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Morphological study of Musa acuminata subsp. malaccensis (Ridley) Simmonds to determine taxonomic characteristics

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ABSTRACT

HARI, P. C. (1989). Morphological study of Musa acuminata subsp. malaccensis (Ridley) Simmonds to determine taxonomic characteristics. *Saussurea* 19: 187-214. In English, French and English abstracts.

This paper is a study of the morphology of *Musa acuminata* subsp. *malaccensis* (Ridley) Simmonds based on 30 collections from the Malaysian States. A number of vegetative and floral characteristics were analyzed to determine characters of the subspecies *malaccensis*.

RÉSUMÉ

HARI, P. C. (1989). Etude morphologique de Musa acuminata subsp. malaccensis (Ridley) Simmonds en vue de déterminer ses caractéristiques taxonomiques. *Saussurea* 19: 187-214. En anglais, résumés français et anglais.

Cette étude de la morphologie du *Musa acuminata* subsp. *malaccensis* (Ridley) Simmonds est basée sur 30 cultures en provenance des Etats de Malaysie péninsulaire. De nombreuses caractéristiques végétatives et florales furent analysées afin de déterminer les caractères propres à la sous-espèce *malaccensis*.

Introduction

The genus *Musa* L. was named after Antonius Musa, physician to Octavius Augustus, first emperor of Rome, 63 BC-AD 14 (COLLA, 1820; BAKER, 1893; SCHUMANN, 1900). The Musaceae, or Banana family are large tree-like herbs. They are native of Tropical Asia, Africa, Australia and nearby islands. There are about 30-40 species and more than 300 edible cultivars.

Some species are planted in summer months in the temperate countries for their spectacular foliage. Others are grown for fiber, but most of all the fruit of the banana is an important food supply in the tropics and an enormous trade all over the world; the major cultivations being located in Central and South America and the Caribbean Islands.

Musa acuminata Colla and *M. balbisiana* Colla are two wild species from which nearly all the edible bananas have originated. Edible diploid forms of *Musa acuminata* are

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thought to be the primary source of the group to which the other species *M. balbisiana* has contributed by hybridization. Edible forms of *M. balbisiana* are known, but no edible diploid (SIMMONDS & SHEPHERD, 1955).

Most edible bananas cultivars of the trade are, like 'Gros Michel', triploid; though a few are diploid. Only few varieties of cultivars are grown commercially. The remainder, some of them very tasty, including the cooking banana, are generally not exported because of either small bunches, small fingers, irregular ripening etc, but they are sold locally on the tropical markets.

For about half a century, the variety exported to Europe was the 'Gros Michel' banana, transported in bulk in refrigerated vessels. Actually it has been largely supplanted by the cultivar 'Valery', now exported from tropical America in boxes and better known as "Chiquita" banana.

Mostly relegated to botanic collections, non-parthenocarpic wild bananas have become more important in recent years to plant breeders as potential material for the improvement of commercial bananas. A large collection, including wild seeded plants and edible cultivars, was introduced from the Far East to Honduras by the United Fruit Company from 1959 to 1961. The purpose of this collection was to establish a plant breeding program with a view to obtain varieties of bananas of economic value and resistant to *Fusarium* wilt and *Cercospora* leaf spot. Notes on this expedition and some of the studies are related in various papers: RICHARDSON & al. (1965), HUTCHISON (1966) and VAKILI (1968).

The material was tentatively classified according to botanical literature. However, despite some good work on the subject, classification was difficult because of the lack of reliable characteristics. This paper describes studies to find characters sufficiently accurate for taxonomic purposes.

Material and methods

Plant material collected in Malaysia between February and May 1961, and cultivated 3 to 4 years in the field in Honduras was used in this study. The collection consisted only of diploid wild seeded banana plants introduced by corms and by seed. Plants from corms were catalogued by an accession number; a different accession number was given to the group progeny issued from the seed of those plants collected in Malaysia at the time the corms were collected. Taxonomic data were therefore taken on few plants (10 or less) of accessions grown vegetatively (clones) and on a large number of plants of the group progeny propagated sexually. The latter will be referred to in this paper by their accession number and as varieties; measurements were done by the biometric system. Only *Musa acuminata* subsp. *malaccensis* is described. Subspecific rank was chosen here as suggested by CHEESMANN (1948-1949) and adopted by SIMMONDS (1957).

Musa acuminata Colla subsp. **malaccensis** (Ridley) Simmonds in Kew Bull.: 466. 1957.
≡ *Musa malaccensis* Ridley in Trans. Linn. Soc. London, Bot. ser. 2, 3: 385. 1893.

This subspecies is widely distributed in Pahang, Malaysia and is also found in Selangor, Perak, Kedah, Kelantan and Perlis, where it usually grows at altitudes ranging from sea level to about 200 m. However, some clones were collected at an altitude of 500 m (see Table 1).

Accession number	*Vernacular name*	*Material collected*	*Altitude (m)*	*Location*	
				Temerloh Pahang	
II-288	Pisang Segun	Corm	60	Kampong Awak Maran road Mile 70	
II-264	Pisang Segun	Seed of II-288	60	Same as above	Plate I
II-287	Pisang Serun	Corm	60	Kampong Awak Maran road Mile 71	
II-326	Pisang Serun	Corm	60	Kampong Awak, 20 miles east of Temerloh	
II-330	Pisang Serun	Seed of II-326	60	Same as above	Plate II
II-327	Pisang Serun	Corm	60	Near Kampong Awak Mile 71	
II-331	Pisang Serun	Seed of II-327	60	Same as above	
				Bentong Pahang	
II-332	Pisang Serun	Seed	100	12 miles south of Karak, Highway Kampong Mantis to Karak	Plate III
II-333	Pisang Serun	Seed	100	Same as above	
II-329	Pisang Serun	Corm	83	10 miles south of Karak, Stream bank Mile 121	
II-341	Pisang Kra	Corm	83	5 miles south of Karak, Bank of Telemong river	
II-340	Pisang Kra	Corm	83	10 miles south of Karak, Bank of Telemong river	
II-339	Pisang Kra	Corm	83	10 miles south of Karak	
II-342	Pisang Kra	Corm	83	5 miles south of Karak, bank of Telemong river	
II-263	Pisang Surong	Seed	100	Vicinity Bentong	Plate IV
II-280	Pisang Surong	Corm	500	Road Bentong Frasers Hill Mile 53	
II-281	Pisang Surong	Corm	500	Same as above	
II-282	Pisang Surong	Corm	500	Same as above	
II-284	Pisang Surong	Corm	800	Road to the Gap, Mile 58, unclassified: lack of flowering specimen	
				Kuala Langat Selangor	
II-276	Pisang Karok	Corm	17	Mile 1, Morib road near Jenjarom	
II-262	Pisang Karok	Seed of II-276	17	Same as above	Plate V
				Upper Perak Perak	
II-355	Pisang Karok	Corm	125	20 miles south of Gerik	
II-344	Pisang Karok	Seed of II-355	125	Same as above	Plate VI
II-357	Pisang Karok	Corm	125	Vicinity Kati, Gerik Highway	
				Ulu Kelantan	
II-334	Rangis	Corm	60	Vicinity Jeram Glugor	Plate VII
				Kubang Pasu Kedah	
II-317	Pisang Utan	Corm	120	Between Nami and Sik	Plate VIII
II-316	Pisang Utan	Corm	120	Near Nami	Plate IX
II-311	Pisang Utan or Biji	Seed	45	Bunkit Tungang, north of Alor Setar	Plate X

Table 1. — Vernacular names and location of collections. From the banana collecting expedition of United Fruit Company, 1959-1961, unpublished notes by the late Paul Allen.

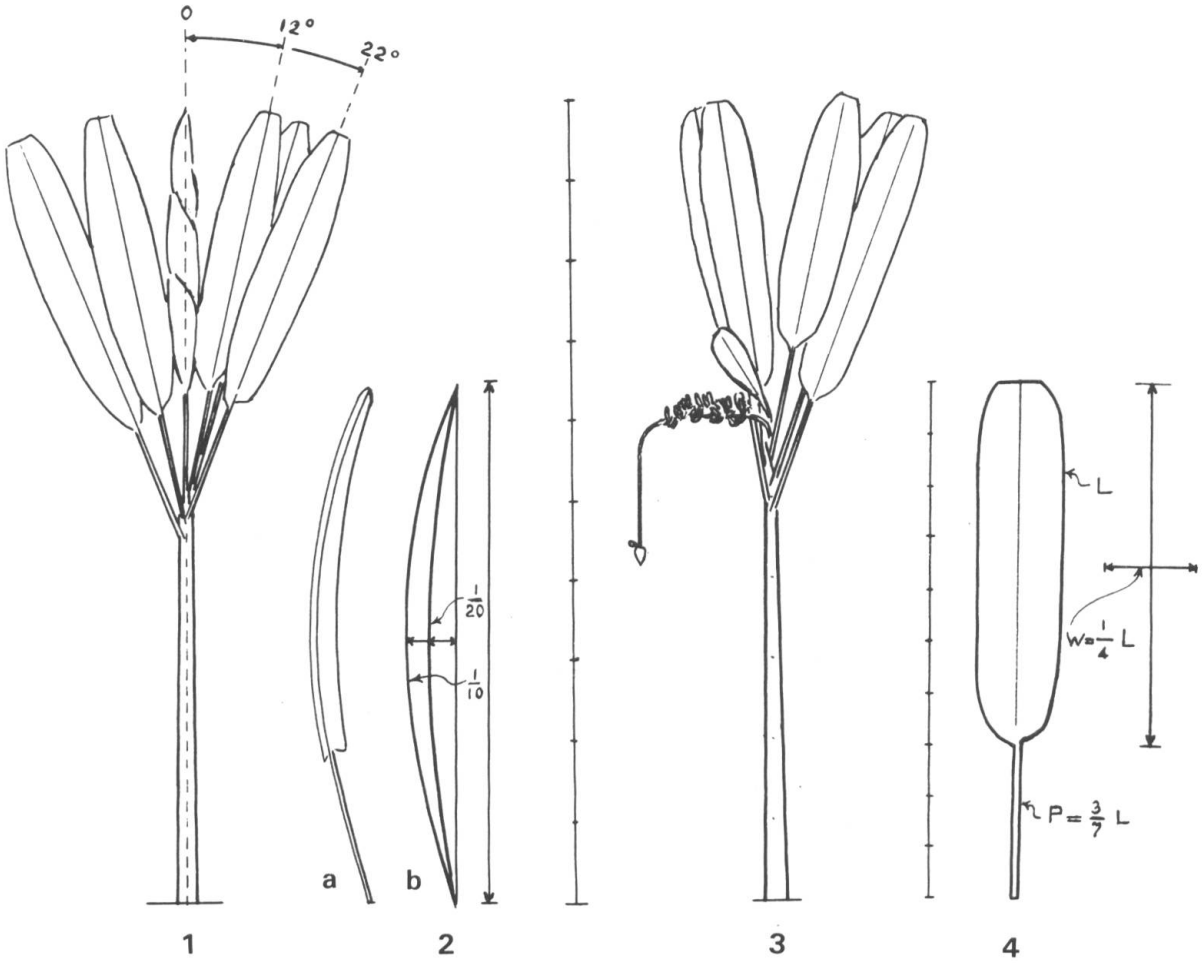

Fig. 1. — Foliage angle to central axis.
Fig. 2. — **a,** schematic petiole and midrib arching; **b,** proportional height of segment from arbitrary chord.
Fig. 3. — Fruit position on proportional height pseudostem-foliage.
Fig. 4. — Ratio petiole-lamina and lamina length/width.

Morphology

Emphasis is given to vegetative as well as on the inflorescence features including measurements. Undoubtedly some size variations are due to geographical location, and the environment in which the plants grow. However, when possible, proportional dimensions have been given and tables on the subject illustrate the reliability of this system.

General habit

Musa acuminata subsp. *malaccensis* is a slender banana developing into a mat of the clump type with numerous pseudostems and usually several bunches of fruits borne simultaneously on the same mat. Suckers are abundant with no less than 2 to 5 around each bearing pseudostem. Pseudostems are erect, well rooted without a tendency for breakage, doubling or uprooting. As a whole, this subspecies of *Musa acuminata* gives a robust appearance adaptable in the tropics under various climatic conditions.

Height. — Heights are measured from ground level to the leaf crown shooting point. *M. acuminata* subsp. *malaccensis* average 4 to 5(-6) m.

The pseudostems are slender with a diameter at one meter above ground level of 12-16 cm. Leaves are erect. In bearing mats, the angle between the plant central axis and the oldest healthy leaves is 12° to 22°. The line to measure leaf angle is the chord from the base of the petiole to the apex of the lamina (Fig. 1).

The petiole and midrib are very rigid as indicated by the slight degree of arching throughout the length of the petiole and midrib. This arching measured from a point at the center of the chord and at a right angle towards the midrib, that is the height of the segment, is only 1/20 to 1/10 the chord length (Fig. 2a, b). This data was taken during maximum turgescence in the early morning.

The ratio of the pseudostem length to the foliage is 4/10 to 5/10 and the fruit shooting points is 5/10 to 6/10 of the total height of pseudostem and foliage (Fig. 3).

Anthocyanic and acyanic variations. — Anthocyanic varieties represent the majority of cases in the subspecies. Presence of anthocyanin responsible for the red and violet coloration is characteristic of the bract of the male bud. Red coloration is present in various degrees of intensity on the structural part of the plant such as the pseudostem, petiole base margin, and midrib (Table 2).

Three of the accessions collected in Temerloh, but also in Bentong and Selangor, are susceptible to bract color mutation (Fig. 5-6). These mutants differ from the anthocyanic varieties as they lack completely or partially the red or purple bract color and instead display a yellow or green bract, with occasionally a colored margin. These acyanic varieties also lack red coloration on the other structural parts. Their foliage is lighter green with less waxiness and could be recognized among the anthocyanic varieties even if they are not in bloom.

Pseudostem blotching. — The basic pseudostem color is light emerald green to light yellow-brown with dark violet blotching. Variations of brown or sepia blotching also occur (Table 2). The degree of blotching varies from light to very dark. In the yellow mutants, blotching is light or absent.

The blotching that appears at the petiole base, is compact and has the raw shape of an arrow head with sharp or rounded edges, terminating toward or extending to the petiole (Plate I to X: **4**).

Foliage

The arrangement of the petioles around the axis give the appearance of a counter-clockwise spiral (when facing the plant) and is much elongated in the young mat (genetic spiral is clockwise). In mats bearing fruit, the vertical distance between petiole bases is 7-15 cm. The petioles arrangement is flabellate, the angle of the spiral being about 180°.

Petiole. — The petioles are long and slender. Petiole length is proportional to the length of the lamina. A constant ratio between petiole and lamina is apparent. Petiole measurements taken on all the varieties available representing over 600 plants gave a proportion almost invariably of 3/7 the lamina length (Fig. 4). One exceptional case is accession II-340 from Bentong; the lamina is unusually long (up to 3.5 m) but the petiole is shorter than the indicated ratio and also more slender. Average petiole length for most *M. acuminata* subsp. *malaccensis* is 90-115 cm (Table 3).

Petioles are light ochre-green and could present a flush of pink or purple when young (Table 2). Also, in some varieties, this color remains on the petioles of mature plants as in the accessions from Kedah (II-311, II-316 and II-317).

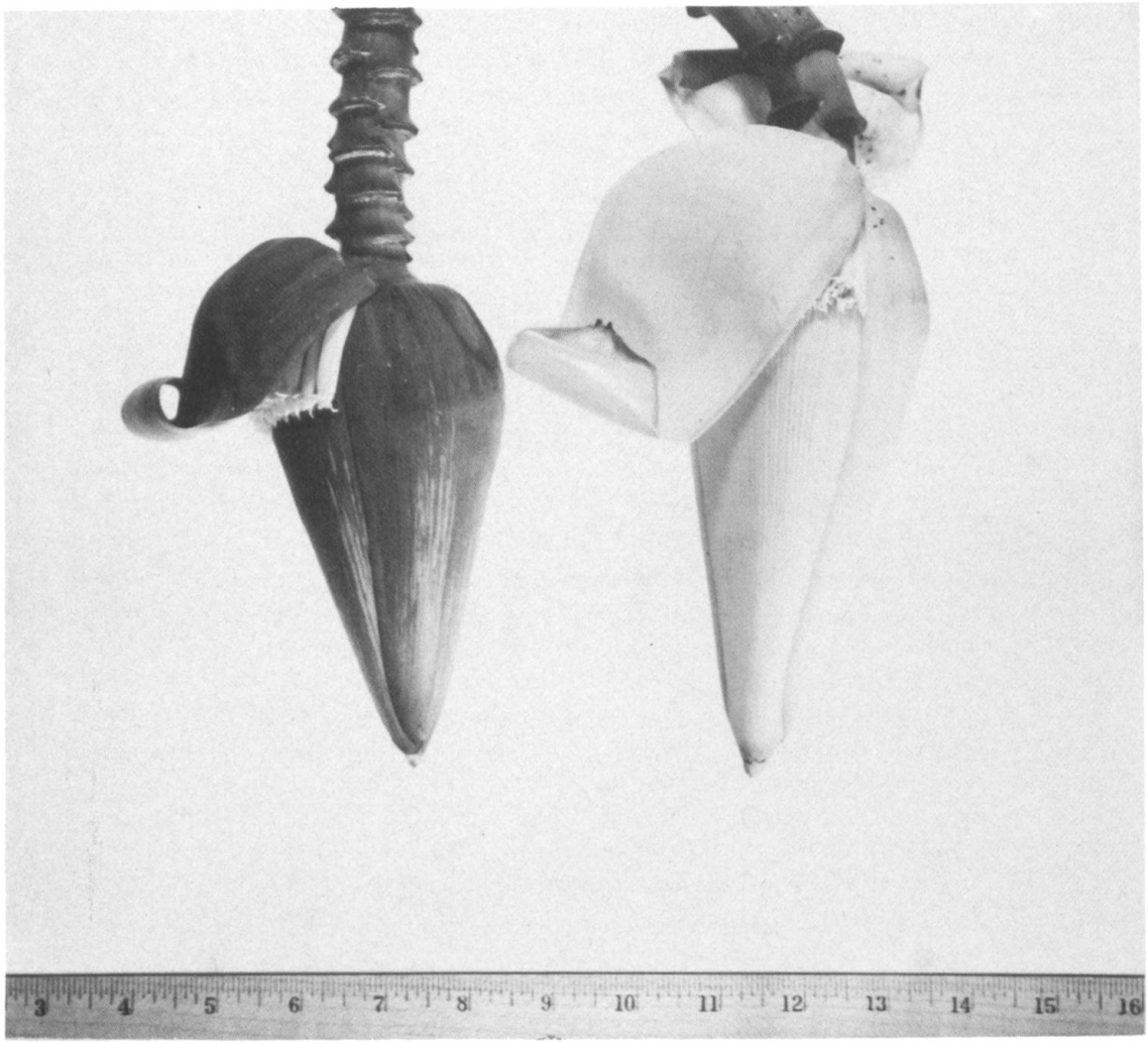

Fig. 5 (left). — Male bud of accession II-330 from Temerloh Pahang.
Fig. 6 (right). — Yellow mutant of same accession.

Male bud bracts color in progressive order of intensity				*Staminate flowers*		*Structural parts*
Location	*Accession*	*Male bud color type*	*Underside bract color*[1]	*Perianth teath color*	*Anther color*	*Waxiness — Color and blotching*
Temerloh	II-326	Yellow	Licht ochre green	Sulfur	Light pink	Waxiness light Lamina light green Midrib pale yellow Petiole light ochre green Pseudostem sheath green or yellowish Blotching on pseudostem and petiole base slight or absent Undersheath color yellowish green Peduncle green, rarely with red flush Suckers without blotching
Temerloh	II-330	Yellow[2]	Light ochre green	Bright sulfur	Pink	
Temerloh	II-264	Yellow	Light ochre green	Sulfur	Pink	
Temerloh	II-331	Yellow[3] green-flush purple	Light ochre green	Yellow orange	Light pink	
Bentong	II-282	Yellow green	Light ochre green	Orange yellow	Light lavender	
Temerloh	II-287	Yellow green	Light ochre green	—	Pink	
Bentong	II-281	Yellow and red	Light red-orange	Yellow orange	Pink	
Selangor	II-276	Yellow streaked red	Light red-orange	Yellow orange	Light lavender	
Selangor	II-262	Yellow streaked red	Light red-orange	Orange yellow	White	
Bentong	II-340	Light vermillon apex yellowish	Pink orange	Orange yellow	—	Waxiness medium to heavy Lamina green Candela (center leaf) green or with flush of pink or purple Petiole and midribs ochre green or with flush of pink or purple (Perak) or redish (Kedah). Petiole margins with redish or purple line parallel to the longitudinal length of the petiole Pseudostem sheath emerald green or greenish brown Blotching on pseudostem brown to deep purple, often heavy as to obscure the basic color Petiole base moderately to heavily blotched Undersheath color flush of pink or purple Peduncle green, rarely with red flush Suckers lamina often blotched dull red
Bentong	II-349	Vermillon	Red orange	Bright yellow	Pale lavender	
Temerloh	II-331	Light vermillon	Red orange	Bright yellow orange	Light pink	
Temerloh	II-330	Light carmine	Greenish orange flush	Bright orange yellow	—	
Temerloh	II-264	Carmine	Greenish orange flush	Sulfur	—	
Temerloh	II-288	Carmine	Greenish and orange flush	Bright yellow sulfur	Pale lavender	
Temerloh	II-327	Carmine dull	Red orange	—	—	
Bentong	II-329	Brick red light	Red orange	—	Light carmine	
Kedah	II-316	Brick red	Red orange	Bright orange yellow	Light carmine	
Bentong	II-332	Light carmine	Pink orange	Bright orange yellow	—	
Perak	II-344	Dark brick red (no waxiness)	Red orange	Deep orange	Pale carmine	
Bentong	II-333	Dark brick red streaked lighter	Red orange	Bright yellow orange	—	
Kedah	II-317	Vermillon streaked carmine	Red orange	Pale yellow orange	Carmine	
Kelantan	II-334	Carminated vermillon	Red orange	Bright yellow orange	Light carmine	
Bentong	II-339	Carminated vermillon	Red orange	Orange	—	
Kedah	II-311	Carminated vermillon	Red orange	Bright orange	Light carmine	
Bentong	II-280	Light carmine	Bright red orange	Yellow orange	Light carmine	
Bentong	II-263	Dark carmine over lighter tone	Bright red orange	Bright orange	Pink	
Bentong	II-341	Carmine over light shade	Red orange	Orange yellow	Bright lavender	
Perak	II-355	Carmine	Red orange	Bright orange	Light carmine	
Perak	II-357	Cramine	Red orange	Orange yellow	Light carmine	

1) Underside of bract always brillant.
2) Yellow buds may display a fine redish thread at the margin.
3) First named color, the dominant one.

Table 2. — Summary of the variations of coloration and waxiness.

Accession number	*Origin*	*Number of plant observed**	*Petiole mean length (cm)*
II-276 — II-262	Selangor	30	90
II-288 — II-264	Temerloh	55	92
II-331	Temerloh	36	90
II-326 — II-330	Temerloh	52	96
II-339	Bentong	15	105
II-263	Bentong	36	105
II-332	Bentong	54	101
II-333	Bentong	52	115
II-355 — II-344	Perak	70	108
II-317	Kedah	20	104
II-311	Kedah	50	102

*The average measurement of two petioles per plant is considered one observation

Table 3. — Petiole mean length for *Musa acuminata* subsp. *malaccensis*.

Accession number	*Origin*	*Number of plant observed*	*Lamina mean length (cm)*
II-276 — II-262	Selangor	29	195
II-288 — II-264	Temerloh	53	222
II-331	Temerloh	35	212
II-326 — II-330	Temerloh	52	243
II-339	Bentong	10	253
II-263	Bentong	36	260
II-332	Bentong	52	251
II-333	Bentong	53	259
II-355 — II-344	Perak	70	237
II-317	Kedah	20	269
II-311	Kedah	50	264

Table 4. — Lamina mean length.

The petiolar canal has a tendency to be moderately closed, with a diameter of 3 cm at lamina base.

Petiole margins are thin, straight or slightly inflexed and generally only 0.5 cm wide. In color, they are like the petiole. At the petiole base these marginal structures remain lying flat against the pseudostem or slightly reflexed.

Leaves. — Mean average length among varieties shows some variations within a restricted limit. These differences exist in the collections from Bentong, Perak, and Kedah which have generally longer lamina than the ones from Temerloh and Selangor. Table 4 gives the mean average of lamina length for the subspecies.

Lamina width is about 1/4 the length (Fig. 4). Here again a relation of length to width gives the same variation. Temerloh and Selangor plants which have shorter leaves than the other groups are also proportionally narrower.

Leaf bases. — The shape of leaf bases has been observed to be relatively uniform among the subspecies and worth considering for taxonomic value.

The bases of young leaves of sucker and immature plants are mostly acuminate. Mature plants have usually an obtuse base on the right and acuminate on the left (viewed

from above), although this is not always the rule as both bases could be obtuse. There is, nevertheless, a certain varietal feature helping differentiate bases of one variety to another. It was observed that the point of attachment of the bases to the petiole is rarely opposite. In most varieties the left base is longer than the right one, varying in length from 1 to 12 cm between attachment points, also the base extends into a narrow wing for a few centimeters more on the left than on the right.

The Bentong varieties of *M. acuminata* subsp. *malaccensis* (Plate III and IV: **6**) which are the most representative of the above feature average a distance of 5.5 cm between base point attachments, always lower at left, never opposite and sometimes 12 cm distant.

In Selangor, Temerloh and Perak plants, the left base is 2.5 cm lower on average and occasionally opposite. Two accessions of Temerloh, II-330 (Plate II: **6**) and II-331 have a few exceptional cases of plants with the right base lower. The northern varieties of *M. acuminata* subsp. *malaccensis* from Kedah State, frequently have opposite bases of 1-2 cm lower at left, as in accession II-316 (Plate IX: **6**). Accession II-317 and II-316 have cases with lower right or lower left bases but this variation does not exceed 1.5 cm in average. The clone from Kelantan (Plate VII: **6**) also has opposite leaf bases.

The leaf apex in all the *M. acuminata* subsp. *malaccensis* is truncate. A cirrus terminates the apex. It is noticeable during the early growth of the leaf and dehisces as the leaf mature.

The foliage of the mature plant in bloom will average 9 to 10 leaves, but because of wind damage, age and other factors, only half of them would be functional when the fruit matures.

Waxiness and colorations

All the *M. acuminata* subsp. *malaccensis* are waxy to a variable amount on some of their structural parts. To a light degree on the pseudostem of mature plants and to a larger extent on petioles, lower lamina surface, bracts and young suckers (Table 2). None of the *M. acuminata* subsp. *malaccensis* have bright coloration. Again the degree of waxiness markedly affects the colors, tending to produce pastel tones rather than bright ones.

Inflorescence

From the time the inflorescence emerges, its structural shape and posture changes continuously until fruit maturation. First vertical, the inflorescence soon becomes horizontal and after the bracts that subtend fruit clusters fall, the fruit develops in a negatively geotropic direction. Taxonomic characteristics of the inflorescence of *M. acuminata* subsp. *malaccensis* reside on one or the other of the structural parts mainly: peduncle, female and male rachis, fruit, male bud.

Peduncle. — In most varieties, after the inflorescence has emerged, the peduncle turns at right angles to the pseudostem and slopes down only slightly to the female rachis which is horizontal. Only one exception was observed (clone, accession II-331 from Temerloh), where the peduncle ascends to an angle of about 50° with the pseudostem axis projecting the same angle through the female rachis. The reverse is also occasionally seen as in clone II-334 (Plate VII); here the peduncle turns and slopes down before redressing again but to a horizontal posture through the female rachis. The weight of fruit on the peduncle and female rachis has no effect on these structures as they tend

to keep their usual habit. On an occasional large fruit raceme the pseudostem slightly bends while the peduncle and rachis kept their rigidity. The peduncle measures roughly 30 cm long and 4 cm in diameter.

Peduncle color. — Peduncles are green, but sometimes bear a red flush on newly shot bunches, which eventually disappears with age. This character could be segregated through the variety. It is observed in accession II-262 from Selangor, II-263 and II-332 from Bentong and II-344 from Perak. In accession II-263, II-357 and II-333 the evanescent red coloration includes the young fruit as well as the peduncle and the male rachis.

Pubescence. — The peduncle is pubescent in most of the accessions, but among them are found segregated glabrous forms.

The degree of pubescence varies from 140 to 730 hairs per cm^2 (Table 5).

Hair length is (0.3-)0.5 to 1.0(-1.5) mm, with both long and intermediate on the same peduncle.

Hair color ranges from light brown to dark purple brown, the latter more frequent; a few white hairs are scattered among them.

Glabrous peduncle. -- These forms are commonly found in Bentong State. The clone from Karak, Bentong is one example, (II-342). From the same State, true seed introduction from three accessions is represented by glabrous varieties in the following proportion: accession II-332 — 51%; accession II-263 — 14%; accession II-333 — 20%. When the peduncle is glabrous, the female rachis is also glabrous. A peculiar character is observed in the glabrous forms: a tiny tuft of minute hairs is present at the extremities of the bract scar of basal hands. When present it is so imperceptible as to require magnification to be seen.

Female rachis and bunch

The surface of the female rachis has a corrugated appearance. The ridges coincide with vascular bundles. There are about as many corrugations as there are fruits in the outer row in the cluster (Fig. 7a, 8a). These corrugations also remain visible on the permanent bract base structure that subtends the fruits (Fig. 7b), which structure is also characterized by the bract scar left by the deciduous bract at an early stage of the inflorescence.

The cushion of the opposite side (Fig. 8b) is smoother, pubescent or glabrous according to the peduncle feature. It protudes 1-2 cm above the female rachis. The female rachis is horizontal, the bunch remains in that posture through fruit maturity. The fruit (or fingers) are negatively geotropic, the hands on top of the rachis bearing straight fingers while the ones below curve strongly toward vertical.

Bunch length taken between basal and apical cluster (hands) is 25-35 cm. Bunches contain 5-10 hands, each hand of 15-20 fruits in biseriated arrangement.

Temerloh in Pahang and Selangor collections have 15-16 fruits per hand while Bentong and the other provinces average 18-20 fruits per hand.

Pendulous fruit raceme. — Pendulous fruit racemes are exceptional in *M. acuminata* subsp. *malaccensis*. The character is probably segregated from cross pollinations of other subspecies. A case actually observed is one among plants produced from seeds of the Selangor variety (II-262, Plate V: **1b**). This interesting specimen bears pendulous fruit racemes with 13-15 hands and long fruit. The fruit was found to be either completely parthenocarpic or with one or few seeds. The pulp flavor is very satisfactory. The morphological features of the plant display all the characteristics of the wild ancestor variety and has the same shape and bud color. The case is mentioned here as short term evolution from a wild seedy type to a natural edible diploid.

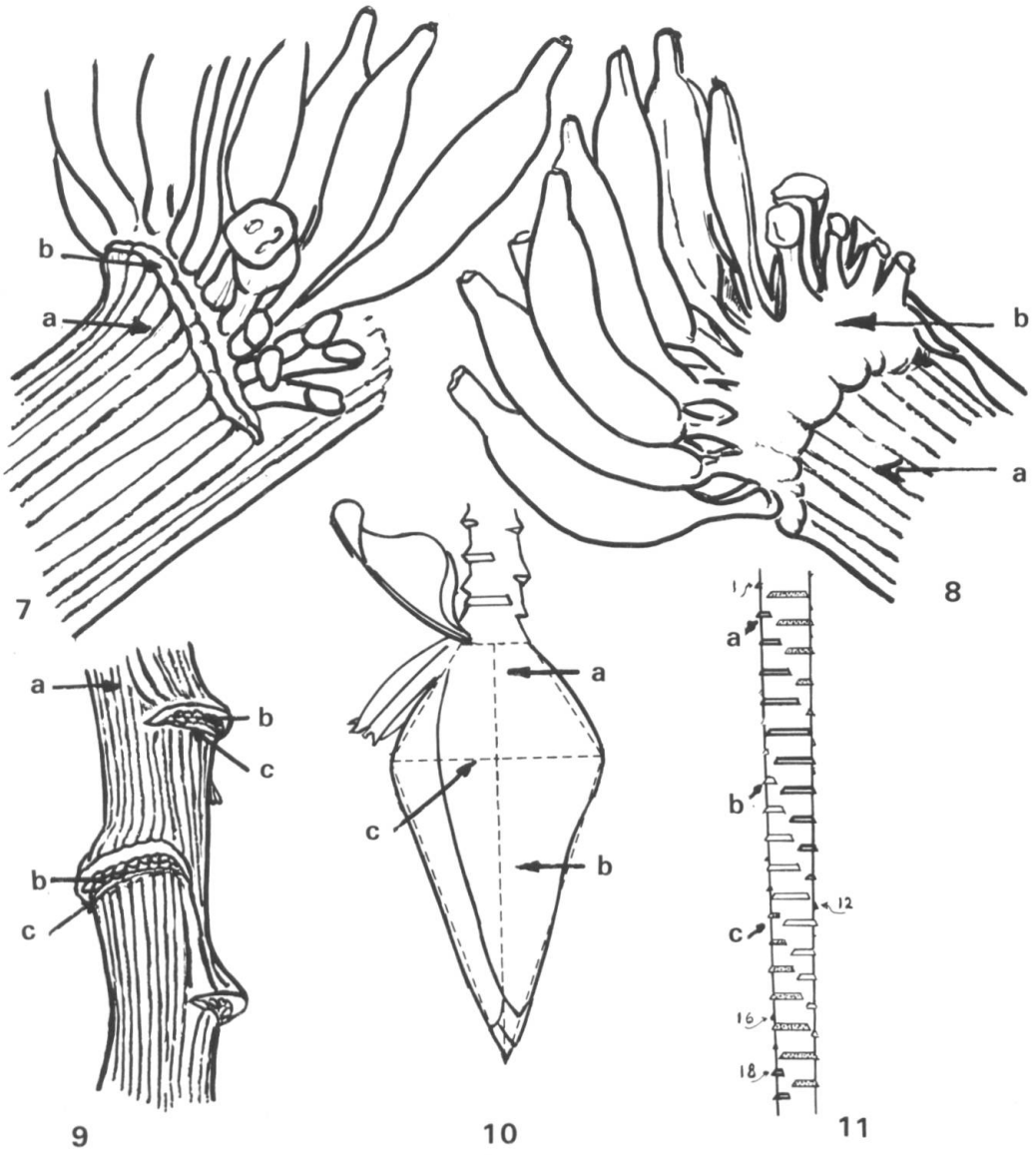

Fig. 7. — Female rachis: **a,** corrugations; **b,** bract structure and scar.

Fig. 8. — Female rachis: **a,** corrugations; **b,** cushion.

Fig. 9. — Male rachis segment: **a,** corrugations; **b,** torus; **c,** cushion.

Fig. 10. — Male bud: **a,** base; **b,** acuminate apex; **c,** arbitrary width.

Fig. 11. — Schematic male rachis: **a,** spiral turn of one row of floral cluster numbered 1-12 and 16-18; **b,** second row; **c,** third row.

Fruit. — The fruits are 8-12 cm long, and 1.5-2 cm in diameter. Fruit shape is uniform for the subspecies with fruit angular in cross section when young and of even thickness throughout the entire length; they become more cylindrical toward maturity. The fruit bears angular, slightly fluted, strongly constricted apices, which are truncated. Styles dehisce cleanly, although a small (1 mm) projection terminates fhe fingers.

Pedicels are strongly constricted, measuring 1-1.5 cm. They are generally glabrous, but very often pubescent at base and rare cases have been observed in which pubescence occurs the length of the pedicel (II-262).

When immature, fruits are green or glauca green (II-333) with few forms having a darker green apex (II-330, II-263). Upon ripening this color intensity is preserved, the apex exhibiting a deeper yellow color than the rest of the fruit. Fruit color at ripening varies from light yellow to orange yellow within the various accessions. Fruit peel is always glabrous.

Fruit maturity. — The fruits mature about 120 days after the inflorescence emerges. They persist only 10-14 days on the raceme, then fall over-ripe on the ground.

Fertility. — Normally developed and atrophied fruits could be found associated on the same raceme (fingers at left of bunch, Plate III). All the accessions have normal seedy fruit and pulp surrounds the seeds. Atrophied fruits are mostly formed of a thick peel, they lack seed and have little or no pulp. These fruits are smaller than normal ones and develop sometimes irregular forms. Two aspects of fertility could be visually observed: racemes with the majority of hands with normal fruits or, on the contrary, racemes with atrophied fruits. Field surveys indicated on the average a higher percentage of normal fruits (50-70%), in collections from Bentong, Kedah, Perak and Selangor, while the Temerloh are slightly below this average.

Seed. — The seeds are located in 2 rows in each of the 3 locules of the fruits. They amount to 60-120 per single fruit and occasionally more in some varieties (II-344, II-332, II-264, II-317).

Closely packed and compressed in the locules, seeds have an irregular shape. The most regular ones have a 5-lobed periphery, with 3 lobes larger and more distinct than the other two. Average seed measure (5-)6 × (4.5-)6.5 mm and 3 mm thickness. The seed is protected with a very adherent membrane. Once this membrane is removed, the rugose surface of the seed appears covered with minute projections of irregular size, mostly apparent around the periphery where they are dispersed at 0.50-0.75 mm apart and protrude 0.25 mm or less. There is also a certain spheric lineal symmetry in the arrangement of these minutes rugosities from the hilum toward the opposite umbo or chalazal point of the seed. This hemispherical eminence is the external manifestation of the internal chalazal mass (McGAHAN, 1961). This protrusion is about 2 mm in diameter and is limited by a circular depression. A minute cavity marks the center of this umbo (Plates I to X: **5**).

Male rachis

The male rachis is the prolongation of the female rachis starting at the last fruit cluster. It is headed by a conical bud consisting of flower clusters covered by bracts. The central axis of this inflorescence continues to grow as long as there are immature fruits on the raceme. All during this time (5 to 6 months) new floral clusters bloom about daily at the opening of the bracts of the male bud. At an early stage the male rachis is subhorizontal and may have a slight curve or angle, eventually becoming pendulous.

Accession number	*Origine*	*Hairs per cm^2*	*Hair length (mm)*	*Hair color*
II-262	Selangor	730	0.5-1.0	Red brown — no white
II-264	Temerloh	180	0.5-1.0	Brown, red and white
II-331	Temerloh	200	0.5-1.0	Purple, brown some white
II-330	Temerloh	140	0.5-1.0	Purple, brown, white
II-339	Bentong	620	1.0-1.5	White, yellow, some red
II-263	Bentong	390	0.5-1.0	Light brown
II-332	Bentong	490	0.5-1.0	Red brown
II-333	Bentong	540	0.8-1.0	Red brown
II-329	Bentong	300	0.3-0.5	Red
II-344	Perak	360	1.0-1.5	Purplish and white
II-311	Kedah	380	0.5-1.0	Dark red, few yellow

Table 5. — Hairs per cm^2, length and color on pubescent peduncle.

Accession number	*Origin*	*Length/Width mean*	*Ratio Length/Width*
II-262	Selangor	10.5 × 5.2	2.0
II-264	Temerloh	11.9 × 5.7	2.1
II-331	Temerloh	10.8 × 5.7	1.9
II-330	Temerloh	11.3 × 5.9	1.9
II-263	Bentong	11.4 × 5.2	2.2
II-332	Bentong	10.8 × 5.5	2.0
II-333	Bentong	10.6 × 5.2	2.0
II-344	Perak	11.3 × 5.3	2.1
II-311	Kedah	9.3 × 5.1	1.8

Table 6. — Length/Width ratio of male bud at fruit maturity.

The male rachis is like the female rachis in form, but the nodal structures are much reduced in size.

The floral clusters are biseriated and disposed in a spiral along the axis. Each cluster contains about the same number of floral units, as there are fruits on the female cluster (16-20 units). The perigone pieces of the male flowers are one third to about half the size of the female flowers. The pistil and ovary are much reduced. Bracts are also proportionally smaller. There is also a decrease in the size of all these structures towards the extremity of the rachis.

The spiral arrangement of the floral clusters is noticeable on the male rachis by the protruding torus visible after the bracts and floral cluster caduce (Fig. 9b). This structure forms a small step at a right angle to the rachis protruding about 4-6 mm. A "cushion" is visible, but almost hidden below the floral scars (Fig. 9c). On rare occasions this "cushion" forms a prominent bulge. Most generally there is a depression below the flower scar where this little cushion is hidden. The nodulous body of the torus and bract scars could tentatively help in the classification of subspecies. Variations of this structure are characterized in the varieties mostly by the following: the edge of the scars is sharp in some cases (II-264 and II-263) and smooth in others (II-331, II-333, II-344). The latter cases have more reflexed scars than the former. The general pattern and projection present little variation, but the actual surface of the scar could be either slightly concave (II-264) or convex (II-330, II-311) or flat (II-332, II-331).

Distance between two floral clusters decreases as the rachis increases. The mean distance measured on the first 20 cm is 0.8-1.2 cm and becomes gradually shorter towards

the end of the rachis. In line with this, there is an interesting detail in relation with the alternate arrangement of the flower cluster forming three longitudinal rows turning in parallel spirals around the rachis (Fig. 11a, b, c). The number of floral clusters (or "nodes") that compose a single spiral of one of these rows is 16 to 18 for most varieties of *malaccensis* (Fig. 11a). As the rachis diminishes in diameter, the scars are closer, and the spiral turn is shorter, but the scar number remains the same per spiral. In fact, the first spiral on the rachis is about twice the length of the next one and so on for the successive spiral turns towards the end of the inflorescence. Some varieties (II-311), have only 10-14 nodes per spiral, but they do not grow a longer rachis. Therefore, we should estimate a smaller number of the male floral clusters in some varieties.

The fully developed male rachis is 3-4 times the length of the female rachis, there is then considerably more male than female flowers born during the inflorescence life. When the fruit matures the rachis length average 74-86 cm without the length of the male bud. There is no appreciable length variation among varieties but the northern and north west ones average shorter rachis, 74-80 cm long. During fruit maturity the rachis grows about 1/10 its length and another 1/10 after maturity. The rachis taper about 1 cm in diameter toward the male bud. It is about 2.5 cm at the beginning and 1.5 cm near the male bud. The male bud stays alive for about another month after the ripe fruit fall and the bract will continue to unfold normally to the last one during which time the male flowers continue to bloom and their anthers produce pollen. Male buds last about 6 months. Unusually, they may dry previous to fruit maturation.

Unfertile raceme. — The male rachis of unfertile fruit racemes may behave differently from normal racemes. They are generally stouter growing frequently 1.20-1.40 m long. They may remain alive a longer period after the estimated maturity period although this can not be accurately evaluated. Their male flowers bear fertile pollen.

Male bud

In most cases the male bud could help differentiate the subspecies. The main features to be considered are form, bract arrangement and color.

Form. — The male bud is roughly conical ovoid. The bud can be divided into two distinct parts: a voluminous base where the flower clusters are located, which has a trapezoidal outline followed by a light depression toward a conical acuminate prolongation about twice the length of the base (Fig. 10a, b). The bud tip is smoothly obtuse and occasionally apiculate. The external side of the bract has light longitudinal corrugations. At mid growth the bud length is about 16 cm, at fruit maturity 10.5-12 cm long. Across the widest part the bud is 1/2 its length (Fig. 10c). The ratio 2:1 length/width is fairly constant. The extremes are represented by the Kedah accession II-311 with a ratio of 1.8 and II-262 of Bentong 2.2. This data was taken from a large number of buds thus indicating clearly less accumination in the Kedah variety, also confirmed by a shorter bud of 9.3 cm average. Two other clones of this province represented by only a few individuals have a ratio of 1.9 (Table 6).

Bract arrangement of male bud. — The bracts are convolute and wind in a clockwise spiral around the rachis. Three types of convolution could be observed during growth of the male bud: convolvulate, coracoid and imbricate (HARI, 1968). In the first condition, the upper bract winds around the bud apex hiding the apices of the lower bracts (Plate IV: **7**); coracoid is a straighter lineal position, with the external bracts almost joining together (Plate IV: **7a**). The bracts are imbricate when the apices of the lower bracts

extend beyond the apices of the upper ones (Plate IV: **7b**, also Plate V). When imbrication develops, 3 to 5 bracts could be imbricate and the degree of imbrication, that is the exposed apex of the imbricate bracts is 4-14 mm.

In most cases the bud will be first convolvulate during the early growth of the male inflorescence, then coracoid for the second to third month and imbricate by the fourth month. Not all the varieties would have the same time sequence. The degree of convolution or imbrication could also vary. However, all the varieties observed became imbricate during at least one stage of bud development.

These various characteristics are typical of *M. acuminata* subsp. *malaccensis* and could be eventually observed on the same plants when several inflorescences of different age are bearing at the time. This morphological variation will confuse classification and in an earlier paper it was recommended to reject this character for infraspecific taxa of *Musa acuminata* (HARI, 1968).

Bud color. — External color of the bract ranges from greenish to yellow to dark red, or carmine on some of the varieties. Table 2 gives a summary of the variation.

Floral part

Female flowers. — The ones born by the female rachis and giving normal fruit are male sterile. Their five stamens are atrophied and their anthers produce no pollen. The perigone pieces are 3.5-4 cm and the ovary 4-5 cm (Plates I, III and IV: **8, 8a**).

Transitional or hermaphrodite flowers. — The next cluster to develop, at the end of the female rachis, is of the intermediate type of flowers. They have hermaphrodite flowers with functional stamens and ovary, and produce normal fruit among atrophied ones or have female and male flowers on the same cluster. Sometimes these neuter clusters are absent.

Staminate flowers. — As related before, early flower clusters born of the male bud have longer units than the subsequent ones. During the unfolding of bracts and clusters average flower size will be 4.5-5.5 cm including ovary. The proportional dimension of these parts remain about the same among varieties. There is also no appreciable change of these measurements due to growth, during the period of pre- and postanthesis (or about two days). The only appreciable change observed is in the size of the stamen filament which grows rapidly increasing its preanthesis length half more (Table 7).

Morphological floral structure (of the male flowers) is also much alike in one variety as it is in another.

The carina shaped free tepals are most generally truncated and finely toothed at apex (II-344), but also it is found to be acuminate (II-330).

In *M. acuminata* subsp. *malaccensis*, the perianth margin and the free tepal are almost translucid. The dorsal perianth is opaque, of a cream white color infused towards apex of the same coloration as the teeth, the perianth base could be so infused or greenish. The ovary is white. There are 5 stamens except on occasional freak units bearing 6 normal ones. Also, an extra sterile stamen has been observed, but rarely, and attached to the perianth. The flat filament is only 1-2 mm wide, of the same color tint as the perianth. The anthers are fertile and bear abundant pollen. The pistil is non-fonctional.

Perianth teeth color. — This color varies according to bud color intensity from sulfur yellow for the acyanic varieties to bright orange in the anthocyanic ones. The same is observed in the anther color from white (exceptional), pink to light carmine (Table 2). The pistil is white at the base and the upper part and stigma are invariably ochre to ochre-

Accession	*Flower (with ovary)*	*Perianth (with Teeth)*	*Ovary*	*Teeth*	*Free tepal*	*Stamen*	*Stamen*		*Pistil (with stigma)*	*Stigma*	*State*
							Filament	*Anther*			
II-330	Pe* 5.1	4.2	0.9	0.5	1.8	3.2	1.4	1.8	3.6	0.5	Temerloh
II-330	Po** 5.2	4.1	0.9	0.5	1.8	3.8	2.2	1.6	3.9	0.4	Temerloh
II-332	Pe 4.5	3.6	0.9	0.5	1.9	3.4	1.6	1.8	3.5	0.5	Bentong
II-332	Po 4.5	3.6	0.9	0.5	1.9	3.9	2.4	1.6	3.5	0.5	Bentong
II-333	Pe 5.1	4.1	1.0	0.4	1.9	3.8	1.3	2.5	3.8	0.4	Bentong
II-333	Po 4.6	3.7	0.9	0.4	1.5	3.5	1.7	1.8	3.6	0.4	Bentong
II-344	Pe 5.1	4.1	1.0	0.4	1.9	3.8	1.3	2.5	3.8	0.4	Perak
II-344	Po 5.5	4.5	1.0	0.4	2.0	4.2	1.8	2.4	4.0	0.4	Perak
Mean	Pe 4.95	4.0	0.95	0.45	1.88	3.55	1.4	2.15	3.68	0.45	
Mean	Po 4.95	3.98	0.93	0.45	1.80	3.85	2.0	1.85	3.75	0.43	

* Previous anthesis
** Post anthesis
Note: Post anthesis measurement is taken on flowers about to fall. Pre anthesis, on the flowers immediately following which are still covered by the bract. Size in centimeters.

Table 7. — Measurement of male flowers.

Group cases	*Time of the day the bract opens and anthesis start*	*Time of the day of the bract and flower cluster fall*	*Approximate anthesis hours period*	*% of cases*
1	Late afternoon	Before dawn	12	13
2	Late afternoon	Before noon following day	18	19
3	Late afternoon	Late afternoon following day	24	39
4	Before noon	Afternoon same day	12	5
5	Before noon	Before noon next day	24	12
6	Before noon	Late afternoon next day	48	10
7	Before noon	Two days later	48-60	2

Table 8. — Anthesis time.

orange. A seed of red or purple dots are present on the middle part of the style, it is also observed on the style of the yellow mutants, but there the color is rather violet.

Anthesis. — The anthesis of each floral cluster on a male bud starts with the opening of a bract. The bract rolls back and roofs over the flower cluster in about a 90° angle.

The process is rapid as a bract and the flower cluster it subtends will open and fall within a day, the bract first then the flower. There is no exact time of the day the anthesis starts, however, it could be observed that certain moments of the day are more propitious to it. A time survey for a 10-day period was carried out with 6 accessions, 5 plants of each. Observations are summarized in Table 8.

The two most streaking points are the period of the day the bract opens, which is late afternoon (71% of the cases) and the short anthesis time from 12 to 24 hours (88% of the cases).

One bract opens at a time, but another bract may open before the previous one has fallen. Both could remain open together a few hours. Also the male bud can be seen without any bract open at a time for a few hours and this occured on average once in a 7 day period. The number of bracts which open at a time has little practical taxonomic value. One or two is the rule for *M. acuminata* subsp. *malaccensis,* exceptionally none and three is rarely observed and when this happens, it lasts less than 6 hours.

Conclusion

The large number of plants available in this collection facilitated this study, with avantage to work with living material. The objective to determine taxonomic characteristics of *Musa acuminata* subsp. *malaccensis* (Ridley) Simmonds is apparently reached as clearly exposed in the text. Moreover, these plants could be determined step by step, by first following the figures stipulating the height of the plant, proportional relation of pseudostem to the foliage, angle of foliage to central axis, bunch posture and other pertinent features given in schematic drawings in Fig. 1 to 4 and the ones of the female and male rachis in Fig. 7 to 11. However, because of slight variations according to the different locations of Malaysian States where those plants are growing, it is useful to report to Tables 1 to 7 giving succinct details of morphology and coloration.

Plates I to X, drawn by the author from living material and generally natural size, are representative of one or more typical varieties from the locations visited. They illustrate the aspect of this interesting wild banana.

As a whole, this work is expected to enable anyone interested in Musaceae to determine with certainty any *Musa acuminata* subsp. *malaccensis* (Ridley) Simmonds.

LEGEND FOR PLATES I TO X

1. Habit; **2.** Fruit raceme $^{3}/_{10}$ natural size; **3.** Hand cluster $^{3}/_{10}$ natural size, axial side; **3a.** Finger, longitudinal section; **3b.** Finger, cross section; **4.** Pseudostem blotching; **4a.** Sucker; **5.** Seed, enlarged 1.7 ×; **6.** Lamina base and apex $^{3}/_{10}$ natural size; **6a.** Petiole cross section at pseudostem; **6b.** Petiole cross section at lamina base; **6c.** Petiole cross section center of mid rib, $^{3}/_{10}$ natural size; **7.** Male bud convolvulate $^{3}/_{10}$ natural size; **7a.** Coracoid bracts arrangement; **7b.** Imbricated bracts; **8.** Female flowers cluster; **8a.** Male flower; **8b.** Female flower.
Drawings by P. Hari, photographs by Maryse Kolakowski.

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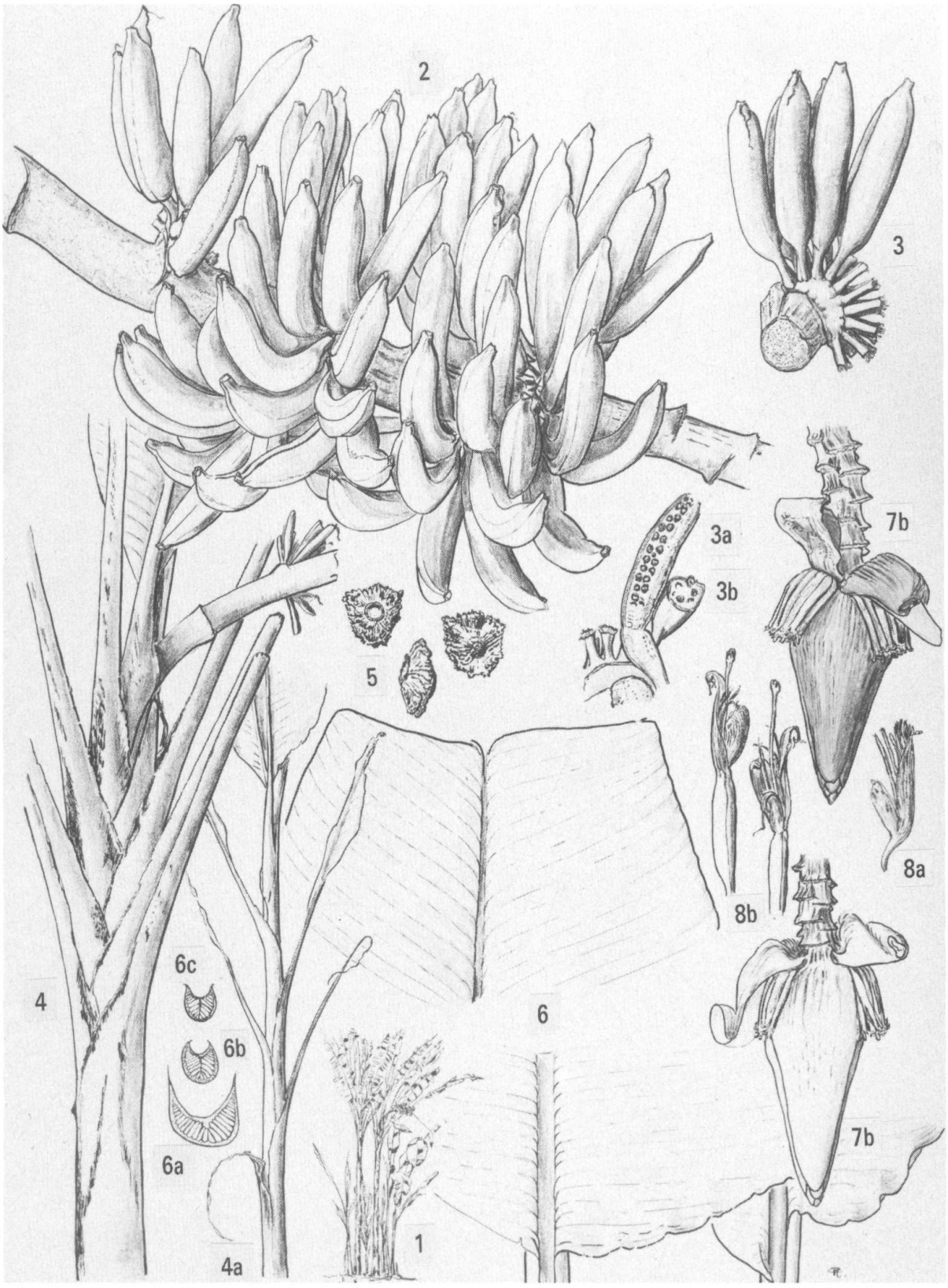

Plate I. — *Musa acuminata* subsp. *malaccensis*.
Accession II-264 from Temerloh, Pahang.

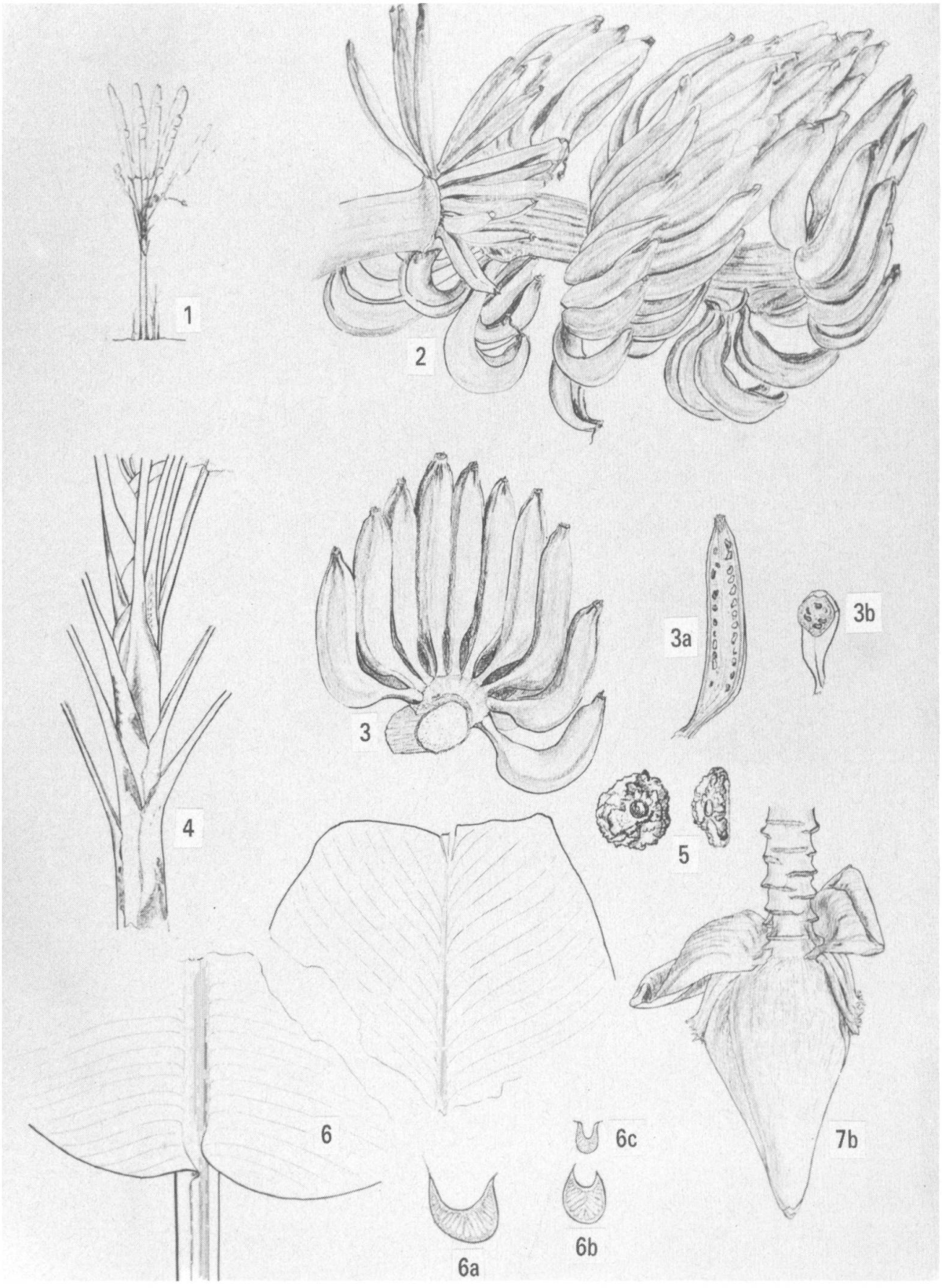

Plate II. — *Musa acuminata* subsp. *malaccensis*.
Accession II-330 from Temerloh, Pahang.

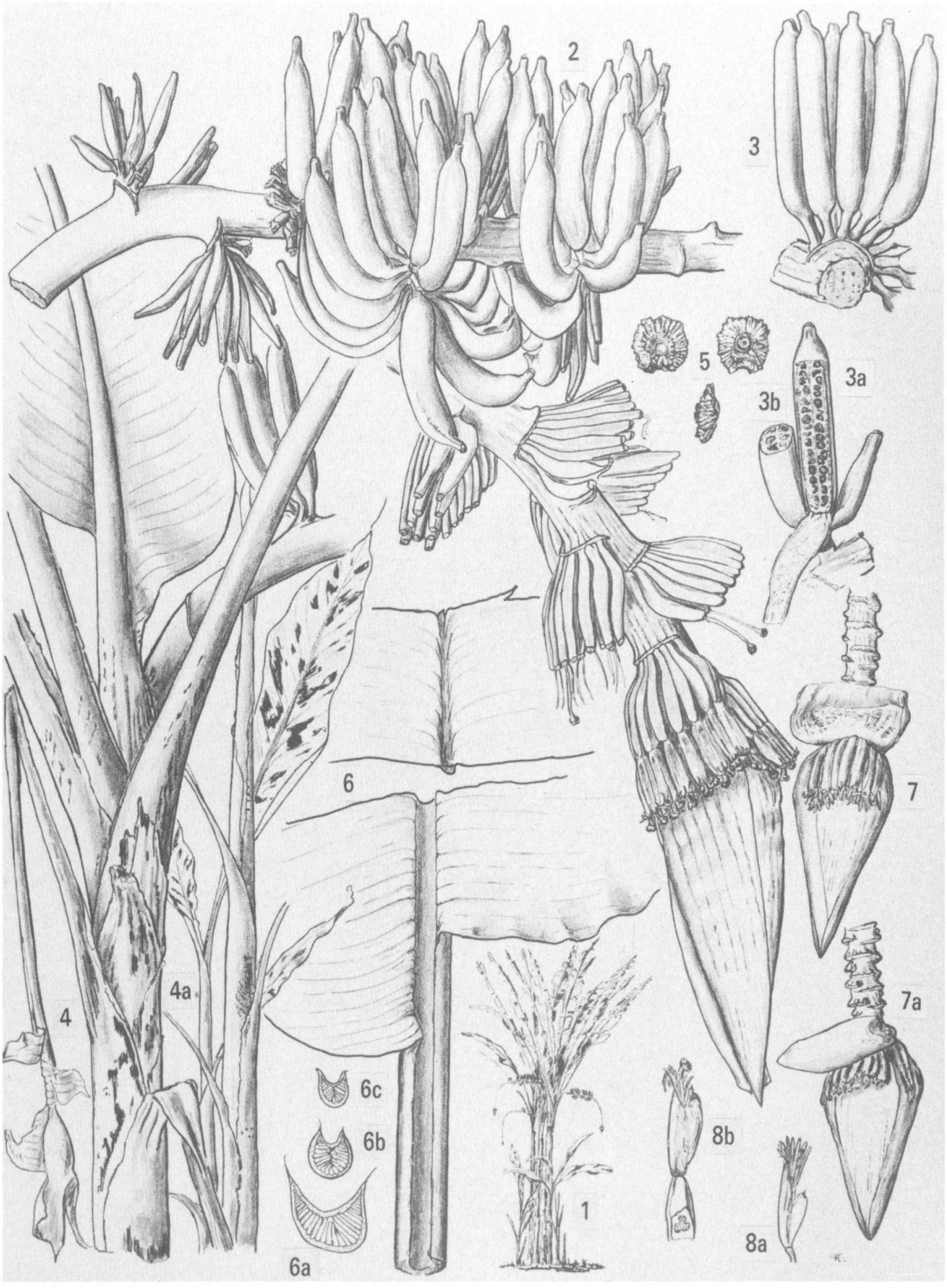

Plate III. — *Musa acuminata* subsp. *malaccensis*.
Accession II-332 from Bentong, Pahang.

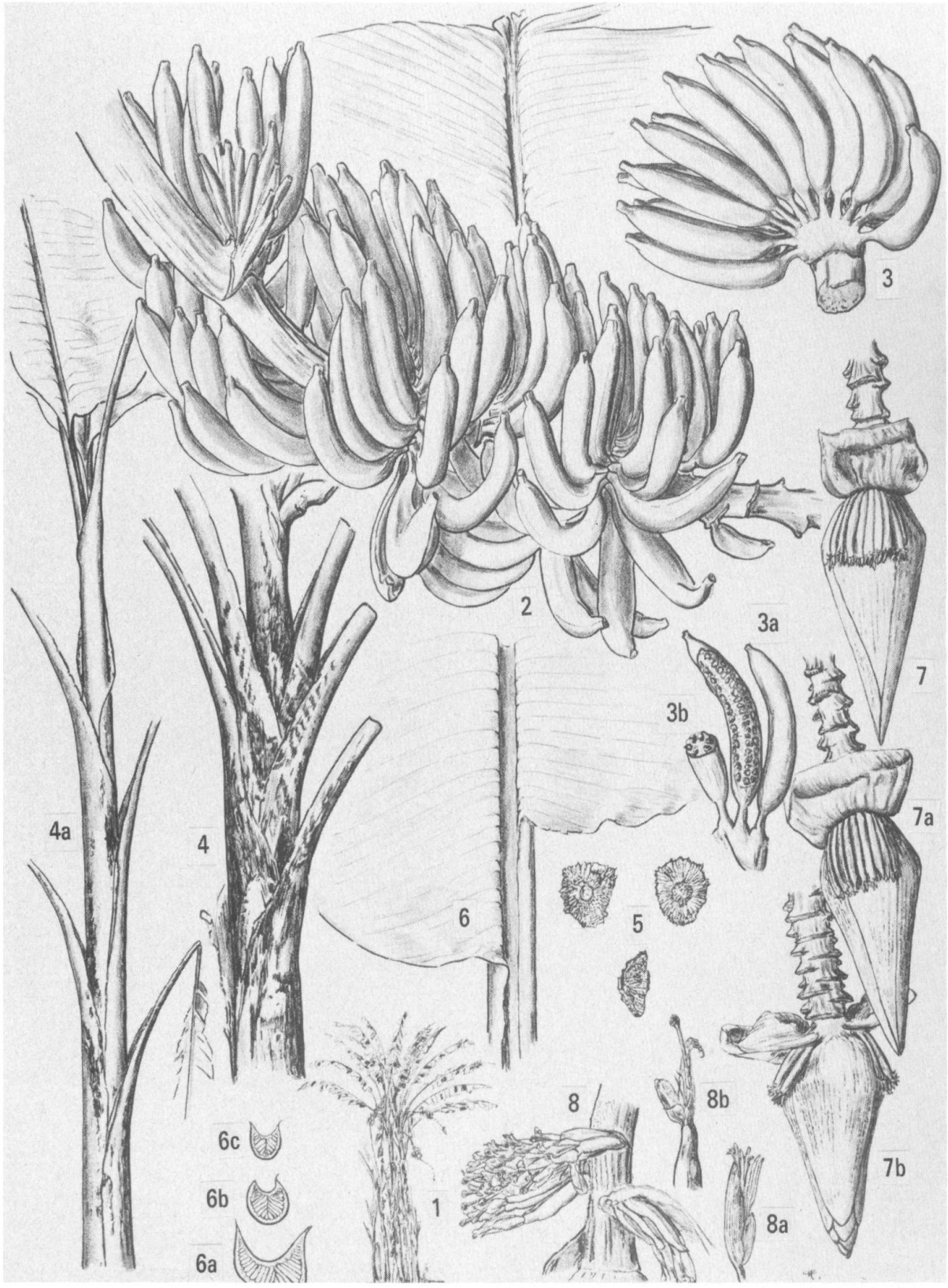

Plate IV. — *Musa acuminata* subsp. *malaccensis*.
Accession II-263 from Bentong, Pahang.

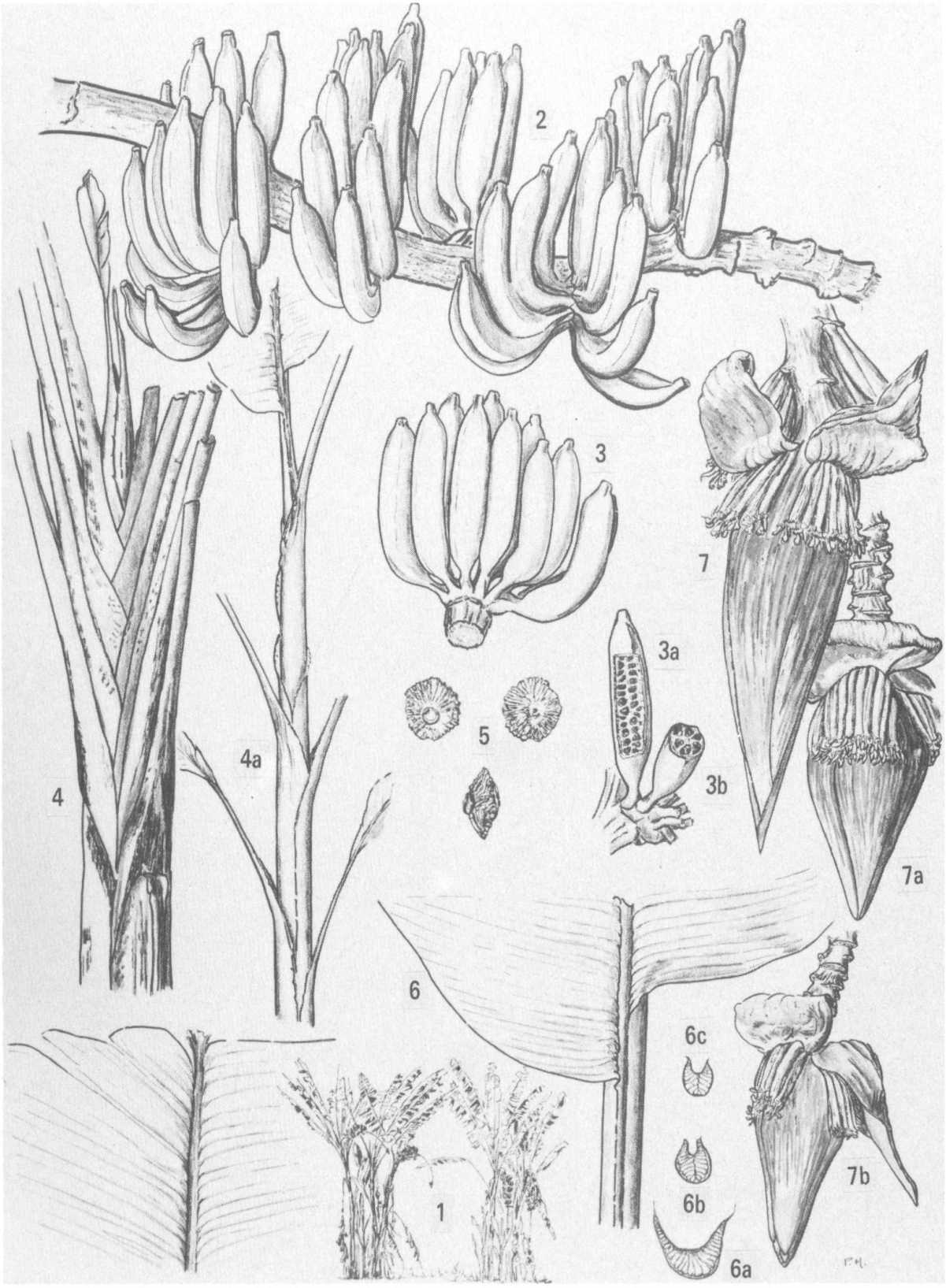

Plate V. — *Musa acuminata* subsp. *malaccensis*.
Accession II-262 from Kuala Langat, Selangor.

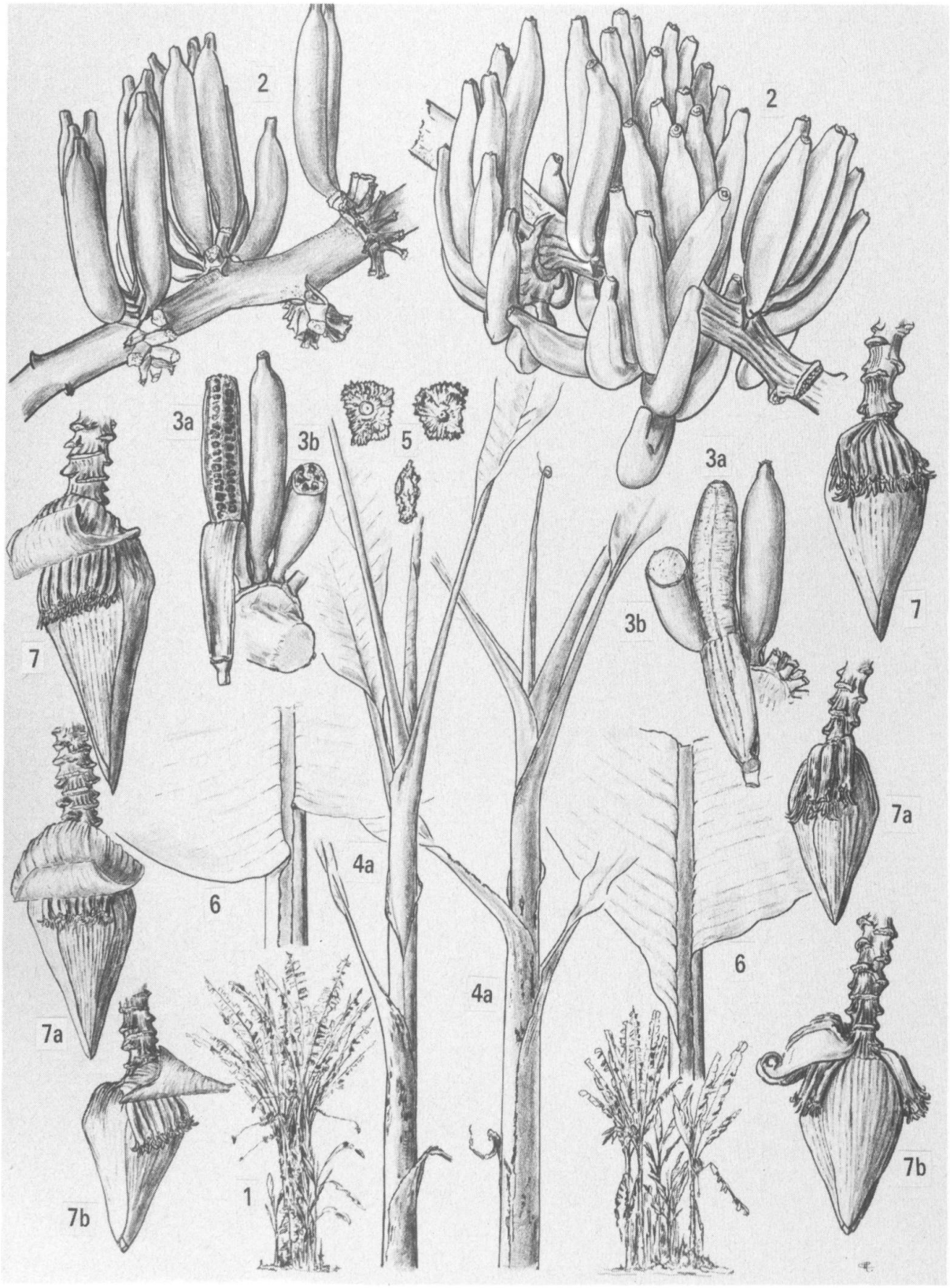

Plate VI. — *Musa acuminata* subsp. *malaccensis*.
Left: accession II-344 from Upper Perak.
Right: parthenocarpic clone, Pisang Lidi.

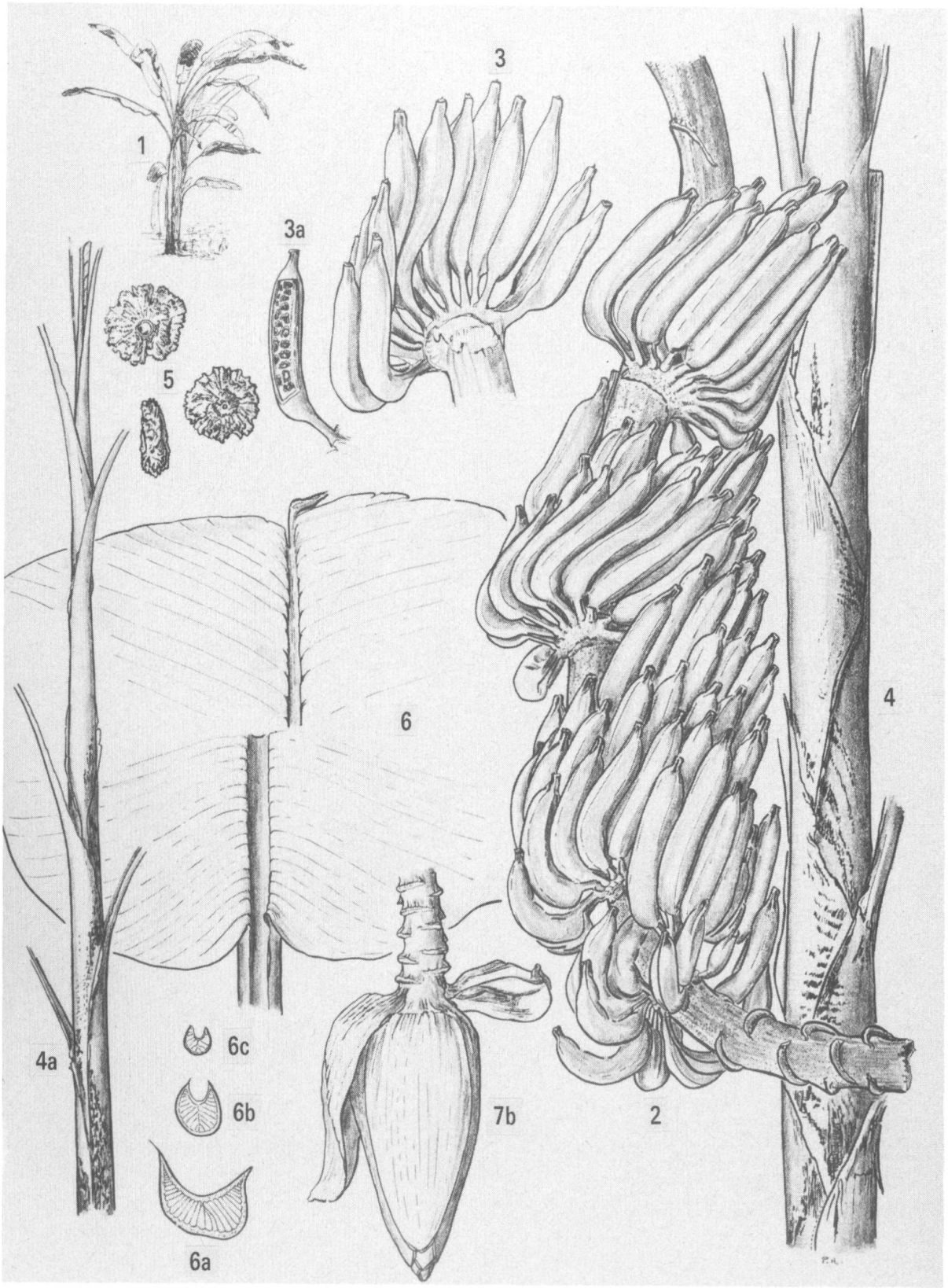

Plate VII. — *Musa acuminata* subsp. *malaccensis*.
Accession II-334 from Ulu Kelantan.

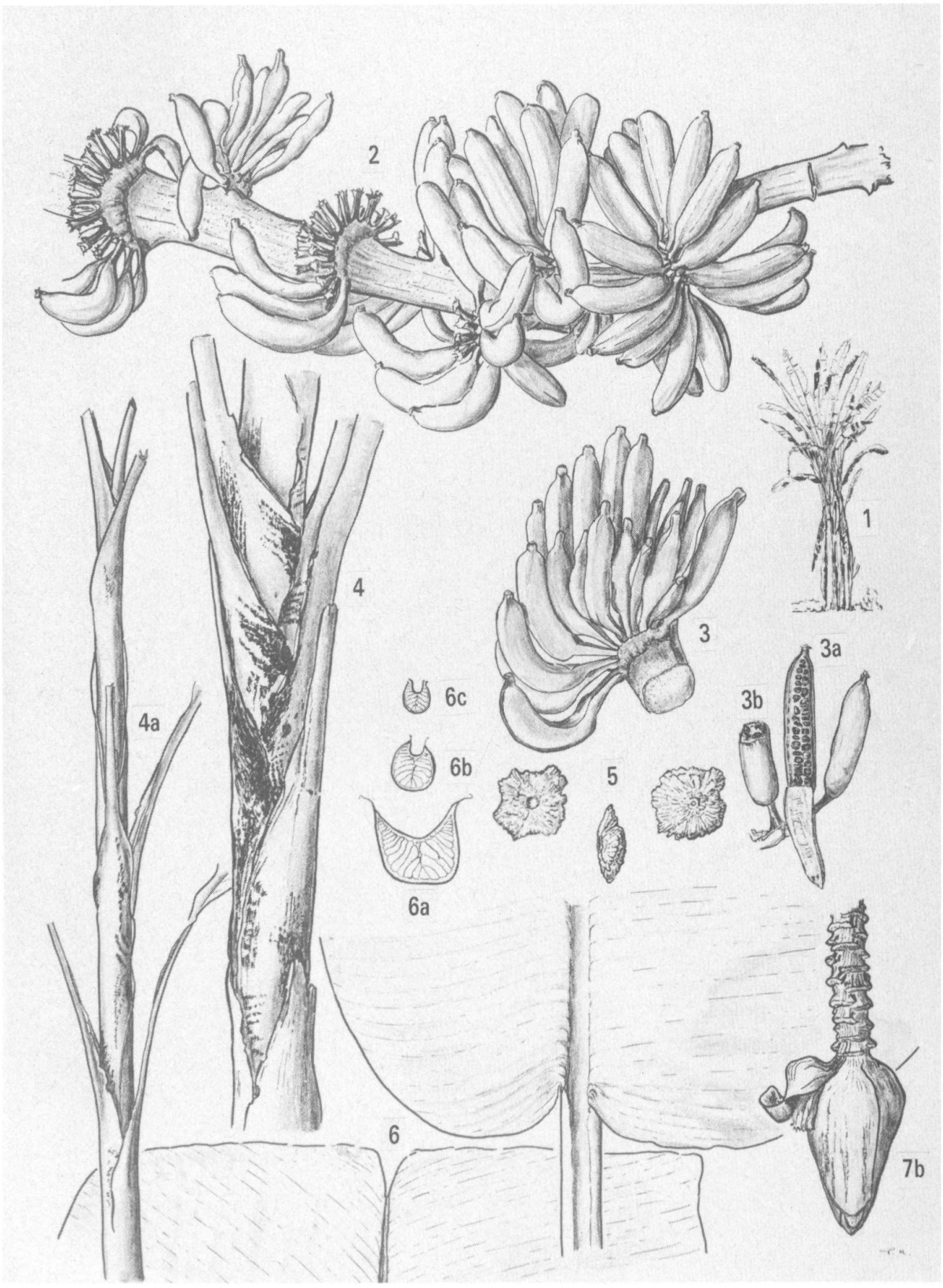

Plate VIII. — *Musa acuminata* subsp. *malaccensis*.
Accession II-317 from Sik, Kedah.

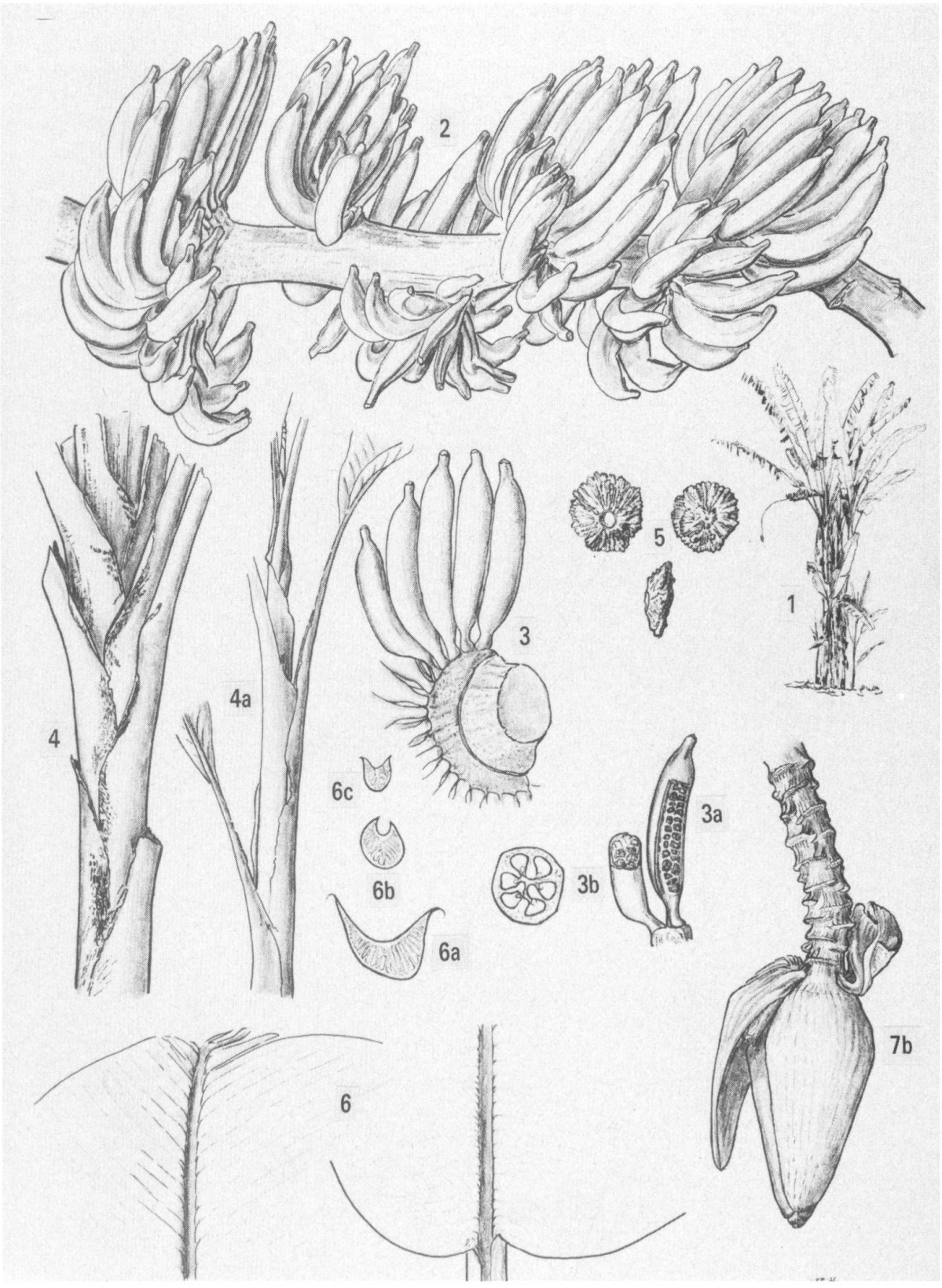

Plate IX. — *Musa acuminata* subsp. *malaccensis*.
Accession II-316 from Padang Terap, Kedah.

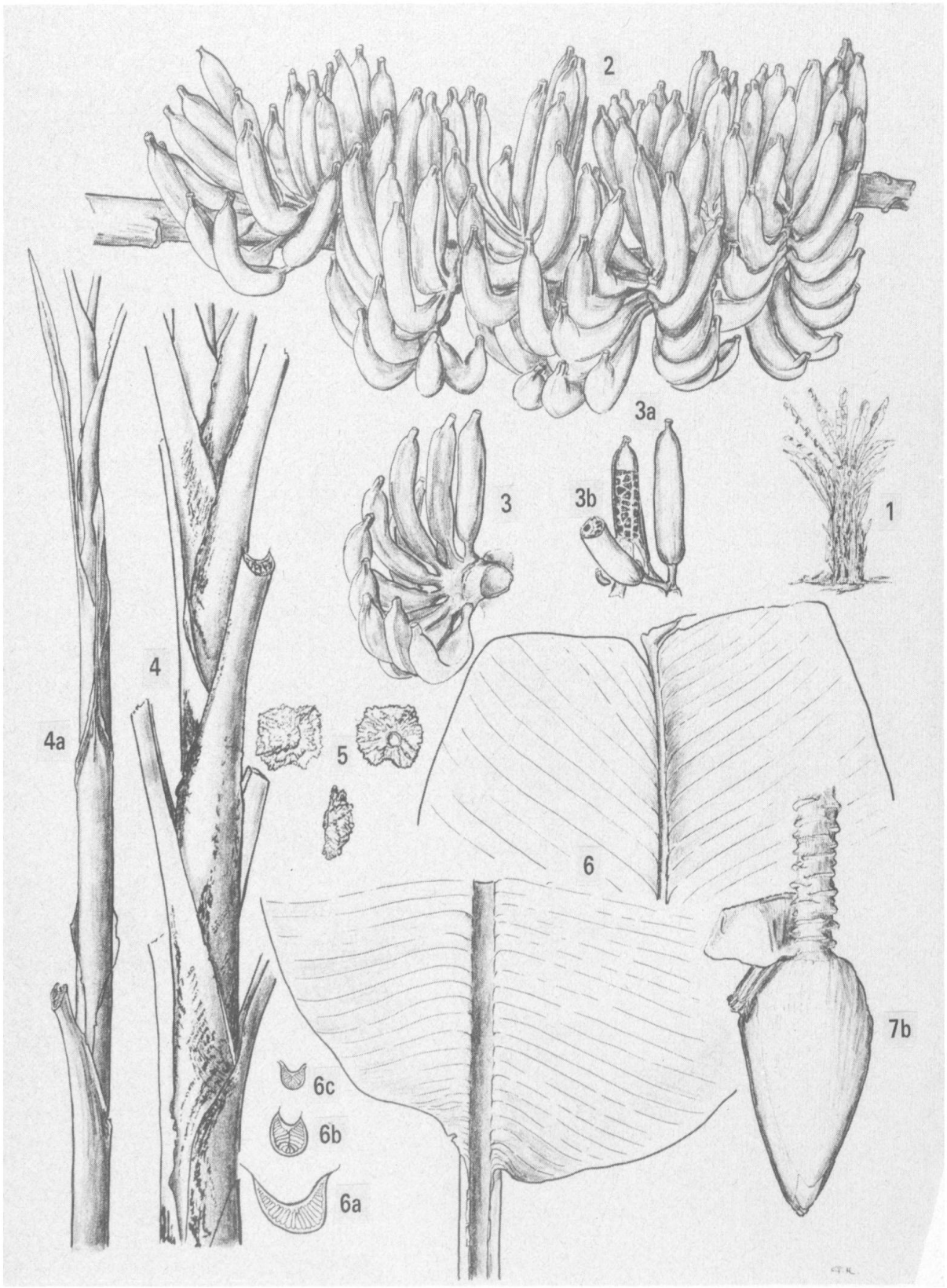

Plate X. — *Musa acuminata* subsp. *malaccensis*.
Accession II-311 from Kebang Pasu, Kedah.