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Full Length Article

Evaluating Taro Genetic Resources Collected from the Northern Provinces of Vietnam

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Abstract

To assess the morphological and agronomic traits of 250 taro accessions collected in the Northern provinces of Vietnam, an experiment was arranged in 2020 at Truc Son village, Toan Son commune, Da Bac district, Hoa Binh province. A total of 250 taro accessions were collected from 20 areas in Northern Vietnam. The North of Vietnam's taro group had diverse growth behaviors and morphological attributes. Therefore, combining morphological and agronomic assessment and yield data, we selected 12 potential accessions with an average corm yield >13 tons/ha to introduce in the evaluation for exploitation using taro genetic resources in Northern Vietnam. These 12 taro accessions were Khoai Thom, Mac Phua Lanh, Co Cai, Hau Dang, Phuoc, Khoai So Do, Hau Dang, Phuoc Bay, Co Kay, Khoai So Ray, Hau Dong and Khoai So, which manifested 13.7, 13.8, 14.3, 17.8, 19.5, 16.0, 15.8, 16.5, 17.9, 18.7, 19.8 and 20 tons/ha respectively corm yield.

Keywords: Accession; Agronomic; Morphological; Plant genetic resources; Taro characteristic

Introduction

Taro belongs to the genus *Colocasia*, within the sub-family Colocasioideae of the monocotyledonous family Araceae. Because of a long history of vegetative propagation, the genus *Colocasia's* taxonomy needs to be precise. Cultivated taro is classified as *Colocasia esculenta*, but the species was considered polymorphic. There are at least two botanical species: i) *Colocasia esculenta* (L.) Schott var. esculenta; ii) *Colocasia esculenta* (L.) Schott var. antiquorum (Schott) Hubbard & Rehder is synonymous with *C. esculenta var. globulifera* Engl. & Krause (Purseglove 1972). *C. esculenta var. esculenta* are characterized by possessing a large cylindrical central corm and very few cormels. Hence, it resembles agronomical as the dasheen type of taro. *C. esculenta var. antiquorum*, on the other hand, has a small rounded central corm, with several relatively large cormels arising from the corm. This variety resembles agronomic as the eddoes type of taro. Most of the taro grown in the Asia/Pacific region is of the dasheen type (FAO 1999).

Vietnam is located in Southeast Asia, considered a cultivated genetic diversity center, the beginning of the Araceae family plants, including Taro. In Vietnam, the taro germplasm is very diverse and distributed in production and naturally at an altitude from 1 to 1500 m above sea level (Hue and Viet 2004). Like other Southeast Asian countries, *Colocasia esculenta* (L.) Schott was domesticated and cultivated by indigenous peoples many years ago. It is an important food source for many ethnic people in Vietnam (Hue *et al.* 2010). In Bac Can, Yen Bai, Lang Son, Hoa Binh, and Ninh Binh provinces, taro growth has brought high income to producers (Nong *et al.* 2006). However, due to the change of agricultural land using the target in rural areas, farming systems and urbanization have threatened the survival of plant resources germplasm in Vietnam. As a result, many taro accessions have been planted and adopted in different regions of Vietnam, in which precious accessions are gradually been lost. Therefore, collecting, conserving and exploiting taro germplasm is essential to stabilizing food production and farmers' income, especially where other crops are limited or inefficient (Ha *et al.* 2015).

From 1990 to 2006, the Plant Genetics Resource Center, now the Plant Resources Center (PRC), collected the taro germplasm and made *ex-situ* conservation in the field, including *C. esculenta var. esculenta* (L.) Schott) and *C. esculenta var. antiquorum* (L.) Schott,) in Vietnam. Plant genetic resource assessment is one of the main contents of conservation activity, including collecting, storing, evaluating, documenting, and exploiting genetic resources (Nghia *et al.* 2014). This article shows the results of assessment of taro accessions collected in the Northern provinces of Vietnam, 2010–2018. These results are essential scientific data that directly serve the taro accessions conservation and efficient exploitation in Vietnam.

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Materials and Methods

Description of study area

The study was conducted at Truc Son village, Toan Son commune Da Bac districts Hoa Binh city of Vietnam, at 20º87' N and longitude 105º27' E, 401 m altitude. The place's mean, minimum, and maximum temperature is 23.5, 12 and 38–39ºC, respectively. The mean precipitation is 1,570 mm per year, mainly from May to September, accounting for 79% of the yearly rainfall (Website of Da Bac district 2023).

Material

The experimental material included 250 taro accessions collected from 20 provinces in Northern Vietnam (Table 1 and Fig. 1). The list of all the accessions collected from all the provinces is given as Supplementary Table S1. The PRC currently conserves 525 taro accessions, including 250 accessions originating in the Northern 20 provinces. Four provinces Son La, Tuyen Quang, Dien Bien, and Lai Chau entailed the most genetic resources taro 36, 26, 25 and 21 accessions, respectively. The following eight provinces had the number of taro genetic resources collected from 10 to 20 accessions, including Lao Cai, Cao Bang, Hoa Binh, Ha Noi, Bac Giang, Phu Tho, Ha Giang and Lang Son provinces. Different places only entailed less than 10 taro accessions.

Methods

All rhizomes were checked for statistics on quantity and quality before planting. Rotten and diseased rhizomes were removed, chosen cormels were healthy and disease-free rhizomes. We use 1 ton of microbial fertilizer and 100 kg P_2O_5/ha at planting time. Two months after planting, 40 kg urea and 30 kg K_2O/ha were added, while 40 kg urea and 70 kg K_2O/ha added 4 months after planting (Nghia *et al*. 2014).

Experimental design and management

Experimental design: Experiments were arranged in collection, sequentially and without replication. Plot size 2.0 m × 1.4 m plots. Double rows plot, with each row 2.0 m long, spaced 0.7 m between rows and 0.4 m plants within a row was arranged providing 6 plants per row, with a population of approximately 35,000 plants per hectare. Corms of the same size were used as a planting material and planted in March 2020. The taro planted at Da Bac district, Hoa Binh province, farming relies on natural water resources.

Morphological data collection

The descriptor documentation of taro (*C. esculenta*) was developed by PRC (2012) and was followed for data collection. Two data sets (qualitative and quantitative) were collected to assess the diversity and find key morphological traits in taro accessions. Among the descriptors developed by La Tuan Nghia *et al.* (2014) to characterize taro accessions, 17 qualitative and 14 quantitative characteristics were used. The selected traits were most distinguished as highly heritable traits and used for analysis. Both foliar and subterranean data were considered. Foliar traits were scored five months after planting, while subterranean characteristics were evaluated at harvest time. Most of the data were recorded on an individual plant basis using sample averages of five plants selected at random from two rows.

Graded quality traits: Based on the characterization and evaluation for taro, build by Plant Resources Center (Vietnam). Each trait will have different levels of expression, observe with the eyes and determine the corresponding expression level of the trait.

Measured quantitative traits: Plant height was measured from the soil surface up to the base of the second youngest, fully formed, fully unfolded leaf on fully mature plants (cm). Leaf blade length and leaf blade width were measured from the base of the sinus to the top of the leaves and across widest parts of the leaves, respectively (cm). The petiole sheath length was measured from the soil surface up to the end of the opened sheath point (cm). "V" angle was used a protractor placed perpendicular to the petiole junction of the leaf so that the edge of the protractor was along the main vein at the sinus, align the right angle up to the main vein of the opposite sinus and determine the angle value (^{0}). Depth of the sinus was measured from the base of the sinus to the point perpendicular to the line passing the top of the lobe leaves (cm). Distance between the main vein junction and base of the sinus was measured from base of the sinus to petiole junction on the upper side of the leaves (cm). The number of secondary veins connected to main vein system of leaf was observed on the under-side of the leaves and counted pair veins (count). Length of corms measured from tail to head and width of corms measured at thickness in the middle of the corm (cm). The number of cormels were individual counted (count). Corm weight and cormel weight of hill were weighted corm and cormels of individual hill, respectively (g). Corm yield was measured by weighing the corms and cormels together (g). It was then converted into yield per hectare using the following formula: Yield per hectare in tonnes.

$$\text{Yield per hectare (tons/ha)} = \frac{\text{Yield per plot (kg)}}{\text{Number of hills}} \times 3.5\ (\text{hill/m}^2)$$

Statistical Analysis

Collecting data and statistics analysis by Excel 2016 software, including Mean, Minimum, Maximum, Standard deviation (SD), coefficient of variation (CV%), n values for quantitative traits. Using software Diva Gis 7.5 to draw distribution maps for 250 taro accessions in North Vietnam.

Results

Growth habit of taro accessions

The growth habits and morphological characteristics of 250 taro accessions were evaluated, including genotype, botanical variety, growth habit, stolon formation, rhizome formation, maturity period, the predominant shape of the lamina, predominant orientation of lamina, leaf lamina margin, leaf margin color, leaf (lamina) color and petiole junction color. Traits of the studied taro germplasm are presented in Table 2 and 3.

The growth characteristics of taro showed all accessions had 100% cultivated genotypes, none of which were semi-wild, wild, hybrid, or ornamental taro. Botanical variety had two dashen and eddoe types, which accounted for 52 and 48%, respectively. Growth behavior was semi-straight growth accounting for 57.2%, followed by straight growth, semi-spreading had the rate of 15.2%, 6.4% and spreading behavior accounts for the rate of 15.2%. The lowest rate was only 1.2%. All the accessions exhibited absent stolon, but branched corm formation.

Maturity of the accessions ranged from early to late. Ten accessions showed an early growth time of 4–6 months (Hau 10162, Quang Ninh; To Hau 11642, Lao Cai; Ma pho 11613, Lai Chau), 130 indicated a medium growth time of 6–8 months (Khoai so tau 11665, Cao Bang; Phuoc gin 10174, Thanh Hoa,; Phuoc hom T15877, Lang Son), while 110 were late maturing taking 8–10 months (Ma phua hom, 11524 Son La; Mon sap T21111, Ha Tinh; Khoai So Ray 1074, Tuyen Quang).

Morphological characteristics of leaves of the taro accessions

The predominant orientation of the lamina is divided into seven levels vertical (tip pointing upwards), semi-vertical (tip pointing upwards), vertical (tip pointing downwards), semi-vertical (tip pointing downwards), semi-horizontal, horizontal, and horizontal with drooping tip (PRC 2012). Most of the taro accessions indicated the predominant orientation of lamina semi-vertical or tip pointing downwards 94% (236 accessions), remaining semi-horizonal and horizontal. The leaf margin color variegation in taro is a very distinct character. Therefore, the leaf margin color of accessions serves to be variable. A 46% accessions (115 accessions) had purple/red edge color followed by pale yellow/cream color in 31.2% (78 accessions) and 22.8% (57 accessions) had green edge color at 22.8% (57 accessions). Four levels of leaf lamina color, including whitish, yellow, light purple and dark purple-green were absent. Leaf lamina color was variable, with 73.6% (184 accessions) found green while 26.4% (66 accessions) showed dark-green color. The petiole junction appeared in five different colors. The yellow color was found at 44% (110 accessions), light purple at 32% (80 accessions), dark purple at 12.8% (32 accessions) and light green at 4% (10 accessions). Out of 250 accessions, 110 were seen as yellow, followed by 80 as light purple, 32 as dark purple, and ten as light green, respectively.

The average plant height of the taro accessions was 75.1 cm, ranging from 48.8 cm to 134 cm. The plant height of the taro accessions was divided into three groups. The group with

Table 1: Number of 250 taro accessions collected in the Northern provinces of Vietnam

Collected provinces	No. of accession	Collected provinces	No. of accession
Bac Giang, Vietnam	14	Lang Son, Vietnam	10
Bac Kan, Vietnam	7	Lao Cai, Vietnam	16
Bac Ninh, Vietnam	1	Ninh Binh, Vietnam	1
Cao Bang, Vietnam	15	Phu Tho, Vietnam	11
Dien Bien, Vietnam	25	Quang Ninh, Vietnam	8
Ha Giang, Vietnam	11	Son La, Vietnam	36
Ha Noi, Vietnam	14	Thai Nguyen, Vietnam	5
Ha Tinh, Vietnam	1	Thanh Hoa, Vietnam	6
Hoa Binh, Vietnam	14	Tuyen Quang, Vietnam	26
Lai Chau, Vietnam	21	Yen Bai, Vietnam	8

Table 2: Growth characteristics of the taro accessions in the Hoa Binh Province, Vietnam (2020)

Characteristics		Accession amount	Rate (%)
Genotype	1. Cultivate	250	100
Botanical variety	1. Dasheen	130	52,0
	2. Eddoes	120	48,0
Growth habit	1. Erect	38	15,2
	2. Semi-Erect	143	57,2
	3. Semi-Prostrate	16	6,4
	4. Prostrate	3	21,2
Stolon formation	1. Absent	250	100
Rhizome formation	1. Yes	250	100
Maturity period	1. Early (4–6 months)	10	4,0
	2. Medium (6–8 months)	130	52,0
	3. Late (8–10 months)	110	44,0

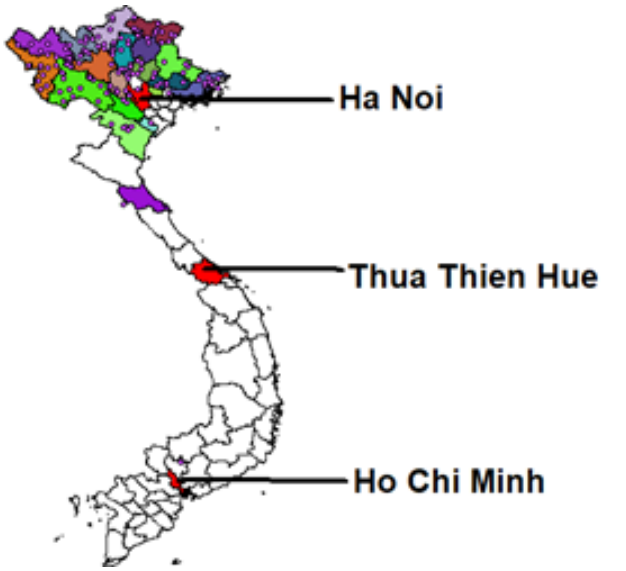

Fig. 1: Map of two hundred and fifty accessions taro distribution in Vietnam

Table 3: Morphological characteristics of stems and leaves of taro accessions in the Hoa Binh Province, Vietnam (2020)

Morphological characteristics		No. of accessions	Rate (%)
The predominant shape of lamina	1. "Cup" shape	250	100
Predominant orientation of lamina	1. Semi-vertical (tip pointing downwards)	236	94,4
	2. Semi-Horizontal	13	5,2
	3. Horizontal	1	0,4
Leaf lamina margin	1. Entire	38	15,2
	2. Undulated (broad waves)	52	20,8
	3. Undulated (narrow waves)	160	64,0
Leaf margin color	1. Green to the edge	57	22,8
	2. Purple/Red edge	115	46,0
	3. Pale yellow/Cream	78	31,2
Leaf (lamina) color	1. Green	184	73,6
	2. Dark green	66	26,4
Petiole junction color	1. Yellow	110	44,0
	2. Light green	10	4,0
	3. Light purple	80	32,0
	4. Dark purple	32	12,8
	5. Color is not uniform	18	7,2

Table 4: Statistical grouping of some agronomic traits of 250 taro accessions in Hoa Binh Province, Vietnam (2020)

Groups and statistical variations		Plant height (cm)	Leave length (cm)	Leave width (cm)	Petiole sheath length (cm)	"V" angle (^{0})	Depth of the sinus (cm)	Distance between the main vein junction and the base of the sinus (cm)	Number of secondary veins connected to main vein (primary) system of leaf lamina
Group	Value	<63	<28	<19	<30	<40	<6	<6	<7
1	Accession amount	17	15	15	18	6	21	22	6
	Rate (%)	6.8	6.0	6.0	7.2	2.4	8.4	8.8	2.4
Group	Value	63–102	28–48	19–33	30–55	40–56	6–10	6–10	7–9.5
2	Accession amount	220	211	203	217	211	214	206	239
	Rate (%)	88.0	84.4	81.2	86.8	84.4	85.6	82.4	95.6
Group	Value	>102	>48	>33	>55	>56	>10	>10	>9.5
3	Accession amount	13	24	32	15	33	15	22	5
	Rate (%)	5.2	9.6	12.8	6	13.2	6.0	8.8	2.0
Mean		75.1	37.0	26.8	37.2	49.9	7.4	7.4	7.7
Max		134	61.6	45.2	78.2	70.0	14.8	15.0	11.8
Min		48.8	16.6	13	15.8	30.0	4.0	4.0	6.4
SD		16.9	8.7	6.3	10.4	7.3	1.8	2.1	0.8
CV%		22.6	23.5	23.5	28.0	14.8	25.5	29.3	10.4

a plant height below 63 cm accounted for 6.8% (17 accessions), the group with a plant height from 63 cm to 102 cm accounted for 88.0% (220 accessions) and the group with a plant height greater than 102 cm accounted for 5.2% (13 accessions). The average collection was valued at 101 cm, which ranged from 33 to 155 cm in plant height (Table 4).

The average leaf blade length was 37.0 cm, ranging from 16.6 cm to 61.6 cm. The group with a leaf blade length was less than 28 cm accounted for 6.0% (15 accessions), the group with a leaf blade length from 28 to 48 cm accounted for 84.4% (211 accessions), and leaf blade length greater than 48 cm, accounted for 9.6% (24 accessions). Leaf blade width ranged from 13.0 to 45.2 cm. The group with a leaf blade width of less than 19 cm accounted for 6.0% (15 accessions), and the group with a leaf blade width of 19 to 33 cm accounted for 81.2% (203 accessions). The leaf blade width was over 33 cm, accounting for 12.8% (32 accessions).

The petiole sheath length ranged from 15.8 to 78.2 cm. The group with a petiole sheath length were less than 30 cm accounted for 7.2% (18 accessions), while that with a petiole sheath length from 30 to 55 cm accounted for 86.8% (217 accessions), the group with petiole length greater than 55 cm, accounted for 6.0% (15 accessions). V-angle ranged from 30^0 to 70^0. The group with V-angle below 40^0 accounted for 2.4% (6 accessions), the group with V-angle from 40^0 to 56^0 accounted for 84.4% (211 accessions), and the group with V-angle greater than 56^0 accounted for 13.2% (33 accessions) among all the accessions (Table 4).

The depth of the sinus ranged from 4.0 to 14.8 cm (Table 4). The group with a depth of sinus below 6 cm accounted for 8.4% (21 accessions), from 6.0 to 10.0 cm accounted for 85.6% (214 accessions), and greater than 10.0 cm accounted for 6.0% (15 accessions). The junction from the main vein to the base of the sinus was 7.4 cm and ranged from 4.0 to 15 cm. The group with the junction from the main vein to the basic of sinus under 6 cm accounted for 8.8% (22 accessions), from 6.0 to 10.0 cm accounted for 82.4% (206 accessions), and greater than 10.0 cm accounted for 8.8% (22 accessions). The number of secondary veins connecting the primary veins was 7.7 and ranged from 6.4 to 11.8. The group with the number of secondary veins connecting to the main vein below 7.0 accounted for 2.4% (6 accessions) from 7.0 to 9.5 accounted for the proportion of the rate of 95.6% (239 accessions) and greater than 9.5 accounted for 2.0% (5 accessions) among all (Table 4).

Table 5: Some morphological characteristics of 250 taro accessions in the Hoa Binh Province, Vietnam (2020)

Characteristics of rhizome		Accession amount	Rate (%)
Corm shape	1. Unbranched round	122	48.8
	2. Unbranched conical	21	8.4
	3. Unbranched elliptical	55	22.0
	4. Unbranched cylindrical	30	12.0
	5. Branched	1	0.4
	6. Branched head	2	0.8
	7. Extremely elongate	18	7.2
	8. Flat and multifaced	1	0.4
Corm flesh color of central part	1. White	247	98.8
	2. Yellow	3	1.2
Color of corm apex	1. White	176	70.4
	2. Pink/Red	74	29.6
Spatial arrangement	1. Clustered	245	98.0
	2. Dispersed	5	2.0
Number of cormels	1. < 5	244	97.6
	2. 5–10	6	2.4
	3. > 10	0	0.0

Table 6: Statistical grouping of factors constituting productivity and productivity of 250 taro accessions in Hoa Binh Province, Vietnam (2020)

Groups and statistical variations		Length of corm (cm)	Width of corm (cm)	Corm weight (g)	Cormel weight (g)	Corm and cormels weight /hill (g)	Yield (tons/ha)
Group 1	Value	<6	<5.3	<122	<20	<230	<6
	No. of accessions	7	50	74	33	139	100
	Rate (%)	2.8	20.0	29.6	13.2	55.6	40.0
Group 2	Value	6–11	5.3–6.8	122–214	20–45	230–390	6–13
	No. of accessions	223	185	161	211	102	138
	Rate (%)	89.2	74.0	64.4	84.4	40.8	55.2
Group 3	Value	>11	>6.8	>214	>45	>390	>13
	No. of accessions	20	15	15	6	9	12
	Rate (%)	8.0	6.0	6.0	2.4	3.6	4.8
Mean		7.8	5.8	125.2	24.2	207	7.2
Max		16.9	9.0	315	72	3600	19.2
Min		4.2	3.3	30	10	120	4.0
SD		2.2	0.8	47.2	9.2	76.6	2.6
CV%		28.4	15.5	37.7	38.2	36.9	36.9

Morphological characteristics of corms and yield of taro accessions

The corm of taro accessions: Nutritionally, roots and tubers have a great potential to provide economic sources of dietary energy in the form of carbohydrates. The energy from corms is about one-third of that of an equivalent weight of rice or wheat due to the high moisture content of tubers. However, high yields of roots and tubers give more energy per land unit per day compared to cereal grains. Generally, the protein content of roots and tubers is low (1–2% on a dry-weight basis). The corm of taro contains more than twice the carbohydrate content of potatoes and yields 135 kcals per 100 g and 11% crude protein on a dry matter basis. These reported carbohydrate and protein values are even higher than other root crops like yam, cassava or sweet potato.

Corm shape: The corm shape of taro accessions is expressed in 10 different shapes. The corm shape of the accessions was evaluated in 8 out of 10 different levels, *viz.*, very diverse, unbranched round, unbranched conical, unbranched elliptical, unbranched cylindrical, branched at the tip of the corm, extremely elongate and many branches (Table 5). The unbranched-round corm shape accounted for the highest proportion 48.8% (122 accessions), followed by the unbranched ellipse, unbranched cylinder, unbranched conical, extremely elongate and branched head corm shapes with a ratio of 22.0% (55 accessions), 12.0% (30 accessions), 8.4% (21 accessions), 7.2% (18 accessions) and 0.8% (2 accessions), respectively. The branched and flat and multifaced corm shapes were the lowest in number (0.4%). The two corm shapes, including unbranched "dumbbell" and corm cluster shapes, had not appeared in the evaluated accessions.

Corm color: The color of the central corm was not very diverse in all the accessions. White corm color accounted for the majority of 98.8% (247 accessions), and the yellow flesh color accounted for 1.2% (3 accessions). The corm apices had two white and pink/red basic colors; the white tip accounted for 70.4% (176 accessions) and 29.6% (74 accessions), respectively. The arrangements of corm with two clustered and scattered types were 98% (245 accessions). The number of corms per hill of taro accessions was placed in three groups (Table 6). In group 1, the number of corms less than 5 accounted for the highest percentage of 97.6% (244 accessions), followed by 5 to 10 corms accounted for 2.4% (6 accessions) in group 2. The quantitative traits including

corm size, weight, weight per hill and yield of the taro accessions and statistical parameters for the above traits (Table 6).

Corm size: The average length of the corm was 7.8 cm and ranged from 4.2 to 16.9 cm (Table 6). The group with a corm length was less than 6.0 cm accounted for 2.8%. The group with a corm length from 6 to 11 cm accounted for the highest proportion, 89.2%, while the corms length greater than 11 cm accounted for 8.0%. The average corm width of the group was 5.8 cm and ranged from 3.3 to 9.0 cm. Group 1, with a narrow corm width of less than 5.3 cm, accounted for 20.0%. Group 2, with a medium corm width from 5.3 to 6.8 cm accounted for the highest (74.0%). Group 3, with a large corm width greater than 6.8 cm, accounted for 6.0%. The group with an average weight below 122 g accounted for 29.6%. The group with an average weight of corm from 122 to 214 g accounted for 64.4%. The group with an average weight of corm greater than 214 g accounted for 6.0% (Table 6).

Cormel weight: Average weight of the cormel was 24.2 g, with variability from 10 to 72 g. In group 1, the average weight of a cormel less than 20 g accounted for 13.2%. In group 2, the average weight of cormel from 20 to 45 g accounted for 84.4%. Group 3 showed a cormel mean weight more significant than 45 g, which accounted for 2.4% (Table 6).

Corm/clump weight: The group with an average weight of corm/clump less than 230 g accounted for 55.6%. Group 2 showed an average weight from 230 to 390 g was 40.8%. However, the group 3 weight clump was more significant than 390 g and accounted for 3.6% (Table 6).

Taro corm yield: The average yield of accession in the taro accessions was 7.2 tons/ha and ranged from 4.0 to 19.2 tons/ha (Table 6). Based on statistical parameters, the corm yield of the taro germplasm was divided into three groups. In group 1 (low production), the mean yield less than 6 tons/ha included 100 accessions and comprised 40% accessions. In group 2 (medium production), the mean yield was from 6 to 13 tons/ha (138 accessions), accounting for 55.2%. Finally, group 3 (high production) had a mean yield of more than 13 tons/ha, with 12 accessions accounting for 4.8%. Thus, most taro accessions exhibited an average and low yield, and only a few indicated high yields.

Discussion

Many authors have mentioned evaluating morphological and agro-biological characteristics of the taro genetic resource. Pasiona (2021) evaluated the morphological characteristics of 17 accessions of taro in the Philippines, including leaf, sheath and corm characteristics. However, this author did not mention the growth behavior and the classification of dasheen and eddoe types of taro accessions. Results indicated 17 taro accessions, 13 of which were identified with their local names.

The evaluation of growth characteristics and morphological characteristics of 250 taro accessions showed that most of the taro accessions in the group grew and developed well due to the influence of hot and sunny conditions in 2020. This implied that the accessions have yet to develop to their full yield potential. The morphological characteristics of taro accessions reflect the nature of the variety. The accessions exhibiting morphological traits were quite diverse, from growth habits to morphological characteristics of taro accessions.

According to Ivancic and Lebot (2000), yield is the most important goal in all taro programs. It is a complex quantitative trait that depends on genotype, environmental factors and genotype × environment interactions. Further complexity comes from the influence over the yield of the size, the nature (mother plant vs. sucker) and the sanitary state of planting materials. Calibration of propagules is a necessary preliminary step before any evaluation process. Plant height and leaf area are essential factors correlated to taro yield (Lebot *et al*. 2006).

The second aspect of taro crop is its eating quality. A good taro cultivar is determined by the chemical composition of corms (*i.e*., by its chemotype) and by a regular and attractive corm shape. It must be non-acrid (low amount of calcium oxalate crystals) and with a relatively high dry matter content (Bradhaw 2010). Corm flesh color is sometimes associated with good quality. For instance, in Vanuatu, yellow corms are particularly appreciated. However, corm quality and corm yield appear to be negatively correlated. Apart from yield and eating quality, a taro ideotype is determined by its maturity period (early accessions are preferred), corm shape, number of suckers, the absence of stolon, number of leaves and verticality of petioles (Bradhaw 2010).

The growth time of the taro accessions also showed that only 4 out of 250 accessions had a short growth period (4–6 months); the rest were in medium-growth and late (Khoai Thom, Khoai So accessions). These short-growing accessions had a low yield, and all had agronomic characteristics belonging to the eddoes type of taro. In this study, 12 potential taro accessions had the highest yield of over 13 tons/ha compared with the rest of the accessions in the evaluated germplasm (Table 6). Thus, the yield potential of these taro accessions belongs to the genotype, which grow optimally and are suitable for cultivation conditions in Hoa Binh province. These taro accessions had yields ranging from 13.7 tons/ha (Khoi Thom accession) to 20 tons/ha (Khoai So accession). The list of 12 potential taro accessions includes Khoai Thom (T.30001), Mac Phua Lanh (10103), Co Cai (28035), Hau Dang (28325), Phuoc (28330), Khoai So Do (28268), Hau Dang (28340), Phuoc Bay (28348), Co Kay (28355), Khoai So Ray (28198), Hau Dong (28041) and Khoai So (28308). These 12 taro accessions originated in Hoa Binh, Yen Bai, Tuyen Quang, Phu Tho, Bac Kan, Cao Bang, Ha Giang, and Ha Noi provinces. Combining the yield, agronomic and morphological characteristics, we propose introducing 12 potential taro accessions for further comparison and introduction of exploitation and use in North

Vietnam. In addition, all the data on the agro-biological morphology of 250 accessions are an essential basis to converse field gene banks for taro genetic resources.

Conclusion

The results showed that 130 accessions of dasheen type and 120 accessions of eddoe type, without wild or semi-wild species. Taro accessions had diversity in plant height morphology, with considerable variation from 48.4 to 134.0 cm. The corm shape of the accessions varied widely in eight different levels. The yield of accessions mainly belonged to the middle yield group (6–13 tons/ha) and low yield group (< 6 tons/ha), there are 12 accessions with high yield (>13 tons/ha).

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Author Contribution

Thi Nga Hoang, Thi Hanh Duong, and Van Tung Vu planned the experiments, Thi Nga Hoang, Kim Chi Nguyen, Van Tung Vu and Thi Hanh Duong, Thi Hoa Nguyen interpreted the results, Thi Nga Hoang made the write-up and Thi Nga Hoang, Van Kien Nguyen statistically analyzed the data and made illustrations.

Conflict of interest

All authors declare no conflict of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper.

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