TROPICAL YAMS AND THEIR POTENTIAL

PART 6. Minor Cultivated *Dioscorea* Species

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PREFACE

The feeding of future generations requires a knowledge of the individual crop plants of the world and their potentials. Crops can be recommended for particular regions only on the basis of potential yields, the costs of production, the food and feed value of the crop, and the way the crop can be processed or otherwise used. For most of the major food crops of the world, a body of information is available. However, tropical roots and tubers, which are widely used as staple foods, have been largely neglected. Only in recent years has an awareness been growing of the potential of these crops to supply large amounts of food in relatively small amounts of space.

Yams are the second most important tropical root, or tuber, crop. The annual production, perhaps 25 million tons, places them second in importance to cassava. But yams are better food than cassava, and although they are usually thought to be more difficult to grow, under some conditions yams outproduce cassava. Yams fill an important role in the diet of many areas of the Tropics—a role that can increase in importance. That role and its potential are not, however, well understood.

The yam is not a single species. Perhaps 60 species have edible tubers; of these about 10 species can be considered crop plants. The literature concerning these species is widespread but fragmentary. This is the *last* of several Agriculture Handbooks in which the major species of yams are individually treated in order to bring the investigator as well as the agriculturist up to date with respect to the status of these important plants. This is part of a research effort cosponsored by the Science and Education Administration of the U.S. Department of Agriculture and the Agency for International Development to introduce, evaluate, and distribute better yam varieties.

Also in "Tropical Yams and Their Potential" series—

Part 1. *Dioscorea esculenta*. USDA Agriculture Handbook No. 457.
Part 2. *Dioscorea bulbifera*. USDA Agriculture Handbook No. 466.
Part 3. *Dioscorea alata*. USDA Agriculture Handbook No. 495.
Part 4. *Dioscorea rotundata* and *D. cayenensis*. USDA Agriculture Handbook No. 502.
Part 5. *Dioscorea trifida*. USDA Agriculture Handbook No. 522.

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TROPICAL YAMS AND THEIR POTENTIAL

Part 6. Minor Cultivated *Dioscorea* Species

By FRANKLIN W. MARTIN and LUCIEN DEGRAS[1]

INTRODUCTION

The Edible Species of *Dioscorea*

Of the 600 species of yams (*Dioscorea*), probably all have been tested as food plants. Some are harmless and useful, and some are poisonous and have been rejected or used only medicinally. Techniques have been developed to detoxify a few of the poisonous species. Few genera have yielded more edible species than *Dioscorea*, and 12 species of yams are fairly well known for their edible tubers. Other species are important sources of steroidal and alkaloidal drugs.

Five or six species of yams (*D. alata* L., *D. rotundata* (L.) Poir with *D. cayenensis* Lam., *D. esculenta* (Lour.) Burk., *D. bulbifera* L., and *D. trifida* L.) can be considered the principal yams of the Tropics and probably account for 95 percent or more of the yams eaten in the Tropics. In the Temperate Zone, two species, *D. opposita* Thunb. and *D. japonica* Thunb., are grown but are little known outside of the Orient. In addition to these species, about 40 or 50 species are collected from the wild or cultivated as crop plants. Some of the least valuable of these are disappearing, and introduced substitutes are being emphasized. The edible yams mentioned in the literature are listed in table 1. The text by Coursey (*9*)[2] and Tanaka's Cyclopedia (*20*) are the principal sources of the species names and geographical origins given in the table.

(*Continued on page 6.*)

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[2]Italic numbers in parentheses refer to items in "Literature Cited," p. 22.

TABLE 1.—*Edible yams of the world*

Species	Geographical origin(s)	Cultivated?	Toxic?
D. abyssinica Hochst.	Ethiopia	Limited	No.
D. acuminata Bak.	Madagascar	No	No.
D. adenocarpa Mart.	Brazil	No	
D. alata L.	Southeast Asia	Yes	No.
D. altissima Sieber ex Presl.	South America	No	No.
D. analalavensis Jum. et Perr.	Madagascar	No	
D. antaly Jum. et Perr.	do.	No	Yes.
D. arachnida Prain et. Burk.	Thailand, Indochina	No	No.
D. bemandry Jum. et Perr.	Madagascar		
D. bemarivensis Jum. et Perr.	do.	No	No.
D. brevipetiolata Prain et. Burk.	Indochina	No	No.
D. bulbifera L.	Asia, Africa	Yes	Yes.
D. cayenensis Lam.	West Africa	Yes	No.
D. cirrhosa Lour.	Taiwan, Indochina	No	
D. colocasiifolia Pax	West Africa	Limited	No.
D. convolvulacea Cham. et Schlect.	Central America	No	No.
D. cumingii Prain et. Burk.	Philippines	No	
D. depauperata Prain et. Burk.	Indochina	No	
D. dodecaneura Vell.	Tropical America	No	
D. dumetorum (Kunth) Pax	Tropical Africa	Yes	Yes.
D. elephantipes (l'Her.) Engl.	South Africa	No	No.
D. esculenta (Lour.) Burk.	Southeast Asia	Yes	No.
D. flandra H. Perr.	Madagascar	No	Eaten uncooked.
D. fargessii Franch.	China	No	
D. flabellifolia Prain et. Burk.	Malaya	Limited	No.
D. gibbiflora Hook. f.	East tropical Asia	No	
D. glabra Roxb.	India to Pacific	Limited	No.
D. glandulosa Roxb.	South America	No	

D. gracillima Miq.	Japan	Yes	Yes.
D. hamiltonii Hook. f.	India to Indochina	No	No.
D. hastifolia Nees.	Western Australia	No	
D. hastuta Mill.	Brazil	No	No.
D. heptaneura Veil.	do.	No	
D. hexagona Bak	Madagascar	No	No.
D. hispida Dennst.	India, Southeast Asia	Yes	Yes.
D. hombuka H. Perr.	Madagascar	No	No.
D. japonica Thunb.	Orient	Yes	No.
D. kamoonensis Kunth	Himalayan Mountains	No	No.
D. kratica Prain et. Burk.	Vietnam	No	
D. laurifolia Wall.	Malaya	No	No.
D. laxiflora Mart. ex. Griesb.	Brazil	No	Yes.
D. lecardi de Wild.	Dry west Africa	No	No.
D. liebrechtsiana de Wild.	Tropical Africa	Limited	No.
D. luzonensis Schauer	Philippines	No	No.
D. macabiha Jum. et Perr.	Madagascar	No	Yes.
D. maciba Jum. et Perr.	do.	No	
D. mamillata Jum. et Perr.	do.	No	
D. matsudai Hayata	Okinawa, Taiwan	No	No.
D. minutiflora Engl.	Tropical Africa	No	No.
D. nako H. Perr.	Madagascar	No	No.
D. nummularia Lam.	Southeast Asia	Yes	No.
D. opposita Thunb.	China	Yes	No.
D. orbiculata Hook.	Malaya	No	Yes.
D. oryzectorum Prain et. Burk.	Indochina		
D. ovinala Baker	Madagascar	Limited	No.
D. pentaphylla L.	Southeast Asia	Yes	No.
D. persimilis Prain et. Burk.	do.	No	No.
D. pierrei Prain et. Burk.	Indochina		
D. piperifolia Humb. et Bonpl.	Brazil	Limited	No.
D. piscatorum Prain et. Burk.	Malaya	No	Yes.

TABLE 1.—*Edible yams of the world*—Continued

Species	Geographical origin(s)	Cultivated?	Toxic?
D. polyclades Hook.	do.	No	Yes.
D. praehensilis Benth.	West Africa	Limited	No.
D. prainiana Kunth	Malaya, Sumatra	No	No.
D. preussii Pax	Tropical Africa	No	Yes.
D. pteropoda Boiv. ex H. Perr.	Madagascar	No	No.
D. puber Bl.	India, Malaysia	No	No.
D. pynaertii de Wild.	Tropical Africa	No	No.
D. pyrifolia Kunth	Cambodia, Malaysia		
D. quartiniana A. Rich.	Tropical Africa	Yes	No.
D. quinata J. F. Gmel	India		
D. quinqueloba Thunb.	Japan	Yes	No.
D. rotundata Poir.	West Africa	Yes	No.
D. sambinarensis R. Kunth	Madagascar	No	No.
D. sansibarensis Pax	East Africa	Limited	Yes.
D. schimperiana Hochst.	East, central Africa	No	No.
D. semperflorens Uline.	Congo	No	No.
D. septemloba Thunb.	Japan		
D. seriflora Jum. et Perr.	Madagascar		
D. smilacifolia de Wild.	West Africa	No	No.
D. soso Jum. et Perr.	Madagascar	No	No.
D. subhastata	Brazil	Limited	No.
D. tanalarum H. Perr.	Madagascar	No	No.
D. tenuipes Franch. et Sav.	Japan	No	
D. tokoro Makino	...do.	No	Yes.
D. transversa R. Brown	Pacific Islands	Yes	No.
D. tricantha Bak.	Madagascar	No	No.
D. trichopoda Jum. et Perr.	do.		
D. trifida L.	Northern South America	Yes	No.

D. trifoliata Grisebach.	...do.	No	No.
D. villosa L.	U.S.A.	No	Yes.

Among the minor species, a few can be distinguished as more important than others. But because this distinction is among types that may not differ significantly, there is no exact point on which the minor species mentioned in this handbook can be distinguished from those not mentioned. The authors consider the following species to be more important than other minor species listed in table 1: *D. dumetorum* (Kunth) Pax, *D. hispida* Dennst., *D. pentaphylla* L., *D. nummularia* Lam., and *D. transversa* R. Brown. All these species are cultivated for food, although probably all have wild races or uncultivated counterparts. All have been introduced from their geographical origins to other regions. All but the last are fairly well known to plant scientists and are available, although perhaps with difficulty. These generalizations are not true for most of the other minor tropical species listed in table 1. All are little known with respect to their potentials as crop plants.

Few other generalities can be made, for these five species represent a mixed group. They come from two continents, some are poisonous, and they differ widely in morphology. These yams merit further study in their areas of origin and wider introduction so that their potentials can be tried. Recently, the almost unknown species *D. transversa* was introduced as a cultivar, 'Wael', to the French West Indies, where it has been highly successful. Study of the minor species will surely reveal varieties of potential for different parts of the Tropics. These minor yams also merit more treatment in the literature, for reliable information concerning them is difficult to obtain.

Domestication and Distribution of Minor Species

The five minor species of yams considered here have been only partially domesticated. Of these, the most primitive is *D. hispida*, which is seldom cultivated but is frequently sought from the wild, especially as a famine food. Its tubers are often near the surface of the soil, making it an easily obtained food, and this availability may compensate somewhat for the great difficulties of ridding it of poison.

On the other hand, the wide distribution of three other species suggests the active intervention of people. In carrying tubers from place to place, people have valued and taken care of them. Apparently, *D. transversa* is still limited in its distribution.

The domestication of *D. dumetorum* must have been related to that of *D. rotundata* (L.) Poir. and *D. cayenensis* Lam., the principal African yams. Chevalier (7) observed a kind of *D. dumetorum* protoculture in which wild yams were gathered for food and the extras planted. Within the tradition of a yam-based culture, the edible qualities of all species were probably tested. *D. dumetorum* has achieved a status between the domesticated species and the wild species (*D. preussii* Pax, *D. liebrechtsiana* de Wild., *D. minutiflora* Engl., and other species).

The events in the domestication of *D. pentaphylla* are difficult to

trace, but the species is so widely distributed that intervention by people must have occurred. With the possible exception of *D. alata*, this species is the most varied of the Asian edible yams. Its races occur from the mountains to the sea and from the hottest Tropics almost to the temperate regions. This species needs study, but such research can only be done after it has been collected over its wide range of distribution. Changes in Asia, destruction of the forest, changes in food habits, loss of cultivars, and the rapid distribution of cultivars because of high-speed transportation may make it impossible to trace further the history of this species that has been so closely related to the activities of people.

With respect to *D. nummularia*, less is known about its origin. Papua New Guinea and Indonesia are where the most variation is seen. *D. transversa* is known only from a few islands of the South Pacific.

Although principally a West African species, *D. dumetorum* is a famine food in Sudan (*8*). This use suggests its presence in considerable quantities. *D. dumetorum* occurs in the eastern deserts of Ethiopia and is common wild and cultivated as far west as Sierra Leone and is seen in Senegal (*4*). To the south, it is common in Zaire, is harvested from the wild in Rhodesia and Transvaal, South Africa, but is apparently unknown on the southeast coast of Africa. *D. dumetorum* may occur in the deserts of Asia Minor but is not seen elsewhere in the Tropics.

Wild yams of *D. hispida* and *D. pentaphylla* have recently been collected in India, apparently the most western extension of these species. *D. pentaphylla* is believed to have reached Hawaii in pre-Columbian times. It reaches north to the Himalayas and south almost to Australia and is common on many islands of the Pacific. *D. pentaphylla* has not found a home in the Tropics of other continents, although it has been sporadically introduced.

D. hispida is common in Southeast Asia and Indonesia and extends at least to Papua New Guinea and the Philippine Islands. Probably, it is cultivated principally in Java.

D. nummularia is now principally a yam of the South Pacific, including Papua New Guinea. It extends throughout Indonesia and is found wild in Malaysia (*5*). It is not known in other parts of the Tropics.

D. transversa, cultivated before only in the South Pacific, has now gained a foothold in the French West Indies.

BOTANY

Classification

All the minor yams belong to the genus *Dioscorea*, the principal genus of the family Dioscoreaceae. The family is usually classified among the monocotyledons, although some evidence of a second cotyledon has been found. The family is characterized by rhizomes, usually reduced to a nodeless structure. Male and female flowers, usually on separate plants, are small and usually inconspicuous, although the inferior ovary

may become quite prominent after fertilization. The floral pattern is based on sets of three.

The minor species belong to two sections of the genus. *D. dumetorum*, *D. hispida*, and *D. pentaphylla* belong to the section Lasiophyton, and *D. nummularia* belongs to the section Enantiophyllum. We do not know the classification of *D. transversa*, a species first described in 1810 by Brown (*2*). Some synonyms and common names are:

Synonyms	*Common names*
D. dumetorum	
D. bucholziana Engl.	Traveller's yam.
D. deamona Hook.	Cluster yam.
D. triphylla Hochst.	Bitter yam.
D. vespertilio A. Chev.	
Helmia dumetorum Kunth	
D. hispida	
D. daemona Roxb.	Asian bitter yam, intoxicating yam.
D. hirsuta Dennst.	
D. triphylla L.	
D. pentaphylla	
	Five-leaflet yam.
D. nummularia	
D. glabra Koorders non Roxb.	
D. hebridensis Kunth	
D. palauensis Kunth	
D. pirita Nadeaud	Pacific yam.
D. seemanii Prain et. Burk.	
Umbium nummularium Rumph.	

Morphology

The three species of the section Lasiophyton—*D. hispida*, *D. dumetorum*, and *D. pentaphylla* (figs. 1–3)—share traits common to the section. Their vines are vigorous and twine to the left, the foliage is pubescent, and the leaf is deeply palmately divided into three to five lobes or leaflets. Leaves are alternate, and the stem is often prickly. The inflorescences are special leafless side branches, often large. Although *D. pentaphylla* is easily distinguished from *D. hispida* and *D. dumetorum*, the latter two are closely related (in spite of origins on different continents) and are easily confused.

D. pentaphylla includes many varieties that have sometimes been distinguished taxonomically (var. *sacerdotalis*, *palmata*, *javanica*, *papuana*, *malaica*). The tubers are extremely variable. Some are long and penetrate deeply into the soil; others are superficial and globose or even pear shaped (fig. 4). The flesh varies in color from white through cream to light yellow and may be purpled by anthocyanin. One principal stem is produced up to 1 centimeter thick, often with heavy prickles at

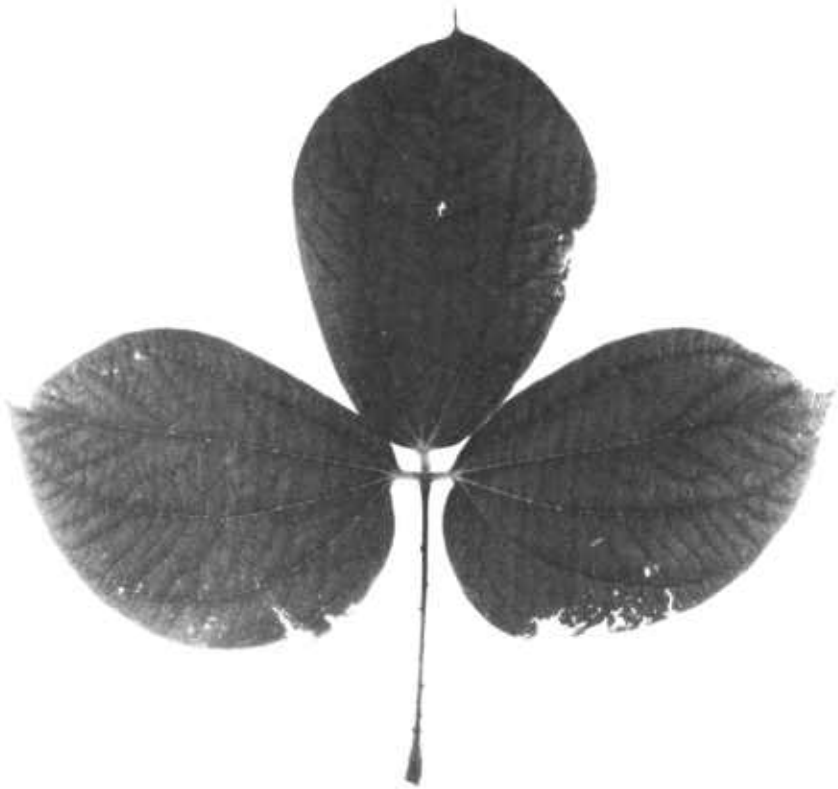

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FIGURE 1.—Leaf of *D. hispida* (× 0.5).

the base, and varying from pubescent to almost glabrous. The pubescence is either off-white or reddish brown. The leaves are divided into three to five leaflets, rather obovate but variable in shape. Male flowers are produced on racemes gathered in groups on a large lateral flowering branch. Female flowering branches hang downward, one to three at each internode, each about 25 centimeters long. Small, nonedible aerial tubers are usually produced in large numbers.

D. hispida is also divided into botanical varieties (var. *mollissima*, *hispida*, and *scaphoides*) based on details of the capsule and pubescence. The tubers, while globose in general, are lobed, sometimes profoundly, making this a difficult tuber to peel (fig. 5). The tubers are usually produced near the surface of the soil and are *extremely poisonous*. The flesh is colored white to light yellow, and the sap is yellowish. The stem is up to 9 millimeters in diameter, usually prickly, and green to light yellow in color. It varies from glabrous to pubescent. The pubescence is white to light brown. Three leaflets are produced, rarely five, with small prickles on the underside of the main vein. The racemes of male flowers

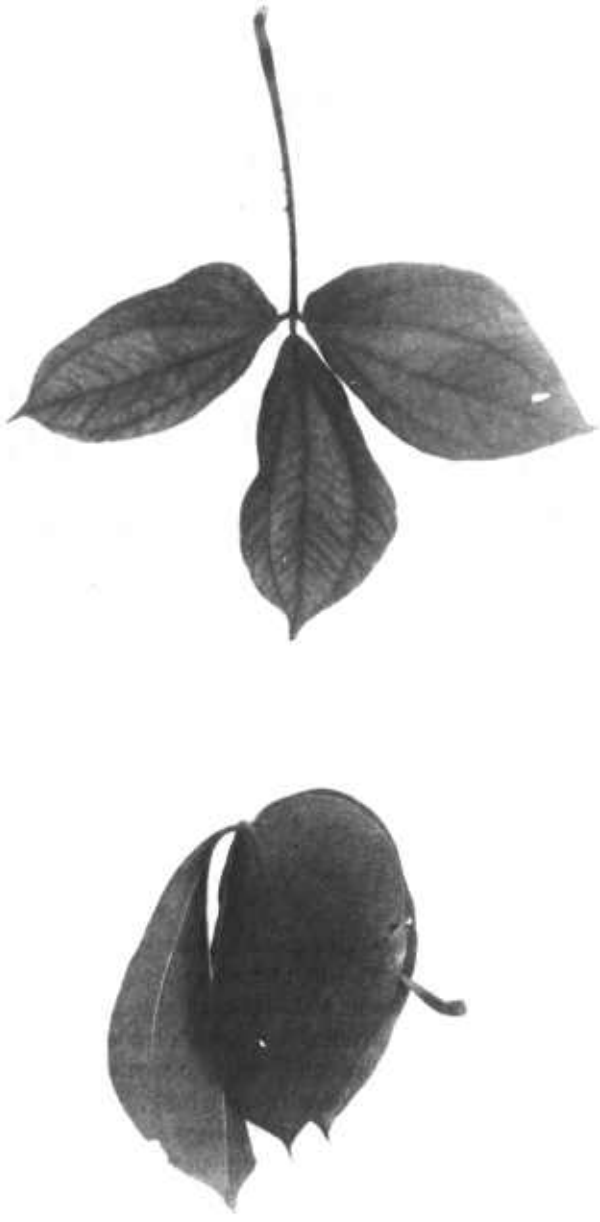

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FIGURE 2.—Leaf of *D. dumetorum* (× 0.33).

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FIGURE 3.—Leaf of *D. pentaphylla* (natural seed).

occur in large panicles. The female flower racemes are produced singly in the axils of the leaf. If the tubers are yellow fleshed, the flowers are odoriferous. Bulbils are not produced.

D. dumetorum, a highly varied species, consists of wild poisonous races and cultivated, less poisonous races. The tubers are rather globose in overall shape and are divided into many lobes difficult to peel (fig. 6). They may be produced near the surface or deep in the soil. The flesh is white to yellow. The stem of up to 8 millimeters is heavily prickled and tough.

The leaves are large, divided into three leaflets. The lateral leaflets are often lobed, especially in the lower part of the plant. All parts are covered with dense pubescence. Bulbils are often present and are spiny. Male racemes are condensed spikes, sometimes in cymes of small flowers. The female raceme is open.

D. nummularia, because it belongs to another section, Enantiophyllum, is distinct from the other four species. The tubers often descend into the soil, occasionally a full meter, and are sometimes deeply lobed into several large, almost independent tubers. These are long and

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FIGURE 4.—Pear-shaped tuber of *D. pentaphylla*.

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FIGURE 5.—Tubers of *D. hispida* covered with fibrous roots.

deltoid, and tend to be covered with small, wiry roots. The flesh is white to reddish and edible. The tuber is said to be perennial in the wild, an unusual condition in edible species. The stems up to 10 centimeters in diameter are round in cross section but sometimes prickled at the base and with indistinct ridges. Upper stems are glabrous. The lower leaves are alternate, but the upper leaves are opposite. Leaves are large, cordate, or somewhat elliptic. The racemes of male flowers occur in groups of one to four, about 4 centimeters long. The racemes of female flowers are single or paired.

D. transversa tubers are generally few (two to eight), linked by short necks to a perennial woody head (fig. 7). They are more or less pear shaped. The skin is whitish with numerous tiny weak rootlets. One to several round or weakly ridged stems are produced, which turn to the right. Prickles are rare. Leaves are alternate, triangular to cordate, bright and smooth on the upper surface, purplish to brownish when young. No bulbil or flower has been observed.

Cytology

Little information is available on the cytology of the minor species. Chromosome numbers reported were summarized by Martin and Ortíz (*12*). *D. hispida* is a tetraploid with 40 chromosomes. *D. dumetorum* chromosomes counts are 36, 40, 45, 54. These are tetraploid, pentaploid, and hexaploid numbers based on 9 or 10. *D. rotundata* and *D. cayenen-*

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FIGURE 6.—Tubers of *D. dumetorum*.

sis also have chromosome numbers based on both 9 and 10 (*14*). *D. pentaphylla* has been reported to have 40, 80, and 144 chromosomes. The latter number, approximating 16-ploid, is untrustworthy. Counts have not been found in the literature for *D. nummularia*.

Probably, the five minor species under consideration here have been slightly improved by primitive selection. Of these, perhaps the most ennobled is *D. dumetorum*, with its poison-free races, followed closely by *D. pentaphylla*, with its extreme diversification. There are no historical records to show how improvement might have occurred, and there are no present attempts to improve these species.

CULTURE

Cultivars

For each of the five minor species considered here, named cultivars exist. These have been selected by primitive farmers for special characteristics and are propagated vegetatively. Little is known of such cultivars, and they are held principally by subsistence farmers. It is difficult

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FIGURE 7.—Tubers of *D. transversa*.

to obtain named cultivars from experiment stations and research workers. Named cultivars in old publications are not always available. Furthermore, common names are not always reliable and differ from one region to another. Any listing of cultivars should be interpreted with caution. It is also important to know the cultivars because *poisonous varieties* of *D. dumetorum*, *D. hispida*, and *D. pentaphylla* are often planted to confound thieves. The use of these yam species without foreknowledge or precaution is dangerous.

The most extensive listing of cultivars of *D. pentaphylla* and *D. nummularia* has been given by Bourret (*1*), who lists more than 20 named varieties of the former and more than 30 of the latter. Even when based on collections from areas other than the French islands of the Pacific, the number of varieties is impressive.

In Cameroon, a study of *D. dumetorum* cultivars (*10*) identified 16

types. The best, selected after tests in several areas, was 'Jakiri'. The following data suggest the promise of this variety:

Cultivar	*Days to mature*	*Yield (tonnes/hectare)*	*Protein (% dry matter)*
D. rotundata 'Oshei'	250–270	22–30	9.0
D. dumetorum 'Jakiri'	210–240	30–45	10.2
D. cayenensis 'Batibo'	270–290	12–18	7.8

In a study of a small collection of *D. dumetorum* in western Puerto Rico over several years, varietal differences were noted in the following characteristics: thorniness of the stem, anthocyanin content and pubescence of the stem, thorniness of the petiole, overall leaf shape, folding and pubescence of the leaves, tuber shape, branching tendency and site of branching, irregularity of the tuber, rugosity of the cortex, amount of surface roots, flesh color, amount of gums exuded on cutting the tuber, ability to sting the flesh, ease of peeling, boiling time required, stickiness of the cooked tuber, flavor, and bitterness. These differences permit ample scope in the selection of better varieties or in improvement by breeding. In a large collection of *D. hispida*, much less variation was seen, and progress through breeding seemed to be limited. In Puerto Rico, sufficient variation has not been introduced with respect to *D. pentaphylla* and *D. nummularia* to permit selection, but these species are known to be highly variable.

In the study of only a small number of clones, erroneous impressions may be gained concerning the entire species. Each of these species, now little known scientifically, merits careful study before wild and cultivated forms are carelessly destroyed.

Growth Cycle

The five minor yam species mentioned here have much in common with other edible species with respect to their growth cycle and requirements, but each also differs with respect to small details. All are propagated from pieces of the tuber, but *D. pentaphylla*, *D. dumetorum*, and *D. nummularia* are also propagated from aerial tubers. All can also be propagated from seeds when available.

All are perennial plants with annually renewed foliage. The tubers are renewed annually and serve only as temporary food reserves used during the growth of the new vine and the new tuber. An exception is *D. hispida*, the new tuber of which arises from a lobe of the old, and therefore the tuber is perennial. It is also possible that the tuber of *D. nummularia* is perennial.

In contrast to other cultivated yams, these minor species are often used as perennials, usually when they are harvested from the wild. However, even when cultivated, they are often left in the soil for 2 or 3 years so that large tubers are produced.

Like all yams, the minor species are adapted to a year-long cycle

that includes abundant rainfall and a pronounced dry season. That dry season may be particularly long in the case of *D. dumetorum*, or short in other cases. The many varieties of *D. pentaphylla* are adapted to areas with distinct rainfall patterns. The success of yams in a particular region is closely associated with selection of appropriate varieties, particularly when long droughts occur.

In addition, yams are adapted to different day lengths. Although the evidence is not clear, it seems that day length is the chief factor controlling the annual cycle of sprouting, vegetative growth, flowering, tuber formation, and dormancy of the tuber. With respect to the minor species, little information is available except that varieties that grow well at one latitude do not necessarily do well at another.

In Guadeloupe, *D. pentaphylla* seems to be more flexible in season of growth than other species. The cultivar 'Wanyal' has been cultivated with normal yields from February to October, and also from October to December of the following year. Bulbils are usually produced from July to October, or occasionally as early as May and as late as December. Flowering occurs principally in October and November. Dormancy of the tuber can be short.

D. transversa can grow beyond its normal season if soil moisture is sufficient, and thus high yields are obtained. If the plants are not staked, dry-matter accumulation peaks at 9 months. If plants are staked, such growth continues until 11 months. Dormancy lasts up to 4 months.

Land Preparation and Planting

Because little has been written concerning the culture of the minor yams, only general instructions can be given based on experience with other yam species and on personal observation.

Although yams are adapted to many soils, important requirements for the minor species as well as the major are that drainage and aeration be provided, and that water supplies be adequate. Loose, deep, fertile soil is best, and poor, exhausted soil is intolerable. Most varieties of yam will not grow well in sandy soils.

Yams benefit from organic material, compost or manure, incorporated in the ground before planting. They are usually planted in individual hills or high ridges to provide drainage and increase aeration of the soil. Yams can be harvested much easier from ridges than from flat ground, holes, or trenches. If the soil is particularly heavy, subsoil plowing may be desirable.

Time of planting is usually adjusted to conform to the beginning of the rainy season. Plant as soon as weather conditions are favorable. The possibility of extending the season of these yams by off-season planting needs study.

The most common planting materials are pieces of the tuber. Tubers for planting are carefully selected to be free of disease and insect damage and are stored out of the sun and where rains or adverse weather cannot

affect them. A few tubers may sprout prematurely, and these sprouts should be removed. Planting can be planned as the rainy season approaches. Tubers are best cut only a few days before planting and are then treated with wood ashes (in some cases) and allowed to dry for several days before planting.

Spacing will affect yields. With *D. transversa*, cultivar 'Wael', 20,000 plants per hectare yielded 16.5 tonnes, and 60,000 plants yielded 23.9 tonnes. Spacing should not exceed 1 meter between plants in any direction.

The appropriate size of the tuber pieces is 100 to 500 grams. Large tuber pieces sprout more vigorously and yield larger tubers than small tuber pieces. Tuber pieces from the stem end of the tuber sprout more readily than those from the tip or intermediate parts of the tuber. Yield as related to planting-piece size was summarized as follows with *D. dumetorum* (*10*):

Piece weight (grams)	125	250	375	500	1,000
Yield (tonnes/hectare)	13.9	21.5	26.1	32.4	44.6

Fertilization

Few experimental data are available on the fertilization of the minor yams. Practical experience has demonstrated that these species can be grown with more or less the same fertilizer treatments as other species. Yams need large quantities of nitrogen during vegetative growth, and potassium during tuber formation. They are efficient in extracting phosphorus from the soil.

A trial done in Cameroon with *D. dumetorum* showed that it responds in the same way as *D. cayenensis* and *D. rotundata* when N is raised from 0 to 160 kilograms per hectare and K from 0 to 240 kilograms per hectare. As well as the two other species, it did not respond to a P variation from 0 to 200 kilograms of superphosphate per hectare. In New Caledonia, Bourret (*1*) has observed that *D. nummularia* 'Bwet' was less susceptible than *D. alata* 'Noumea' to an excess of magnesium in the soil and that it accumulates some minerals at a lower level (Fe, Ni, Cr).

Unfortunately, the needs for different mineral elements do not coincide. A balanced mineral fertilizer applied early during the development of the plants may not supply sufficient potassium at a later date. Because of their vigorous growth over long periods, yams need to be fertilized several times, or continuously.

A treatment that will supply yams the necessary nutrients over a long period is to add composted organic material or manure to the soil. This fertilizer may be mixed with the soil and used to construct mounds with hand tools or rototilled into the soil and formed with soil into ridges by means of a disk plow.

In Mayagüez, P.R., mineral fertilizer supplements have not produced yields greater than those obtained with organic materials.

Care

Soon after the pieces are planted, the vines appear. They climb by twining and need support for maximum growth. Any stake that permits growth up to about 2 meters is adequate. Plants used as supports compete excessively with the yams and reduce yields. Although some varieties of yams can produce adequate yields without staking, lesser yam tubers from unstaked plants seldom reach an adequate size. Poor yield is closely associated in this case with poor vine development.

In Cameroon, *D. dumetorum* is usually not staked, but when it is staked, it yields more. In Guadeloupe, a staking trial gave the following results:

Method	*Yield (tonnes/hectare)*
No stakes	18.9
Stakes of 1 meter	25.7
Stakes of 2 meters	24.6

Apparently, in this species even a 1-meter stake is sufficient to provide the sunlight needed. In another experiment, staking affected not only total yield but also dry-matter accumulation, especially in the final months of growth, as seen below:

Dry-matter percentage of D. transversa *tubers*

	Growth (months)					
	6	7	8	9	10	11
No staking	25–28	23–28	22–29	29–30	29–30	30–32
With staking	23–26	23–26	27–28	29–31	29–36	34–37

During a drought, irrigation should be used. Long dry periods will restrict the growth of the foliage and subsequent tuberization. Drought during the last month of the growing season will limit growth severely. *D. transversa* seems to withstand drought better than *D. alata* cultivars.

Little information is available on the diseases and pests of the minor yams. At Mayagüez, P.R., such yams have never been treated for diseases and insects. In Guadeloupe, *D. transversa* 'Wael' has proved resistant to anthracnose but slightly susceptible to a yam virus complex. When disease and pest problems occur, literature on the major yams should be consulted.

Harvest and Yields

As with most yams, the minor species are harvested after the vines die back, usually at the end of the rainy season. The technique of

premature harvest practiced with *D. rotundata* is seldom used with these species.

D. transversa is known in New Caledonia (*1*) for its ability to regrow when harvested during the season, and this capability has been confirmed in Guadeloupe. Its ability to remain safely in the soil without damage over a long time is expressed by the New Caledonian name, wael, a term meaning partly "does not know the season."

In Puerto Rico, individual plant yields have been recorded: 0.205 to 3.085 kilograms for *D. hispida*, 0.610 to 3.775 kilograms for *D. pentaphylla*, and 0.340 to 4.310 kilograms for *D. dumetorum*. The yields are satisfactory for any *Dioscorea* species. In the wild, *D. dumetorum* has been found with as high as 17 kilograms of tubers for a plant (*13*). *D. hispida* reaches 50 kilograms (*3*). In Guadeloupe, *D. pentaphylla* 'Wanyal' has yielded large tubers of 7 kilograms. *D. transversa* tubers have varied from 600 to 4,000 grams per plant, as good as yields of *D. alata*. Similarly, *D. dumetorum* has yielded more than *D. cayenensis*.

DETOXIFICATION

The best accounts of detoxification of *D. hispida* are given by Ochse and van den Brink (*15*). One method is to cut the tubers in pieces, cover the surface with wood ashes for 24 hours, and then steep them in seawater for several days. The pieces are then washed with freshwater and dried. The process is repeated several times, and the pieces are not eaten until dogs can eat them without noticeable ill effects. Another technique is to dry the slices first, mixed with ashes. In the Philippines, the producted "nambi" is formed by salting the tuber pieces and then pressing them under water until no whitish sap remains. There are many variations, but in every case the process is long and hard.

Coursey (*9*) summarizes techniques for detoxification of yams. *D. dumetorum* is always soaked in water in one way or another and is often cut up or macerated before soaking. Extraction, at least in the latter case, depends on the solubility of the poison in water.

After yams are detoxified, they are almost always tested with domestic animals before being used as human food.

CULINARY CHARACTERISTICS

D. dumetorum is the most unusual of the yams with respect to its cooking characteristics. The yam is soft and succulent at harvest and is easily bruised. A few days after harvest it begins to harden. Tubers harvested only 1 week before cooking were hard, difficult to peel, and required several hours of cooking. Even then they were hard and in some cases not attractive to eat. Therefore, *D. dumetorum* tubers are often sold precooked in West Africa.

D. nummularia and *D. pentaphylla* yam varieties differ in culinary

characteristics. The best are soft, white fleshed, and often delicious. *D. nummularia* seems to be the best of the minor yams for its taste, but the poorest in keeping quality.

COMPOSITION

Although occasional reports on the composition of the minor yams are found in the literature, it is difficult to accept these without some reservations because they are usually based on the analysis of a single specimen. No collections have been assembled which would permit an adequate evaluation of a species. Some analyses given by Brown (*3*) are given below:

[*Per 100 grams fresh cut*]

	Water (g)	*Ash* (g)	*Crude fiber* (g)	*Protein* (g)	*Fat* (g)	*Starch* (g)	*Sugar* (g)	*Calories per kilogram*
D. pentaphylla	74–75	0.6–1.1	0.5–0.6	0.7–2.4	0.2–1.6	17.3–19.2	0.4–1.1	800–1,000
D. alata	64–72	.8–1.4	.7–1.4	1.4–3.5	0–0.3	17.1–27.6	.6–0.9	880–1,200

Similar data are given by Bourret (*1*) for three of the species (table 2).

The chief substance in the tuber other than water is starch. The starch of *D. dumetorum* is fine and difficult to precipitate, with a high gelling temperature and a low viscosity (*18*). Amylose content is only about 14 percent, a little more than half that of most other yams. The starch of *D. hispida* is also fine but rapidly settles from solution. The starch grains of *D. nummularia* are large, and the amylose content is higher (about 26 percent). The starch grains of *D. pentaphylla* are large, up to 110 micrometers in length, with an average of 30 to 40 micrometers. The starches of *D. dumetorum* and *D. hispida* might be useful for industrial purposes when small grain size and low amylose content are desired. Schemes for the production of *D. hispida* starch were presented by Rao and Beri (*17*).

TABLE 2.—*Chemical composition of three minor species of* Dioscorea *compared with* D. alata[1]

[Percentage fresh matter]

Species	Water	Ash	Cellulose	Fats	Protein	Starch
D. alata	59.8	0.6	0.2	0.1	1.6	37
	58.2	1.1	.4	.2	2.2	37
D. nummularia	75.3	.8	.4	.1	1.8	21
	68.9	.8	.7	.2	1.6	28
D. pentaphylla	86.3	.5	1.3	.1	.9	11
D. transversa	67.8	.9	.5	.11	1.8	29

[1]See reference *1*.

Busson (*6*) reported that the tubers of *D. dumetorum* contain 9.9 percent protein. Among the essential amino acids, the content of lysine was good and that of methionine poor. Oyenuga (*16*) reported protein contents of 12.58 and 11.73 percent in *D. dumetorum*, valuable amounts indeed.

An indigestible residue called the "insoluble formic residue" was described by Busson (*6*). It occurs as 12.9 percent of the dry matter of the tuber in *D. dumetorum*, versus 6.9 percent of the tuber in *D. alata*.

The poisons of *D. dumetorum* and *D. hispida* are alkaloids, the most important of which is dioscorine, used in North America to stimulate the heart. The amount of alkaloids varies, but in the more poisonous races of both species less than a normal portion of a cooked yam can kill. ***D. dumetorum* must be used as food only when poison-free races are on hand or when carefully detoxified. *D. hispida* is even more dangerous.** It must be remembered that toxic races of *D. dumetorum* are cultivated to discourage thieves in the yam patch.

POTENTIAL USE

The future of the minor yam species is difficult to assess. On the one hand, it seems that each is declining in importance. Yams in general are competing with other root crops, and changes in agriculture or land use are eliminating wild and unusual varieties. The question is: Can these yams serve better if we know them better? Because they are now so widely scattered, it may now be impossible to assemble them to judge their potential.

On the other hand, experimentation with minor species in the French West Indies has suggested that the minor yams may have unrealized potential. The high yields and disease resistance in *D. transversa* is a case in point. Disease resistance may be of increasing importance, for leaf spot disease of *D. alata* (*Colletotrichum gloeosporioides* forma *alatae*) seems to be spreading. Recent progress with sexual breeding of *D. trifida* (*11*) and *D. rotundata* (*19*) opens new approaches to yam improvement. Success may follow with now infertile species, and introgression with wild species will be developed in the next 10 years. Even though proper sexual crossing may not be achieved, we are confident that by means of tissue culture and cell hybridization the wide genetic background of minor species will contribute to new utilization of yams.

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