Taro Germplasm Evaluated for Resistance to Taro Leaf Blight

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SUMMARY. Taro leaf blight (TLB), caused by the oomycete pathogen *Phytophthora colocasiae*, is a worldwide disease that threatens the sustainable cultivation of the tropical root crop taro (*Colocasia esculenta*). To evaluate taro germplasm from Asia, Hawai'i, and several South Pacific Islands for resistance to TLB, 119 cultivars were planted along the Hamakua Coast of Hawai'i (mean annual rainfall of 130 inches) in plots containing five or 10 plants that were replicated over time from 1993 through 2005. Fresh and dry weights of corms were measured after about nine months, with rotten portions removed and weighed. When epidemics of TLB occurred (in nine out of 12 years), visual estimates of disease severity on leaves were assessed using a modified Horsfall-Barratt scale. The correlations between mean dry weight yields for each cultivar and mean severity of TLB, and, respectively, between mean yields and mean severity of corm rots were calculated. As severity of TLB or severity of corm rots increased (suggesting increased susceptibility of particular cultivars to TLB or corm rots), mean dry weight yields decreased significantly ($r^2 = 0.37$ and 0.22 , respectively). "Multiple comparisons with the best" (MCB) were conducted on fresh and dry weight yields, severity of TLB, severity of corm rots, percentage dry matter of corm, and consumer acceptance. Five cultivars were found to be "among the best" with: 1) fresh or dry weight yields that did not differ from the highest level; 2) severity ratings for TLB that were significantly lower than the highest level, suggesting TLB resistance; and 3) percentage of corm rots that were lower than the highest level, suggesting disease resistance. These cultivars, four of which originated from Palau, were Dirratengadik, Merii, Ngesuas, Ochelochel, and Sawa Bastora. Two commercial cultivars from Hawai'i, Bun Long and Maui Lehua, had fresh and dry weight yields that were significantly lower than the maximum and severity of TLB injury that did not differ from the highest level, indicating that conventional breeding of taro to improve TLB resistance could improve yields of commercial taro cultivars, particularly in areas where epidemics of TLB occur.

Taro was the fifth most-produced root crop in the world during 2010, with global production of 9.0 billion kilograms (Food and Agriculture Organization of the United Nations, 2010). It is one of the most important staple crops in the Pacific Islands, and is grown widely in Africa, Asia, the Caribbean, and South America (Plucknett et al., 1970). It is a non-graminaceous monocot consumed primarily for its starchy corm (Plucknett et al., 1970). In addition, taro leaves serve as a vegetable, providing good sources of dietary fiber and vitamin C (Ferguson et al., 1992).

Taro probably originated in the Indo-Malayan area, where the genetic diversity of the species is highest (Cho et al., 2007; Ivancic and Lebot, 2000). It was probably domesticated in several geographic areas, including Papua New Guinea, from where it was carried by the Austronesians as they migrated to Polynesia, Micronesia, and finally to Hawai'i in 900–1000 CE (Cho et al., 2007). As a result of this distribution,

it is not surprising that taro cultivars of Oceania derive from a common, but narrow, genetic base (Lebot and Aradhya, 1991).

Taro leaf blight, caused by the oomycete pathogen *Phytophthora colocasiae*, is a major disease that threatens the sustainability of taro production globally (Miyasaka et al., 2012; Nelson et al., 2011; Ooka, 1994). In Hawai'i, taro yields have declined over the past 30 years with particularly steep decreases during recent years due, in part, to pests and diseases (Miyasaka

et al., 2012). According to the U.S. Department of Agriculture (USDA, 2006), taro production in 2005 was only 4 million pounds, the lowest amount since record keeping began in 1946. Several factors contributing to this low production were rainy weather, TLB, and taro pocket rot (another disease caused by a *Phytophthora* species) (USDA, 2006).

Phytophthora colocasiae was introduced to Hawai'i during the 1920s and probably contributed to the extinction of dozens of traditional Hawaiian cultivars (University of Hawai'i, 2009). Due to the ease of global transport and trade between countries, TLB has spread to new geographic areas across the Pacific, the Caribbean, and Africa. In 1993, this disease was introduced to American and Western Samoa, where it devastated the traditional Samoan taro cultivars (e.g., Niue) that were highly susceptible to this disease. This epidemic resulted in zero taro production in Samoa from 1994 to 1998 until the introduction of TLB-resistant taro cultivars (Trujillo and Menezes, 1995). When TLB reached the Dominican Republic in 2004, it caused dramatic losses in the production of the TLB-susceptible, commercial taro cultivar (R.P. Duverge, personal communication). Recently, TLB reached Ghana and Nigeria (Bandyopadhyay et al., 2011; Omame et al., 2012).

In Hawai'i, there was a need to evaluate the existing taro germplasm for resistance to TLB. Recent breeding programs have crossed TLB-resistant cultivars from other areas of the world with commercial cultivars in Hawai'i (Cho et al., 2007; Trujillo et al., 2002). However, there is a lack of knowledge about TLB resistance of Hawaiian cultivars and other cultivars maintained in the taro collection at the University of Hawai'i's Kauai Research Station.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
0.1242	gal/100 ft	L·m ⁻¹	8.0520
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
1.1209	lb/acre	kg·ha ⁻¹	0.8922
6.8948	psi	kPa	0.1450
2.2417	ton(s)/acre	Mg·ha ⁻¹	0.4461
(°F – 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

The objective of this 12-year study was to evaluate the taro germ-plasm in Hawai'i for yield, resistance to TLB and corm rot, and corm quality. The Hamakua Coast of Hawai'i Island was well suited for this study due to its high annual rainfall and environmental conditions that are conducive to epidemics of TLB.

Materials and methods

One hundred and nineteen cultivars of taro from China, Easter Island, Hawai'i, Japan, Palau, Philippines, Polynesia, Samoa, and Tahiti were planted at 12 dates and different locations along the Hamakua Coast of Hawai'i Island during 1993–2005 (Table 1). Taro cultivars were planted in plots of five or 10 plants without border rows, using vegetative propagules (huli) that consisted of the lower 12 inches of petiole and the upper 0.25 inches of corm. When possible, huli were prepared from suckers and selected for uniform diameter of the cut surface of corms (minimum diameter of 1 inch). Cultivars were planted in completely randomized designs that were replicated temporally, although the number of replicates varied from two to 12 (cultivars that

were harvested only once were removed from statistical analysis). Certain cultivars died out over time and were replaced periodically from the taro collection maintained at the University of Hawai'i's Kauai Research Station.

Plant spacing varied among years, ranging from 9,680 plants per acre (1.5×3 ft) to 14,520 plants per acre (1×3 ft) as management practices were changed (Table 1). This range of plant spacing falls within that used in commercial taro plantings in Hawai'i, which varies depending upon growers' traditions and mechanical equipment requirements.

Taro cultivars were grown in upland (i.e., non-flooded) fields, and initially, rainfall provided all of the water for plant growth. Mean annual rainfall in Hilo and along the Hamakua Coast is 130 inches per year (National Oceanic and Atmospheric Administration, 2012); however, there can be periods of little or no rainfall over a 2- to 4-week period. During 1994–95, low-rainfall periods resulted in poor survival of vegetative propagules and poor corm quality due to loss of starch. Rainfall was recorded daily at the University of Hawai'i's Waikeke Research Station (lat. 19.653°N, long. 155.071°W; elevation 600 ft).

Beginning with the 1999 planting date, supplemental irrigation was provided to ensure a uniform water supply and good starch production in corms (Table 1). Rainfall catchment water was pumped through irrigation lines fitted with drip emitters (12-inch spacing, 24 gal/100 ft per hour, Ro-drip® tape; John Deere, Moline, IL). An earlier field trial showed that taro corm production was best when irrigation was supplied at 100% of potential evapotranspiration (PET) (University of Hawai'i, 2008). Average weekly PET for the Hamakua Coast of Hawai'i Island was estimated at 0.7 inches of water. Rainfall was monitored weekly at the experimental site, and plants were supplied with supplemental irrigation if needed to provide 100% PET.

Soil analysis was conducted at each planting location to determine pH and to quantify extractable nutrients. Lime (dolomite and crushed coral) was supplied to increase soil pH to the range of 6.0 to 6.5 (Table 1). Phosphorus (P) was banded before

planting in these P-fixing soils using treble superphosphate at a rate of 600 lb/acre for the first eight planting dates; subsequently, P was applied at 400 lb/acre. Nitrogen (N) was broadcast at planting and monthly through five months for a cumulative application rate of 1380 lb/acre for the first five planting dates. In subsequent planting dates, N was applied monthly at half the rate resulting in a total amount of 690 lb/acre. Potassium (K) was broadcast at planting and monthly intervals through five months along with the N fertilizer at a rate of 1190 lb/acre for the first five planting dates. In subsequent planting dates, K was applied at planting and monthly intervals through five months at half the rate, resulting in a total of 590 lb/acre. Such information on fertilizers and amendments is important because nutrient status of plants affects the development of diseases. For example, calcium (Ca) has been shown to improve disease resistance (Rahman and Punja, 2007), whereas N often is reported to increase susceptibility to disease (Huber and Thompson, 2007).

During nine out of 12 years, epidemics of TLB occurred and blight ratings were taken at about five months after planting (Table 1). Horsfall and Barratt (1945) proposed a disease assessment scale comprising logarithmic, not linear, disease severity classes that are symmetrical about 50%. We used a modified Horsfall–Barratt disease assessment scale with 12 categories of disease (0–11) for visual estimation of the proportion of the leaf blade affected by TLB (Fig. 1), starting from the first fully matured leaf blade and continuing through five leaf blades. Our modified scale had slight differences in percent disease for some disease severity classes, compared with the original scale (Horsfall and Barratt, 1945). Ratings for individual leaf blades were converted into the mid-point percentage of the leaf blade affected by the disease (0%, 0.5%, 3%, 7%, 13.5%, 28%, 50%, 72%, 86.5%, 94%, 97.5%, and 100%) and then averaged over five leaf blades. Two raters scored the severity of disease on separate individual plants of a particular cultivar; disease assessments were averaged across both raters.

Harvest of corms occurred at about nine months after planting

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Table 1. Summary of 12 planting dates of taro trials, harvest dates, spacing, location (latitude, longitude), elevation, supplemental irrigation (Suppl. irr.), taro leaf blight (TLB) rating, data collection of corm rot, rainfall during two to six months after planting (MAP), applications of calcium carbonate equivalents (CaCO_3), phosphorus (P), nitrogen (N), and potassium (K).

Date planted	Date harvested	Spacing (plants/acre) ^z	Location (lat., long.)	Elevation (ft) ^z	Suppl. irr.	TLB rating	Corm rot	Rainfall 2–6 MAP (mm) ^z	CaCO_3 (tons/acre) ^z	P (lb/acre) ^z	N (lb/acre) ^z	K (lb/acre)
23 Sept. 1993	1 June 1994	9,680	19.892°N, 155.130°W	430	No	Yes	No	1,544	2.0	600	1,380	1,190
15 Sept. 1994	24 Apr. 1995	14,520	19.892°N, 155.130°W	430	No	No	No	2,008	2.0	600	1,380	1,190
1 June 1995	29 Feb. 1996	14,520	19.892°N, 155.130°W	430	No	No	No	1,347	2.0	600	1,380	1,190
6 Sept. 1996	17 June 1997	14,520	19.869°N, 155.162°W	1,380	No	Yes	No	1,009	2.0	600	1,380	1,190
6 May 1999	20 Jan. 2000	14,520	19.899°N, 155.141°W	540	Yes	Yes	Yes	761	0	600	1,380	1,190
3 Aug. 2000	16 May 2001	14,520	19.905°N, 155.139°W	350	Yes	No	Yes	2,426	2.0	600	690	590
7 Dec. 2000	25 Sept. 2001	14,520	19.899°N, 155.141°W	540	Yes	Yes	Yes	1,406	2.0	600	690	590
4 Oct. 2001	1 July 2002	14,520	19.842°N, 155.137°W	1,090	Yes	Yes	Yes	2,306	2.0	600	690	590
26 Apr. 2003	7 Jan. 2004	10,890	19.835°N, 155.102°W	490	Yes	Yes	Yes	1,187	0	400	690	590
3 Oct. 2003	1 July 2004	10,890	19.835°N, 155.102°W	490	Yes	Yes	Yes	1,555	0	400	690	590
29 Apr. 2004	1 Feb. 2005	10,890	19.835°N, 155.102°W	490	Yes	Yes	Yes	726	0	400	690	590
28 Sept. 2005	23 June 2006	10,890	19.835°N, 155.102°W	490	Yes	Yes	Yes	1,572	0	400	690	590

^z 1 plant/acre = 0.4047 plant/ha, 1 ft = 0.3038 m, 1 mm = 0.0394 inch, 1 ton/acre = 2.2417 Mg/ha⁻¹, 1 lb/acre = 1.1209 kg/ha⁻¹.

(Table 1). One exception was the second planting date when taro was harvested at seven months after planting due to a drought that resulted in early maturation of corms. Fresh weights of corms were determined, and a representative subsample of corms was sliced and then dried to constant weight at 65 °C for ≈ 1 week to determine percent dry matter. Dry weight yields were calculated by multiplying fresh weight yields by percent dry matter. Starting during the fifth planting date, data on corm rots were taken, in which the rotten portion of corms was excised, weighed, and the percentage corm rot was calculated (relative to total fresh corm weight). Thereafter, yields based on corm fresh or dry weights were calculated using the weight of corms with rot removed.

If a sufficient amount of corm tissue was available after the rotten areas were excised and percent dry matter determined, then the remaining corm tissues were pressure-cooked for 30–45 min (at 245 °F and 15 psi) or steamed for 1–3 h until acidity was removed. For table taro, a subsample of cooked corms was cut into cubes; for poi (i.e., traditional food of native Hawaiians), a subsample of cooked corms was mashed using a juicer (Champion model G5-PG710; Plastaket Manufacturing, Lodi, CA). The Hawai'i Community College's food service program helped to prepare the poi and table taro for these taste tests.

Untrained volunteers participated in consumer acceptance tests; many volunteers were from Hui Kalo Moku O Keawe (a community group of taro enthusiasts). The number of volunteers varied from year to year, ranging from 21 to 43. Using a quality ranking scale similar to that of Paull et al. (2000), consumer acceptance of taro cultivars was ranked on a 1 to 5 scale, with 1 = unacceptable quality, 2 = needs improvement, 3 = okay, 4 = good, and 5 = excellent quality.

"Multiple comparisons with the best" was used to determine the subset of cultivars with highest yields, highest apparent TLB resistances, lowest corm rots, and most consumer acceptance (in separate analyses). MCB was calculated using a macro in SAS [version 9.2; SAS Institute, Cary, NC (Westfall et al., 1999)]; it has the advantage of being an efficient multiple comparison procedure that

Fig. 1. Diagrammatic representation of taro leaf blight rating categories, based on a modified Horsfall-Barratt scale from 0 to 11 to estimate the proportion of each leaf blade affected by the pathogen, starting from the first fully matured leaf blade and continuing through five leaf blades. Disease assessment ratings obtained by using this standard area diagram were converted to the midpoint percentage of the range for severity of disease (0%, 0.5%, 3%, 7%, 13.5%, 28%, 50%, 72%, 86.5%, 94%, 97.5%, and 100%), and then averaged across five leaf blades and two scorers.

controls the experiment-wise error rate. It is similar to Duncan's multiple range comparisons in having a control to reduce the number of comparisons, but without having to prespecify which cultivar is "best." After completion, cultivars can be categorized as inferior to the best or among the best; in other words, there were only two groups. It also accommodates unbalanced data, which is important since we do not have data for each cultivar for each year. Due to the unbalanced nature of the data and adjustment for

year of planting, slightly negative adjusted means are possible; such negative values were converted to zero.

In this trial in which cultivars were replicated across years at several different locations, MCB was performed to compare cultivars, with planting date as the block. Characteristics of cultivars compared were fresh and dry weight yields, percentage of corm dry matter, severity of TLB, percentage of corm rots, and consumer acceptance ratings for poi and table taro. Assessments of TLB were conducted in nine

out of 12 years (Table 1); MCB was conducted separately on this parameter, leaving out missing years. Similarly, MCB was conducted separately on percentage of corm rots and consumer ratings of poi and table taro, leaving out missing years.

Mean dry weight yields were correlated with mean severity of TLB or with mean severity of corm rots for each cultivar using PROC GLM (SAS version 9.2). In addition, mean severity of TLB was correlated with mean percentage of corm rots for each cultivar.

Dry weight yields of two cultivars (Bun Long and Lehua Maoli) were linearly regressed over the 12 years to determine whether a trend in yield existed over this period and whether an interaction occurred between cultivars and years. These two cultivars were selected for this analysis because they were planted at all 12 dates. Dry weights of corms for these two cultivars were linearly regressed against rainfall during two to six months after planting; also, severity of TLB was regressed against rainfall during this time. These months were selected for summation of rainfall because this is the period of maximum leaf growth for taro and the early period for corm development (Miyasaka et al., 2003).

Results and discussion

One hundred and nineteen taro cultivars differed significantly for fresh or dry weight yields, severity of TLB, severity of corm rots, corm dry matter, and corm quality (Figs. 2 and 3; Table 2). Cultivar Ngesuas from Palau had the highest dry weight corm yield (Fig. 2). Based on MCB, there were eight other cultivars that did not differ significantly from the maximum value (Fig. 3) and four of them were originated from Palau. Among this group, 'Pololu' was the only traditional Hawaiian cultivar as described by Whitney et al. (1939).

Based on simple linear regression, no significant trend in dry weights of corms over 12 years was found for 'Bun Long' and 'Lehua Maoli' [$P = 0.50$ (data not shown)]. Mean dry weights of 'Bun Long' and 'Lehua Maoli' were 3560 and 3860 kg·ha⁻¹, respectively, or about half of the maximum value. Also, no significant differences in slope were found [$P = 0.85$ (indicating no interaction)] between these two cultivars for dry weight

Fig. 2. (A) Plot of mean dry weight of taro corms against mean severity of taro leaf blight (TLB) for cultivars ($y = 6100 - 73 \times x$; $r^2 = 0.37$, $P < 0.0001$). (B) Plot of mean dry weight of taro corms against mean percentage of corm rot for cultivars ($y = 3140 - 55 \times x$; $r^2 = 0.22$, $P < 0.0001$). Increasing severity of TLB or percentage of corm rots suggests increasing susceptibility to these diseases. Filled circles indicate “among the best” for Hawaiian cultivars, and unfilled circles indicate “among the best” for non-Hawaiian cultivars based on corm dry weight and apparent resistance to TLB or corm rots. Crosses indicate “not among the best” for Hawaiian cultivars, and “x” indicates “not among the best” for non-Hawaiian cultivars; $1 \text{ kg} \cdot \text{ha}^{-1} = 0.8922 \text{ lb/acre}$.

yields as influenced by years (data not shown).

Cultivar Lauoloa Keokeo from Hawai'i had the highest severity of TLB of 73.1% (Table 2). There were 23 cultivars with TLB ratings that differed significantly from the highest [Figs. 2A and 3; Table 2 (severity of TLB in bold font)]. We described the significantly lower TLB rating compared with the maximum value as “apparent” TLB resistance because it is possible that the severity of disease was, on occasion, more a function of the environment than of host resistance. For example, individual plants could “escape” from the presence of *P. colocasiae* due to location in the field.

Of these 23 cultivars that appeared to be TLB resistant, 11 of them originated from Palau and three (Elele Makoko, Hapuu, and Kalalau) were traditional ones from Hawai'i described by Whitney et al. (1939). It was expected that the Palauan cultivars would be disease resistant because they had been selected by Trujillo for their TLB resistance and brought to Hawai'i for conventional breeding (Trujillo et al., 2002). The three Hawaiian cultivars had lower fresh and dry weight corm yields that differed significantly from the highest values (Fig. 3; Table 2), suggesting either that their TLB resistance were very modest or that other factors (e.g.,

susceptibility to other pathogens and pests) could have limited their growth along the Hamakua Coast of Hawai'i Island. Most traditional Hawaiian cultivars did not appear to have a high, natural resistance to TLB. This fact is not surprising since TLB did not reach Hawai'i until the 1920s (University of Hawai'i, 2009), so there was no reason to select for TLB resistance before the arrival of the pathogen.

Two commercial taro cultivars, Bun Long and Maui Lehua, had severity of TLB that did not differ from the highest level, indicating susceptibility to this disease (Table 2). Conventional breeding with blight-resistant cultivars could produce progeny with greater TLB resistance. However, one limitation of conventional breeding of taro is the requirement for simultaneously flowering cultivars. ‘Maui Lehua’ flowers several times during the year, allowing hand pollination with other cultivars that flower synchronously. In contrast, ‘Bun Long’ rarely flowers under the environmental conditions of Hawai'i, even with the application of gibberellic acid, making it difficult to breed conventionally.

Mean dry weight yields of cultivars were correlated negatively with mean severity of TLB in cultivars [Fig. 2A ($y = 6100 - 73 \times x$; $r^2 = 0.37$, $P < 0.0001$)]. In other words, greater TLB resistance for taro cultivars grown along the Hamakua Coast of Hawai'i was associated positively with greater dry weights of corms. Similarly, mean fresh weight yield of cultivars was correlated negatively with mean severity of TLB in cultivars [$r^2 = 0.34$, $P < 0.0001$ (data not shown)]. It was decided to show the linear regression of mean dry weights of cultivars in Figure 2 because values for corm dry weights integrate information about both corm fresh weights and percentage dry matter.

Rainfall at the Waiakea Research Station was summed during two to six months after planting and reported in Table 1. Dry weights of corms of ‘Bun Long’ and ‘Lehua Maoli’ over 12 years were negatively correlated with rainfall summed during two to six months after planting, indicating that the higher levels of rainfall exceeded that needed for optimum growth of taro [Fig. 4 ($y = 5608 - 1.21 \times x$; $r^2 = 0.20$, $P = 0.03$)]. No significant interaction effects between cultivar and year were found ($P = 0.80$). Although ‘Bun

Fig. 3. Venn diagram of taro cultivars that were not significantly different from the maximum for dry weights of corms, cultivars that were significantly different from the maximum value for severity of taro leaf blight (TLB), and cultivars that were significantly different from the maximum value for percentage of corm rot. Within the circle for severity of TLB, cultivars were listed in order of lowest to highest with regards to blight rating; within the non-intersecting circle for percentage of corm rot, cultivars were listed in order of lowest to highest for severity of corm rot.

Long' and 'Lehua Maoli' were considered to be susceptible to TLB (Table 2), severity of TLB for these two cultivars over nine years were not correlated with rainfall summed over two to six months after planting ($P = 0.09$). It is possible that this relationship would have been significant if blight ratings had been taken during drier years without TLB epidemics; however, during drier years, taro growth was limited by water stress (during years without supplemental irrigation) and the greater occurrence of other pests, such as taro planthoppers (*Tarophagus proserpina*) or melon aphids (*Aphis gossypii*).

Cultivar Kai Kea had the highest percentage of corm rot of 45.6% (Table 2). There were 43 cultivars that differed significantly from the highest severity of corm rot [Figs. 2B and 3; Table 2 (corm rot in bold

font)]. Among these, nine originated from Palau and 24 were from Hawai'i.

Corm rots could be caused by many different oomycete and fungal pathogens, including *Pythium* sp., *P. colocasiae*, and *Sclerotium rolfsii* (Ooka, 1994). In another study (Miyasaka et al., 2003), *P. colocasiae* was found to cause some corm rots in 'Bun Long' grown along the Hamakua Coast of Hawai'i, with others due to secondary infections following injury by pests, such as ginger maggot [*Eumerus figurans* (W.S. Ko, personal communication)]. Miyasaka et al. (2001) found a range in severity of corm rots from less than 10% to over 30% over two cropping cycles of 'Bun Long'. Similarly, in this study, 'Bun Long' had a range of severity of corm rots from 4% to 21.2% with an average of 12.9% across eight planting dates, significantly lower than the maximum value.

Mean dry weight yields of cultivars were correlated negatively with severity of corm rots in cultivars [Fig. 2B ($y = 3140 - 55 \times x$; $r^2 = 0.22$, $P < 0.0001$)]. In addition, mean percentage of corm rots in cultivars was positively associated with mean severity of TLB in cultivars [data not shown ($r^2 = 0.11$, $P = 0.0012$)]. One possible explanation for this positive correlation between severity of corm rots and that of TLB is that *P. colocasiae* causes corm rots in addition to leaf blight as found in an earlier study (Miyasaka et al., 2003), so that resistance to TLB could inhibit corm rots directly. An alternate explanation is that the mechanism of disease resistance found in cultivars resistant to TLB is broadly effective against other pathogens.

There were six cultivars ranked "among the best" for both dry weight corm yields and apparent TLB resistance (Figs. 2A and 3). There were seven cultivars ranked "among the best" for both dry weight corm yields and low severity of corm rots (Figs. 2B and 3). Five cultivars were found in both of these two groups: Dirratengadik, Merii, Ngesuas, Ochelochel, and Sawa Bastora (Fig. 3). Four of these cultivars were from Palau and one was from Pohnpei (Table 2). Cultivar Ngeruuch from Palau was not among this promising group of five cultivars due to its high severity of corm rots that did not differ from the highest level. It was the parent of several newly released cultivars, and unfortunately, one of these new cultivars (Pa'lehua) was reportedly more susceptible to pythium rots than the commercial parent (Trujillo et al., 2002). The fact that 'Ngeruuch' was resistant to TLB but not to corm rots indicates that there are separate mechanisms of disease resistance.

Cultivar Merii from Palau had the highest fresh weight corm yield (Table 2). There were 15 other cultivars that did not differ significantly from the highest value (Table 2, fresh weight in bold font) and 10 of them also originated from Palau. Among these cultivars, Mana Okoa was the only traditional cultivar from Hawai'i as described by Whitney et al. (1939). Commercially grown cultivars Bun Long and Maui Lehua had fresh weight corm yields that differed significantly from the maximum, with about half that compared with 'Merii'.

Table 2. Country of origin, fresh weight of corms, dry matter of corms, frequency of weight measurements out of 12 planting dates (Wt freq.), severity of taro leaf blight (TLB) averaged across five leaf blades of one plant, frequency of TLB measurements (TLB freq.), severity of corm rots, frequency of measurements (Rot freq.), consumer acceptance ratings of poi and table taro, and frequency of consumer ratings (Taste freq.) of taro cultivars. Based on statistical analysis using “multiple comparisons with the best,” there are two categories: (A) those not different from the maximum value and (B) those different from the maximum value. Fresh weights of corms, percentage dry matter of corms, and consumer acceptance ratings of poi and table taro are highlighted in bold when values do not differ from the best. Severity of TLB and percentage of corm rots are highlighted in bold when values differ significantly from the maximum, indicating apparent disease resistance. Names of cultivars with both significantly lower severity of TLB and corm rots are highlighted in bold.

Taro cultivar	Origin	Fresh wt [mean $\pm$ SE (kg·ha ⁻¹)] ^z	Dry matter [mean $\pm$ SE (%)]	Wt freq. (no.)	Severity of TLB [mean $\pm$ SE (%)] ^y	TLB freq. (no.)	Corm rot [mean $\pm$ SE (%)] ^x	Rot freq. (no.)	Poi rating [mean $\pm$ SE (1–5 scale)] ^w	Table rating [mean $\pm$ SE (1–5 scale)] ^w	Taste freq. (no.)
A'alii	Hawai'i	8,467 $\pm$ 3,203 b ^v	21.6 $\pm$ 1.9 b	5	47.9 $\pm$ 6.3 a	5	5.8 $\pm$ 7.5 b	4	2.7 $\pm$ 0.36 a	2.7 $\pm$ 0.32 a	2
Adako	Japan	5,843 $\pm$ 3,582 b	17.2 $\pm$ 2.1 b	4	59.2 $\pm$ 7.7 a	4	12.8 $\pm$ 8.7 a	3	ND ^u	ND	—
Akugawai	South Pacific	5,407 $\pm$ 4,129 b	13.2 $\pm$ 2.4 b	3	67.4 $\pm$ 7.6 a	3	26.4 $\pm$ 10.6 a	2	2.69 $\pm$ 0.36 a	2.84 $\pm$ 0.32 a	2
Apii	Hawai'i	1,796 $\pm$ 5,057 b	12.3 $\pm$ 2.9 b	2	ND	—	30.9 $\pm$ 10.6 a	2	ND	ND	—
Apowale	Hawai'i	5,034 $\pm$ 3,576 b	16.0 $\pm$ 2.1 b	4	61.6 $\pm$ 7.6 a	3	32.9 $\pm$ 10.6 a	2	ND	ND	—
Apu	Hawai'i	4,168 $\pm$ 4,128 b	14.3 $\pm$ 2.4 b	3	55.8 $\pm$ 10.8 a	2	ND	—	ND	ND	—
Aweu	Hawai'i	7,665 $\pm$ 4,139 b	20.7 $\pm$ 2.4 b	3	67.4 $\pm$ 7.7 a	3	44.0 $\pm$ 10.6 a	2	ND	ND	—
Bun long	China	15,629 $\pm$ 2,047 b	23.3 $\pm$ 1.2 b	12	61.1 $\pm$ 3.6 a	9	12.9 $\pm$ 5.2 b	8	2.84 $\pm$ 0.14 b	2.92 $\pm$ 0.13 b	12
Burra	Samoa	16,101 $\pm$ 2,520 b	17.5 $\pm$ 1.5 b	8	41.8 $\pm$ 4.8 b	5	0.2 $\pm$ 7.5 b	4	2.51 $\pm$ 0.22 b	2.63 $\pm$ 0.2 b	5
Dirratusoch (P-13)	Palau	8,437 $\pm$ 5,071 b	19.2 $\pm$ 2.9 b	2	ND	—	ND	—	ND	ND	—
Dirrattengadik (P-20)	Palau	26,197 $\pm$ 2,699 a	23.7 $\pm$ 1.6 b	7	34.2 $\pm$ 4.8 b	5	6.3 $\pm$ 6.7 b	5	3.0 $\pm$ 0.19 a	2.88 $\pm$ 0.17 b	7
Eleele Makoko	Hawai'i	5,627 $\pm$ 4,131 b	27.9 $\pm$ 2.4 a	36	41.6 $\pm$ 7.6 b	3	0 $\pm$ 8.6 b	3	ND	ND	—
Eleele Naioea	Hawai'i	10,212 $\pm$ 2,249 b	17.6 $\pm$ 1.3 b	10	60.9 $\pm$ 4.1 a	8	9.2 $\pm$ 5.6 b	7	3.65 $\pm$ 0.17 a	3.43 $\pm$ 0.15 a	9
Fa Eleele	Samoa	6,190 $\pm$ 5,061 b	16.8 $\pm$ 2.9 b	2	ND	—	ND	—	ND	ND	—
Fai Faasi I	Samoa	4,006 $\pm$ 2,697 b	19.5 $\pm$ 1.6 b	7	55.6 $\pm$ 4.8 a	5	42.2 $\pm$ 8.6 a	3	ND	ND	—
Fai Faasi II	Samoa	13,791 $\pm$ 5,061 a	19.5 $\pm$ 2.9 b	2	ND	—	ND	—	ND	ND	—
Falan	Samoa	16,598 $\pm$ 5,061 a	25.5 $\pm$ 2.9 a	2	ND	—	ND	—	ND	ND	—
False Wehiwa	Unknown	15,494 $\pm$ 3,576 b	26.4 $\pm$ 2.1 a	4	55.1 $\pm$ 5.4 a	4	5.4 $\pm$ 7.5 b	4	3.48 $\pm$ 0.25 a	3.2 $\pm$ 0.22 a	4
Filipino Red	Philippines	11,772 $\pm$ 2,917 b	18.3 $\pm$ 1.7 b	6	46.3 $\pm$ 5.4 b	4	5.1 $\pm$ 10.6 b	2	ND	ND	—
Haokea	Hawai'i	9,585 $\pm$ 2,520 b	16.7 $\pm$ 1.5 b	8	54.6 $\pm$ 3.8 a	8	13.0 $\pm$ 6.1 b	6	2.73 $\pm$ 0.2 b	2.57 $\pm$ 0.18 b	6
Hapuu	Hawai'i	7,309 $\pm$ 3,582 b	18.0 $\pm$ 2.1 b	4	23.8 $\pm$ 7.7 b	3	31.0 $\pm$ 10.6 a	2	ND	ND	—
Iliuaua	China	28,264 $\pm$ 3,197 a	17.2 $\pm$ 1.9 b	5	66.6 $\pm$ 6.2 a	4	14.9 $\pm$ 8.6 a	3	ND	ND	—
Ka'ano'i	Unknown	14,621 $\pm$ 2,142 b	22.1 $\pm$ 1.2 b	11	49.1 $\pm$ 3.8 b	8	8.1 $\pm$ 5.6 b	7	3.38 $\pm$ 0.16 a	3.15 $\pm$ 0.14 a	10
Kai Ala	Hawai'i	12,395 $\pm$ 4,144 b	17.4 $\pm$ 2.4 b	3	54 $\pm$ 7.7 a	3	19.5 $\pm$ 8.7 a	3	ND	ND	—
Kai KBS	Hawai'i	9,682 $\pm$ 3,203 b	23.0 $\pm$ 1.9 b	5	50.9 $\pm$ 6.3 a	5	20.6 $\pm$ 7.5 a	4	ND	ND	—
Kai Kea	Hawai'i	5,669 $\pm$ 2,922 b	17.0 $\pm$ 1.7 b	6	61.7 $\pm$ 6.3 a	5	45.6 $\pm$ 7.5 a	4	ND	ND	—
Kalalau	Hawai'i	15,729 $\pm$ 2,250 b	20.2 $\pm$ 1.3 b	10	39.0 $\pm$ 4.1 b	8	3.1 $\pm$ 6.1 b	6	3.13 $\pm$ 0.2 a	3.04 $\pm$ 0.18 a	6
Keone (melim)	Hawai'i	11,828 $\pm$ 2,373 b	22.3 $\pm$ 1.4 b	9	33.3 $\pm$ 4.8 b	6	17.6 $\pm$ 6.7 a	5	2.71 $\pm$ 0.22 b	2.80 $\pm$ 0.20 b	5
Ketuangamea I	Easter Island	9,920 $\pm$ 3,578 b	13.4 $\pm$ 2.1 b	4	63.4 $\pm$ 7.6 a	2	ND	—	2.82 $\pm$ 0.36 a	2.94 $\pm$ 0.32 a	2
Kosro	Micronesia	8,024 $\pm$ 3,578 b	17.5 $\pm$ 2.1 b	4	64.0 $\pm$ 7.6 a	2	ND	—	2.51 $\pm$ 0.36 b	2.45 $\pm$ 0.32 b	2
Kumu-elecle	Hawai'i	9,677 $\pm$ 3,575 b	15.0 $\pm$ 2.1 b	4	61.9 $\pm$ 6.2 a	4	13.5 $\pm$ 8.6 a	3	ND	ND	—
Kuoho	Hawai'i	8,582 $\pm$ 3,575 b	24.0 $\pm$ 2.1 b	4	63.3 $\pm$ 6.2 a	4	11.5 $\pm$ 8.6 a	3	ND	ND	—
L-73-365	Polynesia	10,339 $\pm$ 3,578 b	15.6 $\pm$ 2.1 b	4	44.9 $\pm$ 7.6 a	2	ND	—	2.9 $\pm$ 0.36 a	3.04 $\pm$ 0.32 a	2

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Table 2. (*Continued*) Country of origin, fresh weight of corms, dry matter of corms, frequency of weight measurements out of 12 planting dates (Wt freq.), severity of taro leaf blight (TLB) averaged across five leaf blades of one plant, frequency of TLB measurements (TLB freq.), severity of corm rots, frequency of measurements (Rot freq.), consumer acceptance ratings of poi and table taro, and frequency of consumer ratings (Taste freq.) of taro cultivars. Based on statistical analysis using “multiple comparisons with the best,” there are two categories: (A) those not different from the maximum value and (B) those different from the maximum value. Fresh weights of corms, percentage dry matter of corms, and consumer acceptance ratings of poi and table taro are highlighted in bold when values do not differ from the best. Severity of TLB and percentage of corm rots are highlighted in bold when values differ significantly from the maximum, indicating apparent disease resistance. Names of cultivars with both significantly lower severity of TLB and corm rots are highlighted in bold.

Taro cultivar	Origin	Fresh wt [mean ± SE (kg·ha ⁻¹)] ^z	Dry matter [mean ± SE (%)]	Wt freq. (no.)	Severity of TLB [mean ± SE (%)] ^y	TLB freq. (no.)	Corm rot [mean ± SE (%)] ^x	Rot freq. (no.)	Poi rating [mean ± SE (1–5 scale)] ^w	Table rating [mean ± SE (1–5 scale)] ^v	Taste freq. (no.)
L-73-366	Polynesia	15,161 ± 2,519 b	18.5 ± 1.5 b	8	48.8 ± 5.4 a	5	4.8 ± 7.5 b	4	ND	ND	—
L-73-369	Polynesia	11,954 ± 2,373 b	14.2 ± 1.4 b	9	44.4 ± 4.8 b	6	3.5 ± 6.7 b	5	2.55 ± 0.25 b	2.55 ± 0.22 b	4
L-73-371	Polynesia	13,032 ± 2,918 b	14.3 ± 1.7 b	6	45.2 ± 5.4 b	4	12.3 ± 10.6 a	2	2.83 ± 0.29 a	2.78 ± 0.26 a	3
Lauloa Eleele-ula	Hawai'i	8,466 ± 2,916 b	12.5 ± 1.7 b	6	65.6 ± 6.2 a	4	30.2 ± 10.6 a	2	ND	ND	—
Lauloa Keokeo	Hawai'i	7,148 ± 2,698 b	14.4 ± 1.6 b	7	73.1 ± 6.2 a	5	5.3 ± 8.6 b	3	ND	ND	—
Lauloa Pala	Hawai'i	10,405 ± 5,061 b	14.3 ± 2.9 b	2	ND	—	ND	—	2.72 ± 0.36 a	2.98 ± 0.32 a	2
Lauloa	Hawai'i	10,677 ± 3,197 b	15.7 ± 1.9 b	5	63.1 ± 6.2 a	4	8.3 ± 8.6 b	3	2.23 ± 0.36 b	2.56 ± 0.31 b	2
Palakea-eleele											
Lauloa	Hawai'i	11,253 ± 5,061 b	12.8 ± 2.9 b	2	ND	—	ND	—	2.61 ± 0.36 b	2.58 ± 0.32 a	2
Palakea-keokeo											
Lauloa	Hawai'i	8,928 ± 2,916 b	14.8 ± 1.7 b	6	61.4 ± 6.2 a	4	6.3 ± 10.6 b	2	ND	ND	—
Palakea-papamu											
Lauloa	Hawai'i	13,158 ± 2,701 b	17.8 ± 1.6 b	7	61.9 ± 6.3 a	5	7.2 ± 7.5 b	4	2.80 ± 0.30 a	2.97 ± 0.26 a	3
Palakea-ula											
Lauloa	Hawai'i	6,664 ± 3,583 b	14.4 ± 2.1 b	4	61.0 ± 6.2 a	4	21.6 ± 7.5 a	4	ND	ND	—
Ulaula Omao											
Lehua Maoli	Hawai'i	16,780 ± 2,047 b	22.2 ± 1.2 b	12	53.1 ± 3.8 a	9	16.3 ± 5.2 b	8	3.7 ± 0.14 a	3.53 ± 0.13 a	12
Lehua Palaii	Hawai'i	8,268 ± 2,374 b	14.5 ± 1.4 b	9	67.0 ± 4.1 a	8	18.0 ± 6.1 a	6	2.7 ± 0.25 b	2.70 ± 0.22 b	4
Leo	Hawai'i	1,134 ± 5,050 b	23.8 ± 2.9 a	2	66.2 ± 10.8 a	2	ND	—	ND	ND	—
Maca	Hawai'i	4,374 ± 3,197 b	14.4 ± 1.9 b	5	52.6 ± 6.2 a	4	8.8 ± 8.6 b	3	ND	ND	—
Makalau	Hawai'i	7,908 ± 4,131 b	16.3 ± 2.4 b	3	48.4 ± 7.6 a	3	9.4 ± 8.6 b	3	ND	ND	—
(Molokai)											
Mana Eleele	Hawai'i	12,686 ± 4,144 b	19.4 ± 2.4 b	3	57.3 ± 7.7 a	3	19.4 ± 8.7 a	3	ND	ND	—
Mana Keokeo	Hawai'i	6,949 ± 5,059 b	25.2 ± 2.9 a	2	51.0 ± 10.8 a	2	26.2 ± 10.6 a	2	ND	ND	—
Mana Laulua	Hawai'i	9,368 ± 2,520 b	20.9 ± 1.5 b	8	51.6 ± 4.8 a	7	20.7 ± 6.1 a	6	3.12 ± 0.25 a	3.12 ± 0.22 a	4
Mana Okoa	Hawai'i	18,224 ± 3,586 a	20.8 ± 2.1 b	4	51.1 ± 7.7 a	4	17.8 ± 7.5 a	4	ND	ND	—
Mana Opelu	Hawai'i	6,706 ± 3,584 b	17.2 ± 2.1 b	4	59.7 ± 6.3 a	4	40.9 ± 8.7 a	3	3.13 ± 0.30 a	2.87 ± 0.26 a	3
Mana Ulaula	Hawai'i	3,056 ± 4,145 b	13.1 ± 2.4 b	3	60.5 ± 7.7 a	3	45.4 ± 8.7 a	3	ND	ND	—
Mana Uluuli	Hawai'i	6,760 ± 5,059 b	20.5 ± 2.9 a	2	53.5 ± 10.8 a	2	29.5 ± 10.6 a	2	ND	ND	—
Mana Ulu	Hawai'i	3,155 ± 5,083 b	9.8 ± 3.0 b	2	61.5 ± 10.9 a	2	19.2 ± 10.6 a	2	ND	ND	—
Manapiko	Hawai'i	7,154 ± 3,576 b	16.1 ± 2.1 b	4	64.4 ± 7.6 a	3	8.3 ± 10.6 a	2	ND	ND	—
Manini Kea	Hawai'i	9,890 ± 5,059 b	19.0 ± 2.9 b	2	58.5 ± 10.8 a	2	18.8 ± 10.6 a	2	ND	ND	—
Manini Toretoire	Hawai'i	10,761 ± 2,922 b	19.8 ± 1.7 b	6	59.6 ± 6.2 a	5	22.4 ± 7.5 a	4	2.35 ± 0.36 b	2.35 ± 0.32 b	2
Manini Uluuli	Hawai'i	6,280 ± 4,129 b	20.6 ± 2.4 b	3	49.9 ± 7.6 a	3	29.5 ± 10.6 a	2	ND	ND	—
Manini-opelu	Hawai'i	10,889 ± 3,203 b	18.9 ± 1.9 b	5	53.0 ± 6.3 a	5	29.9 ± 7.5 a	4	ND	ND	—

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Table 2. (*Continued*) Country of origin, fresh weight of corms, dry matter of corms, frequency of weight measurements out of 12 planting dates (Wt freq.), severity of taro leaf blight (TLB) averaged across five leaf blades of one plant, frequency of TLB measurements (TLB freq.), severity of corm rots, frequency of measurements (Rot freq.), consumer acceptance ratings of poi and table taro, and frequency of consumer ratings (Taste freq.) of taro cultivars. Based on statistical analysis using "multiple comparisons with the best," there are two categories: (A) those not different from the maximum value and (B) those different from the maximum value. Fresh weights of corms, percentage dry matter of corms, and consumer acceptance ratings of poi and table taro are highlighted in bold when values do not differ from the best. Severity of TLB and percentage of corm rots are highlighted in bold when values differ significantly from the maximum, indicating apparent disease resistance. Names of cultivars with both significantly lower severity of TLB and corm rots are highlighted in bold.

Taro cultivar	Origin	Fresh wt [mean $\pm$ SE (kg·ha ⁻¹)] ^z	Dry matter [mean $\pm$ SE (%)]	Wt freq. (no.)	Severity of TLB [mean $\pm$ SE (%)] ^y	TLB freq. (no.)	Corm rot [mean $\pm$ SE (%)] ^x	Rot freq. (no.)	Poi rating [mean $\pm$ SE (1–5 scale)] ^w	Table rating [mean $\pm$ SE (1–5 scale)] ^v	Taste freq. (no.)
Manini-owali	Hawai'i	11,491 $\pm$ 3,586 b	11.0 $\pm$ 2.1 b	4	67.9 $\pm$ 6.2 a	4	31.0 $\pm$ 7.5 a	4	2.78 $\pm$ 0.37 a	2.82 $\pm$ 0.32 a	2
Matale	Samoa	8,434 $\pm$ 5,061 b	11.8 $\pm$ 2.9 b	2	ND	—	ND	—	ND	ND	—
Maui Lehua	Hawai'i	13,200 $\pm$ 2,915 b	21.8 $\pm$ 1.7 b	6	54.4 $\pm$ 4.8 a	5	10.0 $\pm$ 7.5 b	4	3.51 $\pm$ 0.25 a	3.46 $\pm$ 0.22 a	4
Meltai (P-16)	Palau	17,528 $\pm$ 2,915 a	25.2 $\pm$ 1.9 b	6	35.8 $\pm$ 5.4 b	5	10.2 $\pm$ 6.7 b	5	3.00 $\pm$ 0.29 a	3.09 $\pm$ 0.26 a	3
Merii (P-12)	Palau	29,516 $\pm$ 2,698 a	21.6 $\pm$ 1.6 b	7	36.3 $\pm$ 4.8 b	6	7.0 $\pm$ 6.1 b	6	2.71 $\pm$ 0.25 b	2.56 $\pm$ 0.22 b	4
Minaya	Philippines	8,805 $\pm$ 3,198 b	20.8 $\pm$ 1.9 b	5	53.8 $\pm$ 6.2 a	3	ND	—	3.30 $\pm$ 0.35 a	3.18 $\pm$ 0.31 a	2
Miyako	Japan	8,186 $\pm$ 2,698 b	18.0 $\pm$ 1.6 b	7	48.8 $\pm$ 7.7 a	4	10.6 $\pm$ 8.7 b	3	ND	ND	—
Moalech (P-8)	Palau	15,035 $\pm$ 3,583 b	20.5 $\pm$ 2.1 b	4	27.7 $\pm$ 5.4 b	4	14.7 $\pm$ 8.6 a	3	2.88 $\pm$ 0.36 a	2.83 $\pm$ 0.31 a	2
Moi (white)	Hawai'i	8,260 $\pm$ 3,575 b	21.5 $\pm$ 2.1 b	4	66.3 $\pm$ 6.2 a	4	0.6 $\pm$ 8.6 b	3	ND	ND	—
Nawao	Hawai'i	6,629 $\pm$ 4,131 b	22.4 $\pm$ 2.4 b	3	56.2 $\pm$ 7.6 a	3	5.9 $\pm$ 8.6 b	3	ND	ND	—
Ngeruuch	Palau	—	—	7	—	6	—	6	—	—	5
(P-10)	—	24,691 $\pm$ 2,698 a	25.1 $\pm$ 1.6 b	—	25.8 $\pm$ 4.8 b	—	17.3 $\pm$ 6.1 a	—	3.09 $\pm$ 0.22 a	3.14 $\pm$ 0.2 a	—
Ngesuas (P-1)	Palau	25,153 $\pm$ 2,520 a	25.8 $\pm$ 1.5 b	8	30.7 $\pm$ 4.4 b	6	3.3 $\pm$ 6.1 b	6	3.25 $\pm$ 0.21 a	3.12 $\pm$ 0.18 a	6
Ngetmadei (P-19)	Palau	20,972 $\pm$ 3,205 a	18.7 $\pm$ 1.9 b	5	34.4 $\pm$ 5.4 b	4	10.2 $\pm$ 7.5 b	4	2.51 $\pm$ 0.36 b	2.68 $\pm$ 0.31 a	2
Nihopuu	Hawai'i	13,257 $\pm$ 2,374 b	18.4 $\pm$ 1.4 b	9	59.7 $\pm$ 4.8 a	7	30.8 $\pm$ 6.7 a	5	2.8 $\pm$ 0.3 a	2.88 $\pm$ 0.26 a	3
Niihau	Hawai'i	5,561 $\pm$ 5,083 b	23.3 $\pm$ 3.0 b	2	53.8 $\pm$ 10.9 a	2	41.6 $\pm$ 10.6 a	2	ND	ND	—
Niue-ulaula	Hawai'i	10,873 $\pm$ 3,203 b	20.6 $\pm$ 1.9 b	5	55.0 $\pm$ 6.3 a	5	8.7 $\pm$ 7.5 b	4	ND	ND	—
Ochab (P-5)	Palau	17,489 $\pm$ 2,922 a	21.4 $\pm$ 1.7 b	6	23.7 $\pm$ 5.4 b	4	1.8 $\pm$ 7.5 b	4	3.07 $\pm$ 0.29 a	3.02 $\pm$ 0.26 a	3
Ochelochel (P-7)	Palau	19,537 $\pm$ 2,520 a	21.6 $\pm$ 1.5 b	8	31.4 $\pm$ 4.4 b	6	0.0 $\pm$ 6.1 b	6	3.13 $\pm$ 0.21 a	3.00 $\pm$ 0.18 a	6
Ohe	Hawai'i	11,155 $\pm$ 3,203 b	22.3 $\pm$ 1.9 b	5	59.5 $\pm$ 5.4 a	5	18.0 $\pm$ 7.5 a	4	ND	ND	—
Oiremch (P-18)	Palau	10,158 $\pm$ 3,200 b	19.1 $\pm$ 2.1 b	5	48.6 $\pm$ 5.4 a	4	32.9 $\pm$ 7.5 a	4	3.36 $\pm$ 0.36 a	3.01 $\pm$ 0.31 a	2
Okinawa	Okinawa	13,701 $\pm$ 2,249 b	25.2 $\pm$ 1.3 b	10	41.7 $\pm$ 4.1 b	7	7.0 $\pm$ 6.1 b	6	2.82 $\pm$ 0.17 b	2.95 $\pm$ 0.15 a	9
Ongdibel (P-3)	Palau	19,443 $\pm$ 2,933 a	18.7 $\pm$ 1.7 b	6	38.7 $\pm$ 5.4 b	4	2.1 $\pm$ 8.6 b	3	2.44 $\pm$ 0.25 b	2.42 $\pm$ 0.22 b	4
Oopukai	Hawai'i	6,884 $\pm$ 3,197 b	14.5 $\pm$ 1.9 b	5	61.1 $\pm$ 6.2 a	4	19.9 $\pm$ 8.6 a	3	ND	ND	—
Paakai	Hawai'i	5,639 $\pm$ 3,576 b	15.7 $\pm$ 2.1 b	4	67.8 $\pm$ 7.6 a	3	35.3 $\pm$ 10.6 a	2	ND	ND	—
Papakolea-koae	Hawai'i	10,650 $\pm$ 2,372 b	22.4 $\pm$ 1.4 b	9	57.2 $\pm$ 4.4 a	7	8.2 $\pm$ 6.1 b	6	3.51 $\pm$ 0.20 a	3.40 $\pm$ 0.18 a	6
Papapuo	Hawai'i	7,528 $\pm$ 4,129 b	19.6 $\pm$ 2.4 b	3	68.3 $\pm$ 7.6 a	3	11.4 $\pm$ 10.6 a	2	ND	ND	—
Piko Eleele	Hawai'i	6,527 $\pm$ 3,197 b	11.9 $\pm$ 1.9 b	5	61.1 $\pm$ 6.2 a	4	4.2 $\pm$ 8.6 b	3	ND	ND	—
Piko kea	Hawai'i	10,798 $\pm$ 2,922 b	12.5 $\pm$ 1.7 b	6	55.1 $\pm$ 6.3 a	5	12.0 $\pm$ 7.5 b	4	2.39 $\pm$ 0.30 b	2.21 $\pm$ 0.26 b	3
Piko Keokeo	Hawai'i	5,281 $\pm$ 2,375 b	15.7 $\pm$ 1.5 b	9	67.7 $\pm$ 4.4 a	7	8.1 $\pm$ 7.5 b	5	2.39 $\pm$ 0.35 b	2.42 $\pm$ 0.31 b	2
Piko Lehua-apei	Hawai'i	9,236 $\pm$ 5,059 b	18.2 $\pm$ 2.9 b	2	58.2 $\pm$ 10.8 a	2	17.6 $\pm$ 10.6 a	2	ND	ND	—
Piko Ulaula	Hawai'i	6,240 $\pm$ 4,131 b	19.9 $\pm$ 2.4 a	3	60.7 $\pm$ 7.6 a	3	15.3 $\pm$ 8.6 a	3	ND	ND	—
Polotu	Hawai'i	14,105 $\pm$ 2,373 b	33.2 $\pm$ 1.4 a	9	49.8 $\pm$ 4.1 a	8	4.9 $\pm$ 5.6 b	7	2.84 $\pm$ 0.19 b	2.82 $\pm$ 0.17 b	7

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Taro cultivar	Origin	Fresh wt [mean $\pm$ SE (kg ha ⁻¹)] ^a	Dry matter [mean $\pm$ SE (%)]	Wt freq. (no.)	Severity of TLB [mean $\pm$ SE (%)] ^b	TLB freq. (no.)	Corm rot [mean $\pm$ SE (%)] ^c	Rot freq. (no.)	Poi rating [mean $\pm$ SE (1–5 scale)] ^w	Table rating [mean $\pm$ SE (1–5 scale)] ^w	Taste freq. (no.)
Pue Uta Samoa	Samoa	14,181 $\pm$ 4,134 b	20.2 $\pm$ 2.4 b	3	ND	—	ND	—	ND	ND	—
Purple Manalud	Philippines	7,932 $\pm$ 2,375 b	21.7 $\pm$ 1.4 b	9	60.4 $\pm$ 4.4 a	7	25.5 $\pm$ 6.7 a	9	2.79 $\pm$ 0.25 b	2.67 $\pm$ 0.22 b	4
Red Moi	Hawai'i	14,572 $\pm$ 2,142 b	19.2 $\pm$ 1.2 b	11	46.2 $\pm$ 4.1 b	8	16.6 $\pm$ 5.6 a	7	2.85 $\pm$ 0.19 b	2.88 $\pm$ 0.17 b	7
Sasa Paepae	Samoa	10,386 $\pm$ 5,061 b	23.0 $\pm$ 2.9 b	2	ND	—	ND	—	2.82 $\pm$ 0.36 a	2.77 $\pm$ 0.32 a	2
Sasa Uliuli	Samoa	8,180 $\pm$ 4,134 b	11.9 $\pm$ 2.4 b	3	ND	—	ND	—	ND	ND	—
Sawa Bastora	Pohnpei	23,301 $\pm$ 2,373 a	19.1 $\pm$ 1.4 b	9	32.7 $\pm$ 4.8 b	6	1.6 $\pm$ 6.7 b	5	2.3 $\pm$ 0.22 b	2.24 $\pm$ 0.20 b	5
Sawa Puctata	Samoa	10,252 $\pm$ 5,061 b	17.2 $\pm$ 2.9 b	2	ND	—	ND	—	ND	ND	—
Senorita	Philippines	6,703 $\pm$ 5,061 b	19.9 $\pm$ 2.9 b	2	ND	—	ND	—	ND	ND	—
Tahitian	Tahiti	5,158 $\pm$ 2,922 b	17.8 $\pm$ 1.7 b	6	57.6 $\pm$ 5.4 a	5	26.6 $\pm$ 7.5 a	4	ND	ND	—
Talo Manua	Samoa	10,496 $\pm$ 4,134 b	19.8 $\pm$ 2.4 b	3	ND	—	ND	—	3.51 $\pm$ 0.36 a	3.52 $\pm$ 0.32 a	2
Talo paepae	Samoa	5,439 $\pm$ 5,061 b	13.9 $\pm$ 2.9 b	2	ND	—	ND	—	2.17 $\pm$ 0.36 b	2.30 $\pm$ 0.32 b	2
Teatea I	Easter Island	10,618 $\pm$ 5,061 b	9.4 $\pm$ 2.9 b	2	ND	—	ND	—	ND	ND	—
Teatea II	Easter Island	14,452 $\pm$ 3,578 b	12.7 $\pm$ 2.1 b	4	60.7 $\pm$ 7.6 a	2	ND	—	2.52 $\pm$ 0.36 b	2.51 $\pm$ 0.32 b	2
Terrekaki (P-2)	Palau	18,766 $\pm$ 2,922 a	20.4 $\pm$ 1.7 b	6	38.3 $\pm$ 5.4 b	4	5.6 $\pm$ 7.5 b	4	2.58 $\pm$ 0.29 b	2.70 $\pm$ 0.26 a	3
Tsuronoko	Japan	8,036 $\pm$ 5,061 b	9.5 $\pm$ 2.9 b	2	ND	—	ND	—	2.66 $\pm$ 0.36 a	2.63 $\pm$ 0.32 a	2
Uahiapale	Hawai'i	6,787 $\pm$ 3,203 b	16.8 $\pm$ 1.9 b	5	50.3 $\pm$ 6.3 a	5	8.3 $\pm$ 7.5 b	4	ND	ND	—
Ulaula Kumu	Hawai'i	5,818 $\pm$ 2,696 b	13.8 $\pm$ 1.6 b	7	56.8 $\pm$ 4.4 a	7	19.6 $\pm$ 6.1 a	6	2.45 $\pm$ 0.29 b	2.19 $\pm$ 0.26 b	3
Ulaula Moano	Hawai'i	8,591 $\pm$ 2,521 b	19.4 $\pm$ 1.4 b	8	49.4 $\pm$ 4.8 a	6	18.3 $\pm$ 7.5 a	4	ND	ND	—
Ulaula Poni	Hawai'i	10,870 $\pm$ 4,131 b	12.2 $\pm$ 2.4 b	3	47.7 $\pm$ 7.6 a	3	9.3 $\pm$ 8.6 b	3	ND	ND	—
Unknown No. 97	Unknown	11,659 $\pm$ 5,059 b	23.1 $\pm$ 2.9 b	2	63.4 $\pm$ 10.8 a	2	5.3 $\pm$ 10.6 b	2	ND	ND	—
Unknown No. 151	Unknown	3,501 $\pm$ 2,374 b	18.8 $\pm$ 1.4 b	9	65.6 $\pm$ 4.4 a	7	38.0 $\pm$ 6.7 a	5	2.68 $\pm$ 0.36 a	2.69 $\pm$ 0.32 a	2
Vaeae Uliuli	Samoa	6,985 $\pm$ 4,134 b	12.6 $\pm$ 2.4 b	3	ND	—	ND	—	1.82 $\pm$ 0.36 b	2.28 $\pm$ 0.32 b	2
Wchiwa	Hawai'i	13,983 $\pm$ 2,141 b	25 $\pm$ 1.2 a	11	51.4 $\pm$ 3.8 a	9	12.9 $\pm$ 5.2 b	8	3.5 $\pm$ 0.22 a	3.52 $\pm$ 0.20 a	5
Yellow benahi	Philippines	8,481 $\pm$ 5,061 b	20.8 $\pm$ 2.9 b	2	ND	—	ND	—	ND	ND	—
Yen 614	Polynesia	20,660 $\pm$ 5,061 a	12.9 $\pm$ 2.9 b	2	ND	—	ND	—	2.66 $\pm$ 0.36 a	2.53 $\pm$ 0.32 b	2

^a1 kg ha⁻¹ = 0.8922 lb/acre.

^bSeverity of TLB was based on a modified Horsfall-Barratt disease assessment scale with 12 categories of disease (0–11) for visual estimation of the proportion of the leaf blade affected by TLB, starting from the first fully matured leaf blade and continuing through five leaf blades. Ratings for individual leaf blades were converted into the midpoint percentage of the leaf blade affected by the disease (0%, 0.5%, 3%, 7%, 13.5%, 28%, 50%, 72%, 86.5%, 94%, 97.5%, and 100%), and then averaged over five leaf blades.

^cPercentage of corm rots were determined by the ratio of fresh weight of excised, rotten portion of corms relative to total fresh weight of corms.

^wTo prepare poi, taro corms were pressure-cooked or steamed and then mashed. To prepare table taro, corms were pressure-cooked or steamed and then cubed; 1 = unacceptable, 2 = needs improvement, 3 = okay, 4 = good, 5 = excellent quality.

^xMeans in a column followed by the same letter are not significantly different from each other.

^yND = not determined, either due to measurements not taken or due to measurements taken only once.

Fig. 4. Plot of dry weights of corms of taro cultivars Bun Long and Lehua Maoli at 12 planting dates vs. rainfall summed during two to six months after planting (MAP). Simple linear regression ($y = 5608 - 1.21 \times x$) showed a significant, negative relationship ($r^2 = 0.20$, $P = 0.029$); 1 mm = 0.0394 inch, 1 $\text{kg} \cdot \text{ha}^{-1}$ = 0.8922 lb/acre.

Fig. 5. (A) Plot of mean consumer acceptance ratings for poi against mean corm dry matter for taro cultivars ($y = 2.02 + 0.044 \times x$; $r^2 = 0.26$, $P < 0.0001$). (B) Plot of mean consumer acceptance ratings for table taro against mean percentage of corm dry matter for cultivars ($y = 2.13 + 0.037 \times x$; $r^2 = 0.25$, $P < 0.0001$). Consumer acceptance for poi or table taro was ranked on a 1 to 5 scale, with 1 = unacceptable quality, 2 = needs improvement, 3 = okay, 4 = good, and 5 = excellent quality.

Fresh weights of corms were reported in Table 2 because these values are of economic interest to growers.

Cultivar Pololu from Hawai'i had the highest percentage dry matter of the corm (Table 2) and a dry weight yield that did not differ significantly from the highest value. However, its fresh weight yield was significantly lower than the maximum value (Table 2). There were five other cultivars that did not differ significantly from the highest percentage dry matter (Table 2, dry matter in bold font). Among this group, three cultivars were from Hawai'i and none were from Palau.

Cultivar Lehua Maoli, a traditional cultivar from Hawai'i described by Whitney et al. (1939), had the highest consumer acceptance rating for poi of 3.70 and for table taro of 3.53 (Table 2). This preference was not surprising since the consumer acceptance panel consisted mostly of local residents of Hawai'i Island. Interestingly, in a study conducted on the Island of Molokai, 'Lehua Maoli' was the 15th highest rated for acceptability of poi and the second highest rated for "microwaved" (i.e., table taro) (Paull et al., 2000).

There were 32 other cultivars that did not differ from the highest rating for poi, and 34 other cultivars that did not differ from the highest rating for table taro (Table 2, poi or table taro ratings in bold font). Among the group that did not differ from the highest ratings of both poi and table taro, there were nine from Palau. Commercial cultivar Bun Long which originated from China was among the lower-rated group for both poi and table taro.

Mean consumer acceptance ratings for poi were correlated positively with mean corm dry matter for cultivars [Fig. 5A ($y = 2.02 + 0.044 \times x$; $r^2 = 0.26$, $P < 0.0001$)]. Similarly, mean consumer acceptance ratings for table taro were positively correlated with mean corm dry matter for cultivars [Fig. 5B ($y = 2.13 + 0.037 \times x$; $r^2 = 0.25$, $P < 0.0001$)].

Starch content in taro flour prepared from peeled, dried, and ground corms was reported to range from 73% to 76% in several cultivars from Hawai'i (Jane et al., 1992). Mean consumer acceptance ratings for poi or table taro were indicative of a preference for high starch content. Interestingly, in Figure 5, the cultivar

with the highest mean corm dry matter, but poor consumer acceptance ratings for poi or table taro, was Pololu. Comments from consumers indicated that this cultivar produced poi that was considered too sticky and table taro that was considered too dry.

Among the five cultivars identified earlier as promising (Dirratengadik, Merii, Ngesuas, Ochelochel, and Sawa Bastora), several also had undesirable qualities. For example, 'Dirratengadik' was considered as unacceptable to consumers for table taro; 'Merii' and 'Sawa Bastora' were considered as unacceptable for both poi or table taro. Comments from consumers indicated that these cultivars lacked the dark purplish corm color valued by Hawaiians, high starch content preferred in table taro, and gummy texture preferred in poi. Corms of 'Sawa Bastora' also had an undesirable, bitter taste. In addition, Palauan cultivars produce runners (i.e., stolons or lateral stems), a wild-type characteristic that could increase invasiveness and difficulty in farm management.

Conclusions

Taro cultivars differed significantly in severity of TLB caused by *P. colocasiae* and in severity of corm rots. Increasing levels of apparent resistance to TLB and to corm rots in cultivars were associated with increased dry weight corm yields. "Multiple comparisons with the best" is a useful statistical procedure to identify promising cultivars among more than 100 candidates for conventional breeding with commercial parents to improve disease resistance and yields. Five taro cultivars were identified as "among the best" for high corm yields, apparent TLB resistance, and low severity of corm rots. These cultivars were Dirratengadik, Merii, Ngesuas, Ochelochel, and Sawa Bastora. In addition to these desirable traits, these five cultivars have undesirable characteristics (e.g., unacceptable consumer acceptance and wild-type traits). Conventional breeding with commercial cultivars could result in progeny with higher yields, improved TLB resistances, and acceptable consumer ratings.

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