Variations of Leaf and Storage Roots Morphology in *Ipomoea batatas* L. (Sweetpotato) Cultivars

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Abstract

***Ipomoea batatas* L. is one of the main crops in the world and is planted mainly for its tuber. This vegetative plant is hard to distinguish between their wide varieties during the harvesting period. We sought a general comparison of variations across different varieties of sweet potato leaves. A total of 6 different local varieties of sweet potato leaves were characterised for leaf width, length, thickness, area, shape, arrangement, margin, venation and the colour index (in L*a*/b*). The morphological characteristics of the storage roots were also found to be different for the different varieties. Hence, the leaf morphology can be used to distinguish the different varieties of sweet potato plant in Malaysia.**

Keywords: *Ipomoea batatas*; leaf morphology; Sweet Potato; SLA; varieties

INTRODUCTION

Ipomoea batatas, or sweet potato originated from the Northwest of South America and is dispersed world-wide due of its high yield potential and wide adaptability. It belongs to the family Convolvulaceae and can be further divided into varieties or cultivars. Currently there are over 6000 varieties of sweet potatoes world-wide and they are basically distinguished by storage roots' skin colour, flesh colour, and some, by origin (CIP, 2008).

Unlike the potato which is a tuber, or thickened stem, the sweet potato is a storage root (CGIAR, 2004). Sweetpotato varieties exist in many colours of skin and flesh, ranging from white to deep purple, although white and yellow-orange fleshes are the most common. Some examples of varieties sweet potato are Kotobuki (Japanese), Georgia Jet, Fernandez, Red Jewel and Okinawa. Sweet potatoes are grown in hot and dry weather for about 3 months before the yields are harvested. The yield vary from 10 to 16 t/ha in weight and 61 to 352/m^2 in number, whereas the yields of roots varied from 1 to 16 t/ha (Villareal et al., 1979).

Sweet potato (*Ipomoea batatas* L.) was once described by Longe (1986) as herbaceous creeping plant with smooth, lightly moderate green leaves and sometimes comes with a purple pigmentation along its veins. However, as the number of varieties increase, this definition no longer provides an accurate description of the leaf morphologies of the different sweet potato varieties. The study of *Ipomoea batatas* leaves has been limited, and mostly focussed on the nutritive aspect of these leaves. Sweetpotato plants are grown mainly for their storage roots, hence study of their leaves are limited.

Currently, sweet potatoes are distinguished based on their storage roots. In larger farms where several varieties of sweet potato are planted, this method is often labour consuming and might influence the growth and development of the storage roots due to repeated pulling and planting action on the plant. Therefore, *Ipomoea batatas* leaves morphology could be used as an indicator to distinguish between the varieties to ease the process of harvesting the storage roots. Hence, this study will provide some information on the morphological variations between these local sweet potato leaves. To our knowledge, no studies have been conducted to compare the leaves morphology of different local sweet potatoes varieties in Malaysia. In this study, we report the general variation in leaf and storage roots morphology for six different local varieties of sweet potatoes leaves; *Ipomoea batatas* var. Batu Kelantan (BK), *Ipomoea batatas* var. Batu Biasa (BB), *Ipomoea batatas* var. Oren (Oren), *Ipomoea batatas* var. Vitato (Vit), *Ipomoea batatas* var. Indon (Indon) and *Ipomoea batatas* var. Biru Putih (BP). These local varieties are commonly found in marketplace and used in local food industries.

MATERIALS & METHODS

Study Area – The leaves of the different varieties of *Ipomoea batatas* were measured in the sweet potato farm in Tanjung Sepat, Kuala Langat, Selangor (N02º 40.552' E101º 33.822'). A total of 6 varieties of sweet potato were planted in this area. The leaves which are approximately 5 to 7 days old were used for measurement. Plants were harvested randomly from the central row for all samples. All the varieties are grown under same environment and soil condition.

Measurements – Due to variation in leaf characteristics and practical constraints, we choose the maximum leaf width and length as our parameters. Maximum leaf width is the measurement at the widest point perpendicular to the mid vein (Williams III and Martinson, 2003). Total of 50 leaves (n=50) were used in measurements. The thickness of the leaves was measured using a micrometer (Mitutoyo, Japan).

Leaf and storage roots morphologies - The shape, arrangement, margin, apex, base, leaf surface and venation of the leaves were observed and recorded (Wayne's Word, 2009; Swink and Wilhem,1994). The L*a/b readings were measured using chromameter (Minolta Chromameter CR-200, Japan). The morphologies of the storage roots Skin colour, flesh colour, etc) were recorded and tabulated.

Statistical Analysis - The data accumulated were subjected to statistical analysis using SPSS 15.0 (SPSS, USA). The significant differences between the varieties were determined through ANOVA and Tukey's range test.

RESULTS & DISCUSSIONS

The mean measurements for leaf width, length, thickness and colour index are shown in Table 1. The width (Figure 1a) of the different leaves varieties does not have significant variations. However, the Biru Putih variety has a slightly higher mean width compared to the others. In Figure 1 (b), the difference in leaves length is significant. The Oren variety has the highest mean length followed by Batu Biasa, Biru Putih, Indon, Batu Kelantan and Vitato variety has the lowest mean length. Leaf size might be affected by self-shading whereby the leaf located at the bottom might be slightly larger to facilitate the absorption of sufficient amount of sunlight to allow them to continue photosynthesis. Magdolna and Jozsef (2005) showed a definite correlation between leaf size and water supply. When leaf size increase, it shows that the water supply in that area is sufficient.

The thickness of the leaves from the different varieties of *Ipomoea batatas* is significantly different (Figure 1c) with the variety Batu Kelantan and Batu Biasa having thicker leaf compared to the others. McClendon (1962) reported that the variation in leaf thickness contributes to the variation in photosynthetic rate of the plant. Pieters in 1960 conducted a study to correlate the photosynthetic rate of Acer *Psedoplatanus* with the thickness of mesophylls. Since all the varieties were planted in the same soil and condition, the variation in leaves thickness among these varieties is small. The variation in leaf thickness can be contributed by leaf age, stress history and in young leaves, by the effects of leaf growth (McBurney, 1992).

Leaf colour can be estimated by visual assessment but often the result is subjective and cannot be quantified. Therefore, we used a chromameter coordinate in a Munsell colour system as a reference to quantify the colour of the *Ipomoea batatas* leaves in this study. The L*a*/b* value is used to compare the colour of the leaves (Figure 1d). Both the Batu Kelantan and Batu Biasa varieties have smaller L*a*/b* values and thus they have a greener colour. As the green colour on leaves implies the chlorophyll pigments in the leaves, L*a*/b* value can be used as a parameters to evaluate the chlorophyll level in the leaves. The L*a*/b* scores can be affected by leaf position, growth stage, cultivars and N fertilisation (Anand and Byju, 2008).

Table 2 shows the leaf descriptions for the 6 different varieties of *Ipomoea batatas* L. *Ipomoea batatas* variety Oren, Indonesia and Vitato possessed cordate shaped leaves while both the variety Batu Biasa and Batu Kelantan have hastate shaped leaves. Hastate leaves have triangular base whereas cordate shape resembles a love shape with pointed tip and large base. Biru putih can be distinguish from the other plant because their young leaves have cordate shape but the mature leaves have hastate shape. Problem usually arose when the leaves shape does not entirely fits into a description but somewhat a mixture or modification from general descriptions. Hence, a more detailed observation has to be done to distinguish the different types of varieties. The Oren leaves variety has a broader and more rounded width from the leaf apex to the leaf base compared to the Indon leaves which has a narrower width from the apex and a wider base. The Vitato leaves variety has a slightly pointed protrusion at its maximum width and a less rounded leaf base. On the other hand, although the Batu Kelantan and Batu Biasa leaves varieties both have hastate shaped leaves the Batu Kelantan variety leaf has a narrower width, less pointed apex and more rounded base compared to the leaf of the Batu Biasa variety. In

addition to that, the Batu Biasa leaf variety has a more distinctive pointed curve at its maximum width. All these features must be included when leaves morphology are used in distinguishing the different *Ipomoea batatas* L. varieties. While it was observed that variation in plant size reflects variation primarily in environmental conditions, variation in leaf shape are often more inheritable and independent of the environment (Dickinson et. al, 1987). Another study had mentioned that the shape of the leaves is a response to the plant long term ecological and evolutionary history. The limiting factors from the environment may also modify the finished form and shape of a tree's leaves (The Pennsylvania State University, 2009).

All the varieties have alternate arrangement which only one leaf emerged from each node on the plant. The leaves also have entire margin and arcuate venation. Arcuate venation refers to the formation of primary veins for the midrib of the leaf. The venation system of the leaves serves to transport water and solutes to the leaf lamina through the venation system (Roth-Nebelsick et al., 2001). While broad leaves may be stabilised by a set of major parallel veins, narrow and mid-sized leaves were stabilised by a central midrib with rectangularly branching laterals (Roth-Nebelsick et al., 2001). This shows that the venation system in *Ipomoea batatas* leaves are independent of size. Hence, the venation pattern in leaves reveals the water transport system in the plant. It was that found plants from tropical rainforest which exposed to high level of humidity showed high venation density compared to plants from deciduous forest (PyykkoÈ, 1979). While 5 of the varieties having caudate apex, Indon can be distinguish from the group by having a broadly acute apex. Both the Batu Kelantan and Batu Biasa varieties have hastate base whereas the Oren, Indon, Vitato and Biru Putih varieties have cordate base. Hastate base refers to the leaf having triangular shaped base and cordate base refers to leaf with slightly rounded bottom.

Larger surface area in leaves have been associated with increasing light absorption and shown reduced or almost zero expression of lobes and edges. The presence of complex edges and lobes in larger leaves will enable them to disperse absorbed heat very rapidly. This thus explains the presence of lobes and edges on margin of leaves. In our study, we found out that all the *Ipomoea batatas* varieties have entire margin in their leaves with no presence of lobes and edges. Thus, we can deduce that this plant has a good cooling system which helps to transmit heat from the plant. Besides, the surface area of these leaves will also affect the transpiration rate in the plant (Table 2). The Oren, Indon and Vitato varieties have waxy and rugose surface, whereby it resembles peppermint leaf although their shape is different. All the young leaves have waxy surface except for the leaf of the Biru Putih variety which has glabrous leaf surface for both young and mature leaf. Waxy surface are usually observed in younger leaves which function to prevent or minimise the transpiration rate from the leaves as the leaves where located at the top of the plant. Glabrous refers to the smooth and hairless surface of the leaf. The matured leaves for all the varieties have glabrous surface.

The storage root morphologies such as shape, skin colour, flesh colour and tuber placement of the 6 different varieties are taken into consideration in this study (Table 3). Looking at their skin colour, the Oren variety can be distinguished from the rest of the group because it has purple skin colour. The Batu Kelantan and Biru Putih variety have cream coloured skin whereas Batu Biasa, Indon and Vitato have brownish skin. Besides

skin colour, the flesh colour of these different varieties also differs from one another. Both the Batu Kelantan and Batu Biasa have yellow coloured flesh. The Oren and Vitato varieties have orange flesh which indicates the presence of high amount of beta carotene whereas, the Indon variety has purple flesh which distinguish it from others. The Biru Putih variety can be easily distinguished from the others by its variegated pink flesh colour. The shape of these storage roots does not have significant variation between Indon, Vitato and Biru Putih variety. However, the Oren and Batu Kelantan varieties have round shape instead of longish shape storage roots. The Batu Kelantan variety has a smaller and narrower storage roots compared to other varieties. All the storage roots were form close to the main root of the plant except for the Biru Putih variety which the storage roots were located far from the main root. Figure 2 shows the different *Ipomoea batatas* leaves varieties and their corresponding storage roots.

In leaf morphological study, often fluctuations in readings affect the results of the study. The problem of inconsistency in leaf measurement and reading is partly contributed by the non-uniform distribution of radiation, humidity and heat on individual leaves (New Mexico State University, 2007). Sweet potato plant which is prone to high frequency of somatic mutations might cause these variations to occur between the varieties (Love et al., 1978).

As the conclusion, both the significantly different width and thickness can be used as parameters to distinguish between these varieties. In addition to that, combination of leaves shape, apices and bases can be used as potential parameters to distinguish the sweet potato plants across different varieties. Hence, leaf morphologies can be used to distinguish the 6 different varieties of sweet potato plant used in this studyespecially during the harvesting period. The variation in storage roots morphology can be used to complement the leaf morphology.

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TABLES

Table 1: Leaf measurements of different varieties of *Ipomoea batatas* leaves.

Variety	Width (cm)	Length (cm)	Thickness (mm)	Upper leaf surface L*a*/b*	Lower leaf surface L*a*/b*
BK	9.143 ± 0.252z	8.867 ± 0.306z	0.287 ± 0.023z	-28.694 ± 1.338z	-31.270 ± 2.465z
BB	9.292 ± 0.312z	9.736 ± 0.326y	0.287 ± 0.045y	-28.552 ± 1.947z	-33.396 ± 1.493z
Oren	9.310 ± 0.289z	10.438 ± 0.479x	0.240 ± 0.056x	-22.148 ± 5.005z	-9.318 ± 0.251z
Indon	9.544 ± 0.386z	9.567 ± 0.508w	0.257 ± 0.021w	-23.673 ± 0.561z	-31.141 ± 0.190z
Vitato	10.147 ± 0.625z	8.700 ± 0.529v	0.240 ± 0.056v	-23.967 ± 2.803z	-31.289 ± 2.399z
BP	10.511 ± 0.372z	9.700 ± 0.487u	0.253 ± 0.015u	-23.931 ± 1.319z	-28.524 ± 5.120z

Abbreviation: *Ipomoea batatas* var. Batu Kelantan (BK), *Ipomoea batatas* var. Batu Biasa (BB), *Ipomoea batatas* var. Oren (Oren), *Ipomoea batatas* var. Indon (Indon), *Ipomoea batatas* var. Vitato (Vitato) and *Ipomoea batatas* var. Biru Putih (BP).

*For each column, means followed by the same letter are not significantly different ($p<0.05$), Tukey HSD mean procedure.

Table 2: Leaf Morphologies for the 6 Different Varieties of *Ipomoea batatas*

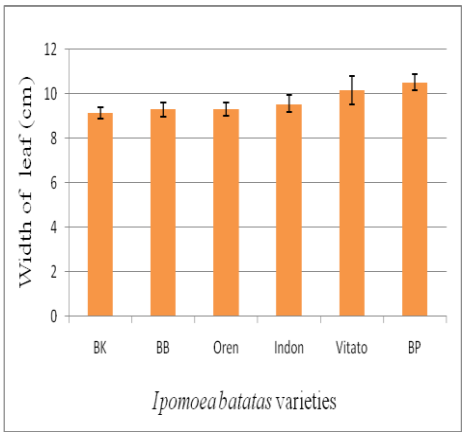
Variety	BK	BB	Oren	Indon	Vit	BP
Shape	Hastate	Hastate	Cordate	Cordate	Cordate	Cordate (Y) & Hastate (O)
Arrangement	Alternate	Alternate	Alternate	Alternate	Alternate	Alternate
Margin	Entire	Entire	Entire	Entire	Entire	Entire
Venation	Arcuate	Arcuate	Arcuate	Arcuate	Arcuate	Arcuate
Apex	Caudate	Caudate	Caudate	Broadly acute	Caudate	Caudate
Base	Hastate	Hastate	Cordate	Cordate	Cordate	Cordate
Surface :						
(a) Young	Waxy	Waxy	Waxy, Rugose	Waxy, Rugose	Waxy, Rugose	Non-waxy, Rugose
(b) Mature	Glabrous	Glabrous	Glabrous	Glabrous	Glabrous	Glabrous

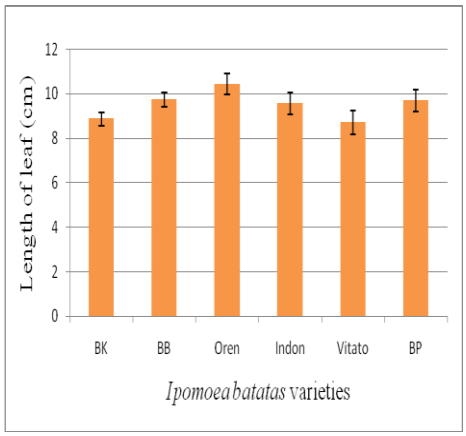
Table 3: Storage Root Morphologies for the Different Sweet Potato Varieties

Variety	Skin colour	Flesh colour	Shape	Storage Roots placement
Batu Kelantan	Cream	Yellow	Round	Close to main root
Batu Biasa	Light brown	Cream	Narrow and small	Close to main root
Oren	Purple	Orange	Round	Close to main root
Indon	Brown	Purple	Longish	Close to main root
Vitato	Light brown	Orange	Longish	Close to main root
Biru Putih	Cream	Variegated Pink	Longish	Storage roots located far from main root

FIGURES

a





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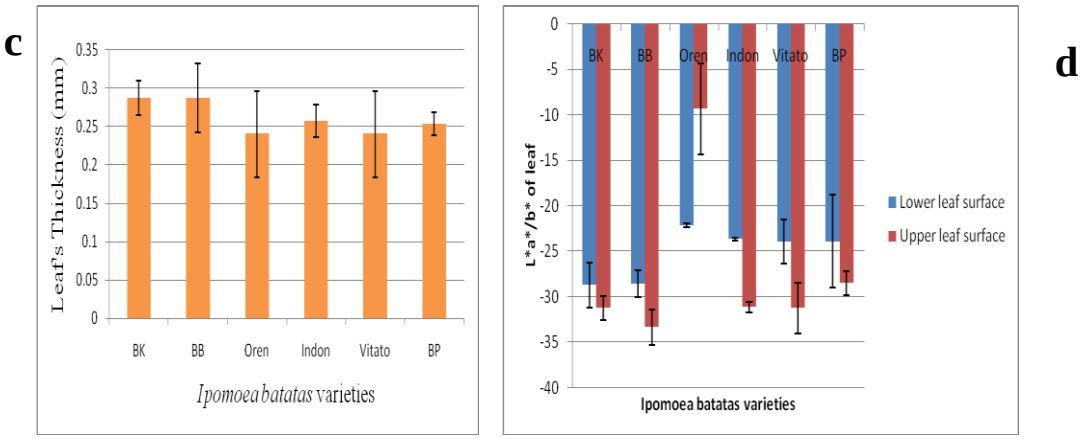

Figure 1: The measurements of leaves morphology in *Ipomoea batatas* L. (From left): (a) Graph of Width of leaves for different *Ipomoea batatas* L. varieties, (b) Graph of Length of leaves for different *Ipomoea batatas* L. varieties, (c) Graph of Thickness of leaves for different *Ipomoea batatas* L. varieties and (d) Graph of L*a*/B* reading for the Upper and Lower surface of *Ipomoea batatas* leaves.

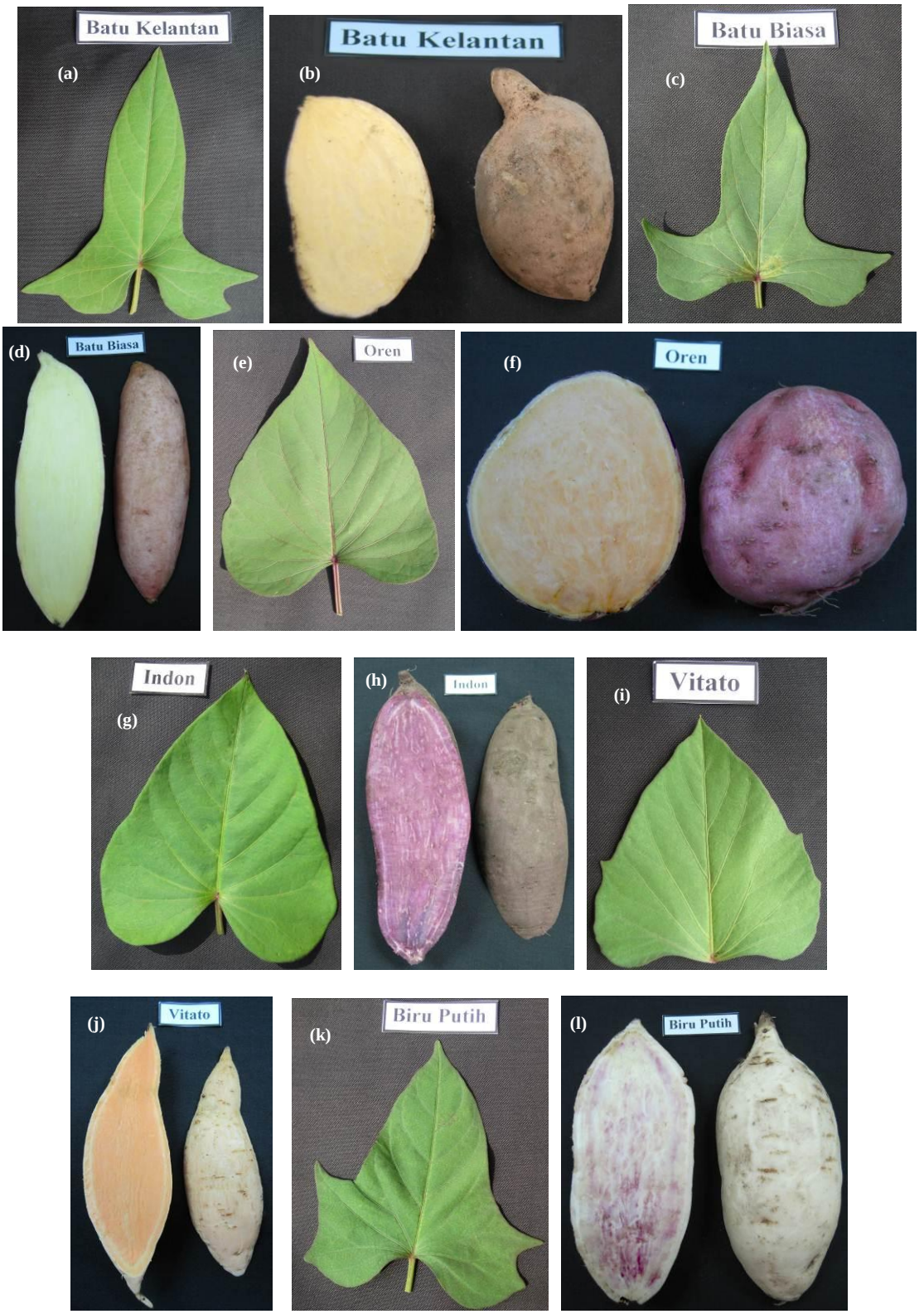

Figure 2: Ipomoea batatas leaf and storage root according to varieties. (From left) (a) *Ipomoea batatas* var. Batu Kelantan leaf, (b) *Ipomoea batatas* var. Batu Kelantan storage root, (c) *Ipomoea batatas* var. Batu Biasa leaf, (d) *Ipomoea batatas* var. Batu Biasa storage root, (e) *Ipomoea batatas* var. Oren leaf, (f) *Ipomoea batatas* var. Oren storage root, (g) *Ipomoea batatas* var. Indon leaf, (h) *Ipomoea batatas* var. Indon storage root, (i) *Ipomoea batatas* var. Vitato leaf, (j) *Ipomoea batatas* var.Vitato storage root, (k) *Ipomoea batatas* var.Biru Putih leaf and (l) *Ipomoea batatas* var. Biru Putih storage root.