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A morphological survey of foliar trichomes of *Croton* L. (Euphorbiaceae) in Thailand

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ABSTRACT. The morphology of foliar trichomes of 23 species of *Croton* in Thailand was studied by scanning electron microscopy and by light microscopy. Seven main trichome types characterized by their morphology were found, namely, stellate, fasciculate, multiradiate-rosulate, dendritic, lepidote, glandular and simple types. Some trichome subtypes are useful for species identification, particularly stellate rotate trichomes with a central porrect ray are found only in *C. tiglium*, appressed stellate trichomes in *C. griffithii* and glandular trichomes are restricted to *C. caudatus*, *C. crassifolius* and *C. hirtus*.

KEY WORDS: Foliar trichomes, *Croton*, Euphorbiaceae, Thailand.

INTRODUCTION

Croton L. is one of the largest genera in the family Euphorbiaceae with ca 1,300 species, distributed mainly in tropical and subtropical regions. Several studies of *Croton* using morphological, anatomical and molecular characters have been published (Berry et al., 2005; Esser, 2005; Webster, 1993; Webster et al., 1996).

Thirty-one species of *Croton* have been enumerated for Thailand, including two undescribed species (Esser, 2005). The genus in Thailand is monoecious, with many foliar trichome types. Inflorescences are usually bisexual with pistillate flowers at the lower part and staminate flowers at the upper one. Leaves have glands at the base next to the petiole. Stamens are inflexed in bud, a character not found in any other genera in the inaperturate pollen clade of the Crotonoideae (Smith, 2002). The genus has various medicinal uses, particularly, in Thailand, the leaves of *C. stellatopilosus* Ohba are used as a source of anti-ulcer drug (Plaunotol). Stem and bark of *C. roxburghii* N.P.Balakr. are antidiarrhoeal and normalize menstruation (Esser, 2005; Smith, 2002).

Trichomes have several important characters that can be studied with the microscope and can be useful for comparative systematics. Variation in trichome types can provide insight into evolution and relationships within and among species (Payne, 1978; Theobald et al., 1979). In many plant groups, trichomes are frequently present, easily observable, and often possess variation patterns. Taxonomic characters of particular types of trichomes have been investigated in many groups, particularly ferns and flowering plants such as *Cornus* (Cornaceae) (Hardin and Murrell, 1997), *Cuphea* (Lythraceae) (Amarasinghe et al., 1991), *Quercus* (Fagaceae) (Bussotti and Grossoni, 1997) and *Tilia* (Tiliaceae) (Hardin, 1990).

Webster et al. (1996) standardized the terminology of trichome morphology in *Croton*, and characterized the variation in foliar trichomes within 36 of the 40 sections of the genus. Their study shows great trichome variation within *Croton* including stellate, fasciculate, multiradiate-rosulate, dendritic, lepidote, papillate and glandular. In addition, Webster et al. (1996) discussed possible transformational series with three possibilities for which stellate or fasciculate hair are primitive. The first one is branched stellate or fasciculate hairs being reduced to simple hairs. The second one is transitional from stellate or fasiculate hairs being altered to multiradiate to dendritic, and the third possibility is stellate hairs being transitionally changed to lepidote ones.

The aim of this study was to observe the

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morphological types of trichome in Thai *Croton* by scanning electron microscopy (SEM) and by light microscopy.

MATERIALS AND METHODS

Leaf samples were collected from natural populations of 23 species of *Croton* (Table 1). Terminology follows Webster et al. (1996). For light microscopy, trichomes were isolated from dry leaves then put on a glass slide, fixed in water or 10% glycerine, then sealed with a glass cover slide and examined with an Axio Star plus (Zeiss) microscope. For SEM, pieces of dry leaves, 10 x 10 mm were mounted on aluminium stubs with single-sided adhesive tape and air-dried. The stubs were then sputter-coated with pure gold and examined with a JSM-6460LV SEM operated at 10kV. The slides prepared and the herbarium specimens are kept at Walai Rukhavej Research Institute, Mahasarakham University, Thailand.

RESULTS

The seven trichome types found in the species examined are described in detail below and summarized in Table 1.

I. Stellate type (Figs. 1, 2, 5, 6). This type is characterized by star-shaped trichomes in one plane which are usually flattened onto the lamina with 12–24 radii, 0.2–0.5 mm diam. and 0–30 % webbing. The type is divided into two subtypes according to the absence or presence of porrect radii. Subtype Ia, stellate rotate and one porrect radius occurs only in *C. tiglium*, with 12–15 radii, 0.3–0.5 mm diam. and 0–15 % webbing. Subtype Ib, appressed stellate is flattened and found only on the lower leaf surface in *C. griffithii*, *C. kerrii* and *C.* aff. *longissimus*. It has 18–24 radii, 0.2–0.4 mm diam. and is 15–30 % webbed. In addition, *C. delpyi* exhibits appressed stellate trichomes on both leaf surfaces, clearly showing transitional forms from appressed stellate to rosulate and to multiradiate (Fig. 6)

II. Fasciculate type (Fig. 9). In this type the radii are ascending rather than in one plane and never flattened onto the lamina, with 2–13 radii, sometimes stalked stipitate and with 0–15 % webbing. This type occurs in *C. caudatus*, *C. crassifolius*, *C. hirtus* and *C. stellatopilosus*, in all of which fasciculate hairs are sparse on the upper leaf surface and very dense on the lower one.

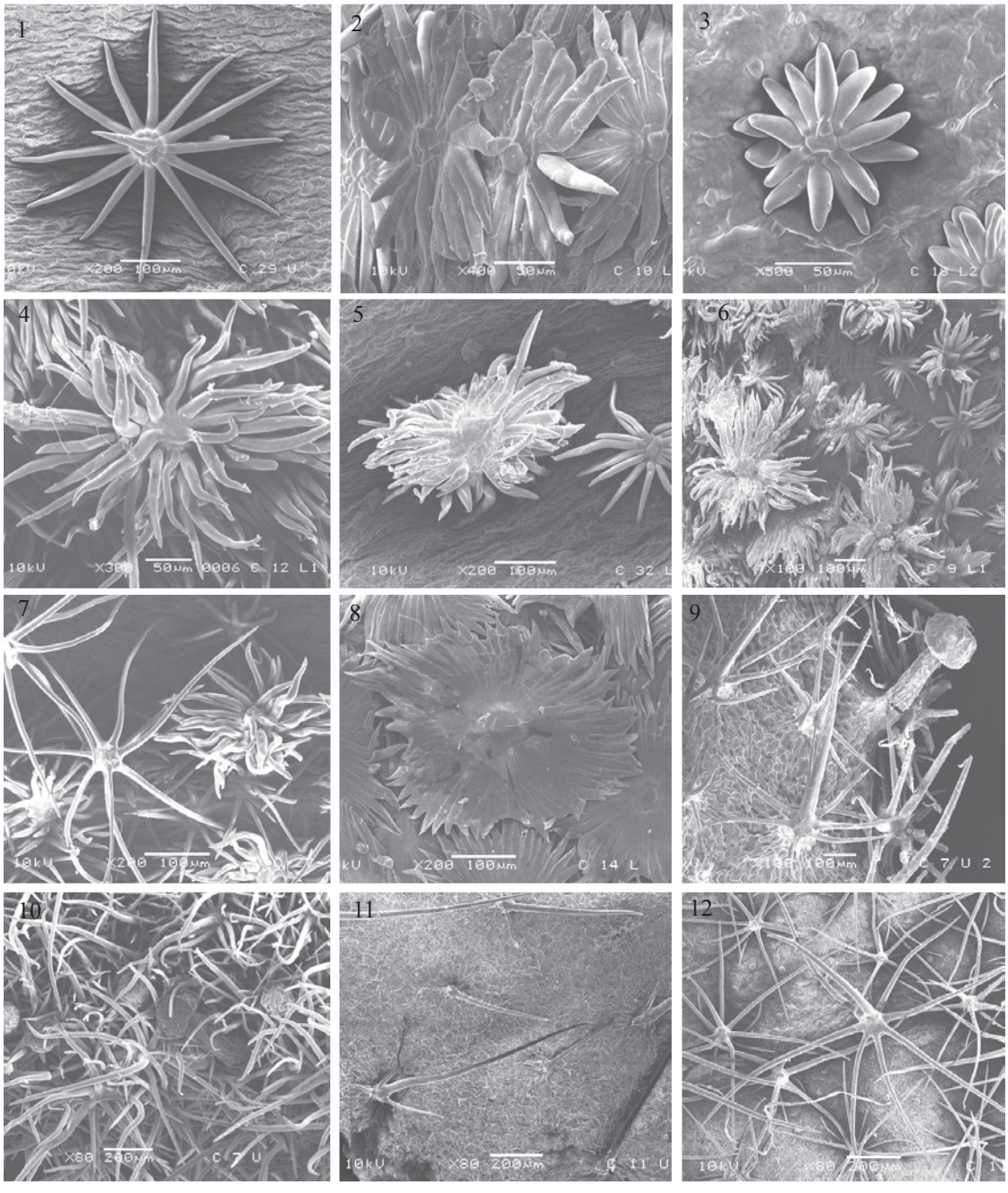
III. Multiradiate-rosulate type (Figs. 3, 4, 5, 6, 7). This type is different from the fasciculate type by having more than 8 radii. Rosulate hairs are regarded as a subset of the multiradiate type with shorter radii (0.12–0.27 mm) (Webster, 1996). This type has 13–53 radii, 0.2–0.4 mm diam., 0–30 % webbing, and is divided into two subtypes. Subtype IIIa, appressed-rosulate trichomes, are found in *C. acutifolius*, *C. bonplandianus*, *C. columnaris*, *C. decavatus*, *C.* aff. *longissimus* and *C. robustus*. Subtype IIIb, rosulate trichomes, is found in *C. krabas*, *C. delpyi*, *C. hutchinsonianus*, *C. stellatopilosus* and *C.* aff. *thorelii*.

IV. Dendritic type (Figs. 10, 12). This is characterized by the radii being inserted at different levels on an axis. It has 13–27 radii, 0.3–1 mm diam. and 0–30 % webbing and occurs in *C. caudatus*, *C. crassifolius*, *C. hirtus* and *C. stellatopilosus*.

V. Lepidote type (Fig. 8). This trichome type is usually flattened and more or less shield-like and scaly with the radii connected by webbing. This type has 31–70 radii, 0.2–0.6 mm diam. and 50–100 % webbing. It is divided into two subtypes based on a complete continuum in the degree of webbing. Subtype Va, lepidote-subentire trichome, has 80–100 % webbing, 0.3–0.6 mm diam. and more radii. This subtype occurs in *C. cascarilloides*, *C. kongensis*, *C. poilanei*, *C. roxburghii* and *C. sepalinus*. Subtype Vb, dentate lepidote trichome, has 50–80 % webbing and occurs in *C. poomae* which has a dense indumentum on the lower leaf surface but rarely on the upper one.

VI. Glandular type (Fig. 9, 10). This is present on the leaf and along the leaf margins of *C. caudatus*, *C. crassifolius* and *C. hirtus*. The glandular trichome has a bulbous expanded base and a narrowly elongated neck. The trichome is 0.4–0.6 mm long and 0.1–0.3 mm diam. at the base.

VII. Simple type (Fig. 11). This trichome type is stiffly erect, directed upward from an inclined base (Payne, 1978). This type is found only in young leaves of *C. hirtus*, and trichomes are 0.4–0.8 mm long. This type shows distinct transitional states from simple to 2–5-radiate porrect to fasciculate, multiradiate and dendritic (Fig. 11 and 12).



Figures. 1–12. Foliar trichome types in *Croton*: 1. *C. tiglium*, stellate rotate with central porrect ray; 2. *C. griffthii*, appressed stellate; 3. *C. columnaris*, appressed rosulate; 4. *C. hutchinsonianus*, rosulate; 5. *C.* aff. *longissimus* transitional types from appressed stellate to rosulate; 6. *C. delpyi*, transitional types from appressed stellate to rosulate and to multiradiate; 7. *C. stellatopilosus*, transitional types from multiradiate porrect to dendritic; 8. *C. kongensis*, lepidote-subentire; 9. *C. crassifolius*, fasciculate and glandular; 10. *C. crassifolius*, dendritic and glandular; 11. *C. hirtus*, transitional from simple to 2–3-radiate porrect; 12. *C. hirtu*s, dendritic.

Table 1. Characteristic features of foliar trichomes of the Thai *Croton* species investigated. Type I: Stellate trichome; Type II: Fasciculate trichome; Type III: Multiradiate – rosulate trichome; Type IV: Dendritic trichome; Type V: Lepidote trichome; Type VI: Glandular trichome, Type VII: simple.

species	trichome type	Subtypes and transitional states	diameter (mm)	number of radii	% of webbing (as defined by Webster, 1996)	Voucher specimen
C. acutifolius Esser	Type III	appressed rosulate, transitions from multiradiate to dendritic	0.2–0.3	33–35	15-30	*Senakun* 04-3
C. bonplandianus Baill.	Type III	appressed rosulate	0.3–0.4	13–19	0–15	*Senakun* 03-2
C. cascarilloides Raeusch.	Type V	lepidote-subentire	0.3–0.5	55–70	80–100	*Senakun* 04-12
C. caudatus Geiseler.	Type II, IV, VI	fasciculate, dendritic, glandular	0.3–0.5	4–7	0–15	*Senakun* 03-1
C. crassifolius Geiseler.	Type II, IV, VI	fasciculate, dendritic, glandular	0.6–0.8	10–13	0–15	*Senakun* 03-8
C. columnaris Airy Shaw	Type III	appressed rosulate	0.06–0.16	17–20	15–30	*Senakun* 04-7
C. decalvatus Esser	Type III	appressed rosulate	0.2–0.4	22–35	0–15	*Senakun* 04-17
C. delpyi Gagnep.	Type I, III	transitions from appressed stellate to rosulate and to multiradiate	0.3–0.6	9–50	15–30	*Senakun* 04-18
C. griffithii Hook.f.	Type I	appressed stellate	0.2–0.25	18–24	15–30	*Senakun* 04-24
C. hirtus L'Her.	Type II, IV, VI, VII	simple, 2–5 radiate porrect, fasciculate, dendritic, glandular	0.8–1	2–13	0–15	*Senakun* 03-7
C. hutchinsonianus Hosseus	Type III	rosulate	0.5–0.7	27–40	15–30	*Senakun* 04-1
C. kerrii Airy Shaw	Type I	appressed stellate	0.3–0.4	15–16	15–30	*Senakun* 05-3

Table 1. Continued.

species	trichome type	Subtypes and transitional states	diameter (mm)	number of radii	% of webbing (as defined by Webster, 1996)	Voucher specimen
C. kongensis Gagnep.	Type V	lepidote-subentire	0.4–0.6	42–57	80–100	*Senakun* 03-9
C. krabas Gagnep.	Type III	transitions from rosulate to multiradiate	0.3–0.5	18–23	0–15	*Senakun* 03-10
C. aff. *longissimus* Airy Shaw	Type III	transitions from appressed stellate to rosulate	0.3–0.6	17–52	15–30	*Senakun* 04-15
C. poilanei Gagnep.	Type V	lepidote-subentire	0.2–0.3	32–35	80–100	*Senakun* 03-6
C. poomae Esser	Type V	dentate lepidote	0.3–0.4	40–42	50–80	*Senakun* 03-11
C. robustus Kurz	Type III	appressed rosulate	0.3–0.5	37–38	15–30	*Senakun* 03-14
C. roxburghii N.P.Balakr.	Type V	lepidote-subentire	0.3–0.4	31–40	80–100	*Senakun* 03-21
C. sepalinus Airy Shaw	Type V	lepidote-subentire	0.3–0.5	30–44	80–100	*Senakun* 04-19
C. stellatopilosus Ohba	Type II, III, IV	fasciculate, rosulate, transitions from multiradiate to dendritic	0.4–1	7–27	0–30	*Senakun* 03-3
C. aff. thorelii Gagnep.	Type III	transitions from rosulate to multiradiate	0.3–0.5	50–53	15–30	*Senakun* 05-1
C. tiglium L.	Type I	stellate rotate and porrect	0.3–0.5	12–15	0–15	*Senakun* 04-8

DISCUSSION

Differentiation of *Croton* species using characters of trichome type variation could be useful for the distinction of the Thai taxa. For example, stellate rotate trichomes with a central porrect ray are found only in *C. tiglium*, appressed stellate trichomes in *C. griffithii* and glandular trichomes are restricted to the leaf and leaf margin of *C. caudatus*, *C. crassifolius* and *C. hirtus*. Some species show transitional forms or states. *C. stellatopilosus* shows transitional states from multiradiate to dendritic types (Fig. 7); *C. delpyi* shows distinct transitional states from appressed stellate to rosulate and to multiradiate (Fig. 6); *C. krabas*, *C.* aff. *longissimus* and *C.* aff. *thorelii* show transitional states from appressed stellated to rosulate (Fig. 5) and *C. hirtus* exhibits distinct transitional states from simple to 2–5-radiate to fasciculate, multiradiate and dendritic.

According to our findings in this study, trichomes can be used for differentiating the species of *Croton* in combination with other characters such as leaf venation and margin, fruit size, number of stamens, size of inflorescences and growth habit (herb, shrub and tree).

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