Journal of Nature Studies 13 (2): 41-55
ISSN: 1655-3179

Characterization of Phenotypic Variation in Selected Croton [*Codiaeum variegatum* (L.) Rhumph. ex A. Juss.] Varieties and Natural Mutants

Pablito M. Magdalita[1]*, Nerissa K. Torreta[2] and Rachel C. Sotto[2]
[1]Crop Science Cluster and Institute of Plant Breeding, College of Agriculture
University of the Philippines Los Baños, 4031, College, Laguna, Philippines
[2]Plant Biology Division, Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines Los Baños, 4031, College, Laguna, Philippines
*Corresponding Author, pabsmagdalita@gmail.com

ABSTRACT – Thirty-six croton [Codiaeum variegatum (L.) Blume] varieties and natural mutants were characterized phenotypically based on the leaf length, leaf width, petiole length, leaf shape, leaf margin, leaf base and leaf apices. The leaf and petiole color were also characterized based on the Colour Chart of the Royal Horticultural Society of London (RHS 1966 5th ed.). The different varieties and natural mutants were grouped based on their predominant leaf color, hence giving rise to the establishment of the red-leaf group, green-leaf group and yellow-leaf group varieties. A relatively small morphological variation was observed within each of the three groups in terms of quantitative traits like leaf length, leaf width, and petiole length. However, large variability was observed for qualitative traits including: leaf shape, leaf margin, leaf base and leaf apices. In addition, large variation for leaf and petiole colors within the red-leaf, green-leaf and yellow-leaf groups were observed. In particular, leaf color variation was unique in each of the 36 croton varieties and natural mutants characterized. Furthermore, two new natural mutants namely: 'Sporting Philippine Red' and 'Bay Mutant' and one seed-derived genotype 'Tilapia Yellow' were isolated and first described in this study.

Keywords: crotons, [(Codiaeum variegatum L.) Rhumph. ex A. Juss.] mutants, phenotype, varieties

INTRODUCTION

The garden croton or "san francisco" [(Codiaeum variegatum L.) Rhumph. ex A. Juss.], a tropical foliage ornamental belongs to the genus Codiaeum and a member of the Euphobiaceaea family. Codiaeum is the second largest genera with about 7,000 known species described (Cheers 1999, Macoboy 1974). There are only six known basic species of Codiaeum from which hybrids were developed (Taylor 1938). Garden crotons are natives of the Malaccan Islands, and are widely grown in the Philippines, Papua New Guinea, India, Sri Lanka, Thailand, Indonesia, Malaysia and some other Pacific Islands countries. They are also popular in East Asia and Java, Australia and now they are widespread all over the tropics (Stamps and Osborne 2003, Taylor 1938).

Crotons are beautifully variegated leafy perennial ornamental plant that can be classified as shrubs or trees with glabrous branches and prominent leaf scars (Brown 2008). They can grow from about 1 m to more than 3 m high. In the wild, the crotons can be seen as evergreen shrub that has large, leathery and shiny leaves. In contrast, in the home gardens, the cultivated crotons are usually smaller and come in amazing diversity of leaf shapes and colors. Since they are hardy, adaptable to a wide range of environmental conditions and easy to grow and maintain, they became a popular plant for landscaping urban subdivisions, parks, playgrounds, schools, golf courses including memorial parks. They are popularly used for interior decoration in homes and buildings and as hedge plant in many tropical

gardens. In addition, they are used as potted ornamental plants and sold in garden shops as gifts for any occasion and as souvenir for special occasions (Gilman, 1999).

The leaf of crotons is probably green in its original natural state, but in cultivated forms, it has striking variegations and also streaked, blotched or banded with different colors when grown in appropriate light conditions (Ogunwenmo et al., 2007). This makes croton one of the most interesting ornamentals. However, it has a flexible response to various light conditions. When grown at different light intensities and growing conditions, it shows different leaf colors. The shaded leaves are more greenish than those exposed to full sun. The mosaic pattern on the leaves may also be influenced by light intensity (Supaporn et al., 2000).

The interesting leaf color differences in crotons leads to the evolution of several hundred varieties that were bred and selected for their beautiful foliage. These varieties evolved as sport mutants that are different from the parent plant. In addition, some cultivars came from seeds of naturally seed-producing cultivars (Magdalita 2011). While there are several named varieties, only some have been characterized. In addition, many natural mutants that produce a lot of color variations and leaf patterns have been isolated, but these selections have not been characterized. Hence, there is a need to characterize the existing phenotypic variation for better understanding of the variety and as a prerequisite for varietal development, selection and mass propagation. This study aimed to characterize the leaf and petiole color variations of the selected croton varieties and natural mutants based on the Colour Chart of the Royal Horticultural Society of London (RHS 1966, 5th ed.).

MATERIALS AND METHODS

Collection and identification of samples. The different cultivars and natural mutants of crotons collected from different places including: Los Baños and Bay, Laguna, Indang, Cavite, Lucban, Quezon, Boac, Marinduque, Calapan, Oriental Mindoro, San Jose, Batangas and Del Gallego, Camarines Sur. They were grown at the Crop Science Cluster (CSC) and Institute of Plant Breeding (IPB), College of Agriculture, (CA) University of the Philippines, Los Baños (UPLB), Laguna. They were planted under full sun in the ornamental breeding block and utilized for phenotypic characterization. The different varieties were identified based from the compiled checklist of croton cultivars in the book entitled, "A Codiaeum Encyclopedia Crotons of the World" by Frank B. Brown (2008) and the pamphlet entitled, "Ornamental Plants of the Philippines" by Benito S. Vergara (2007). They were given the standard cultural management requirements for crotons.

Characterization of leaf morphology. Thirty-six croton cultivars and natural mutants belonging to three different groups, ie. 14 red-leaf, 9 green-leaf and 13 yellow-leaf groups were characterized. Five leaf samples each were taken from five plants giving a total of 25 leaf samples for each cultivar were characterized for morphology and the measurement for leaf length, leaf width and petiole length were gathered. Similar leaf sampling was conducted for croton by Mollick and Yamasaki (2012). Leaf length was taken from the base of the leaf to the tip of the leaf, while leaf width was measured on the widest middle portion of the leaf. The petiole length was measured from the petiole base to the leaf base. The leaf characteristics described were: leaf shape, leaf base, leaf margin and leaf apices. These characteristics were determined based from the books entitled, "Vascular Plant Systematics" by Alfred E. Radford (1974), "Taxonomy of Flowering Plants" by C. L. Porter (1959) and "Plant Systematics" by S.B. Jones, Jr. and A.E. Luchsinger (1986). These references were used as guides in determining the different leaf characteristics.

Description of leaf and petiole color variations. The leaf color variation of the 36 selected croton varieties and natural mutants was determined through the use of the Colour Chart of the Royal Horticultural Society (RHS) of London (RHS 2007 5th ed.) fifth edition. This colour chart contains 202

numbered hues, printed as 4 lightnesses each, named A, B, C and D, for a total of 808 colors identified, e.g., as RHCC 7 B, which is a combination of yellow and green. The leaf color was taken from a total of 25 leaf samples (5 leaves per plant, 3 mature and 2 young leaves) for each cultivar (5 plants per cultivar was used) that were carefully matched with the color chart and the corresponding color hue was identified, and further matched with the color coordinate to determine the description of the actual color. In addition, the adaxial surface of the young and the old leaves was further characterized for color variations. The establishment of the three groups of crotons like the red-, green- and yellow- leaf group was based on visual observation, that both mature and young leaves in each cultivar have about 80-90% of either the red, green or yellow colors.

Documentation. In this study, phytography was used to document the descriptive terminology of plants and their component parts for the purpose of providing an accurate and complete vocabulary for description and identification. Phytographic studies provide the researcher with a vocabulary for use in intelligent communication about plants, help in the understanding of the use of relative terms; and help any person observe plants more critically and describe them more precisely (Radford et al., 1974). The whole plant of each variety and the adaxial and abdaxial leaf surfaces of the leaves were photographed using a digital camera.

Statistical analysis. The average or mean and the standard error for the data on leaf length, leaf width and petiole length of all leaf samples for each variety and natural mutant were computed. The data were presented in the form of a bar graph. The data for color were described qualitatively based from the Colour Chart of the Royal Horticultural Society of London (RHS 1966 5th ed.) and were also presented in tabular form.

RESULTS AND DISCUSSION

Red-leaf croton group. The different croton varieties and natural mutants belonging to the predominantly red-leaf group exhibited distinct phenotypic differences in leaf colors like varying shades of red to maroon. Based on leaf measurements, the different red-leaf croton cultivars and natural mutants displayed marked differences in terms of leaf length, leaf width and petiole length (Figure 1). This result has some agreement to the previous report that croton cultivars show significant phenotypic variation for leaf quantitative parameters (Mollick et al., 2011). For instance, 'Queen Victoria' had the longest leaf followed by 'Joana Goldfinger', with an average of 26.5 cm and 22.5 cm, respectively. 'Queen Victoria' also had the longest leaf petiole of about 8.0 cm. For leaf width, the cultivar 'Excellent' had the widest leaf measuring 9.8 cm. The variety 'Picasso's Paint Brush' had the shortest petiole and narrowest leaf, hence it was named after the paint brush.

The red-leaf croton group also showed different characteristics based on leaf shape, base, margin and apex (Table 1). Based on the leaf margin, the variety 'Undulatum' showed undulate leaf margin, hence the name "undulatum", while the rest of the varieties have an entire leaf margin. In addition, the variety 'Grubell' showed a linear-interrupted leaf shape.

The leaf base, margin, and apex of the different red-leaf croton cultivars and natural mutants differed considerably (Table 1). The same observation was reported for 29 croton cultivars characterized in Okinawa Island, Japan (Mollick and Yamasaki, 2012). These red-leaf croton cultivars had cuneate, attenuate and acute leaf bases. In addition, the leaf shape of the different varieties and natural mutants displayed distinctive characteristics of striking beauty and form. For example, the varieties 'Undulatum', 'Queen Victoria' and 'Bay Mutant' have lanceolate leaves, while 'Philippine Red' and 'Mrs. Robertson' have ovate leaves. 'Candy Cane' has also ovate leaves but twisted. 'LM Rutherford and 'Excellent' have trilobe leaves, but 'Picasso's Paint Brush' has "needle-like" or "paint brush-like" leaves.

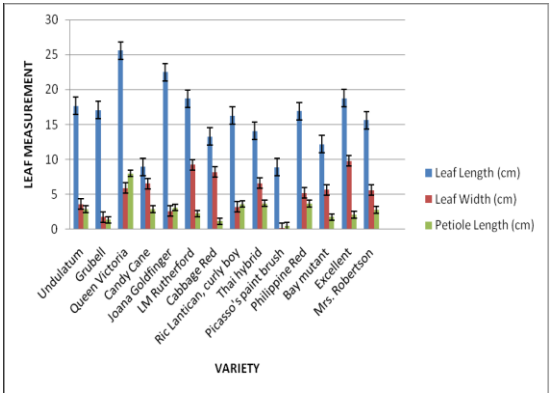

Figure 1. Leaf measurements (cm) of the different red-leaf colored croton cultivars and natural mutants.

Table 1. Leaf characteristics of the different red-colored croton varieties and natural mutants.

Varieties and Natural Mutants	Leaf Characteristics			
	Shape	Base	Margin	Apices
'Undulatum'	lanceolate	cuneate	undulate	caudate
'Grubell'	linear-interrupted	cuneate	entire	mucronate
'Queen Victoria'	lanceolate	cuneate	entire	acuminate
'Candy Cane'	ovate - twisted	cuneate	entire	mucronate
'Joana Goldinger'	linear	attenuate	entire	acute
'LM Rutherford'	trilobe	rounded	entire	acute
'Cabbage Red'	elliptic	rounded	entire	obtuse
'Curly Boy' or 'Ric Lantican'	linear - twisted	attenuate	entire	mucronate
'Thai Hybrid'	obtuse-twisted	cuneate	entire	mucronate
'Picassos Paint Brush'	narrow needle-like	truncate	entire	acute
'Philippine Red'	ovate	acute	entire	acute
'Bay Mutant'	lanceolate	acute	entire	cuspidate
'Excellent'	trilobe	attenuate	entire	acuminate
'Mrs. Robertson'	ovate	attenuate	entire	acute

The leaf base of the red-leaf cultivars and natural mutants also varied considerably. For example, the varieties 'Undulatum', 'Grubell', 'Queen Victoria', 'Candy Cane' and 'Thai Hybrid' have cuneate leaf base while 'Joana Goldinger', 'Ric Lantican' or 'Curly Boy', 'Excellent' and 'Mrs. Robertson' have attenuate leaf base. 'LM Rutherford' and 'Cabbage Red' have rounded leaf base, while

'Philippine Red' and 'Bay Mutant' have acute leaf base. Only one variety, 'Picasso's Paint Brush' has a truncate leaf base (Figure 2).

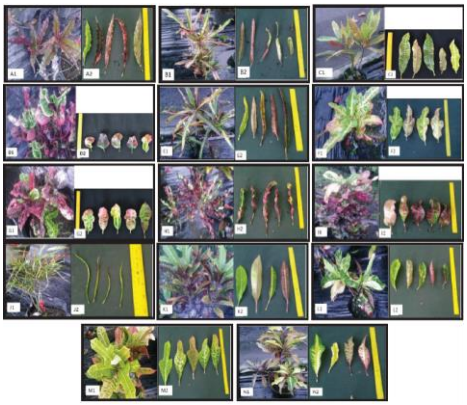

Figure 2. Growth habit , leaf morphology and the different leaf color variations of Codiaeum variegatum var. 'Undulatum' (A1&A2), 'Grubell' (B1&B2), 'Queen Victoria' (C1&C2), 'Candy Cane' (D1&D2), 'Joana Goldfinger' (E1&E2), 'LM Rutherford' (F1&F2), 'Cabbage Red' (G1&G2), 'Curly Boy or Ric Lantican' (H1&H2), 'Thai Hybrid' (I1&I2), 'Picasso's Paint Brush' (J1&J2), ' Philippine Red' (K1&K2), 'Bay Mutant' (L1&L2), 'Excellent' (M1&M2) and 'Mrs. Robertson' (N1&N2).

In terms of leaf apices, 'Ric Lantican' or 'Curly Boy', 'Thai Hybrid', 'Grubell' and 'Candy Cane' had a mucronate apex. 'Queen Victoria' and 'Excellent' had acuminate leaf apices while 'Joana Goldinger' and 'LM Rutherford' had acute leaf apices. The 'Undulatum', 'Cabbage Red' and 'Bay Mutant', respectively have caudate, obtuse and cuspidate leaf apex.

The leaf color varies considerably in the different varieties, and this is the most striking aspect on its beauty, hence the name variegatum was given to the name of this species. This striking phenotypic diversity for leaf color has been attributed to somatic mutation in the plant caused by the presence of transportable elements like the Ty1-copia retrotransposon (Mollick et al., 2011). Transportable elements or mobile gene units of the genome have been reported as a mechanism for somatic mutation in many plant species (Wessler, 1988; Chapparo et al., 1995). In addition, this is the most difficult to characterize because the color variations are greatly pronounced in each of the varieties. Characterization of leaf color in 44 varieties to establish genetic relationship was done using amplified fragment length polymorphism (AFLP) markers (Deng et al., 2010). In the present study, the color variation of the different red-leaf croton cultivars were characterized and shown in Table 2.

Table 2. Leaf and petiole color variation of the different red-colored croton cultivars and natural mutants.

Varieties and Natural Mutants	Leaf Surface		Petiole	
	RHCC #	ULC Name	RHCC #	ULC Name
'Undulatum'	59 A	ruby red	79 A	plum purple
			144 C	light yellow-green
'Grubell'	29 D	peach	144 C	light yellow-green
'Queen Victoria	6 D	sulphur yellow	152 B	medium yellow-green
'Candy Cane'	66 D	pale red-purple	142 B	agathia green
'Joana Goldfinger'	179 D	pale greyed-red	143 C	scheele's green
'LM Rutherford'	179 D	pale greyed-red	59 B	indian lake
			142 B	agathia green
'Cabbage Red'	39 A	jasper red	8 A	mimosa yellow
	135 A	strong green		
'Curly Boy' or 'Ric Lantican'	34 A	strong orange-red	135 C	light green
	23 C	cadmium orange		
'Thai Hybrid'	59 B	indian lake	77 A	violet purple
'Picasso's Paint Brush'	8 C 179 D	mimosa yellow pale greyed-red	152 A	strong yellow- green
'Philippine Red'	12 A	nasturtium red	47 A	currant red
	139 A	strong green		
	46 A	currant red		
'Bay Mutant'	5 D	dresden yellow	77 C	light purple
'Excellent'	46 A	currant red	150 D	Sap green
	141 A	strong green	145 A	Strong yellow green
	6 B	sulphur yellow		
'Mrs. Robertson'	7 C	light yellow	71 A	beetroot purple
			145 C	light yellow-green

The mature leaves mostly contain different shades of red, hence they were grouped under this color, but the young leaves contain a blend of red, yellow and green (Table 2). Also within this group, their leaves have shades of purple, orange and yellow (Figure 2). For instance, the mature leaves of variety 'Undulatum' is ruby red (RHCC 59 A) and greenish reddish on the entire leaf surface. 'Grubell' has two leaf types ie. the linear and the interrupted types. The leaves are peach red (RHCC 29 D) and light green from the base to the leaf tip with yellowish edging. 'Queen Victoria' has reddish maroon mature leaves with light greenish portion in between the secondary veins, while the young leaves are light green. The extended leaf of 'Candy Cane' is twisted with a mucronate apex. The mature leaf is generally pale red purple (RHCC 66 D) while the lamina is dark green. Mature leaves of 'LM Rutherford' are pale greyed-red (RHCC 179 D) with light green areas in between the secondary veins. The mature leaves of 'Cabbage Red' are jasper red (RHCC 39 A) with dark brown mosaic patterns, while the young leaves are generally mimosa yellow (RHCC 8 A).

Mature leaves of 'Curly Boy' or 'Ric Lantican' are green while the underside of the elongated twisted leaves ranges from strong orange red (RHCC 34 A) to cadmium orange (RHCC 23 C) turning

maroon towards the tip. Vergara (2007) described the midrib as red with irregular yellow to red markings in the presence of yellow blotches turning red throughout the leaves. This variety was named after Dr. Ricardo M. Lantican, a National Scientist for plant breeding and genetics of the National Academy of Scientist and Technology (NAST Philippines 2006). Mature leaves of 'Thai Hybrid' are indian lake red (RHCC 59 B) while the young leaves are reddish purple. Picasso's Paint Brush' has pale greyed-red (RHCC 179 D) mature leaves but has mimosa yellow (RHCC 8 C) primary vein. The mature leaves of 'Philippine Red' is nusturtia red (RHCC 12 A) to currant red (RHCC 46 C), while the young leaves are dark green (RHCC 139 A).

The 'Bay Mutant' had leaves with a mixture of colors: the underside of the mature leaves was light purple (RHCC 77 C), while the upperside was dresden yellow (RHCC 5 D) with greenish patterns. This mixture of colors in the leaves suggest that this genotype could be a mutation from the 'Philippine Red' since the mutant plant was taken as a cutting from an plant growing in Bay, Laguna, hence the name 'Bay Mutant'. Similarly, 'Pedro Escuro' is a sport mutant taken from 'Johanna Coppinger' (Vergara 2007). It had trilobe leaves with prominent gold midrib, while the young leaves tend to become pure yellow (Vergara 2007). It was named after Dr. Pedro B. Escuro, a National Scientist for genetics and plant breeding of NAST (NAST Philippines 2006).

Green-leaf croton group. The leaf length, leaf width and petiole length of the nine cultivars and natural mutants were characterized (Figure 3). The longest leaves were observed in 'Julian Banzon' green form with an average length of 29.22 cm. The difference was very minimal with the leaf length of 'Julian Banzon' yellow form having 27.34 cm. In contrast, the shortest leaf was observed in 'Philippinensis in the Philippines Green' with 8.0 cm. The widest leaf was observed in 'Ovafolium I' with 7.66 cm, while 'Philippinensis in the Philippines Green' had the narrowest leaf with 0.90 cm leaf width. The longest petiole was observed in 'Julian Banzon Green' with 7.50 cm long, while the shortest petiole was observed in 'Philippines in the Philippines Green' with an average of 0.68 cm (Figure 3).

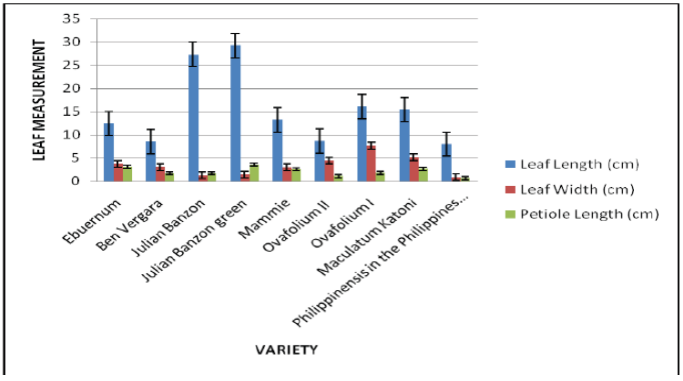

Figure 3. Leaf measurements of the different green-leaf croton [Codieaum variegatum (L.) Blume.] varieties and natural mutants.

The green-leaf group also showed different characteristics based on leaf shape, leaf base, leaf margin and leaf apex. Based on leaf shape, four green-leaf cultivars ('Julian Banzon Green', 'Julian Banzon Yellow', 'Mammie' and 'Philippinensis in the Philippines Green') have linear leaf shape while

'Ebeurnum' has oblong leaves and 'Ovafolium' I has ovate leaves (Table 3). All eight varieties have attenuate leaf base. In contrast, only one green-leaf variety called 'Mammie' has rounded leaf base.

In terms of leaf margin, five green-leaf cultivars ('Julian Banzon yellow', 'Julian Banzon green', 'Mammie', 'Ovafolium I', and Philippines in the Philippines') have entire leaf margin (Table 3). On the other hand, 'Ebuernum' and 'Ben Vergara' have undulate leaf margin. 'Ovafolium II' has repand leaf margin while 'Maculatum Katoni' has lobed leaf margin. In terms of leaf apices, three green-leaf cultivars ('Ebuernum', 'Ben Vergara' and 'Ovafolium II') have cuspidate leaf apices, while 'Philippinensis in the Philippines' and 'Mammie' have rounded leaf apex.

Table 3. Leaf characteristics and leaf measurements of the different green-leaf croton cultivars and natural mutants.

Varieties and Natural Mutants	Leaf Characteristics			
	Shape	Base	Margin	Apices
'Ebuernum'	oblong	attenuate	undulate	Cuspidate
'Ben Vergara'	lanceolate	attenuate	undulate	Cuspidate
'Julian Banzon yellow'	linear	attenuate	entire	Acute
'Julian Banzon green'	linear	attenuate	entire	Acute
'Mammie'	linear	rounded	entire	Rounded
'Ovafolium II'	entire	attenuate	repand	Acuminate
'Ovafolium I'	obovate	attenuate	entire	Cuspidate
'Maculatum Katoni'	oak shaped	attenuate	lobed	Acuminate
'Philippinensis in the Philippines (green)'	linear	attenuate	entire	Rounded

The leaf color of the green-leaf cultivars ranged from light to strong yellowish green (Table 4). For example, 'Ebuernum' has light greenish (RHCC 3 C) to moderate yellowish green (RHCC 138 A) leaves (Figure 4). 'Ebuernum' is similar to 'Ben Vergara' with leaf colors ranging from dark green (RHCC 135 A) to light yellowish (RHCC 1 C). The yellowish young leaves have dark green spots sprinkled near the midrib. Earlier description of 'Ebuernum' by Vergara (2007) indicated that this variety has light green leaves at the base but almost yellow at the top, while the mature leaves are dark green. On the other hand, 'Ben Vergara' has light green leaves at base and almost yellow at top while the mature leaves with wavy margin are dark green (Vergara 2007). It was named after Dr. Benito S. Vergara, a National Scientist for plant physiology of NAST who contributed enormously in improving rice varieties to produce richer harvests (NAST Philippines, 2006).

There are two forms of 'Julian Banzon' namely: the green and the yellow which have both long, narrow and drooping leaves. This description jibed with the previous one published by Brown (1995). The green form is a natural mutant isolated from the yellow form, since it was taken by the senior author from the yellow form growing at the Institute of Plant Breeding (Magdalita 2011). The mature leaves of 'Julian Banzon' yellow form is deep yellowish green (RHCC 141 B), while the young leaves are predominantly brilliant greenish yellow. On the other hand, the 'Julian Banzon' green form has brilliant greenish yellow (RHCC 3 B) mature leaves and moderate green (RHCC 135 B) young leaves. This cultivar was named after Dr. Julian A. Banzon, a National Scientist for biophysical chemistry who studied the use of coconut as a renewable source of fuels (NAST Philippines 2006).

Table 4. Leaf and petiole color variation of the different green-colored croton cultivars and natural mutants.

Varieties and Natural Mutants	Leaf Surface		Petiole	
	RHCC #	UCL Name	RHCC #	UCL Name
'Ebuernum'	138 A	moderate yellowish green	144 C	strong yellowish green
	144 A	strong yellowish green	150 C	brilliant yellowish green
	148 B	moderate yellowish green	59 D	strong purplish red
	2 C	light yellowish green		
	3 C	light greenish yellow		
	3 D	light greenish yellow		
	148 D	grayish yellowish green		
'Ben Vergara'			145 B	light yellowish green
	143 A	strong yellowish green	63 C	strong purplish pink
	1C	light yellowish		
'Julian Banzon Yellow'	141 B	deep yellowish green	144 C	strong yellowish green
	135 B	moderate green	63 D	light purplish pink
	3 B	brilliant greenish yellow		
	5 C	light greenish yellow		
'Julian Banzon Green'	3 B	brilliant greenish yellow	144 B	strong yellowish green
	135 B	moderate green	145 C	light yellowish green
'Mammie'	13 A	moderate olive green	144 B	strong yellowish green
	59 A	brilliant greenish yellow	145 B	light yellowish green
	15 B	light greenish yellow	144 C	strong yellowish green
	57B	deep yellowish green		
	141 B	strong yellowish green		
	17 D	light yellow		
'Ovafolium II'	8 A	brilliant yellow	58 B	strong purplish red
	134 A	vivid yellowish green	154 D	light yellowish green
	144 B	strong yellowish green		
	8 C	light greenish yellow		
'Ovafolium 1' (green)	134 A	vivid yellowish green	150 C	brilliant yellowish green
	5 B	brilliant greenish yellow		
'Maculatum Katoni'	135 B	moderate green	63 C	strong purplish pink
	141 B	deep yellowish green	12 A	strong yellowish
			143 C	Green
	2 C	light yellowish green	145 C	light yellowish green
	3 C	light greenish yellow		
	143 C	deep yellowish green		
'Philippinensis in the Philippines' (green)	6 A	brilliant greenish yellow	138 B	moderate yellowish green

Figure 4. Growth habit , leaf morphology and the different leaf color variations of Codiaeum variegatum var. 'Ebuernum' (A1&A2), 'Ben Vergara' (B1&B2), 'Julian Banzon yellow' (C1&C2), 'Julian Banzon green' (D1&D2), 'Mammie' (E1&E2), 'Ovafolium II' (F1&F2), 'Ovafolium I' (G1&G2), 'Maculatum Katoni' (H1&H2) and 'Philippinensis in the Philippines' (I1&I2).

Yellow-leaf croton group. The 13 cultivars and natural mutants belonging to the yellow-leaf croton group have distinguishing characteristics exhibited on their leaf shape, base, margins and apices. For instance, 'Sunray' had the longest leaves with an average length of 26.94 cm, while 'Ovafolium yellow' had the shortest leaf length of 12.7 cm. In terms of leaf width, 'Imelda Marcos' had the widest leaf measuring 22.18 cm while 'Yellow Interruptum' had the narrowest leaf measuring 1.20 cm. For petiole length, 'Banana' exhibited the longest petiole of 4.96 cm, while the 'Yellow Interruptum' had the shortest petiole of 0.74 cm (Figure 5).

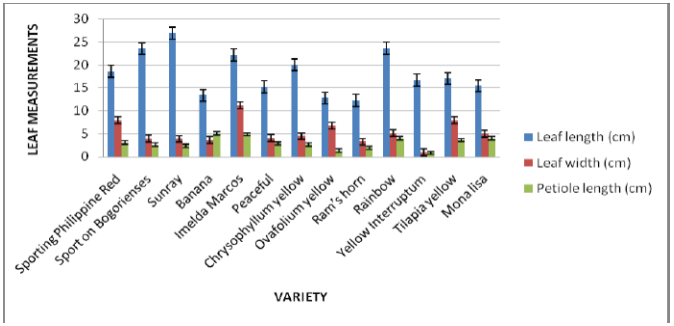

Figure 5. Leaf measurements of the different yellow-leaf croton cultivars and natural mutants.

The yellow-leaf group has two dominant leaf shapes namely: linear and elliptic. 'Sunray', 'Ram's Horn', 'Yellow Interruptum', and 'Monalisa' have linear leaf, while 'Imelda Marcos', 'Peaceful', 'Chrysophyllum Yellow' and 'Tilapia Yellow' have elliptic leaf (Table 5). The 'Sporting Philippine

Red' and 'Ovafolium Yellow' have obovate leaf, while 'Banana' has ovate leaf. Two varieties ('Sport on Bogorienses' and 'Rainbow') have lanceolate leaf. In terms of leaf base, 11 varieties have petiolate leaf base, while 'Sunray' and 'Monalisa' have cordate leaf base.

The three dominant leaf margins of the yellow-leaf group are entire, sinuate and lobed (Table 5). Four cultivars have entire leaf margin, while five cultivars have sinuate leaf margin. 'Imelda Marcos' and 'Tilapia Yellow' have lobed leaf margin. 'Tilapia Yellow' is the popular name given by the senior author since the leaf width is similar to the body width of the fish locally called 'tilapia'. In addition, these two genotypes are morphological similar particularly for leaf color, hence 'Tilapia Yellow' could be either a mutant isolated from 'Imelda Marcos' or a seedling progeny of 'Imelda Marcos'. Furthermore, six cultivars have acuminate leaf apex (Table 5). In terms of leaf base, 11 out of 13 (85%) yellow-leaf croton cultivars have petiolate type.

Table 5. Leaf characteristics of the different yellow-leaf croton cultivars and natural mutants.

Varieties and Natural Mutants	Leaf Characteristics			
	Shape	Leaf base	Margin	Apices
'Sporting Philippine Red'	obovate	petiolate	sinuate	acute
'Sport on Bogorienses'	lanceolate	petiolate	entire/ sinuate	acuminate
'Sunray'	linear	cordate	sinuate	acuminate
'Twisted Banana'	ovate	petiolate	entire/ sinuate	rounded
'Imelda Marcos'	elliptic	petiolate	lobed	acute
'Peaceful'	elliptic	petiolate	entire/ sinuate	acuminate
'Chrysophyllum Yellow'	elliptic	petiolate	sinuate	acute
'Ovafolium Yellow'	obovate	petiolate	entire	obtuse
'Ram's Horn'	linear	petiolate	entire	acuminate
'Rainbow'	lanceolate	petiolate	sinuate	mucronulate
'Yellow Interruptum'	linear	petiolate	entire	acuminate
'Tilapia Yellow'	elliptic	petiolate	lobed	acuminate
'Monalisa'	linear	cordate	sinuate	rounded

The 13 cultivars and natural mutants belonging to the yellow-leaf group have leaf colors ranging from pale to strong yellow green to grey yellow red (Figure 6). For instance, the natural mutant 'Sporting Philippine Red' which is generally yellow was isolated from 'Philippine Red'. It was a cutting taken by the senior author from this cultivar (Magdalita 2011). Mature leaves are predominantly strong grey yellow red (RHCC 181 A), with splashes of green in between the secondary veins (Figure 6).

Mature leaves of 'Peaceful' are predominantly aureolin (RHCC 12 A), while the young leaves are pale yellow green (RHCC 144 D). Leaves of 'Chrysophyllum Yellow' are mimosa yellow (RHCC 8 A) plus irregular green patterns on the upper leaf surface. The 'Ovafolium Yellow' has young leaves that are strong yellow (RHCC 14 A) but the mature leaves are scheele's green (RHCC 144 B). Young leaves of 'Ram's Horn' are strong yellow (RHCC 2 A), while the mature leaves are dark green. The young leaves of 'Rainbow' are aureolin (RHCC 12 B), while the mature leaves are pea green (RHCC 149 B).

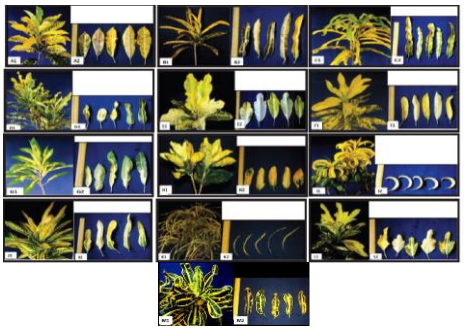

Figure 6. Growth habit, leaf morphology and the different leaf color variations of Codiaeum variegatum var. 'Sporting Philippine Red' (A1&A2), 'Sport on Bogorienses' (B1&B2), 'Sunray' (C1&C2), 'Twisted Banana' (D1&D2), 'Imelda Marcos' (E1&E2), 'Peaceful' (F1&F2), 'Chrysophyllum Yellow' (G1&G2), 'Ovafolium Yellow' (H1&H2), 'Ram's Horn' (I1&I2), 'Rainbow' (J1&J2), 'Yellow Interruptum' (K1&K2), 'Tilapia Yellow' (L1&L2) and 'Monalisa' (M1&M2).

The young leaves of 'Sport on Bogorienses' are strong yellow orange (RHCC 14 A), while the mature leaves are chartreuse green (RHCC 1 C) with yellow edges. The mature leaves of 'Sunray' are strong yellow (RHCC 2 A), while the young leaves are medium green (RHCC 137 A). The mature leaves of 'Imelda Marcos' are sulphur yellow (RHCC 6 A), while the young leaves are strong green white (RHCC 157 A). 'Imelda Marcos', which was named by Brown (2008) during his visit to the Philippines is obviously a local hybrid with broad leaf having a strong yellow green (RHCC 154 A) color. However, the same author agreed with Prof. Pancho to change the name of this variety to 'Lemon Top' as Prof. Pacho, a leading Filipino botanist refused to pose for a photo with a potted plant of 'Imelda Marcos', flatly saying that "under no circumstances he would not sit next to a plant named for Mrs. Marcos", hence to date, some people would call it this variety with either names.

In terms of petiole color, 'Sunray', 'Banana', 'Peaceful', 'Ram's Horn' and 'Rainbow' have petioles with different shades of aureolin color (Table 6). For example, the 'Yellow Interruptum' and 'Tilapia Yellow' have canary yellow (RHCC 9 B) petioles, while the 'Sporting Philippine Red' has medium yellow orange (RHCC 14 B) petioles. The pastel yellow-petioled varieties included: 'Imelda Marcos' with sulfur yellow (RHCC 6 A), 'Chrysophyllum' with mimosa yellow (RHCC 8 A) and 'Monalisa' with lemon yellow (RHCC 13 B).

On the overall, the 36 croton varieties and natural mutants indeed have leaves that showed a wide variability of colors. This variability is most probably caused by the spontaneous mutation (Esau et al. 2005) occurring in the plant itself. It has been found that croton varieties in the Philippines contain variable chromosome numbers ranging from 2n = 24 to 2n = 124 (Pancho and Hilario, 1963). Genetic mutation and chromosome variability could account for the wide variation in leaf colors within the plant species (Bruce, 1943; Boldrini et al., 2003). In addition, the high variation in choromosome numbers and karyotypes may account for the morphological diversity among the cultivars of this species (Deng et al., 2010a).

Table 6. Leaf and petiole color variation of the different yellow-leaf croton cultivars and natural mutants.

Varieties and Natural Mutants	Leaf Surface		Petiole	
	RHCC#	UCL Name	RHCC#	UCL Name
'Sporting Philippine Red'	181 A	strong greyed-yellow red	14 B	medium yellow-orange
'Sport on Bogorienses'	1 C	chartreuse green	14 A	strong yellow-orange
'Sunray'	137 B	medium green	12 A	aureolin
'Twisted Banana'	137 C	light green	12 A	aureolin
'Imelda Marcos'	154 A	strong yellow-green	6 A	sulphur yellow
'Peaceful'	144 D	pale yellow-green	12 A	aureolin
'Chrysophyllum Yellow'	2 C	light yellow	8 A	mimosa yellow
'Ovafolium Yellow'	144 B	scheele's green	14 A	strong yellow-orange
'Ram's Horn'	2 A	strong yellow	12 A	aureolin
'Rainbow'	149 A	pea green	12 B	aureolin
'Yellow Interruptum'	154 A	strong yellow-green	9 B	canary yellow
'Tilapia Yellow'	154 A	strong yellow-green	9 A	canary yellow
'Monalisa'	146 A	strong yellow-green	13 B	lemon yellow

SUMMARY, CONCLUSION AND RECOMMENDATION

Thirty-six selected croton cultivars and natural mutants were characterized morphologically to assess the leaf morphological characteristics, and describe the leaf and petiole colors. This is important because the results will be the basis for selection of desirable cultivars and mutants with attractive colors and unique plant architecture and leaf form that can be used for propagation and multiplication of the selections for scientific and commercial use. Three major groups such as: red-leaf group, green-leaf group and yellow-leaf group were formed based on the predominant leaf colors of the leaves. The leaf quantitative traits that were assessed included: leaf length, leaf width and petiole length, while the leaf qualitative characteristics evaluated were leaf shape, leaf base, leaf margin and leaf apex. The leaf and petiole color variations in all 36 varieties and natural mutants were determined using the Colour Chart of the Royal Horticultural Society of London (RHS 1966 5th ed.). The different varieties and natural mutants differ slightly in terms of leaf length, leaf width and petiole length. In contrast, the different cultivars and natural mutants had marked differences in terms of leaf shapes, leaf bases, leaf margins, leaf apices, leaf colors and petiole colors. All cultivars and natural mutants belonging to any of the three groups had leaves having a mixture of different colors. The degree of coloration also varies from the young to mature leaves usually with two to four color combinations in each leaf. Two new natural mutants namely: 'Sporting Philippine Red' and 'Bay Mutant' and one seed-derived genotype locally called 'Tilapia Yellow' were identified and first described in this study. The distinct leaf color differences are unique and peculiar to crotons only. This is possibly due to the nature of crotons being a continuous mutant so that it can create unexpected variability anytime which can be manifested dramatically in the distinct coloration of the leaves. The uniqueness of leaf colors in the 36 crotons cultivars and natural mutants is a potential advantage for cultivating these species in large numbers as commercial ornamental plants. Since they are hardy, fairly insensitive to pests and diseases, and highly adaptable to a wide range of adverse environmental conditions and climate trends, it is recommended that they can be used by internal decorators as indoor plants for homes and buildings, potted plants for used as

souvenir gifts for special occasions, and by florists as fillers or greens in floral arrangements and in bouquets.

ACKNOWLEDGMENTS

The Croton Breeding Project is supported by the Institute of Plant Breeding and Crop Science Cluster, College of Agriculture, University of the Philippines Los Baños. The authors would like to thank Ms. Karen R. Daquioag, Ms. Maria Fe H. Cayaban, Ms. Maria Jenina C. De Leon, Mr. Chris Rey M. Lituanas, Mr. Marcelino T. Gregorio, and Mr. Bill Anderson for the various help rendered for the completion of this study.

STATEMENT OF AUTHORSHIP

Dr. Pablito M. Magdalita is the Project Leader of the project on "Breeding and Selection of Ornamental Crops for Climate Change Adaptation" from where this study was based, and also wrote the paper. Ms. Nerissa K. Torreta and Dr. Rachel C. Sotto facilitated the botanical characterization work and formatting of the paper.

REFERENCES

Boldrini KR, Blone NC, Pagliarini MS. 2003. Chromosome transfer among pollen mother cells of garden crotons [Codiaeum variegatum (L.) Blume]. Cytologia 68:341-344.

Brown, BF. 2008. A Codiaeum Encyclopedia Crotons of the World. Valkaria Tropical Garden, Florida, USA.

Bruce AP. 1943. Chromosome number and phylogenetic relationships in the Euphorbiaceae. Am J Bot 30:527-543.

Chaparro JX, Werner DS, Whettem RW, O'Malley DM. 1995. Characterization of an unstable anthocyanin phenotype and estimation of somatic mutation rates in peach. Journal of Heredity 86:186-193.

Deng M, Chen J, Henry RJ, Li Q. 2010. Genetic relationship of Codiaeum variegatum cultivars analyzed by amplified fragment length polymorphism markers. HortScience, 45(6):868-874.

Esau EB, Denton DA, Ayodele AE, Ogunwenmo KO, Fapohumda SO. 2005. The establishment of the Babcock University Garden Croton Germplasm Repository. Babcock University Academic Congregation Colloquium Series 2:29-36.

Gilman EF. 1999. Codiaeum variegatum. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, USA.

Jones SB and Luchsinger AE. 1986. Plant Systematics. 2nd ed. McGraw-Hill, Inc., New York, USA.

Magdalita PM. 2011. Ornamental Crops Breeding. In: IPB-CSC Annual Report for 2011. IPB-CSC, College of Agriculture, UP Los Baños, College, Laguna.

Mollick AS, Shimoji H, Denda T, Yokota M, Yamasaki, H. 2011. Croton (Codiaeum variegatum (L.) Blume) cultivars characterized by leaf phenotypic parameters. Scientia Horticulturae 132:71-79.

Mollick AS and Yamasaki H. 2012. Phenotypic variations in Croton (Codiaeum variegatum (L.) Blume) characterized by digital image-based procedure. Acta Horticulturae, 937:393.

Ogunwenmo KO, Idowu OA, Innocent C, Esau EB, Oyelana OA. 2007. Cultivars of [Codiaeum variegatum (L.) Blume.] (Euphorbiaceae) show variability in phytochemical and cytological characteristics. Afr J Biotech 6(20):2400-2405. Available online at http://www.academicjournals.org/AJB

Pancho, JV. and Hilario FI. 1963. Chromosome numbers and intraspecific hybridization in croton [Codieaum variegatum (L.) Blume.]. Philipp Agric 47:104-112.

Porter, CL 1959. Taxonomy of Flowering Plants. W. H. Freeman and Company, San Francisco, USA.

Radford AE, Dickison WC, Massey JR, Bell CR. 1974. Vascular Plant Systematics Harper and Row, New York, USA.

[RHS] Royal Horticultural Society of London. 1966. RHS Colour Chart. Flower Council of Holland.

Supaporn S, Supachitra C, Boon-Long P. 2000. Adaptation of croton 'Baisom' [Codiaeum variegatum (L.) Bl. 'Baisom'] leaves to different light intensities. J. Sci Res. Chulalungkorn University, Bangkok, Thailand 25(2):257-269.

Stamps RH and Osborne LS. 2003. Croton production and use. Circular ENH 878, Series of the Environmental Hort EIDS, Dept, Florida Coop Ext Services, IFAS, Univ Florida EIDS, http://edis.ifas,ufl.edu. Accessed June 20, 2012.

Wessler SR. 1988. Phenotypic diversity mediated by the maize transposable elements Ac and Spm. Science 242:399-405.

Vergara BS. 2007. Ornamental Plants in the Philippines: Codiaeum. Island Publishing House Inc, Sta. Mesa, Metro Manila, Philippines.

JOURNAL OF NATURE STUDIES
(formerly Nature's Bulletin)
ISSN: 1655-3179