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CLASSIFICATION OF CITRUS SPECIES ON YAP ISLAND AND ULITHI ATOLL OF THE FSM

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Abstract

The *Citrus spp.* found on Yap and four inhabited islands of the Ulithi Atoll (Mogmog, Falalop, Asor, and Fassarai Islands) of Yap State of the Federated States of Micronesia (FSM) were collected and classified to the species level using morphological characteristics and isozyme analysis. Citrus individuals collected on Yap Island were determined to belong to one subgenus, six species, and three were hybrids between species while those collected on Mogmog and Falalop Islands belonged to three species. On both islands three hybrids between species were identified among the individuals collected. On the other hand citrus collected on Asor Island were classified into two species and one hybrid while those samples collected on Fassarai Island belonged to two species.

Keywords: citrus, isozyme genotype, morphological character, Yap Island, Ulithi Atoll

Introduction

Although environmental conditions would allow for the production of citrus in Yap State of the Federated States of Micronesia (FSM), citrus production in Yap State and the FSM has not become an agricultural industry of economic importance (TOMINAGA et al. 1995b). Tropical fruits, including citrus, are grown throughout the FSM by home owners for personal consumption (TOMINAGA et al. 1995a)

A survey of the distribution of *Citrus spp.* grown on Yap Island and four inhabited islands (Mogmog, Falalop, Asor, and Fassarai Islands) of the Ulithi Atoll was conducted. Seventy-one samples consisting of leaves, fruit, and shoots of the citrus species surveyed were collected and the individuals were classified based on morphological characteristics (leaf and fruit shape, number and color of the seed, embryony) and the isozyme genotype of the leaf enzymes. Additionally the Brix and acidity content of the fruits were determined. Since flowers were not available for botanical classification purposes, the classification to the species level was based on both morphological and isozyme data to ensure accuracy.

Materials and Methods

The survey of *Citrus spp.* was carried out on Yap and the four inhabited islands of the Ulithi Atoll from October 17 to 30 of 2001. Sample collection consisted of thirty-nine *Citrus spp.* samples collected on Yap, twelve samples collected on Mogmog, ten samples collected on Falalop, four collected on Asor, and six citrus samples collected on Fassarai Island for a total of 71 *Citrus*

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spp. samples collected. A sample consisted of 30 leaves and 3 fruits from each tree except when the tree had no fruit then only 30 leaves were collected.

At the time of sampling, morphological characters such as leaf shape, presence and shape of leaf wings, leaf flavor, fruit shape, stylar end convexity, fruit diameter and weight, fruit shape index, and rind color were determined. Using these data, the morphological classification was done according to the scheme developed by IWAMASA (1976). The samples were then frozen and conveyed to Kagoshima University for flesh weight, percent flesh, seed number, seed weight, embryony, embryo color, Brix and acidity determinations and isozyme analysis. Isozyme analysis consisted of glutamate oxaloacetic transaminase (GOT) and peroxidase (Px) content determinations which was then related to sample genotype. The methods described by YAMAMOTO et al. (1998) were used to determine isozymes and leaf genotype and subsequent classification into species using these data were determined by the method of HIRAI et al. (1986, 1987). All data were used to categorize each sample into species. The species were described according to the classifications developed by SWINGLE (1967).

Results and Discussion

Yap Island

Based on the morphological characters of the 39 samples collected on Yap Island, the samples could be classified into eight citrus groups. Six samples were papedas, 3 were pummelos, 10 sweet oranges, 6 ponkan mandarins, 6 calamondins, 4 sour oranges, 1 lime and 3 un-identified citrus (Table 1). On the other hand, isozyme genotyping resulted in a classification of the citrus samples into 5 papedas (Purutt), 3 pummelos, 7 sweet oranges, 4 mandarins (India type), 5 mandarins (China x India type), 6 calamondins, 3 sour oranges, and 6 un-identified citrus (Table 1). Based upon morphological characters, isozyme genotype, and embryony the *Citrus spp.* collected on Yap Island belong to 1 subgenus papeda and 38 species and hybrids. And the species and hybrids within the 38 samples were 3 pummelos (*Citrus grandis* (L.) Osbeck), 2 sour oranges (*C. aurantium* L.), 5 sour orange hybrids (*C. aurantium* hybrid), 1 lime hybrid (*C. aurantifolia* hybrid), 3 papedas (Purrut) (*C. hystrix* DC.), 2 papedas hybrids (*C. hystrix* hybrid), 6 calamondins (*C. madurensis* Lour.), 7 sweet oranges (*C. sinensis* (L.) Osb.), and 9 mandarins (*C. reticulata* Blanco). The nine mandarins identified were of two types, the India and the China x India type (Table 1).

Mogmog Island

The 12 samples collected from citrus plants growing on in Mogmog Island were classified, using morphological characteristics, into 4 groups. Six of the samples were papedas, three were calamondins, one was sweet orange and 2 were un-identified citrus. Isozyme genotyping revealed that the genotype of the Mogmog Island samples could be separated into 6 papedas (Purutt), 2 calamondins, 1 sweet orange, and 2 un-identified citrus. When the classification scheme is based upon morphological characters, isozyme genotyping, and embryony the citrus samples could be separated into 5 papedas (Purrut) (*C. hystrix* DC.), 1 papeda (Purrut) hybrid (*C. hystrix* hybrid), 3 calamondins (*C. madurensis* Lour.), and 1 calamondin hybrid (*C. madurensis* hybrid), 1 sweet orange (*C. sinensis* (L.) Osb.), and 1 sour orange hybrid (*C. aurantium* hybrid) (Table 2).

Falalop Island

Based on morphological characters the 10 samples collected on Falalop Island were

classified into 3 groups (2 limes, 2 lemons, and 6 papedas). Isozyme genotyping resulted in classifying the same samples into four groups (6 papedas (Purutt), 1 Tahiti lime, 2 lemons and 1 unidentified citrus). When morphological characters, isozyme genotype and embryony were used as classification tools, the same samples fell into seven groups (5 papedas (Purrut) (*C. hystrix* DC.), 1 papeda (Purrut) hybrid (*C. hystrix* hybrid), 3 calamondins (*C. madurensis* Lour.), 1 Tahiti lime (*C. aurantifolia* Swing.), 1 Tahiti lime hybrid (*C. aurantifolia* hybrid), 1 lemon (*C. limon* Burm. f.), and 1 lemon hybrid (*C. limon* hybrid) (Table 3).

Asor Island

The four samples collected on Asor Island when classified using only morphological characters could be placed into three groups (1 papedas, 2 calamondins, 1 lime). Isozyme genotyping revealed that the same samples could be classified into two groups (1 papedas (Purutt) and 3 calamondins). When morphological characters, isozyme genotype and embryony were used as classification tools, the four samples fell into three groups (1 papedas (Purrut) (*C. hystrix* DC.), 2 calamondins (*C. madurensis* Lour.), and 1 calamondin hybrid (*C. madurensis* hybrid)) (Table 4).

Fassarai Island

Classification of the six samples collected on Fassarai Island using morphological characters only, placed the samples into two groups (5 papedas and one lime). Isozyme genotyping placed the samples into two groups as well (5 papedas (Purutt) and 1 Tahiti lime). When morphological characters, isozyme genotyping, and embryony were used as classification tools, the samples could again be grouped into two groups (5 papedas (Purrut) (*C. hystrix* DC.) and 1 Tahiti lime (*C. aurantifolia* Swing.)) (Table 5).

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Table 1. Characteristics of leaves and fruits of citrus collected on Yap Island of the FSM

No	Leaf[w] wing	Stylar[x] end convex	Fruit			Seed Number	Embryo		Brix	Acidity (%)	Isozyme genotype			Species assumed by		Species[z] identified by morphology and isozyme analysis
			Weight (g)	Shape index	Flesh (%)		Embryony	Colour[y]			Got-1	Got-2	Px	Morphology	Isozyme analysis	
1	L	N	1058	114	61	42	Mono	C	8.6	0.5	FF	MM	BB	Pummelo	Pummelo	*C. grandis* (L.) Osb.
2	M	N	942	120	51	5	Mono	C	10.5	0.3	FF	MM	BB			
3	M	No fruit									FF	MM	BB			
4	M	N	73	125	64	43	Poly	PG	7.5	1.7	FF	MM	CC	Papeda	Un-identified	Subgenus papeda
5	N	C	107	86	63	0	-	-	6.8	1.2	FS	MM	DD	Sour orange	Un-identified	*C. aurantium* hybrid
6	N	C	60	97	78	9	Mono	NG	7.7	1.9	FS	MM	CC	Lime	Un-identified	*C. aurantifolia* hybrid
7	N	N	48	99	69	12	Poly	G	8.1	1.7	FS	MM	CC	Sour orange		*C. aurantium* hybrid
8	N	C	78	94	73	16	Poly	G	7.9	1.9	FS	MM	CC			
9	S	N	227	110	54	27	Mono	C	8.1	0.4	SA	MM	BD	Sweet orange	Sour orange	*C. aurantium* hybrid
10	S	N	127	104	69	36	Poly	PG	8.1	0.5	SA	MM	BD			*C. aurantium* L.
11	S	N	261	105	62	42	Poly	C	7.8	0.6	SA	MM	BD			
12	L	C	31	62	58	10	Mono	G	8.6	1.5	SM	MM	CC	Papeda	Papeda (Purrut)	*C. hystrix* DC.
13	L	C	23	66	49	6	Mono	NG	9.2	1.9	SM	MM	CC			
14	L	C	22	70	58	6	Poly	G	9.4	1.9	SM	MM	CC			*C. hystrix* hybrid
15	L	C	28	61	43	5	Poly	G	9.6	1.9	SM	MM	CC			
16	L	C	23	54	47	0	-	-	8.6	1.1	SM	MM	CC			*C. hystrix* DC.
17	N	N	28	109	73	6	Poly	G	7.2	0.6	SM	MM	DF	Calamondin	Calamondin	*C. madurensis* Lour.
18	N	N	27	109	76	8	Poly	NG	10.8	1.0	SM	MM	DF			
19	N	N	21	111	76	7	Poly	G	8.4	1.2	SM	MM	DF			
20	N	N	24	114	76	8	Poly	PG	11.5	1.0	SM	MM	DF			
21	N	N	28	109	79	7	Poly	G	8.4	1.0	SM	MM	DF			
22	N	N	33	115	-	11	Poly	G	-	-	SM	MM	DF			
23	S	N	248	105	61	37	Mono	C	7.9	0.6	SS	MM	BD	Sour orange	Un-identified	*C. aurantium* hybrid
24	S	N	209	100	95	16	Poly	PG	7.6	0.8	SS	MM	DD	Sweet orange	Sweet orange	*C. sinensis* (L.) Osb.
25	N	N	174	107	74	18	Poly	PG	10.1	0.3	SS	MM	DD			
26	N	N	266	93	70	25	Poly	C	7.7	0.3	SS	MM	DD			
27	N	N	225	97	65	16	Poly	C	7.6	0.2	SS	MM	DD			
28	N	N	193	104	72	25	Poly	C	8.2	0.4	SS	MM	DD			
29	N	N	285	102	72	29	Poly	C	8.4	0.3	SS	MM	DD			
30	S	No fruit									SS	MM	DD	Un-identified		
31	S	N	336	102	64	6	Poly	PG	7.9	0.2	SS	MM	CC	Sweet orange	Mandarin (India type)	*C. reticulata* Blanco
32	N	No fruit									SS	MM	CC	Un-identified		
33	N	No fruit									SS	MM	CC			
34	N	No fruit									SS	MM	CC	Ponkan		
35	N	No fruit									SS	MM	CD		Mandarin (China type x India type)	*C. reticulata* Blanco
36	N	N	108	118	72	7	Poly	G	8.5	0.7	SS	MM	CD			
37	N	N	171	122	69	10	Poly	G	8.6	0.4	SS	MM	CD			
38	N	N	165	121	75	9	Poly	G	8.6	0.2	SS	MM	CD			
39	N	N	135	116	53	15	Poly	G	8.4	0.4	SS	MM	CD			

Abbreviations, [w]L=Large, M=Medium, S=Small, N=Without wing, [x]C=With convex, N=Without convex, [y]PG=Pale green, C=Cream, G=Green, NG=Nile green,
[z]Species classification based on Swingle (1967).

Table 2. Characteristics of leaves and fruits of citrus collected on Mogmog Island in Ulithi Atoll of the FSM

No	Leaf[w] wing	Stylar[x] end convex	Fruit			Seed Number	Embryo		Brix	Acidity (%)	Isozyme genotype			Species assumed by		Species[z] identified by morphology and isozyme analysis
			Weight (g)	Shape index	Flesh (%)		Embryony	Colour[y]			Got-1	Got-2	Px	Morphology	Isozyme analysis	
1	N	No fruit									FS	MM	DD	Un-identified	Un-identified	*C. aurantium* hybrid
2	N	No fruit									FS	MM	DF		Un-identified	*C. madurensis* hybrid
3	L	C	21	61	60	1	Mono	G	9.2	1.1	SM	MM	CC	Papeda	Papeda (Purrut)	*C. hystrix* DC.
4	L	C	28	64	45	6	Mono	G	9.2	0.9	SM	MM	CC			
5	L	C	32	68	65	12	Mono	G	8.2	1.7	SM	MM	CC			
6	L	C	20	62	50	2	Poly	G	8.0	1.1	SM	MM	CC			*C. hystrix* hybrid
7	L	No fruit									SM	MM	CC			*C. hystrix* DC.
8	L	No fruit									SM	MM	CC			
9	N	N	16	104	80	7	Poly	G	7.5	0.9	SM	MM	DF	Calamondin	Calamondin	*C. madurensis* Lour.
10	N	No fruit									SM	MM	DF			
11	N	No fruit									SM	MM	DF			
12	S	No fruit									SS	MM	DD	Sweet orange	Sweet orange	*C. sinensis* (L.) Osb.

Abbreviations, [w]L=Large, M=Medium, S=Small, N=Without wing, [x]C=With convex, N=Without convex, [y]PG=Pale green, C=Cream, G=Green, NG=Nile green,
[z]Species classification based on Swingle (1967).

Table 3. Characteristics of leaves and fruits of citrus collected on Falalop Island in Ulithi Atoll of the FSM

No	Leaf[w] wing	Stylar[x] end convex	Fruit			Seed Number	Embryo		Brix	Acidity (%)	Isozyme genotype			Species assumed by		Species[z] identified by morphology and isozyme analysis
			Weight (g)	Shape index	Flesh (%)		Embryony	Colour[y]			Got-1	Got-2	Px	Morphology	Isozyme analysis	
1	N	C	18	80	59	2	Poly	C	7.8	0.8	FF	MM	CC	Lime	Un-identified	*C. aurantifolia* hybrid
2	N	C	25	92	73	0	-	-	8.5	1.9	FF	SM	CC		Tahiti lime	*C. aurantifolia* Swing.
3	N	C	108	77	55	7	Mono	PG	6.3	1.4	FS	SM	CD	Lemon	Lemon	*C. limon* hybrid
4	N	No fruit									FS	SM	CD			*C. limon* Burm. f.
5	L	C	33	64	64	5	Mono	PG	8.4	1.4	SM	MM	CC	Papeda	Papeda (Purrut)	*C. hystrix* DC.
6	L	C	37	58	59	18	Mono	PG	8.2	1.6	SM	MM	CC			
7	L	C	38	65	66	13	Poly	PG	8.1	1.6	SM	MM	CC			*C. hystrix* hybrid
8	L	C	24	65	56	4	-	-	7.8	1.2	SM	MM	CC			
9	L	No fruit									SM	MM	CC			*C. hystrix* DC.
10	L	No fruit									SM	MM	CC			

Abbreviations, [w]L=Large, M=Medium, S=Small, N=Without wing, [x]C=With convex, N=Without convex, [y]PG=Pale green, C=Cream, G=Green, NG=Nile green,
[z]Species classification based on Swingle (1967).

Table 4. Characteristics of leaves and fruits of citrus collected on Asor Island in Ulithi Atoll of the FSM

No	Leaf[w] wing	Stylar[x] end convex	Fruit			Seed Number	Embryo		Brix	Acidity (%)	Isozyme genotype			Species assumed by		Species[z] identified by morphology and isozyme analysis
			Weight (g)	Shape index	Flesh (%)		Embryony	Colour[y]			Got-1	Got-2	Px	Morphology	Isozyme analysis	
1	L	C	32	55	59	11	Poly	G	8.0	1.1	SM	MM	CC	Papeda	Papeda (Purrut)	*C. hystrix* DC.
2	N	N	14	110	79	12	Poly	G	7.7	1.6	SM	MM	DF	Calamondin	Calamondin	*C. madurensis* Lour.
3	N	N	15	106	75	10	Poly	G	7.8	1.1	SM	MM	DF			
4	N	N	8	111	73	8	Poly	G	8.3	1.3	SM	MM	DF	Lime		*C. madurensis* hybrid

Abbreviations, [w]L=Large, M=Medium, S=Small, N=Without wing, [x]C=With convex, N=Without convex, [y]PG=Pale green, C=Cream, G=Green, NG=Nile green,
[z]Species classification based on Swingle (1967).

Table 5. Characteristics of leaves and fruits of citrus collected on Fassarai Island in Ulithi Atoll of the FSM

No	Leaf[w] wing	Stylar[x] end convex	Fruit			Seed Number	Embryo		Brix	Acidity (%)	Isozyme genotype			Species assumed by		Species[z] identified by morphology and isozyme analysis
			Weight (g)	Shape index	Flesh (%)		Embryony	Colour[y]			Got-1	Got-2	Px	Morphology	Isozyme analysis	
1	S	C	25	82	71	2	Mono	PG	6.6	1.3	FF	SM	CC	Lime	Tahiti lime	*C. aurantifolia* Swing.
2	L	C	31	54	55	4	Mono	PG	8.4	1.4	SM	MM	CC	Papeda	Papeda (Purrut)	*C. hystrix* DC.
3	L	C	15	59	56	3	Mono	G	8.6	0.8	SM	MM	CC			
4	L	No fruit									SM	MM	CC			
5	L	No fruit									SM	MM	CC			
6	L	No fruit									SM	MM	CC			

Abbreviations, [w]L=Large, M=Medium, S=Small, N=Without wing, [x]C=With convex, N=Without convex, [y]PG=Pale green, C=Cream, G=Green, NG=Nile green,
[z]Species classification based on Swingle (1967).