Print ISSN 2094-1064
Online ISSN 2244-0437

Liceo Journal of Higher Education Research
doi: http://dx.doi.org/10.7828/ljher.v16i1.1372

Phenotypic Characterization and Ethnobotanical Inventory of Chili Pepper (*Capsicum* spp.) Cultivars in Cebu Island, Philippines

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ABSTRACT

Capsicum spp. (chili) is recognized as an economically important spice, but the cultivation and extensive production is not maximized due to farmers' problem of classifying local vs. exotic cultivars. In the present investigation, samples (n = 24) of *Capsicum* spp. cultivars were collected from 3 major growing locations (Dalaguete, Alcoy, and Cebu City) in Cebu Island, Philippines, and their morphological characters and their uses were evaluated. Twenty-seven (27) discrete morphological characters of *Capsicum* spp. were utilized to classify chili cultivars (Cluster Analysis) followed by Principal Component Analysis (PCA) to visualize the variability in the morphological data and relatedness among purportedly different chili cultivars. Results show that the chili pepper of Cebu as mostly similar in terms of fruit type, fruit attachment, inflorescence characteristics, and leaf attachment. At the same time, major variations were observed in leaf apices, leaf margins, leaf bases, and fruit shapes. Factor loadings show that the first two principal components collectively explained 69.62% of the total variance. At the same time, cluster analysis revealed that leaf surface, inflorescence form, inflorescence type, stamen fusion, fruit shape, fruit orientation, and stem form are usable characters that delineated two major clusters of chili pepper cultivars. Cebu's chili pepper as widely used as a spice, as a condiment, as a vegetable, used in herbal medicine, and as a good source of income to farmers. Future studies may focus on the utilization of other taxonomic markers to further resolve cultivar assignments and classification.

Keywords: chili peppers, *Capsicum* spp., morphology, ethnobotany, Cebu Island, Philippines

INTRODUCTION

Chili pepper (*Capsicum* spp.) is a widely cultivated vegetable and spice (Ali, 2006; Costa et al., 2009) that is known to have essential dietary, nutritional, and medicinal properties (Reifschneider, 2000; Dagnoko et al., 2013; Khan et al., 2014). They are grouped into either non-pungent (i.e., sweet bell pepper, *C. annuum*) or pungent group (i.e., hot chili, *C. frutescens*). At present, *C. annuum* and *C. frutescens* are 2 of the five domesticated species found in tropical Asia (Ali, 2006) and are reported to be the most utilized cultivated species in the Philippines. The Philippine Council for Agriculture, Aquatic and Natural Resources Research

and Development [PCAARD] reported that the main producers of bell pepper and chili in the country are the Cordillera Administrative Region (CAR) (45%) and Ilocos Province (13%) from Luzon and some municipalities in Northern Mindanao (17%). The increasing demand for chili pepper in the last five years by both domestic and foreign markets is indicative of the economic value of this agricultural commodity (Lumawag, 2015; Padillo, 2017).

Chili peppers are specifically identified by farmers based on identifiable characters, i.e., flower and seed colors, shape of calyx, number of flowers per node as well as fruit orientations (Basu & De, 2003; Aguilar-Melendez et al., 2009). Chili pepper growers also match purportedly new varieties to existing local cultivars (i.e. cultivated varieties) through visual comparison. Cultivars are the assemblages of plants selected for desirable characteristics and are maintained during the propagation period (Devi et al., 2017). Like other important crops, morphological characters of chili peppers are useful for classifying different chili peppers (International Plant Genetics Research Institute [IPGRI], 1983), selection of commercially viable cultivars, and in establishing genetic conservation programs of local germplasms (Chandan et al., 2016; Deka et al., 2016). However, one of the critical issues that Philippine chili pepper growers currently face is commonly confused cultivars of native chili peppers vs. imported chili peppers. For instance, the imported Red bird's eye chili (*C. annuum* 'Red bird's eye chili) from Thailand is commonly identified as the Philippine native 'siling labuyo' (*C. frutescens* 'Siling labuyo') by farmers and consumers. The only most obvious difference is the fruit orientation in their pedicels, where the former cultivar's fruits are observed to be drooping down, while the latter's fruits are borne erect (Veneracion, 2018). In terms of pungency (i.e., spiciness or "heat"), the 'siling labuyo' of the Philippines is spicier than its Thai counterpart (Veneracion, 2018). This taxonomic issue has an important impact on the marketability of our native 'siling labuyo,' as well as on the correct selection of cultivars to be propagated and conserved in the Philippines (Altoveros & Borromeo, 2007).

In other countries, conservation of chili pepper is actively pursued by local communities not only because of its culinary properties as vegetable, spice, and condiment but also due to its medicinal use and value (Milla, 2006). Its fruits also bear phytochemicals that relieve health-related conditions like cancer, cardiovascular diseases, diabetes, sore throats, coughs, asthma, and toothache (Wahyuni et al., 2013; El-Ghoraba et al., 2013). In the Philippines, studies on traditional medicine report that *C. frutescens* L. (red chili pepper) leaves are

pounded and rubbed on the chest to ease asthmatic attack in Iligan (Olowa et al., 2012) and to treat arthritis in Batan Island (Abe & Ohtani, 2013). In Agusan del Sur, this species is eaten raw during or after social gathering and is also considered a wild edible plant (Kim & Song, 2012). In Cebu province, the roots of *C. frutescens* cultivar ('sili kulikot') have been recorded to aid metabolism (Miano et al., 2011; Rosales et al., 2018). Anecdotal reports from local chili producers support our reconnaissance survey that there are only a few municipalities that produce chili in the province. Unlike the major chili farms in Mindanao, chili plantations in Cebu are mostly located in upland barangays of few municipalities, namely: Badian, Alcoy, Dalaguete in Southern Cebu; Talamban for Central Cebu and Poro, Tudela, and San Francisco in the Northern Cebu. In these areas, evaluation of chili cultivars diversity and ethnobotany is not yet reported in scientific literature.

While morphological characterization studies are an essential component of any crop's breeding program, a survey of its use and value must also be conducted to be able to widely disseminate the potential uses of chili pepper, especially on the aspect of traditional medicine. Available publications on these topics for Philippine chili pepper, particularly those which delved on the use of taxonomy as a tool to support ethnobotany, are scant. Such taxonomic tool includes observable characters that are useful to farmers and consumers and could aid in the proper identification of the cultivar without necessarily employing organoleptic property testing. This study, therefore, will address this research gap and hopefully support country-level initiatives to increase propagation, production / marketing, and enhance germplasm conservation in the future.

FRAMEWORK

The premise of this research is anchored on the phenetic species concept, one of the alternative, contemporary species concepts which was extensively discussed in the papers of de Queiroz (2005). Compared to the widely accepted biological species concept which focuses on intrinsic reproductive isolation of a population, the phenetic species concept posits that the best classification system is the one that has defined overall similarities among species that could be used to form phenetic cluster amongst them, quantitatively (Ereshefsky, 1994). With numerical taxonomy as its supporting structure, this phenetic species concept defines species as a set of organisms that look similar to each other, but clearly from other sets. It also specifies some degree of "phenetic similarity" which could

be measured by phenetic distance statistics. The use of phenetics in resolving taxonomic disputes and disagreement on the acceptance of a taxon has its own limitations and intrinsic biases. For instance, plant taxonomists rarely agree on how many continuous characters are necessary to resolve intraspecies variation; and whether or not discrete leaf characters are sufficient enough to revise a taxon's previous classification, even in the absence of reproductive structures. These situations often result in arbitrary decisions, leading to what we commonly referred to as taxonomic pluralism.

Taxonomic pluralists argue that a plurality of equally correct classification is a safer position, then aiming for a single, correct classification emphasized by taxonomic monists (Ereshefsky, 1994). In this paper, we adhere to the philosophy of taxonomic pluralism because our data, like the rest of taxonomic studies on chili pepper cultivars were constrained due to some factors such as asynchronous ripening of fruits across different cultivars, heterogeneity in edaphic properties such as pH and fertilizer inputs and other confounding factors that influence plant's growth and development. Therefore, the classification and clustering of cultivars in this study resulted from the selected character states and such may be different in other occasions that would employ a a different set of characters to be examined.

OBJECTIVES OF THE STUDY

This study aimed to (a) characterize the phenotype of Capsicum spp. cultivars from different locations of Cebu Island, Philippines, using multivariate statistical analysis and (b) survey its ethnobotanical uses (e.g., uses, ways on gathering, preparation, and processing).

METHODS

Description of the study sites

Cebu province (123°25' E & 124°30' E and between 9°25' N & 11°21' N) has a land area of 4,944 square kilometers, composed of 44 municipalities and 6 component cities (DEN-VII, 2019). Cebu is mostly mountainous and rugged with depressed peaks creating mountain ranges extending from Medellin to Santander in the south that account for <50% of the entire land area (DEN-VII, 2019). Cebu's climate is tropical wet, and dry. It has a fair distribution of temperature and rainfall all over the year (Cebu Provincial Agricultural Profile, 2015), making the province suitable for farming and agriculture. Cebu has 163,328 hectares or about 32% of land area for agriculture as stated from the Provincial Agriculture Office, making 60% of households in Cebu for livelihood dependent on farming (Awit, 2017).

Three areas were selected as study sites, namely: Dalaguete (9.7837° N, 123.5056° E), Alcoy (Southern Cebu) (9.7117° N, 123.4608° E), and Cebu City (Central Cebu) (10.3157° N, 123.8854° E) (Fig. 1). These sites were selected based on the recommendation from the DENR-VII, suggesting that these localities propagate most chili pepper cultivars and produce the most number of chili pepper in the entire province. The survey covered orchards or small-scale chili plantations own by private individuals. The sources of planting materials were either from the seeds of the previous chili harvests, local nurseries, or purchased from neighboring islands.

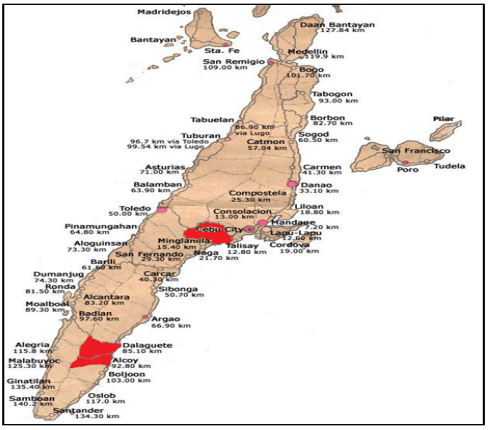


Figure 1. Map of Cebu province showing the three study sites (red shaded regions): the chili pepper growing areas of the City of Cebu (middle) and the municipalities of Dalaguete and Alcoy (bottom). Retrieved as https://pasarelapr.com/detail/map-of-cebu-province-17.html

Phenotypic characterization of chili pepper cultivars

Phenotypic characters were chosen based on the International Plant Genetic Resources Institute (IPGRI) descriptors for chili, with modification (IPGRI, 1995). Discrete characters of stem and leaves, as well as reproductive structures (flowers and fruits), were purposively chosen to minimize error due to variation of planting elevation and edaphic factors (Table 1). The visual evaluation was used for macroscopic characters, while magnifying glass and trinocular microscope were utilized to observe microscopic morphological details during field and lab characterization, respectively.

Five (5) chili cultivars from 6 sitios in 3 municipalities known for the cultivation of chili were characterized and evaluated phenotypically. Plant samples were cut from their branching point and were collected for measurement. Proper plant pressing for each voucher specimen was done to preserve the specimens for further morphological analysis. Photo documentation for each collected plant and the study area were taken. Global Positioning System (GPS) of each chili species and cultivar were also noted. All chili species were taxonomically verified based on the guide for pepper taxonomy by Erwin (2017). Voucher specimen were made and deposited at the Cebu Normal University Herbarium (CNU-H).

Table 1

Morphological characters and character states of Capsicum stem, leaf, flower and fruits

Plant parts	Morphological characters	Abbrev.	Codes for morphometric analysis
Stem	Stem type	StTy	1=culm; 2=ancipital
	Stem form	StFm	1=herbaceous-angled; 2=ancipital
Leaves	Leaf shape	LSh	1=oblanceolate; 2=lanceolate
	Leaf base	LBs	1=oblique; 2=attenuate; 3=cuneate; 4=aequilateral
	Leaf apex	Lfx	1=acuminate; 2=acute; 3=mucronulate; 4=apiculate; 5= aristulate; 6=cuspidate
	Leaf division	LDv	1=simple; 2=biternate; 3=compound
	Leaf venation	LfV	1=reticulate; 2=pinnate; 3= alter-pinnate
	Leaf margin	LfM	1=entire; 2=undulate; 3=lacerate; 4=lobed
	Leaf attachment	LfAt	1=petiolate
	Leaf arrangement	LfAr	1=alternate; 2=dextrorse
	Leaf surface	LfsF	1=glabrous; 2=lanuginous only on its veins; 3=mammilate
Flowers	Inflorescence type	Inty	1= monochasium; 2=dichasium
	Inflorescence form	Infm	1= centrifugal; 2=explanate
	Perianth type	Petp	1=monochlamydeous
	Perianth form	Pefm	1=explanate
	No. of floral structures	FlSt	1= monocyclic/complete

Table 1 continued.

Plant parts	Morphological characters	Abbrev.	Codes for morphometric analysis
	Flower symmetry	FlSym	1=actinomorphic
	Flower attachment	FlAt	1=pedicellate
	Stamen type	StTy	1=filanterous
	Stamen arrangement	StAr	1=exserted
	Stamen number	StNr	1=halostemonous/pentandrous
	Stamen fusion	StFu	1=distinct; 2=connate
	Stamen cvclv	StCv	1=uniseriate
Fruit	Fruit type	FrTy	1=berry
	Fruit shape	FrSh	1=bell-shaped; 2=horn-shaped; 3=crescent; 4=ovate; 5=linear
	Fruit orientation	FrOr	1=appressed; 2=reclined
	Fruit attachment	FrAt	1=stalk attached to stem
	Calyx orientation	CalO	1=cup-shaped; 2=pateriform

Sampling design and data gathering for ethnobotanical study

Snowball sampling was employed to determine the Key Informants (KIs) of the study based on the following inclusion criteria: (1) native villagers of the land, (b) local traditional herbalist or mananambal, and (3) adults who are knowledgeable of the plants present in the three study sites (Dalaguete, Alcoy and Cebu City) of Central and Southern Cebu (Rahman et al., 2019). To determine the complete pool of KIs, the first key informants were asked to distinguish other possible informants who had the same qualifications as them (Espinosa et al., 2014). Preliminary investigation through an ocular visit of the study site as conducted, considering the number of possible respondents and assessing the site's environmental and cultural features. A semi-structured interview was employed in order to obtain detailed information (i.e., different species and cultivars and socio-economic importance of *Capsicum* spp.) from the KIs of the study sites. Also, KIs were asked to guide the location where the chilis were gathered.

Data analyses

Agglomerative Hierarchical Clustering (AHC) and Principal Component Analysis (PCA) were used to explain the sources of variability of the studied chili pepper species (and cultivars). Specifically, AHC using Ward's method (i.e. applying Euclidean distance) showed similarity measures of the qualitative variables and was employed to group the specimens based on overall morphological similarity (i.e. shown in dendrogram). Eigenvalues and factor scores obtained from PCA were used to determine the relative discriminative power of the axes and their associated characters. All collected data were analyzed using SPSS (Version 20.0). Ethnobotanical use of chili pepper cultivars as determined, and responses were classified into the following use categories: food/ vegetable, condiment/ ingredient, source of income, food odor remover, fertilizer, insecticide and medicinal use. Species Use Value (SUVis) formula was used to calculate the frequency of uses by informants (n=65) for each *Capsicum* spp. cultivar. One use report was counted per one-plant-species mentioned by one informant. The formula for Species Use Value (SUVis) is expressed below:

$$[\![SUV]\!]\_is=(\sum [\![UV]\!]\_is\ )/n\_i$$

Where: SUVis= species use value;
n_i= total number of informants

RESULTS AND DISCUSSION

General morphological characteristics of Cebu's chili pepper

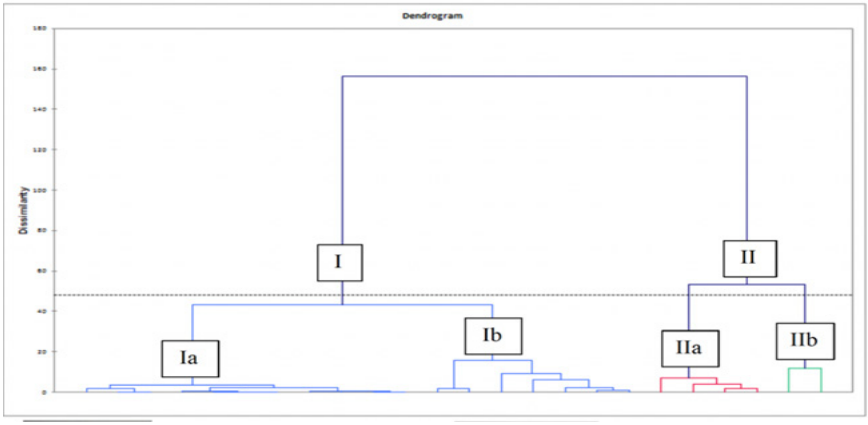
Results from the morphological characterization noted that Cebu's chili pepper cultivars were observed to have leaf, fruit, and flower characters that integrated each other, resulting in overlapping morphological features. These overlapping character states are indicative of the genus' highly variable horticultural varieties. However, general description of its morphology showed a range of character states that may be utilized to describe all cultivars, as follows:

The stem possesses a culm stem type, with a more angulated stem form. Leaf shapes are either lanceolate or ovate, with leaf apex and base as acute and unsymmetrical oblique, respectively. Most cultivars possess reticulate leaf variation, the margin is entirely arranged under an alternate leaf phyllotaxy. Although mammilate and lanuginous leaf pubescence were observed in few cultivars, most possess glabrous leaf surfaces. Reproductive character states

are more varied in fruits over their flowers, where cultivars were described to possess bell-shaped, ovate, crescent, horn-shaped, and linear fruit shapes, in order of decreasing frequency. While all cultivars possess a berry fruit type, fruit orientation, on the other hand, is mostly appressed, followed by a reclined stem. In terms of flower characteristics, the type and form of the inflorescence are mostly dyscrasia and explanatory. Chili pepper cultivars in Cebu all possess a monocylic floral structure, actinomorphic symmetry, and pedicellate attachment. Stamen type is filanterous while the perianth type and form are monochlamydeous and explanate, respectively.

Classic botanical literature on cultivated chili peppers indicate that chili pepper is an herbaceous or semi-woody plant that is either annual (i.e., hence, *C. annuum*) or perennial (for other chili pepper species and cultivars) and may grow from 1.5 to 4 ft high. Flowers axillary, solitary, or two or three in a fascicle; corolla white, greenish-white, light yellow or purple; petals five, connate, rotate to semi-campanulate; calyx varying from pateriform to cup-shaped; stamens five, adnate, dehiscence longitudinal; carpels connate in a two to four-celled ovary; fruit varying from globose to elongated conical; seeds discoid, smooth or subscabrous, embryo peripheric (Erwin, 2017).

Classification of chili cultivars using Agglomerative Hierarchal Clustering (AHC) UPGMA dendrogram based on the phonetic analysis of stem, leaf, flower, and fruit morphology of Cebu's chili pepper cultivars showed colored groupings according to the two main clusters (Fig. 2). Cluster I (blue) is further divided into two subclusters, while Cluster II (violet) with two corresponding subclusters. Cluster I is represented by three (3) cultivars of *C. annuum*, while Cluster II is represented by two (2) cultivars of *C. frutescens*.



C. annuum cv. . Sweet bell Pepper

C. annuum cv. "Perfection group" pepper

C. annuum cv. Finget chili pepper/ "Sili espada"

C. frutescens cv "Siling Labuyo"

C. frutescens cv Dwarf chili pepper "Sili kulikot

Figure 2. UPGMA dendrogram based on the phonetic analysis of stem, leaf, flower, and fruit morphology of Cebu's chili pepper cultivars. The horizontal dashed line (i.e., phenon line) suggests a level of similarity at which the various cultivars from two Capsicum species (C. annuum and C. frutescens) are believed to distinct, thereby producing two (2) major clusters, each with two subclusters. Actual photos of chili pepper cultivars collected from fieldwork (scale: coin dm= 2.3cm).

Results show that the main characteristic that split species in Cluster I from the cultivars of Cluster II is fruit orientation, where the former has a droopy fruit habit. In contrast, the latter has a distinctive erect habit. This fruit habit is a good taxonomic marker. It is a widely accepted morphological character useful to farmers, especially that Thai chili pepper (*C. annuum* var. Bird's eye pepper), for instance, resembles closely the fruit shape of *C. frutescens* cv. Siling labuyo. The only difference with these cultivars is that the former has a pendent (i.e., hanging) habit, and the latter has a distinctly erect habit. Other characters that were contributory to the separation of the two clusters include leaf surface, inflorescence form, inflorescence type, stamen fusion, fruit shape, and stem form.

As shown in Cluster I (Fig.2), the two subclusters (noted as Group 1a and Group 1b) are largely represented by *C. annuum* cv. Sweet bell pepper & *C. annuum* cv. Perfection group pepper and *C. annuum* cv. Finger chili pepper, respectively. The following characters distinguished one subcluster leaf shape, leaf apex, leaf venation, and fruit shape. Group Ia is mainly represented by sweet bell peppers and is characterized by its sweet, non-pungent variety. This group possesses a calyx that is pateriform (i.e., saucer-shaped), and fruits are squarish and sub-truncate. Another cultivar from Ia is known as "Perfection group" chili pepper, has a pateriform calyx, but fruit shapes are largely conical, with a pendent or lateral orientation at maturity. On the other hand, Group Ib is represented by finger chili pepper. Its distinguishing characters include a calyx that embraces the base of the fruit, has an elongated, conical fruit with a pendent orientation (Erwin 2017). This group is widely known as cayenne chili peppers in many parts of the world.

Cluster II (Fig.2) is represented by *C. frutescens*, of which there are two cultivars identified (Group IIa – cv. Siling labuyo and Group IIb – cv. Sili kulikot). The distinguishing phenotypic character common to both cultivar is the possession of a cup-shaped calyx that embraces the base of the fruit. Similarly, both cultivars also possess a linear-shaped fruit and a distinctly erect fruit habit. In other countries, this group is known as the "Tabasco group," which is reported to have a very pungent odor. Erwin (2017) noted that this group is represented by cultivars of medium height, and possess pods that are borne singly, in pairs, or clusters (~1 – 3in long), and the fruits are compressed at the base and often appear above the foliage.

Classification of chili cultivars using Principal Component Analysis (PCA)

In the PCA results, Table 2 showed the eigenvalues, variability, and cumulative values. Eigenvalue shows the quantity that will determine the importance of the principal components. Factor 1 explained 50% of the variance while factor 2 showed 19%, and these two factors explained 70% of the cumulative variance in the data set. This value further suggests that PC1 and two sufficiently described inherent variability among the different *Capsicum* cultivars. PCA is an exploratory method that reduces the original variables into a lower number of orthogonal non-correlated variables (also called eigenvalues). It also helps visualize correlations among the variables and between these variables and the factors. We can look at the grouping of the samples and visualize proximities among statistical units (Kucharczyk et al., 2012).

Table 2

Eigenvectors for the morphological characters in the ten principal components analyzed for Capsicum cultivars in Cebu Island, Philippines

PC	Eigenvalue	Variability (%)	Cumulative %
1	**7.069**	**50.495**	**50.495**
2	**2.677**	**19.122**	**69.617**
3	2.099	14.990	84.607
4	0.751	5.362	89.969
5	0.443	3.168	93.137
6	0.437	3.123	96.259
7	0.233	1.666	97.926
8	0.145	1.037	98.963
9	0.100	0.713	99.675
10	0.045	0.325	100.000

From the eigenvalues, it showed that the two principal components (PC) are the most important. Table 3 shows the characters with the highest values in PC1 and PC2. PC1 has inflorescence form (0.974), leaf venation (0.127), leaf apex (0.086), leaf margin (-0.419) and leaf arrangement (-0.436) as the most important differentiating characters. PC2, on the other hand, has leaf margin (0.725), leaf division (0.677), leaf arrangement (0.582), leaf base (0.194), and inflorescence form (0.092) as the most important characters. It showed from the two principal components that leaf margin and leaf arrangement are the characters common in them. In PCA, Eigenvalues represent the relative contribution of each PC in presenting the general variability of examined chili pepper species/ cultivars, and its numerical value is a direct indicator of the weight of a specific component in the overall variability of a set of data (Kucharczyk et al., 2012).

Table 3

Eigenvectors of the morphological characters in relation to the first and second principal components

	Factors	
	Principal Component PC1 (F1)	**Principal Component PC2 (F2)**
Inflorescence form	0.974	-0.009
Leaf venation	0.127	-0.488
Leaf apex	0.086	-0.645
Leaf margin	-0.419	0.725
Leaf arrangement	-0.436	0.582
Leaf division	-0.585	0.677
Leaf base	-0.761	0.184
Inflorescence type	-0.894	0.092

Figure 3 showed the dispersion of the characters that really show great divergence from all other characters. For example, inflorescence form character can be found on the rightmost part of the axis and is the most diverged. This coincides with the correlation between variables and factors table (Table 3) as for PC1's case. Leaf venation and leaf apex followed the most diverged after inflorescence form in PC1. Leaf margin, division, and arrangement are after the leaf apex and venation, clumped together on the upper-left hand of the axis. Leaf base and inflorescence type in PC1 are the last characters as determinants for differences. In PC2, leaf margin, division, and arrangement go together as

the primary determining characters. Then, leaf base and inflorescence type show the secondary determining characters. The inflorescence form, leaf venation, and apex are the least determining characters here, which is contrary to PC1's as the greatest determining character.

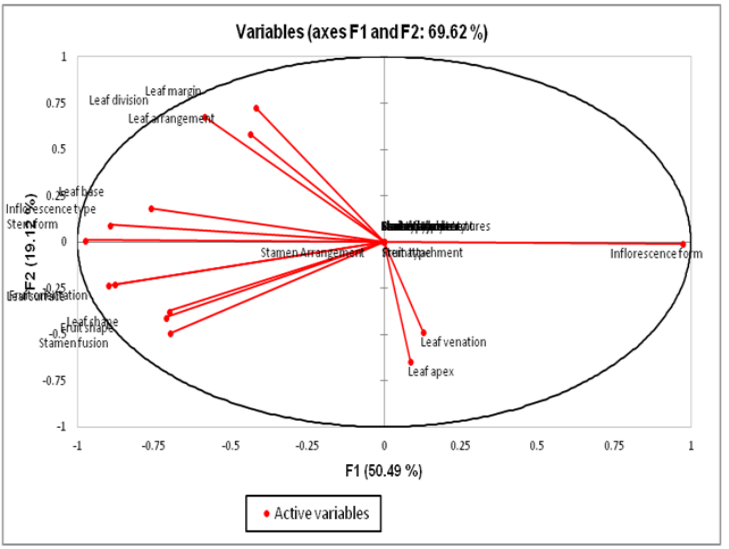


Figure 3. Projection of *Capsicum* cultivar's morphological variables on the first and second factor planes reflected in the correlation circle.

The position of the cultivar's centroids along the PC axes represents their association to the different morphological variables. Under PC1, inflorescence form registers as the most important character that could differentiate *C. annuum* and *C. frutescens*, while leaf margin is the most important under the second principal component.

While the characters that spread across the axis stand for determining the distinctiveness of the species, the biplot in Figure 4 shows an augmented data on which specific species (sample) belong to this kind of distinctiveness. Simply put, biplot shows the relationship or distribution of the 24 samples with their determining distinct characteristics. The biplot shows that the characters are evenly distributed on the right and left hand of the axis, which represent the two major groupings according to the dendrogram. The correlation between the grouping of factor scores and the clustering of samples in the dendrogram implies that the results from Agglomerative Hierarchical Clustering (AHC)

coincide with the results in the Principal Component Analysis (PCA). Both methods are confirmatory to each other results. The differences in the characters and character states help show relatedness among different species. Therefore, morphological characterization is a critical component in establishing similarities and distinctiveness of the *Capsicum* spp. cultivars in Cebu.

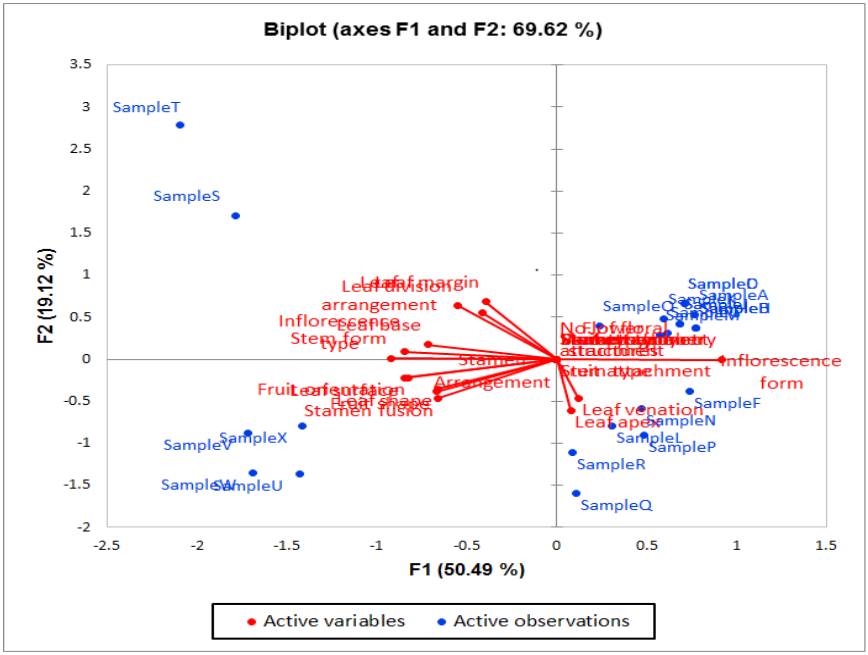


Figure 4. Biplot illustrates the sample cultivars (blue dot), their determining distinct characters (red dot), and the distances between observations (i.e., cultivars).

The morphological variation that deals in the external appearance (size, shape, color, structure, and pattern) (Acton, 2013) are affected by adaptation of plants to photoperiod, conditions of soil, and resistance to diseases (Debouck et al., n.d). Cultivars are bred to produce desirable traits selected and cultivated with the specific or combination of characteristics that are genetically fixed with the offspring retaining the plant's unique characteristic from one generation to the next (Kays, 2011). This showed that even if most chili species are selectively bred, they still have similarities with other species in terms of their morphology. In fact, one staff of the Department of Agriculture local office in Dalaguete (Tirso

Tangpus pers comm., 2016) stated that farmers cultivate chili seeds coming from companies who selectively bred chili species with desirable traits that would be in demand in the market. Considering that monocropping of a single chili cultivar is encouraged to address this market demand, it is expected that most chilis cultivated in the locality are cultivars.

Ethnobotany of chili cultivars in Cebu

A total of 24 specimens were collected from the different collection sites in Cebu Island, Philippines. Cultivar names and scientific names of each specimen are identified. Among the three collection sites in Cebu, Alcoy has the highest number of collected specimens (n=14), followed by Dalaguete (n=7) and Cebu City (n=3).The different uses of the *Capsicum* spp. Cultivars, as reflected from the responses of informants (n=65), are summarized in Table 4. In terms of food, three cultivars (*C. frutescens* cv. Sili Kulikot, *C. annuum* cv. Perfection group pepper, and *C. annuum* cv. Finger chili pepper) are frequently used as a complementary ingredient for foods (Table 4).

Table 4

Ethnobotanical uses of Capsicum spp. cultivars

Local name/cultivar name	Scientific name	Food/ Vegetable	Condiment/ ingredient	Source of income	Food Odor Remover	Fertilizer	Insecticide	Medicina uses
Sweet bell pepper	*Capsicum annuum*	✓	✓	✓				
Perfection group pepper	*Capsicum annuum*	✓	✓	✓	✓		✓	✓
Finger chili pepper	*Capsicum annuum*	✓	✓	✓	✓	✓		✓
Sili Kulikot	*Capsicum frutescens*	✓	✓	✓	✓		✓	✓
Sili Labuyo	*Capsicum frutescens*	✓	✓	✓		✓		

In terms of species use index of the chili cultivars used as a food, *C. annuum* cv. Finger chili pepper has the highest use index of 0.74, indicating that among the different cultivars, finger chili is the most frequently used commodity in preparing local cuisines. As a condiment, *C. frutescens* cv. Sili Kulikot and *C. annuum* cv. Finger chili pepper has the highest use index of 0.48. Among

these cultivars, *C. frutescens* cv. Sili Kulikot has the highest use index of 0.14. Sili kulikot is an alternative source of dried chili powder, in lieu of *C. frutescens* cv Siling Labuyo because the latter is more expensive. Chili pepper growers are commonly cultivating sili kulikot either under backyard farming or large-scale production systems. In the last few years, there has been an increasing demand for sili kulikot due to the low supply of siling labuyo made into chili paste, chili oil, and chili sauces.

Capsicum spp. cultivars offer various uses to the community. They are used for foods (ingredient and garnish), condiment, effective insecticides, source of income, odor-removing agent, fertilizer to plants and a medicine that cures various health problems. In terms of food, the leaves and fruits are used to complement the food. Based on the species use index, *C. annuum* cv. Sili Espada is widely used as an ingredient for some Visayan food recipes ("inun-unan," "sinigang," "tinola," and "dinuguan"). This is commonly used because it has low pungency from other *Capsicum* cultivars that can complement any Visayan food, and it is widely grown by the farmers in the area as a business. *C. annuum* cv. Sili Espada functions as a condiment together with *C. frutescens* cv. Sili Kulikot is commonly used as an ingredient for spiced vinegar or sauces. Both of the cultivars are widely distributed in the area for income purposes (farmers' business). Their degree of pungency is favorable for dishes, business (food markets and pharmaceutical companies), and a strong insecticide, especially *C. frutescens* cv. Sili Kulikot effectively kills various kinds of insects affecting the crops. *C. frutescens* cv. Sili Kulikot, *C. annuum* cv. Finger chili pepper and *C. annuum* cv. Perfection group pepper is dominantly used as an effective remover of odors from fresh meat such as fish meat, chicken meat, etc.

Two of the cultivars are used as an insectide: *C. frutescens* cv. Sili Kulikot and *C. annuum* cv. Sili Atsal. *C. frutescens* cv. Sili Kulikot has the highest use index of 0.08, followed by *C. annuum* cv. Perfection group pepper with a useful index of 0.06. In removing raw odors of fresh meat (i.e., fish, chicken, etc.), four cultivars are mentioned. *C. frutescens* cv. Sili Kulikot, *C. annuum* cv. Sili Espada and *C. annuum* cv. Perfection group pepper cultivars all have the highest UVs value of 0.06. In terms of use as fertilizer, *C. annuum* cv. Sili Espada and *C. annuum* cv. Sweet bell pepper is the only cultivars known to have been used as fertilizer; both cultivars have 0.06 values. In medicine, three cultivars were listed to have medicinal uses. These are *C. annuum* cv. Sili Espada, *C. frutescens* cv. Sili Kulikot, and *C. annuum* cv. Sweet bell pepper. According to the interviews, these cultivars

are known for treating body pain, asthma, arthritis and cure insect allergies (i.e., caterpillar hairs, ant bites, etc.). Among the listed fruits, *C. frutescens* cv. Sili Kulikot has the highest UVis value of 0.26, followed by *C. annuum* cv. Sweet bell pepper and *C. annuum* cv. Sili Espada both having 0.06 UVis value.

The application of chili pepper in treating health conditions and other ailments is well supported by other literature. Chili peppers are known to possess beta-cryptoxanthin, lycopene, fibers, and phytochemicals – generally classified as carotenoids - that help boost the immune system, increasing the body's metabolism, reduce cholesterol, and aid in battling cancer cells. Also, chili possesses Vitamins A, C, and K, which inhibits cell damage, cell malfunction, and uncontrolled multiplication. As for the medicinal uses of cultivars, for instance, *C. frutescens* cv. Sili Kulikot, *C. annuum* cv. Sili Espada and *C. annuum* cv. Sweet bell pepper as reported to be used as a liniment to treat insect allergies and body pain. Treatment is rubbing the affected areas with pounded chili or mixed with ointment (i.e., omega, efficascent, etc.). Sili Kulikot was also used to treat asthma and arthritis by drinking extracted chili juice or grounded chili mixed on water. Thus, chili peppers are good sources of nutrients (Rosales et al., 2018). Due to its high nutritional value, *C. annuum* cv. Sili Espada and *C. annuum* cv. Perfection group pepper is also used as fertilizers which could give nutrients to the growing chili plant. Chili is also used as ornamental plants for their wide range of fruit colors – white, green, orange, light orange, red, deep red, violet, etc. Lastly, least of the interviews mentioned that chili could be used as forage. Local birds (i.e., maya, mynah, etc.) feed on fresh and dry chili fruits, while chili leaves are feed on carabaos.

CONCLUSIONS

Morphological characterization of chili pepper cultivars (under two species of *Capsicum*) in Cebu Island is an essential step towards knowing which attributes are useful not only to horticulturists and biologists but most importantly to farmers who are growing and producing this spice. This study is useful in locating essential morphological characters that could be used as morphological markers to easily identify chili pepper cultivars and their corresponding uses and value. To any user of chili pepper, proper identification is an indispensable tool to fully maximize the use and value of a cultivated chili pepper variety, particularly in sustaining quality and consistency of local cuisines where recipes are gold standard and the basis of the large-scale commercial food system. Knowing distinguishable

phenotypic characters of chili pepper will also minimize confusion on what cultivar to propagate and conserve. As we continue to innovate methods and improve our production system, we must aspire to pursue a further investigation on which chili pepper cultivars are heat tolerant and those that can sustain growth even under minimal water input. Future studies may consider ecological parameters (i.e., bioclimatic factors, biophysical factors), which may affect the phenotypic characteristics of the different cultivars. Further, these factors must be included in the analysis of interrelated variables that may likewise explain variations of cultivars across the various ecological landscapes.

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ACKNOWLEDGEMENTS

We acknowledge the Local Government Unit of the municipality of Dalaguete, Alcoy, and Cebu City for the assistance during the field survey and to all key informants for the eagerness to share ethnobotanical knowledge related to chili pepper. We also express our gratitude to the Department of Environment and Natural Resources – Region 7 (DENR-7) and the CNU Research Institute of Tropical Biology and Pharmacological Biotechnology (RITBPB) for the assistance provided in the conduct of this study.