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Variety Trials, Sensory Evaluations and *in-Vitro* Multiplication of Sweetpotato (*Ipomea batatas*) in the Western Pacific

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ABSTRACT

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is one of the important subsistence food crops grown in the Northern Marianas. The quality and production of sweetpotato was severely affected in recent years, mainly by the introduction of major diseases and pests, paucity of quality planting material and natural disasters. Field trials of new varieties and sensory evaluations (taste testing) were successfully conducted throughout the islands of Saipan, Rota and Tinian. Seventeen varieties of tissue-cultured sweetpotato were evaluated for tolerance to insect pests and diseases, tuber quality, shape, yield, taste, texture and other superior agronomic and morphological characters. Red-purple skin varieties IB 098, IB 0701, IB 0702, IB 195 and IB 083 rated excellent for taste, texture, quality of tubers, easy cooking, plant growth and high yield. Yellow-orange and red-purple varieties with medium size tubers (9.0 cm) were preferred over the white skin and white flesh varieties. Sweetpotato weevil (*Cylas formicarius elegantulus*), flee beetle (*Chaetocnema affinis*), katydid (*Phaneroptera furcifera*) and grasshopper (*Locusta migratoria manilensis*) were the main insect pests that caused damage to the crops although rodents were also responsible to some extent. Bacterial stem and root rot (*Erwinia chrysanthemi*), leaf spot and stem blight (*Alternaria* spp.), scab (*Elsinoe batatas*) and anthracnose (*Collectrotrichum* spp.) were among the diseases observed. The introduced varieties were identified as economically and culturally important and have been tested for superior characteristics in the Pacific region. Selected varieties were propagated through tissue culture and distributed to the farmers throughout the Commonwealth. Results indicate that new varieties performed well in local soil and climatic conditions of the Northern Mariana Islands. Small collections of sweetpotato in the field at the Agriculture Research Station have been successfully maintained; however, land, labor and high production costs are limiting factors.

Keywords: constraints, Marianas, production, root crops, tissue culture

Abbreviations: BA, 6-benzyl adenine; **CNMI**, Commonwealth of the Northern Mariana Islands; **CePCT**, Center for Pacific Crops and Trees; **CREES**, Cooperative Research, Extension and Education Service; **CSREES**, Cooperative State Research, Extension and Education Service; **IAA**, indole-3-acetic acid; **NMC**, Northern Marianas College; **NRCS**, Natural Resource and Conservation Service; **SPC**, Secretariat of the Pacific Community; **TC**, tissue culture; **USDA**, United States Department of Agriculture

INTRODUCTION

Roots and tubers are important sources of food, nutrition and cash income for small-scale farmers in the Northern Mariana Islands. The increased incidences of insect pests and diseases and constraints affect production and marketing quality of these crops in the Commonwealth of the Northern Mariana Islands (CNMI) pose challenging tasks to small farmers (Nandwani *et al*. 2007; Nandwani 2009). Sweetpotato is an economically important food crop and is highly valued for its cultural, dietary and agriculture production in the CNMI (USDOI-OLA 1999). Nutritionally, sweetpotato is rich in fiber, calcium, potassium, iron, vitamin A, vitamin B1, vitamin B2, and vitamin C. The tubers are baked, roasted or boiled, and leaves represent a significant source of vitamins, especially folic acid (Anderson *et al*. 2007; Bourke 2009). In addition to being an important traditional food crop, sweetpotato is a significant export commodity. The island of Rota is the major producer of sweetpotato in the CNMI. The rainfall in the Sabana conservation area on the island of Rota is estimated to be as high as 260 cm annually, where sweetpotato is grown for commercial production. There are approximately a dozen cultivars of sweetpotato cultivated locally mainly white skin varieties. Sweetpotato is the most widely produced root crop in the CNMI. The total area under sweetpotato production in the CNMI in 2007 was 29 ha (Clark 2009). The total production of sweetpotato and quantity increased for 5 years between 2002 and 2007 (**Table 1**). Annually, over 50% of the sweetpotato produced on the island of Rota was exported to the neighboring island of Guam (approx. 1361 kg/week) and Saipan both for consumption as well as for traditional cultural ceremonies (Nakamoto *et al*. 1996).

The objectives of the sweetpotato variety trials program in the Northern Marianas are to introduce tissue-cultured plants of new varieties and to select high-yielding, drought, disease and insect pest-tolerant varieties with good tuber quality through selection and field evaluation. The seedlings derived from tissue culture (TC) were evaluated in a series of trials and on-farm trials in all three main islands of the Northern Marianas.

Traditional planting methods using shoot apexes for sweetpotato are time-consuming and labor-intensive. If the parent plant is infected with diseases, they are transmissible to the next generation, in spite of the application of fungicides or insecticides. Most commonly, diseases spread to new crops when infected cuttings are used as propagating material (Jackson 1991). TC is considered the most potential system to achieve the goals of producing quality and disease-free planting material (Taylor 1998). High production costs due to increased labor and management, spread of soil-born diseases and pests, limited genetic diversity and shortage of quality planting material are the major constraints of sweetpotato production in the CNMI (Esguerra and Rengiil 2000). Among the diseases, bacterial wilt, scab, anthracnose, stem and root rot are the most common in the CNMI (Quebral *et al*. 1989; Matalog 1992; Kohler *et al*. 1997). To meet the challenges of sweetpotato cultivation,

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Table 1 Production of sweet potato in the Northern Marianas for five years during 2007 and 2002.

	Year		Island					
			Rota		Saipan		Tinian	
	2007	**2002**	**2007**	**2002**	**2007**	**2002**	**2007**	**2002**
No. of farms	58	44	31	21	26	23	1	-
Area (acres)	71	35	65	29	(D)	6	(D)	-
Production (tons)	159.773	78.154	144.469	67.177	(D)	109.77	(D)	-

D: Detail may not add to total due to rounding; -: not applicable/available
Source: Agriculture Census 2007, Department of Commerce, CNMI

Northern Marianas College's Cooperative Research, Extension and Education Service (NMC-CREES) initiated a TC program on sweet potato in 2006 for the production of disease-free and quality propagating materials. After screening accessions at the Agriculture Experiment Station and on-farm trials, selected lines propagated through TC were distributed to the local farming community. This paper reports the results of field evaluations of tissue-cultured sweetpotato accessions in the local soil and climatic conditions of the CNMI.

MATERIALS AND METHODS

Approach

Seventeen elite varieties of sweetpotato were imported, while evaluation and selection of promising varieties was done under local conditions. The TC laboratory of the NMC-CREES imported several pathogen-tested (virus-indexed) TC sweetpotato varieties into the CNMI for screening and evaluation. A total of 17 varieties were tested in the CNMI in 2007, 2008 and 2009 (**Table 2**). Parents or the names of pure line of each accession and their origin are listed in **Table 3**. TC plants of new varieties were imported from the Centre for Pacific Crops and Trees (CePCT), Secretariat of the Pacific Community (SPC), Fiji. Upon receipt of package, plantlets were transferred to plastic bags with commercial potting mix (ACE Hardware, Saipan) and kept in the nursery (57% shade, 60-70% humidity) for 2-3 weeks for hardening and acclimatization. Well hardened plants were transferred to the field at the As Perdido Agriculture Experiment Station, Saipan. A randomized plot was selected, cleared of shrubs, grasses and tilled. Plantlets were transferred to the field with 45-cm inter-plant spacing and 60-cm between rows. Plants were rain-fed or irrigated when required and fertilized with commercial grade fertilizer (NPK, 16: 16: 16) at the time of planting. Plants were monitored periodically and data were collected on several specific morphological characters evaluated in each trial. They included plant characters such as growth, tuber quality, tuber shape, skin and flesh color, yield, insect pest and diseases, maturity etc. At least six replicates (plants) of each variety were planted in the trials. Three, two and one trials were conducted in the islands of Saipan, Rota and Tinian, respectively. CREES Crop Protection staff conducted scouting of crop for insect pest infestation and diseases damage. Field trips to all the three island locations were undertaken to the study areas, photos of plants and plant parts were taken and documented. Soil analysis of experimental sites in three islands conducted through the Agriculture Diagnostic Center, University of Hawaii at Manoa, Hawaii.

Taste testing

New varieties were evaluated for eating quality by taste testing (sensory evaluation) after harvesting. Tubers of the 17 varieties were harvested, cleaned, washed and prepared for the taste testing evaluation. Tubers were boiled, peeled off and cut into small pieces. All the varieties were displayed in aluminum foil trays and labeled. Five taste testing evaluations were conducted; two on the island of Saipan in January 2008 and January 2009, one on the island of Rota in August and November, 2008, and one on the island of Tinian in August 2008. A survey form was prepared for the participants to fill out during the taste testing. Participants of ages from 18 to 65 years (male and female both) including youths, students, faculty, researchers and extension agents, farmers, in the community were participated in the sensory evaluation. At least 60 participants evaluated the cooked tubers in the event held on the island of Saipan in January 2008 and on the island of Rota in August 2008. Approximately 35 participants, mainly students, faculty, staff and administrators participated in the event held on the NMC campus in January 2009 in Saipan. Data were collected on taste, texture and acceptability of corms through survey form and interviewing the people.

Micropropagation

Shoot-tip explants (apical buds) and nodal segments of sweetpotato were collected from the TC plants grown at the As Perdido Agriculture Experiment Station. Explants were washed in running tap water and shoot tips were excised from the apical apices to about 1 cm. The explants were dipped in 70% ethanol for 30 sec. They were sterilized in 2% sodium hypochlorite solution and washed several times with sterile distilled water to remove the sterilizing agent. Shoot tips and nodal segments (0.5-1.0 cm) were cultured on Murashige and Skoog (MS) medium (Murashige and Skoog 1962) containing 6-benzyl adenine (BA, 1.0 mg/l; Phytotechnology Lab., USA) and sucrose (30 g/l) at 23°C under a 12-h photoperiod (2500 lux). The regeneration and multiplication protocol was adopted from Chee *et al*. (1992) and modified in the in-house TC laboratory with MS medium containing indole-3-acetic acid (IAA) and BA for shoot bud induction and multiplication. Explants were subcultured on fresh medium after 4-5 weeks for multiplication. Well-elongated shoots were cultured on basal MS medium free of plant growth regulators for root induction. Regenerated plantlets were transferred to pots with potting soil (ACE Hardware, Saipan) for hardening in the nursery (57% shade, 60-70% humidity). Well-hardened plantlets were transferred to the field after 2-3 weeks.

Table 2 On-farm and on-station variety trials of sweet potato in the islands of Saipan, Rota and Tinian. A total of 17 varieties were tested in five trials during the period from 2007 to 2009; taste testing was also conducted.

Trial	**Island**	**Planting**	**Harvesting**	**Farm location**	**Taste testing (Month, Year and Place)**
1st	Saipan	May and August 2007	October and December 2007	Agriculture Experiment Station, As Perdido	January 2008 As Perdido Agriculture Station
2nd	Rota	February 2008	August 2008	1. Sabana Conservation Area 2. Sinapalo village	August 2008 NMC-CREES
3rd	Rota	August 2008	November 2008	Iguan village	Field Day, November 2008 On-farm, Iguan
4th	Tinian	February 2008	August 2008	Experimental plot, NMC-CREES	August 2008
5th	Saipan	November 2008	March 2009	Agriculture Experiment Station, As Perdido	March 2009 As Perdido Agriculture Station

Fig. 1 (**A**) Experimental field of variety trials of sweetpotato in Sabana village, Island of Rota. (**B**) Sweetpotato crop ready to harvest (105-days old). (**C**) Cleaning, washing of freshly harvested tubers preparing for taste testing. (**D**) Medium size, red-skin tubers (var. IB 1701). (**E**) White skin tubers (IB 234). (**F**) Light purple tubers (IB 283). (**G**) Preferred leaves (trilobes) for culinary/soup making (IB 234). (**H**) Sweetpotato weevil damage in tubers. (**I**) Structural deformities (cracks) in 'jumbo' tubers of over mature crop. (**J**) Micropropagation of sweetpotato var. IB 195; Induction of shoot buds. (**K**) Well rooted plantlets on MS medium. (**L**) Two-weeks old hardened plantlets in the nursery. (**M**) Var. IB 218 (pale yellow). (**N**) Var. IB 083, rated high for good taste. (**O**) Sensory evaluation of sweetpotato varieties at the As Perdido farm, Saipan.

RESULTS

The objective of the current study was to enhance selection of exotic varieties of sweetpotato to specific niches and to meet the needs of farmers and thereby strengthen the varietal diversification process. Varieties were evaluated and selected, first under local conditions in on-station trials on the island of Saipan in the CNMI (**Fig. 1B**) and then trials were conducted on the islands of Rota (**Fig. 1A**) and Tinian. Selected varieties were multiplied through TC and plantlets were sent to the two islands. Three variety trials of sweetpotato were conducted in Saipan in 2007, 2008 and 2009. A preliminary trial was conducted on the islands of Rota and Tinian in 2008. The main objective of the variety trials program was to select high-yielding, disease and pest-tolerant cultivars with good tuber quality characteristics acceptable to farmers and consumers in the CNMI. Results showed that all sweetpotato varieties included in the study could adapt to different locations but the varietal choice varied between locations, indicating the need for varietal diversification. The selected varieties of sweetpotato were identified as economically and culturally important ones that have been tested for their adaptability and superior characteristics such as growth, yield, tolerance to insect pests and diseases in the region.

Field evaluation

Names and country of origin of imported sweetpotato varieties and results obtained from the variety trials and evalua-

Table 3 Results of field evaluation of new varieties of tissue culture sweet potato conducted at the As Perdido Experiment Station in Saipan from 2007-2009.

Variety name	CePaCT No.	Origin	Mean tuber weight (g)	Mean tuber size (cm)	Mean yield/plant (kg)	Color of skin and pulp of tuber	Insect Pest Damage		Resistance to diseases**
							Sweet potato weevil *	Common insect pests	
IB 083	IGI	Solomon Islands	70	9.0	0.6	Light purple and white-pale yellow	-	Katydid, Short horn grasshopper, Rodents	HT
IB 087	WV5		364	15.0	0.7	White and pale yellow	+	Katydid minor damage, Flea beetle, Grasshopper, Rodents	T
IB 195	Kuma 2		510	15.0	1.5	Purple and white	+++	-	T
IB 197	Toni		200	10.0	1.0	White and white	-	Clean	T
IB 216	Anuta 2		210	10.0	1.5	Light purple and white	+++	-	T
IB 218	Dorio		230	10.0	1.2	White and white	-	Clean	T (scab)
IB 234	Jimi		260	18.0	0.8	White and white	+	Clean	T
IB 285	SI 267		600	18.0	1.4	Light purple and white	+	Clean	HT
IB 0701	ACC 213		254	13.0	1.6	Purple and white	+	-	T (bacterial wilt)
IB 0702	ACC 268		214	13.0	1.5	Purple and pale yellow	-	-	HR
IB 098	N/A	Papua New	150	14.0	1.0	Purple and pale yellow/orange	+++	Rodents	S (rot)
IB 111	Kekori	Guinea	110	11.5	1.1	White and white	-	Katydid, Short horn grasshopper, Flea beetle, Rodent	T
IB 248	PO16		465	11.5	1.2	White and pale yellow	+	-	HT
IB 283	PNG 1164		454	18.0	0.9	White and pale white	+	Leaf minor	S (root rot)
IB 288	RB 455	N/A	264	15.0	0.8	Purple and pale yellow	-	-	S (root rot)
IB 294	G 214	N/A	300	16.0	0.7	Light purple and yellow	++	-	T
IB 296	N/A	N/A	510	12.0	1.5	Purple and pale white	++	Katydid, Grasshopper, Flea beetle, Rodent	S (root rot, scab)

*Level of Sweet Potato Weevil damage-+, low; ++ Moderate; +++; High
**S; Susceptible, T; Tolerant, HT; Highly Tolerant

tions conducted in Saipan are summarized in **Table 3**. All the varieties survived under field conditions and produced tubers in local soil and climatic conditions on three islands of the CNMI, Saipan, Rota and Tinian. The average period from planting to harvesting of crop was ~4 months. Higher yield was obtained from the trials conducted in the wet season (July to December) compared to the dry season (February-May). Varieties IB 216, IB 195, IB 0701, IB 296, IB 285 produced high yields (> 2 kg/plant), var. IB 197, IB 218, IB 234, produced moderate yields (average 1.0 kg/plant) comparable to others, which produced < 1 Kg plant yield (**Fig. 1C**). Two varieties, IB 285 and IB 195, produced big and heavy tubers (jumbo) up to 800 g; however, the taste of jumbo tubers was rated average or low by the consumers. Medium size (9.0-12.0 cm), round-oval shape, red-purple skin tubers were preferred over white skin and irregular shape tubers (**Figs. 1D-F**). On average, 4-5 tubers/plant were harvested for most varieties. Trilobiate, young, tender leaves of var. IB 218, IB 288 were preferred over vars. IB 1701, IB 1702, IB 083, IB 087, IB 098 for culinary and soup making (**Fig. 1G**). Minor damage (5%) on crops by insect pests such as flee beetle (*Chaetocnema affinis*), katydid (*Phaneroptera furcifera*), grasshopper (*Locusta migratoria manilensis*), and leaf minor (*Acrocercops* sp.) was observed. Among the diseases, bacterial stem and root rot (*Erwinia chrysanthemi*), leaf spot (*Phyllostica colocasiophilla*), stem blight (*Alternaria* spp.), anthracnose (*Collectrotrichum* spp.) and scab (*Elsinoe batatas*) were observed in the varieties at a low level. Sweetpotato weevil (*Cylas formicarius elegantulus*) (**Fig. 1H**) and rodent damage was observed when the crop was harvested late e.g. over 4 months. Traditionally, farmers begin harvesting the crop early e.g. at 3 months to avoid sweetpotato weevil attack and rodent damage. Overly mature crops also resulted in morphological and structural deformities in tubers such as cracks in the skin, irregular shape, discoloration, etc., which makes them unmarketable (**Fig. 1I**).

Tissue culture

TC plants of selected varieties from the 1st trial were raised in the NMC-CREES laboratory and sent to the islands of Rota and Tinian for preliminary trials. Nodal explants (1.0-1.5 cm) began to develop shoot buds after 2-3 weeks culture. Shoot buds (3-4) regenerated from a single explant in 4 weeks. After 4 months of culture, about 80% of explants regenerated shoots. MS medium with 1.0 mg/l BA was suitable for shoot bud induction and multiplication. Incorporation of auxin (IAA) in the medium enhanced callus formation in the explants. Rooting was spontaneous on MS medium without plant growth regulators (**Figs. 1J-L**). The regeneration protocol from nodal segments was previously reported for sweetpotato (Chee *et al*. 1992).

Taste testing

Results of a survey on sensory evaluation of boiled tubers, taste, texture, color of flesh and skin, acceptability of all the varieties is shown in **Table 4**. The varieties IB 083, IB 087, IB 234, IB 248, IB 285, IB 0701 and IB 0702 rated excellent in taste, quality, tuber size, easy cooking. Handling, shorter time in cooking, sweetness and soft texture were the preferred choice of acceptability by the consumers. Red-purple skin, purple flesh, yellow-orange flesh was preferred over white skin and white flesh varieties. IB 216, IB 218, IB 283, was among the moderately acceptable due to less sweet taste and texture (**Figs. 1M-O**). Varieties produced large tubers (jumbo) were not preferred due lower rating in taste and problems in handling and marketability.

DISCUSSION

Root and tuber crops are underutilized despite the fact they are "rooted" in the culture of the Pacific Islands and are a significant resource for addressing many challenges (Taylor 2009). The importance of exchange of plant germplasm,

Table 4 Results of sensory evaluations (taste testing) of 17 new varieties of sweet potato. Tubers of all the varieties harvested same day and cooked (boiled) same time.

Variety (CePaCT No.)	Taste	Texture	Color (cooked)
IB 083	Best	Soft	Yellow
IB 087	Best	Soft, Moist	White
IB 098	Good	Semi-hard	White
IB 111	Acceptable	Soft, Dry	Yellow
IB 195	Good	Hard, Dry	White
IB 197	Good	Soft, Dry	Yellow
IB 216	Acceptable	Semi-hard, Dry	Yellow
IB 218	Best	Soft	Yellow
IB 234	Best	Hard, Moist	White
IB 248	Best	Semi-hard	White
IB 283	Acceptable	Soft	Yellow
IB 285	Best	Soft	White
IB 288	Good	Soft, Dry	Yellow
IB 294	Best	Soft	Yellow
IB 296	Good	Semi-hard, Dry	White
IB 0701	Best	Hard, Moist	Yellow
IB 0702	Best	Hard, Moist	Yellow

specifically plant genetic resources for food and agriculture in the Pacific region, has been reported by Taylor and Tuia (2009). The effect of climate change on the demand and production of sweetpotato worldwide was presented by Rosegrant (2009) at the Root and Tuber conference held in Lima, Peru. In the United States, the National Sweetpotato Collaborators Group reported the effects of meristem culture on yields of heirloom sweetpotatoes in the field (Jackson *et al.* 2009), study on variety differences, storage conditions and fertilizer effects on sweetpotato storage trials (Stoddard and Saltveit 2009), evaluation of sweetpotato genotypes to resistance of soil insect pests in Charleston, South Carolina (Jackson 2010).

Micropropagation has been widely used as a biotechnological tool to propagate plants and to study physiology for more than a century now (Desjardinsa *et al*. 2009). Reports on the application of TC in tuber crops using meristem culture, virus indexing and *in-vitro* regeneration in sweetpotato varieties are available in the literature (Ng *et al*. 1984; Gaba and Singer 2009). Virus-free (indexed) sweetpotato planting material had a significant impact on farm income and yield in China (Fuglie *et al*. 1999).

All 17 varieties of sweetpotato imported in the CNMI survived and produced tubers in local soil and climatic conditions on the three islands of Saipan, Rota and Tinian. Although soil type is classified as clay in the experimental sites, the cropping history, cultural practices and other environmental factors were different, including pest and diseases pressures and other variables that influence plant performance. No consumer preference was observed for the color of cooked varieties; however, a purple skin and yellow flesh were favorable. Naholowaa *et al*. (2003) conducted a survey and assessment of local awareness of traditional root crops and to study the market potential for value-added products made from taro (*Colocasia esculenta* (L.) Schott), sweetpotato (*Ipomoea batatas* (L.) Lam). and cassava (*Manihot esculenta* Crantz) in Guam.

Sweetpotato is one of the important crops with added advantage in storms and frequent typhoons due to ground cover plants (low-growing). Because of the frequency of typhoons, taller varieties are heavily damaged by storms in the CNMI. IB 083, IB 087, IB 0701, IB 0702, IB 216 varieties showed considerable high tolerance to insect pests and diseases, produced high yields, tested good and quality tubers.

There is growing demand of selected varieties and the farming community has asked for seed from the grower farmers. New varieties were found to have spread in the villages among farming community through their networking. Farmers use a combination of criteria such as early maturity, quality tuber, high yield, good cooking quality and taste of new varieties for the production. The major contribution of the program has been the propagation and multiplication through TC. It also offers the benefit of new genetic material to the farmers and helps promote genetic diversity. The initial results obtained from the variety trial program hold great promise for the farming community and significant gains in the adaptability of many varieties by selecting and propagating superior varieties using *in vitro* systems.

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REFERENCES

Anderson P, Kapinga R, Zhang D, Hermann M (2007) Vitamin A for Africa in Sub-Saharan Africa. In: *Proceedings of the 13th ISTRC Symposium*, November, 2003, Tanzania, pp 711-720

Bourke RM (2009) Sweetpotato in Oceania. In: Loebenstein G, Thottappilly G (Eds) *The Sweetpotato*, Springer Science Business Media B.V., Dordrecht, pp 489-502

Chee RP, Schultheis JR, Cantliffe DJ (1992) Micropropagation of sweetpotato (*Ipomoea batatas* L.) In: Bajaj YPS (Ed) *Biotechnology in Agriculture and Forestry, High-Tech and Micropropagation III*, Springer Verlag, Berlin, **19**, 108-117

Clark CJF (Admin.) United States Department of Agriculture, National Agricultural Statistics Service 1 (2009) 2007 Census of Agriculture, Northern Mariana Islands, Commonwealth and Island Data, Geographical Area Series, Part 56, pp 32

Desjardins Y, Dubuc JF, Badr A (2009) *In vitro* culture of plants: A stressful activity! *Acta Horticulturae* **812**, 29-50

Esguerra N, Rangiil G (2000) Insect pests of root crops in Micronesia. PCCCRE Pub. 18/00 (3.0), Palau Community College, Koror, Palau, p 8

Fuglie OK, Zhang L, Salazar FL, Walker ST (1999) *Economic Impact of Virus-Free Sweet Potato Planting Material in Shandong Province, China*. International Potato Center, Lima, Peru, pp 1-29

Gaba V, Singer S (2009) Propagation of sweetpotatoes, *in situ* germplasm conservation and conservation by tissue culture. In: Loebenstein G, Thottappilly G (Eds) *The Sweetpotato* (Part 1), Springer, The Netherlands, pp 65-80

Jackson DM (2010) Resistance of National Sweetpotato Collaborators Group Genotypes to soil insect pests Charleston, S. C., 2009. National Sweetpotato Collaborators Group Progress Report 2009, American Society of Horticultural Sciences-Southern Region, Orlando, FL, 2010, pp 50-51

Jackson DM, Ling KS, Harrison HF Jr. (2009) Effects of meristem culture on yields of heirloom swetpotatoes in the field. National Sweetpotato Collaborators Group Progress Report 2008, American Society of Horticultural Sciences-Southern Region, Atlanta, Georgia, 2009, pp 12-13

Jackson G (1991) *Sweet Potato Scab*, Pest advisory leaflet South Pacific Commission, pp 1-4

Kohler F, Pellegrin F, Jackson G, McKenzie E (1997) *Diseases of Cultivated Crops*, Pacific Island Countries, South Pacific Commission, Noumea, New Caledonia, 187 pp

Matalog VE (1992) *Common Plant Diseases of the Commonwealth of the Northern Marianas Islands*, Land Grant Programs, Northern Marianas College, Saipan, 4 pp

Murashige T, Skoog F (1962) A revised medium for rapid growth and bioassays for tobacco tissue culture. *Physiologia Plantarum* **15**, 473-497

Ng SY, Hahn SK 1984 Application of tissue culture to tuber crops at IITA. Biotechnology in international agricultural research: proceedings of the intercenter seminar on International Agricultural Research Centers (IARCs) and Biotechnology 3-27 April 1984, pp 29-40

Nandwani D (2009) Field trials of tissue culture taro (*Colocasia esculenta* (L.) Schott) in the Northern Mariana Islands. *Fruit, Vegetable and Cereal Science and Biotechnology* **3**, 38-43

Nandwani D, Tenorio J, Duponcheel L, Badilles A, Manglona R (2007) Sustainable agriculture practices in the Commonwealth of the Northern Mariana Islands. *Journal of Environment Monitoring and Restoration* **3**, 53-58

Naholowaa QL, Marutani M, Wayte KM (2003) Concept test of value-added root crops. *Micronesica* **7 (Suppl)**, 41-53

Nakamoto ST, Homer KR, Donald AM (1996) Evaluation of Agricultural Statistics for ADAP. ADAP Project Report. Agriculture Development in the American Pacific (ADAP). **95-1**. Honolulu, Hawaii: Land Grant Institutions of the Pacific/ADAP Project, 1996, 25 pp

Quebral FC, Cabrera IT, Tudela AF (1989) Checklist of plant diseases in the Commonwealth of Northern Marian Islands. Cooperative Research, Extension and Education, Northern Marianas College, 39 pp

Rosegrant WM (2009) Roots and tubers: Opportunities and challenges under growing resource scarcity. In: *15th Triennial Symposium of the International Society for Tropical Roots Crops*, 2-6 November, 2009, Lima, Peru

Stoddard CS, Saltveit M (2009) National Sweetpotato Collaborators Group Progress Report 2008, American Society of Horticulture Sciences-Southern Region, Atlanta, Georgia, 2009, pp 12-13

Taylor M (1998) Biotechnology in the South Pacific island region. *Acta Horticulturae* **461**, 55-64

Taylor MB, Tuia VS (2009). The importance of germplasm development and exchange in meeting the challenges of the 21st century in the Pacific region. *Acta Horticulturae* **829**, 231-239

USDOI-OLA (United States Department of the Interior-Office of Insular Affairs) (1999) (on-line). A Report on the State of the Islands 1999. U. S. Department of the Interior-Office of Insular Affairs, pp 24-32