colocasia esculenta *(L.) Schott.) populations were evaluated for breeding purposes in several locations of Papua New Guinea. All evaluated populations were found to be susceptible to taro leaf blight* (Phytophthora colocasiae) *and the Alomae-Bobone virus complex. Absence of taro leaf symptoms was mainly due to isolation of the population (the pathogen did not reach the population). Flowering ability was relatively high. At least a few plants were found to be flowering in each population. The analysis of quantitative variation indicates that there was relatively high uniformity in leaf dimensions and number of lamina veins within populations. Relatively low variation of measured quantitative characteristics and uniformity in qualitative traits indicate that seed propagation may be extremely rare and that at least some PNG wild taro populations may consist of a single clone. In breeding wild taro genotypes can be used as sources of genes for the improvement of flowering ability, environmental adaptability (for swampy or dry land conditions), growth vigour and earliness.*

Key words: *Wild taro,* Colocasia esculenta*, variability, population characteristics.*

INTRODUCTION

Taro, *Colocasia esculenta* (L.) Schott., belongs to the monocotyledonous family *Araceae*, the aroids or the *Arum* family. It is believed to have originated from the Indo-Malayan region (Plucknett 1984) and spread to almost every tropical region.

People usually distinguish two groups of *C. esculenta* taro: wild (naturally growing) and cultivated. Cultivated taro is usually grown as a root and/or vegetable crop. In the Pacific region, taro used to be a very important crop. It played an important role in the people's customs and traditions. Nowadays, taro is being replaced by other more adaptive crops (such as sweet potato, cassava etc.) because of pests and disease problems and taro's requirements for high soil fertility.

In Papua New Guinea (PNG), the main pest of taro is taro beetle (*Papuana* spp) which is considered as one of the main limiting factors in taro production. Similarly, the most important taro diseases in PNG are taro leaf blight (caused by *Phytophthora colocasiae* Racib.), Alomae-Bobone virus complex (ABVC) and the nematode disease - Mitimiti (caused by *Hirschmanniella miticausa*). Taro leaf blight is considered as a relatively new disease in PNG. According to Packard (1975) and Connell (1978), it appeared around the beginning of the second world war. Similar situation is with Mitimiti, which has recently been introduced to several new places with soil and planting materials.

The diseases and pests of taro in PNG are the main reasons that a breeding programme is needed. The local taro germplasm seems to be a good base for breeding for yield and quality, but not sufficient for breeding for resistance or tolerance against pests and diseases.

The dynamics of the creation of new genetic variability among cultivated taro is very limited because of continuous vegetative propagation. Taro cannot respond fast to the dynamic changes in the environment.

Wild taro is considered to be more dynamic. The existing wild genotypes together with the structure of their populations are predominantly the result of the natural selection under natural conditions while cultivated taros are mainly the result of artificial selection.

In the past, wild taro was considered as a weed or as an exotic plant type. In many cases, these plants were undesired, especially when they penetrated into gar-

---

[1] Research Officers, Department of Agriculture and Livestock, Bubia Agriculture Research Centre, P.O. Box 1639, Lae, Papua New Guinea.

den plots. Because of their environmental fitness and long stolons, they could spread very fast inside relatively clean and fertile areas. In some Pacific countries, wild taro is used as vegetable crop. Corms of some special wild genotypes can also be used as food.

There are not much data on wild taro germplasm in PNG or elsewhere. A survey of wild together with cultivated taro germplasm in PNG was reported by Matthews (1990). Another survey was done by Lebot and Aradhya (1991). The scientists involved in taro research were much more interested in cultivated genotypes.

PNG is considered to have high diversity of wild *Colocasia* germplasm but little is known about this diversity.

The aim of this study was: (i) to evaluate the variation of wild taro populations, (ii) to determine the main characteristics which are typical for wild genotypes, (iii) to determine the main factors of environmental pressure on wild taro populations and (iv) to determine the value of the wild taro germplasm for breeding (which genetically controlled characteristics could be used in breeding programmes)

Characterization of wild taro populations in PNG

Systematic studies of wild taro populations in PNG were initiated together with taro breeding programme in November 1993 at Bubia Agricultural Research Centre (BARC). The main objective was to investigate variation and to estimate the value of wild germplasm for breeding work.

Previous breeding experience and results indicated that wild genotypes can be efficiently used as donors of genes for several specific characteristics in breeding programmes: resistance to taro leaf blight, resistance to nematodes, tolerance to Alomae - Bobone virus complex, specific environmental adaptability (swampy or dryland conditions), earliness, flowering ability and growth vigour.

General characteristics of wild taro populations and communities

Taro (*Colocasia esculenta* (L.) Schott) is traditionally divided into two groups: cultivated and wild or naturally growing taro. The cultivated taros are expressing special characteristics as a result of long term artificial and natural selection. In this group, the 'guided' or artificial selection is more important than the natural one.

Cultivated genotypes express several characteristics which are biologically negative such as reduced flowering and larger corms. Wild taro populations are under permanent pressure of natural selection. Genotypes tend to reach the equilibrium structure of the population which will insure the stability in space and time. The dynamics of the environment has to be followed by the dynamics of the population. In comparison with the cultivated group, wild taro populations are much more dynamic. The main indicator of their dynamics is flowering ability. Wild genotypes of PNG are characterized by high level of fertility and seed set.

One may conclude that the existing flowering ability, fertility, and protogyny together with cross-pollination mechanisms are sufficient to insure high dynamics of wild taro populations. The main limitation, however, is the small chance of a seed to germinate and to develop to a mature plant. The seeds are very small and if they germinate, they do not have much chance to develop further because of 'aggressive' growth of stronger taro plants developed from stolons and other competing plant species in the community. In natural conditions, seed multiplication of wild taro is probably of minor importance in comparison with vegetative propagation.

Regarding single taro plants, it is relatively simple to separate wild from cultivated individuals. The basic characteristics of wild genotypes are small, elongated corms with high concentration of calcium oxalate. Another very typical characteristic is the production of very long stolons. Stolon producing cultivars usually have shorter runners.

Taro is considered to be a partly cross-fertilizing species, propagated vegetatively. Permanent or predominant vegetative propagation of taro under heavy selection pressure logically results in low variability, especially when all individuals in a population belong to the same clone. In areas isolated from migration, where flowering does not occur, the population can consist of only one or few closely related genotypes (mutations derived from the same ancestor). Such a genotype (or a group of closely related genotypes) is characterized by a certain level of adaptability which can sometimes be very low if there is no competition among different taro genotypes and other species present in the community.

When there is no genetic variability the selection pressure is directed to the same genetic base. The chance of each individual to survive depends only on the specific position in the micro environment.

In areas where taro flowers, the genetic structure depends on several factors such as level of cross-fertilization, seed set, chances of a seed to germinate and develop to a mature plant, history of the population (do all plants involved in intercrossings originate from one seed or from several), environmental pressure, frequency of mutations and migrations. Natural taro populations are very rarely in a stage of population equilibrium of Hardy-Weinberg type. The populations possess limited genetic variability. Genotypes in the population are in special equilibrium with the natural pressure.

Propagation and dispersal

Generally, taro can be propagated by seeds or in a vegetative way. According to Purseglove (1972), flowering of cultivated taro is not frequent.

Vegetative propagation is obviously the most important. The climate in most parts of PNG is favourable for taro. Frequent flowering and frequent seed set are good indicators. The seeds, however have very little chance for developing to mature individuals.

New taro genotypes in nature can be created by genetic recombination (hybridization, self-pollination) and mutations. Because of low frequencies, mutations are usually considered less important, but in some cases, they may play the key role in evolution. In continuous vegetative propagation (continuous mitosis), mutations are the only source of variation within certain clone.

Taro propagation is closely related to taro dispersal. Wild taro can be dispersed through seeds or through vegetative parts (for example stolons, suckers and parts of corms) by water, animals, people or landslides.

From an ecological point of view, the most interesting way of dispersal is by water. Taro plants or seeds 'travel' down stream until they reach a certain barrier. If the place is suitable, they start growing and multiplying. Once the first 'colony' is established and stabilized, spread inside the micro-environment can be very fast because of the efficient growth and spread of stolons. If the colony is developed vegetatively from one plant, then there will be no genetic variation. When mutations are neglected, there will be only one genotype.

One interesting point of the dispersal by rivers or creeks is 'travelling' to places which are already inhabited by other wild taros or sometimes where both cultivated and wild taros exist. These places are usually called 'meeting sites' and can be rich with variation. If several genetically different individuals, which appear to be on the same area, flower and produce seeds, then the offspring generations will show a variety of genotypes. The genetic segregation takes place immediately in the first resulting offspring generation because of predominant heterozygosity of the parents. The individuals, which will be able to develop and pass the selection pressure will be incorporated into the existing population structure. Such a population will be characterized by overlapping generations.

People are also playing an important role in the dispersal of wild taro. These plants are usually not desired in garden plots because it is difficult to get rid of them. They can resist even very strong herbicides. If they are thrown out of the garden plot, they will continue to grow and very soon they 'return' by long stolons (sometimes more than two metres long) back to the clean garden area. For this reason, farmers often throw them further away or into small streams or rivers.

Classification of wild taro genotypes

Wild taro genotypes cannot always be clearly distinguished from cultivated types. In some Pacific countries, such as the Solomon Islands, it is possible to find wild taro as a crop (used as a vegetable or even as a root crop).

Wild genotypes have several advantages when grown to provide green leaves. The growth is continuous, almost indeterminate, leaf regeneration is fast and the plants spread by themselves. The basic division of wild taro germplasm based on the authors' research and experience includes four groups.

1. *"True" wild taros*: The plants are maximally adapted to typical natural environmental conditions with strong pressure of natural selection. The main characteristics are: fast leaf regeneration, extremely long stolons, small elongated corms, continuous growth and predominantly high concentration of calcium oxalate.

2. *Wild taro genotypes with some characteristics of cultivated types:* The genotypes belonging to this group can be characterized by larger and well shaped corms and determinate growth. Sometimes the concentration of oxalates in corm is low. This results in the possibility of using them as normal food. These genotypes are also spreading by stolons, similarly to "true" wild types.

3. Wild genotypes with some of the genetic material originating from cultivated germplasm: Because of high level of cross-fertilization, hybrids between cultivated and wild genotypes occur frequently in all areas where the majority of taros flower naturally. This is the main reason why taro breeders in PNG keep wild taro germplasm strictly separated from the cultivated genotypes.

Wild genotypes usually produce more pollen, attract more insects - vectors and pollen is easily spread. The offspring generation results in immediate segregation because of high level of heterozygosity of the parents. The individuals usually express several "wild" characteristics.

The main problem for breeders is in fitness of the individuals with some "wild" genes. They usually germinate better, grow better and faster inside greenhouse, are less affected by diseases and generally have healthier appearance. The breeder can easily reject the genotypes, which have high yield potential but slow early growth, and select "semi-wild" types.

In natural conditions the hybrids (wild x cultivated taro) are exposed to the selection pressure and the general tendency is the return to the most suitable genotype which is wild. The majority of characteristics originating from cultivated genotypes will be eliminated but some will remain. The plants will predominantly express wild characters.

Allard (1992) came to a similar conclusion when studying changes in barley germplasm. When populations had been formed by bulking seeds produced by F_2 families which were advanced into F_3, F_4 and later generations under conditions of competition, the wild alleles rapidly became predominant.

4. "Escapes" from cultivation: Taro plants can remain for a long time in an abandoned field or garden. Frequently they become stable members of a particular plant community. In the long term, genetically based stability will possibly be achieved through genetic recombination followed by natural selection. In this way biologically negative traits (large corm etc.) will be eliminated and "wild" genes will become predominant. The resulting individuals can be considered as wild types with some genes originating from cultivated germplasm and not as "escapes".

"Escapes" from cultivation remain genetically more or less unchanged. The phenotypic changes are mainly the result of the effects of the environment.

According to the environmental adaptability, wild taro germplasm can be divided into:

- wetland or swampy types
- dryland or upland types (they usually rot in swampy environment)
- intermediate or neutral types (adapted for wide range of environments)
- genotypes tolerant to shade
- genotypes tolerant to salinity.

For taro breeders, the most useful systematization includes data about resistance and/or tolerance to pests and diseases. The majority of resistance genes against *Phytophthora colocasiae* (taro leaf blight) Alomae - Bobone virus complex (ABVC) and nematode infections caused by *Hirschmanniella miticausa* in PNG and the Solomon Islands originate from wild germplasm.

Another very useful approach in classification of wild taro genotypes is according to the ploidy level which includes three main groups: diploids (2n = 28), triploids (3n = 42) and tetraploids (4n = 56).

MATERIALS AND METHODS

The studies include wild taros growing: (a) out of their original environment (44 collected samples) and (b) in their original or natural environment.

Wild taro studied out of its original environment in this paper originated from Mt. Hagen area, Kuk, Dolsor, swampy areas near Hati Agricultural College (Western Highlands Province); Barawaghi (Simbu Province); Boana, Gaing, Wampit region, Omsis, Lake Wanum, Gabensis, Labu Butu, Lae area, Wapi, Bukaua, Situm, Upper Markham Valley and Bubia (Morobe Province); Bangkok (Thailand); Phillppines and Solomon Islands. The collected (wild taro) material was planted at the agricultural research farm at Bubia Research Centre inside alleys of *Gliricidia sepium* planted at a spacing distance of 7 metres.

The first screening was conducted immediately after the growth had been fully established. This screening included mainly the resistance to TLB (taro leaf blight) and tolerance to ABVC (Alomae - Bobone virus complex). Unfortunately all genotypes were found to be susceptible or their level of resistance (tolerance) was too low.

Detailed study of the collected germplasm took place from March to July, 1994. Wild genotypes were analyzed for growth vigour, earliness, density tolerance, leaf position, leaf shape, flowering ability, self-compatibility, fertility and corm characteristics. As a result of this analysis, wild taros were classified into four groups;

1. *true wild taro,*
2. *wild taro with some characteristics of cultivated genotypes,*
3. *Wild taro with some of the genes originating from cultivated genotypes via natural crossings,*
4. *escapes from cultivation.*

Plants with at least one desired characteristics (excluding flowering ability) were immediately used in hybridization.

Wild populations in their original (natural) environment were studied in 16 locations in Morobe and Madang Provinces. In addition, the study included three artificially created, segregating populations and two "populations" of cultivars (Numkowi, Ph-15). The total number of studied populations was 21 (Table 1). The data (plant height, leaf length, leaf width, number of leaves in function, number of veins, population density, frequency of flowering plants, corm flesh pigmentation, stolone number and length, incidence of TLB, incidence of ABVC) were collected during the rainy season in July - August, 1994. Leaf measurements were taken on maximally developed leaf.

RESULTS

Studies of wild taro populations out of their original environments

The analysis of wild taro 'populations' out of their original environments indicated that variation within and between studied samples of these wild taro populations was not high. There was high uniformity in leaf shape, lamina position, plant height, flowering ability, corm shape and corm flesh pigmentation. The most significant differences appeared in leaf petiole pigmentation.

Table 1. **List of taro populations studied in their original environments.**

Location number	Location/population name
1	Bubia Mountain (Morobe Province)
2	Brahman (Madang Province)
3	Labu 1, close to Markham River, near Lae (Morobe Province)
4	Labu 2, next to Labu 1
5	Omsis, road to Bulolo (Morobe Province)
6	Open pollinated population "N", Bubia A.R.C. field (Morobe Province)
7	Ph-17 (semi-wild genotypes) Bubia A.R.C.
8	Numkowi (local cultivar), Bubia A.R.C.
9	Open pollinated population "P", Bubia A.R.C.
10	Population developed from cross: wild genotype from Bangkok x genotype S-NK from the Solomon Islands, Bubia A.R.C.
11	Population from area between Gebensis and Wabit village (Morobe Province)
12	Population 1km away from location 11
13	Wampit area, road Lae-Bulolo (Morobe Province)
14	Samsam village, road Lae-Bulolo
15	Mumeng River (island), Morobe Province
16	Labu plantation (Morobe Province)
17	Yong, road to Boana (Morobe Province)
18	Moimbung, road to Boana
19	Bema, road to Boana
20	Bema, 1km away from location 19
21	Boana (Morobe Province)

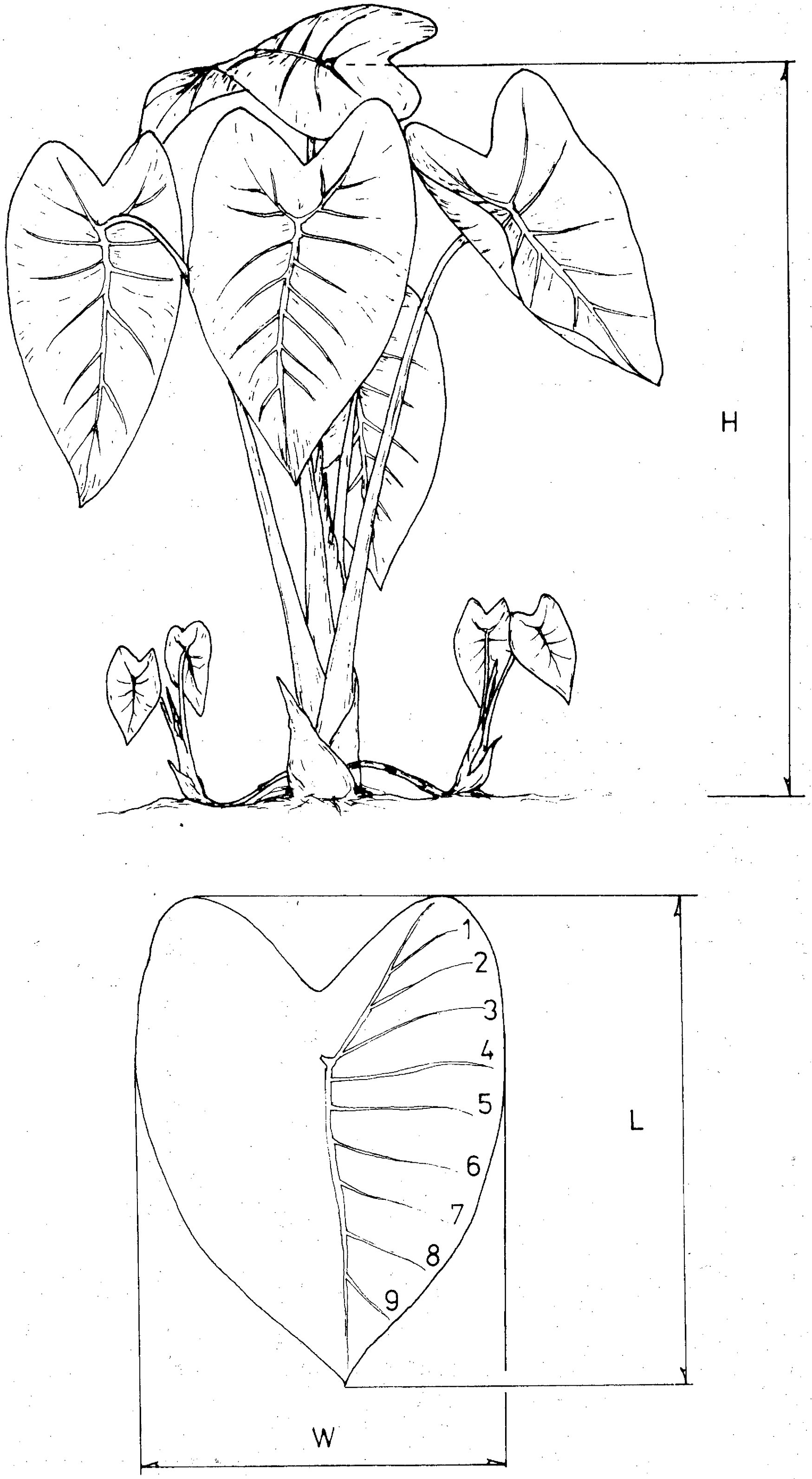
Table 2. **Variation of plant height measured (cm).**

Location	N	Mean	S. Dev	C.V.	Min.	Max.
1	30	102.01	14.52	14.23	77.8	131.8
2	40	122.57	11.05	9.01	102.2	149.5
3	20	85.57	8.63	10.08	71.2	108.5
4	40	64.74	6.68	10.32	50.0	80.0
5	40	105.61	13.64	12.91	79.8	149.2
6	50	60.83	9.67	15.90	41.3	85.3
7	30	87.03	7.14	8.20	74.5	106.8
8	30	70.58	5.98	8.47	61.0	82.5
9	61	67.41	10.61	15.74	45.5	93.5
10	50	54.64	10.55	19.31	34.9	78.9
11	30	97.00	7.73	7.97	80.7	112.2
12	29	133.25	16.39	12.30	95.7	165.8
13	20	106.66	26.87	25.19	33.3	150.0
14	20	139.47	15.66	11.23	104.4	165.7
15	21	57.41	12.71	22.14	40.0	85.6
16	30	87.20	15.04	17.25	61.5	121.5
17	25	94.68	22.73	24.01	57.5	129.0
18	26	101.96	26.31	25.80	60.6	145.0
19	30	150.71	24.00	15.92	89.0	230.0
20	27	134.28	14.58	10.86	103.5	180.3
21	51	106.70	16.34	15.31	75.6	133.0

Table 3. **Variation of leaf length measured (cm).**

Location	N	Mean	S. Dev.	C.V.	Min.	Max.
1	30	48.68	4.58	9.41	41.2	58.5
2	40	51.38	3.39	6.60	45.0	58.5
3	20	41.80	4.82	11.53	33.3	51.0
4	40	27.08	3.56	13.15	14.4	34.2
5	40	43.22	6.42	14.85	22.9	55.2
6	50	36.58	6.46	17.66	25.4	50.4
7	30	37.34	3.16	8.46	32.6	46.9
8	30	53.95	4.07	7.54	44.8	63.5
9	61	41.38	6.02	14.55	26.2	52.7
10	50	36.31	6.42	17.68	22.7	58.1
11	30	29.66	2.73	9.20	25.5	36.0
12	29	58.38	7.43	12.73	43.4	73.3
13	20	37.07	2.87	7.74	31.6	42.2
14	20	53.70	7.58	14.11	44.2	69.0
15	21	33.79	5.91	17.49	22.2	43.5
16	30	41.75	5.45	13.05	30.6	53.0
17	25	47.28	9.48	20.05	33.3	66.1
18	26	48.45	9.06	18.70	33.0	67.0
19	30	64.22	7.36	11.46	49.5	82.5
20	27	69.31	7.37	10.63	58.0	88.1
21	51	50.40	11.07	21.96	29.5	83.5

Figure 1. **Taro plant and leaf lamina showing parts measured; H - plant height, L - leaf length, w - leaf width, 1...9 - number of veins.**



The majority of the collected wild genotypes had green leaves with some red pigmentation on upper portion of the leaf petiole. Only few accessions were characterized by other types of petiole pigmentation (purple or purple-brown, dark red, light red, light green or white-green, green with purple or red stripes, red with green stripes and green with light white-green stripes). Genotypes with these (for wild taro) usual pigmentations were considered to have some genes originating from cultivated genotypes. Most of them produced both runners and suckers.

Quantitative characteristics (plant height, leaf dimensions etc.) could not be studied properly. The field conditions at Bubia ARC were not natural for wild taro. Plants were more or less all seriously affected by drought. For this reason it was decided to study quantitative characteristics in naturally grown wild taro populations, in their original environments.

Studies of naturally grown wild taro populations

1. Population size and density

The majority of investigated naturally growing wild taro populations were growing in optimal environments. The micro-environments were usually not uniform. Taro plants were forming associations or communities with other plant species.

The size of populations depended on several factors such as vigour of wild taro individuals, number and vigour of stolons, presence of *P. colocasiae* - leaf blight, density pressure of other plant species, insects, shade, soil moisture etc. It was difficult to find large population with uniform density. Populations were often split into smaller sub-populations which included from thirty to two hundred taro individuals. The most frequent average densities within populations varied from 0.8 to 4 taro plants per square metre. The typical (compact) taro populations however, were usually very dense (overcrowded) with eight or more individuals per square metre.

The largest series of populations were found in Brahman (Madang Province) with more than 15,000 taro plants. The density was very high, varying from 6 - 10 plants per square metre. This extreme density was probably the result of optimal, humid climate, rich soil, low population pressure of other plant species and high

Table 4. **Variation of leaf width measured (cm).**

Location	N	Mean	S. Dev.	C.V.	Min.	Max.
1	30	36.79	4.34	11.80	29.7	46.2
2	40	37.84	2.50	6.61	31.5	42.6
3	20	31.02	4.06	13.09	23.6	39.3
4	40	19.97	2.42	12.12	14.6	24.9
5	40	31.47	4.06	12.90	22.8	40.5
6	50	25.09	4.86	19.37	16.2	37.6
7	30	25.72	2.15	8.36	22.4	31.0
8	30	37.41	3.18	8.50	31.2	43.4
9	61	28.98	4.83	16.67	19.5	39.7
10	50	24.76	5.49	22.17	14.8	43.3
11	30	21.80	2.20	10.09	18.4	26.2
12	29	42.93	5.47	12.74	33.2	55.7
13	20	26.19	2.81	10.73	20.9	32.5
14	20	39.88	5.78	14.49	31.9	51.6
15	21	25.47	4.65	18.26	16.0	32.6
16	30	31.40	4.60	14.65	22.9	42.2
17	25	31.03	6.64	21.40	21.2	44.3
18	26	31.36	6.72	21.43	20.7	47.1
19	30	41.58	4.65	11.18	31.4	52.7
20	27	45.59	5.80	12.72	33.2	60.9
21	51	34.37	7.41	21.56	23.0	53.7

Figure 2. **Frequency distribution for number of veins (counted on half of the leaf blade) and leaf blade length estimated in a wild taro population in Boana (Morobe Province). The distributions indicate the presence of two distinct sub-groups within the population.**

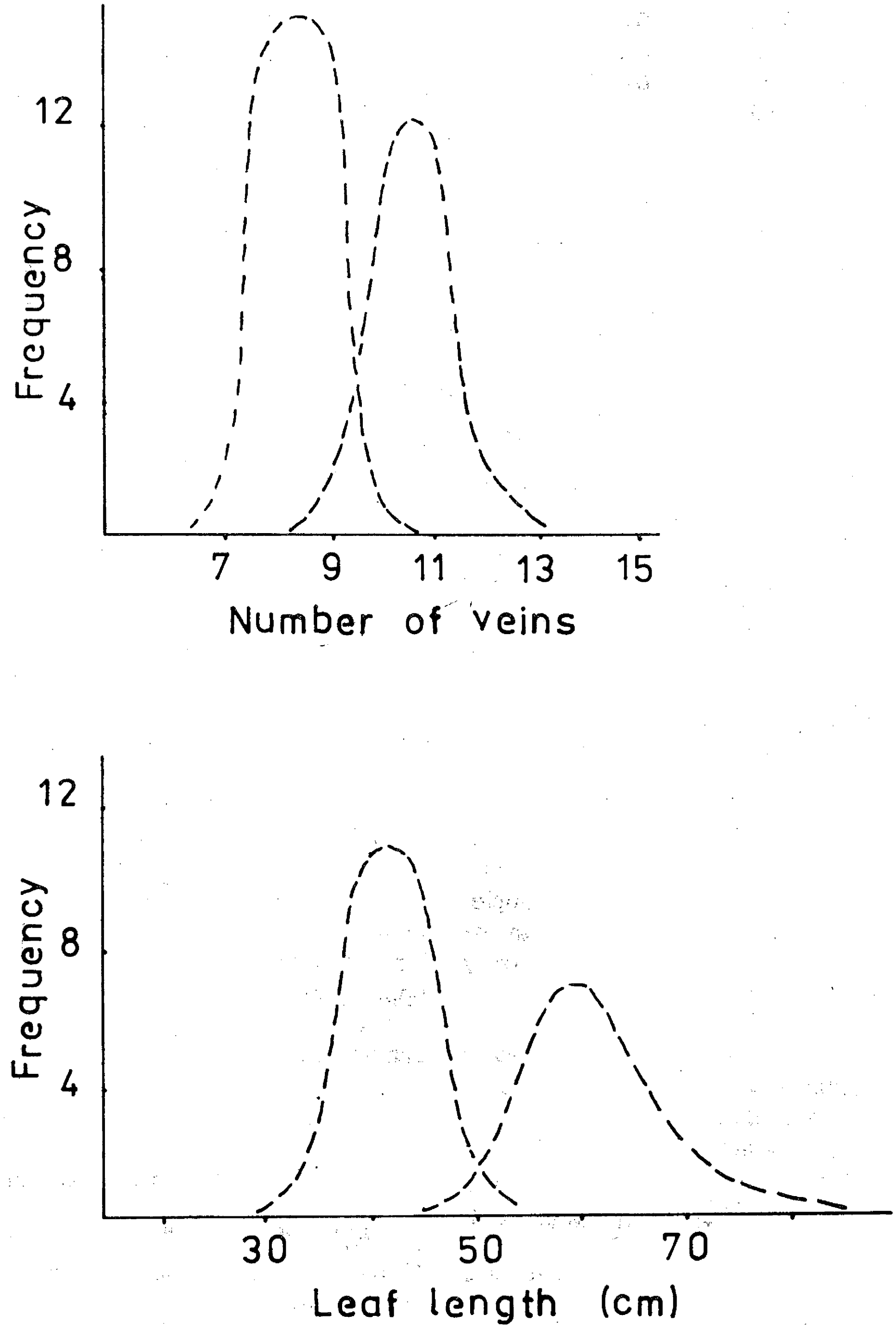


Table 5. **Variation of leaf width: leaft length ratio.**

Location	N	Mean	S. Dev.	C.V.	Min.	Max.
1	30	0.75	0.027	3.60	0.70	0.81
2	40	0.74	0.024	3.24	0.68	0.79
3	20	0.74	0.021	2.84	0.70	0.79
4	40	0.74	0.084	11.35	0.58	1.24
5	40	0.73	0.067	9.18	0.60	1.00
6	50	0.68	0.050	7.35	0.57	0.90
7	30	0.69	0.043	6.23	0.62	0.89
8	30	0.69	0.033	4.78	0.61	0.76
9	61	0.70	0.062	8.86	0.55	0.93
10	50	0.68	0.097	14.26	0.47	1.24
11	30	0.73	0.027	3.70	0.68	0.82
12	29	0.74	0.071	9.59	0.66	1.07
13	20	0.71	0.073	10.28	0.62	0.91
14	20	0.75	0.069	9.20	0.52	0.84
15	21	0.75	0.024	3.20	0.71	0.81
16	30	0.75	0.032	4.27	0.70	0.86
17	25	0.66	0.042	6.36	0.52	0.71
18	26	0.65	0.058	8.92	0.49	0.74
19	30	0.65	0.021	3.23	0.62	0.71
20	27	0.66	0.042	6.36	0.50	0.71
21	51	0.69	0.118	17.10	0.59	1.49

pressure of *Phytophthora* leaf blight.

Continuous presence of *P. colocasiae* caused fast dying of taro leaves. Plants were uniformly susceptible and had only few younger leaves in function (Table 7). The reduced number of leaves enabled more plants to grow in the same area. The relationship, *P. colocasiae*: density of wild taro populations is far from being simple. This pathogen is continuously present. The heaviest pressure of the pathogen takes place during rainy season.

Wild taro population in Brahman will be studied in future more systematically. For this reason, in September 1994, several wild and semi-cultivated taro genotypes with different levels of resistance to the leaf blight were inserted inside naturally growing sub-populations.

2. Incidence of taro leaf blight and viruses

All investigated wild taro populations were found to be susceptible to the leaf blight and Alomae-Bobone virus complex. Two populations on the road to Boana (the altitude between 950 and 1050m) were found to be free of *Phytophthora* symptoms. Later, the test of the sampled plants at Bubia ARC showed that there was no resistance. The populations were free of the pathogen due to isolation or "escape".

3. Leaf and corm pigmentation

Leaf laminas of wild taro plants in all locations were more or less uniformly green. Leaf petioles were in majority green with some red pigmentation on the upper portion, next to the junction with the leaf lamina. Corm flesh pigmentation was white-yellow and uniform in all populations.

4. Plant height

Plant height was highly influenced by the environment. Population in location 19 (road to Boana) showed variation range (min. - max.) of 141.0 cm, C.V. 15.92% (Table 2). The plants were growing on slope and the tallest individuals were found on partly shaded spots or in small depressions which provided the taro plants with more water.

Populations growing on open, not shaded area were

Table 6. **Variation of number of veins (on one half of the leaf lamina).**

Location	N	Mean	S.Dev.	C.V.	Min.	Max.
1	30	10.03	0.41	4.08	9	11
2	40	11.17	0.59	5.28	10	12
3	20	7.95	0.59	7.42	7	9
4	40	9.55	0.70	7.33	8	11
5	40	10.05	0.77	7.66	8	12
6	50	8.24	0.91	11.04	7	11
7	30	9.43	0.99	10.50	8	12
8	30	9.87	0.56	5.67	9	11
9	61	9.62	1.04	10.81	6	11
10	50	9.60	0.98	10.21	7	11
11	30	8.30	0.52	6.27	7	9
12	29	10.59	0.85	8.03	9	12
13	20	10.20	0.68	6.67	9	12
14	20	10.20	0.74	7.26	9	11
15	21	9.57	0.66	6.90	8	10
16	30	10.83	0.78	7.20	9	12
17	25	8.92	0.93	10.43	7	11
18	26	9.23	1.12	12.13	7	11
19	30	9.93	0.44	4.43	9	11
20	27	10.18	0.54	5.30	9	11
21	51	9.31	1.35	14.50	7	13

characterized with smaller and shorter plants. As an example is the population from Mumeng River island - location 15 (Table 2).

5. Leaf dimensions

Taro leaf length and width are highly correlated characteristics (Table 9). The largest leaves were observed generally on higher altitudes (> 1000 m) - location 19, 20, 21, (Fig. 1), (Tables 3 and 4). Leaf width: leaf length ratios (Table 5) indicate that the basic leaf shapes of wild taros in all studied populations were more or less the same. The density tolerance depends strongly on leaf shape. Long and narrow leaves are usually associated with vertical position, which enables more light to penetrate. Narrow leaves required for breeding for density tolerance (with w:l ratio lower than 0.5) were not found.

6. Number of leaf lamina veins

The number of veins counted on one half of the leaf blade (Fig. 1, Table 6) varied from 6 to 13 across populations. Variation of this characteristic within naturally grown wild taro populations was generally low in comparison with other measured traits. An exception was the population from Boana (location 21). Additional observation and analysis of variability indicated that the population consisted of two sub-groups (Fig. 2, Table 8).

Separation of the population from Boana into two subgroups resulted with the decrease of coefficient of variation (C.V.) for plant height, leaf length, leaf width and the number of veins (Table 8). This sounds logical because they are correlated characteristics (Table 9).

7. Number of leaves per plant

The number of leaves in function, counted on the main stem, was generally low (Table 7). The main reason was *Phytophthora* leaf blight or other factors associated with high density or presence of twisting plants. Generally, higher number of leaves was observed in artificially created populations (number 6,8,9,10-Table 7).

Table 7. **Variation of number of taro leaves (counted on the main stem).**

Location	N	Mean	S.Dev.	C.V.	Min.	Max.
1	30	1.90	0.39	20.53	1	3
2	40	3.15	0.42	13.33	2	4
3	20	3.15	0.36	11.43	3	4
4	40	2.17	0.67	30.87	1	3
5	40	2.55	0.74	29.02	1	4
6	50	4.96	1.23	24.80	2	7
7	30	2.87	0.76	26.48	2	5
8	30	4.33	0.74	17.09	3	6
9	61	4.54	0.88	19.38	3	7
10	50	4.06	1.01	24.88	2	6
11	30	2.37	0.48	20.25	2	3
12	29	4.38	1.27	28.99	3	8
13	20	3.10	0.43	13.87	2	4
14	20	3.45	0.50	14.49	3	4
15	21	2.76	0.68	24.64	2	4
16	30	2.07	0.51	24.64	1	3
17	25	2.92	0.89	30.48	2	5
18	26	3.08	0.47	15.26	2	5
19	30	3.40	0.61	17.94	2	5
20	27	2.92	0.46	15.75	2	4
21	51	3.02	0.67	22.18	2	5

Table 8. **Variability of the population 21 (Boana) after separation into two sub-groups.**

	Group	N	Mean	S.Dev.	C.V.	Min.	Max.
Plant height (cm)	A	28	100.47	14.99	14.92	75.6	129.5
	B	23	114.29	15.30	13.39	85.4	133.0
Leaf length (cm)	A	28	42.69	5.48	12.84	29.5	51.2
	B	23	59.79	8.93	14.93	47.4	83.5
Leaf width (cm)	A	28	28.56	4.79	16.77	23.0	44.0
	B	23	40.21	5.82	14.47	30.2	53.7
Number of veins	A	28	8.39	0.68	8.10	7	10
	B	23	10.43	1.21	11.60	9	13
Number of leaves	A	28	2.86	0.52	18.18	2	4
	B	23	3.22	0.79	24.53	2	5
Leaf width : leaf length ratio	A	28	0.701	0.160	22.82	0.59	1.49
	B	23	0.673	0.026	3.86	0.64	0.72

Table 9. **Correlations between studied wild taro characteristics.**

	A	B	C	D	E
B	0.9715**				
C	0.7565**	0.7694**			
D	0.4328*	0.5188*	0.4369*		
E	0.1930	0.1459	- 0.1406	- 0.1211	
F	-0.4149	- 0.1936	- 0.1694	0.1965	- 0.3443

* P < 0.05
** P < 0.01

A ..... Leaf length
B ..... Leaf width
C ..... Plant height
D ..... Number of veins
E ..... Number of leaves
F ..... Leaf width : leaf length ratio

8. Flowering ability

All studied taro populations were found to have at least a few flowering plants. The frequency of flowering plants varied from 3 to 100%. The highest frequency of flowering plants were observed among artificially created wild populations (populations grown out of their natural environment).

Seed set was found to be very common, similarly to flowering ability.

Good flowering ability of wild taro has already been efficiently used in PNG Taro Breeding Programme. Wild taros were used in basic crosses (in cycle zero of the recurrent selection). The offspring generations were vigorously flowering but had several undesired wild characteristics (low yield, low eating quality). The flowering ability was improving from cycle to cycle automatically because, in absence of artificial treatment with flowering hormones, the non-flowering genotypes were not able to contribute to the gene pool of the next cycle (generation).

DISCUSSION

Processes and structure of wild taro populations are much different from those described in classical population studies. Wild taro is predominantly vegetatively propagated. This does not mean that the genetic recombination is not present. The flowering process and seed set is very common but the chances of seed to germinate and develop to a mature individual are extremely low.

It is difficult to say what is the important source of genetic variations of wild taro: hybridization, self-pollination or mutagenesis. Genetic changes in vegetatively propagated individuals are subjected to bud mutations. The frequencies of occurrence of these mutations, according to Wright (1977) seem to be no greater than the rates usually ascribed to gene mutations. The mutation rate of an individual gene is very low, but when taking into account thousands of genes and thousands of plants (with numerous buds) in large taro populations, one can easily conclude that mutants are always present.

Phenotypic uniformity of wild taro populations is not necessarily associated with genotypic uniformity. Phenotypic uniformity is mainly the result of a long term evolution while genotypic uniformity originates from continuous vegetative propagation.

The evolution of taro is probably slow due to predominant vegetative propagation. There are several factors which are responsible for the evolution of wild taro populations such as interspecific competition, interaspecific competition, environmental pressure (climate, diseases, pests), frequency and efficiency of genetic recombinations and frequency of mutations.

Intraspecific and interspecific competition can be often characterized as a density pressure. Broad leaves of taro are not suitable for high densities, but they can be very efficient in control of the number other plant individuals (belonging to other species) in a community. Heavy density pressure and individual differentiation in wild taro communities usually results in certain balanced density where no more individuals can be accepted.

Balanced density is not equal to optimal density. It provides certain level of stability in a plant (taro) community. Optimal density of taro plants in a community is usually much lower. Lower densities enable other plant species present inside or around particular community to spread, increase their number and become dominant. The domination can affect taro population seriously, especially if twisting plants and climbers are involved. They usually do not eliminate taros completely, but they can reduce their number significantly. One of the typical species that taros in PNG hardly resist is the giant *Mimosa*. It is one of few species which can destroy taro populations totally.

Stable wild taro communities in Papua New Guinea and Solomon Islands are overcrowded. In such communities taro plants are thin and the leaf number is reduced. The process of self-thinning in wild taro communities results in very uniform, compact, dense and stable populations. Taro individuals in a community usually have very similar genetic structure. Frequently they originate from the same plant and for this reason they are affected more or less equally.

Overcrowded communities can be found among several vegetatively propagated perennial species, especially grasses. The structure, processes and regulation mechanisms in such communities were described by Yoda *et al.* (1963), Kays and Harper (1974) and Hutchings (1979).

Very intensive processes can be observed on the edges of a balanced, stable and overcrowded community. The edge of a community is the place where two communities meet. It can be characterized as a place of permanent "struggle" for dominance. As an example are wild taro populations within plant communities in Brahman.

The competition on edges of wild taro communities in Brahman was very strong. Interspecific competition (competition between plants belonging to different species) was much more important. The incidence of the leaf blight was lower and the plants were stronger. They produced more and longer stolons. They tried to expand to the area inhabited by other plants, mainly grasses. Grasses too, were healthier and stronger on the edge and tried to expand inside taro population. The actual edge probably represented the equilibrium between the expansion of taros and the penetration of grasses.

Based on limited number of short term observations, it is impossible to describe and characterize processes in wild taro populations and communities. Vegetative propagation requires even longer period of time for their investigation.

All investigated PNG wild taro populations were found to be susceptible to taro leaf blight (TLB) and to Alomae-Bobone virus complex (ABVC). As a result of continuous presence of TLB, the average number of matured functional leaves per plant appears to be very low in number. Lower number of leaves enables more plants to grow per unit area.

For pioneer taro breeding, wild genotypes are extremely important source of genes for disease resistance, flowering ability, seed productivity, specific environmental adaptability, earliness and growth vigour.

Papua New Guinea wild taro populations analyzed in this paper are showing relatively high uniformity in majority of the qualitative characteristics; plant pigmentation, corm shape, corm pigmentation, leaf shape, and quantitative characteristics; plant height, leaf dimensions, number of leaves, number of veins on leaf surface.

The relatively low variation within populations is mainly the result of continuous vegetative propagation and limited chances of a seed to germinate and develop to a mature plant.

REFERENCES

ALLARD, R.W. (1992). Predictive methods for germplasm identification. pp. 119-146. *In: Plant breeding in the 1990s.* Ed. by Stalker, H.T., and Murphy, J.P.; C.A.B. International.

CONNELL, J. (1978). The death of taro: Local response to a change of subsistence crops in the North Solomon Islands. *Mankind* 11: 445-452.

HUTCHINGS, M.J. (1979). Weight - density relationships in ramet populations of clonal perennial herbs with special reference to the power law. *J. of Economy* 67: 21-33.

IVANCIC, A. (1992). Final report on taro breeding. UNDP/UNV/FAO/Ministry of Agriculture and Lands, Solomon Islands. *(Unpublished).*

KAYS, S. and HARPER, J.L. (1974). The regulation of plant and tiller density in grass sward. *J. of Ecology* 62: 97-105.

LEBOT, V. and ARADHYA, K.M. (1991). Isozyme variation in taro

Colocasia esculenta (L) Schott. from Asia and Oceania. *Euphytica* 56: 55-66.

MATTHEWS, P.J. (1990). The origins, dispersal and domestication of taro. *Ph.D, Thesis.* Australian Nat. University.

PACKARD, J.C. (1975). The Bougainville taro blight. University of Hawaii, Pacific Islands Programme. *Miscellaneous Working Papers, 1975*: 1.

PLUCKNETT, D.L. (1984). Edible Aroids. *In: Evolution of Crop Plant.* Simmonds, N.W., (Ed.) Longman. London and New York.

PURSEGLOVE, J.W. (1972). *Tropical Crops-Monocotyledons.* Longman London.

WRIGHT, S. (1977) Evolution and the genetics of populations Vol. 3. *Experimental results and evolutionary deductions.* The Univ. of Chicago Press. Chicago and London. p. 145.

YODA, K., KIRA, T., OGAWA, H. and HOZUMI, K. (1963). Self thinning in overcrowded pure stands under cultivated and natural conditions. *J. of Biology, Osaka City Univeristy* 14: 107-129.