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TROPICAL YAMS AND THEIR POTENTIAL

PART 5. *Dioscorea trifida*

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SCIENCE AND
EDUCATION
ADMINISTRATION

Pesticides used improperly can be injurious to people, animals, and plants. Follow the manufacturer's directions and heed his precautions. Consult with appropriate authorities concerning the legality of using particular pesticides.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dust; wear protective clothing and equipment if recommended for a particular pesticide.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary landfill, or crush and bury them in a level, isolated place.

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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 yield, 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 fifth 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 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 *Dioscorea cayenensis.* USDA Agriculture Handbook No. 502.

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TROPICAL YAMS AND THEIR POTENTIAL

Part 5. *Dioscorea trifida*

By FRANKLIN W. MARTIN and LUCIEN DEGRAS[1]

INTRODUCTION

Of the 9 to 12 principal cultivated species of yam, none is less well known than the American species *Dioscorea trifida* L., or cushcush (fig. 1). Nevertheless, in those areas where it is produced, *D. trifida* is known as the best of the yams because of its flavor and cooking qualities. Although only of minor importance in the New World, the potential of cushcush should be fully examined.

Yams have never achieved in America the important position as a staple food that they obtained in Africa, Asia, and the islands of the Pacific. The same purpose has been served by other species such as cassava (*Manihot esculenta* Crantz), sweetpotato (*Ipomoea batatas* Poir), and tanniers or yautias (*Xanthosoma* spp.). As important elements of the tropical forests, however, yam species were plentiful. Experimentation led to the exploitation of some yam species (*D. composita* Hemsl.) as fish poisons. The vigorous species *D. convolvulacea* Schlecht. et Cham. has been distributed widely throughout Central America as a minor cultivated or wild tuber crop. In Guatemala, it is known as "madre de maíz" and used chiefly as a famine crop. The species *D. dodecaneura* Vell. may have been even more widespread in South and Central America. A few even less important edible species are *D. adenocarpa* Mart., *D. piperifolia* Willd., *D. trifoliata* Grisebach., and *D. sinuata* Well. In addition, tubers of a species of a related genus, *Rajania cordata* L., were harvested from the wild and occasionally cultivated on the islands of the Caribbean. The species is a famine food in Puerto Rico. It is highly likely that other edible species of yam also occur.

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FIGURE 1.—A mature plant of *D. trifida*.

On the other hand, introduced yams from the Old World (*6*)[2] have tended to displace American species, and cultivation of the minor ones is rapidly disappearing. Only a good species could compete with the better Asian and African introductions. Of the edible American species, only *D. trifida* L. merits special attention. A cultivated species today, it is appreciated as a special yam wherever it is grown; and in a few regions, such as the French West Indies, it continues to compete with introduced and more prolific yam species.

History and Origin

D. trifida is believed to have been domesticated in South America. It presently ranges from eastern Peru through tropical Brazil, to the Guyanas, and beyond to the islands of Trinidad and Tobago, and all of the West Indies (*4*). Only a few forms of the species are known in the Greater Antilles, suggesting that these islands represent the extremes of the distribution pattern. A limited number of named varieties are recognized in the westernmost parts of the range (eastern Peru). For example, nine named clones are to be found in the gardens of the Aguaruna Jivaros (a primitive tribe of Peru) (*14*). In the Guyanas, a wide range of cultivated as well as wild forms exists, and this area may be thought of as the probable center of origin. In this region, varieties normally flower and seeds are produced abundants, providing the opportunity for evolutionary changes through the sexual process and for improvement by cross-breeding methods. *D. trifida* may be the only cultivated yam species to retain sexuality fully.

Among the many tribes that utilize *D. trifida,* none use it as a staple, in part because of competition with the ever-present cassava and in part because of the seasonal limitations of the species. Since in any region a mature tuber is available only during a short season, the species cannot be utilized as a staple food except for brief periods.

Geographic Distribution

The present geographic distribution is not much more ample than the pre-Columbian. *D. trifida* has been introduced on a small scale in Sri Lanka and apparently has been widely received. It is a minor yam in New Caledonia, to which it came from the New Hebrides. If found in other tropical areas of Asia or Africa, it has not received any special attention.

The potential for developing better *D. trifida* varieties has

[2] Italic numbers in parentheses refer to items in "Literature Cited," p. 24.

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FIGURE 2.—Leaves of *D. trifida* showing variable amounts of lobing, petiole wings, and mosaic virus.

been recognized in Trinidad and in Guadaloupe. The best study of the species is that of Henry (*18*), a Ph. D. thesis from McGill University. The most extensive breeding work has been done by the Institut National de la Recherche Agronomique (INRA) plant breeding station (*10, 11*).

BOTANY

Classification

Dioscorea trifida belongs to the small section Macrogynodium, a South and Central American section. The species is easily distinguished from related species such as *D. bernoulliana, D. urophylla,* and *D. dugesii* by the prominent wings of the stem (*3*). A list of synonyms would be long and will not be given here, but those names most likely to be encountered are *D. brasiliensis* Willd. and *D. brasiliana* Poir. Synonyms for its scientific name, *D. triphyla* and *D. triloba,* often found in old botanical literature, probably refer at times to *D. trifida.* Among common names are yampi (yampie) in northern South America and Jamaica, aja or aje in Cuba, maona in eastern Peru, mapuey in Puerto Rico, and cushcush in many different regions. In Brazil, it is called "cara doce" (sweet yam) (*5*). The French name is cousee-couche.

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FIGURE 3.—Petioles of various yam species. *D. trifida* is at the left and shows typical wings.

Morphology

From 5 to 12 stems normally arise from a mature cushcush plant. These stems are distinguished by the presence of two to eight membranous wings that vary in number from plant to plant, and even on different regions of the same plant. Usually more wings are found on thick stems than on thin stems. Wings are reduced or sometimes absent on younger stems. The wings may serve as external support for the stems or as an aid in climbing. Stems vary in thickness from 2 to 8 millimeters. They climb by twining clockwise (crossing the stem to the left).

The alternate (rarely opposite) leaves are large, up to 25 centimeters in length and width, from light to dark green, rugose, and glabrous except for a few hairs sometimes seen along main veins (fig. 2). They are deeply and sharply divided into three to seven segments, the middle of which is three-veined. The underside of the leaf is dotted with pellucid lines. Stomata are 22 by 30 micrometers. The petiole is long, with wings continuous with the leaf blade (fig. 3).

The time of flowering varies, seedlings flowering earlier than plants from tubers. By shifting the time of planting, the season of flowering can be varied. Thus, flowering is controlled in part by the maturity of the plant and in part by other factors.

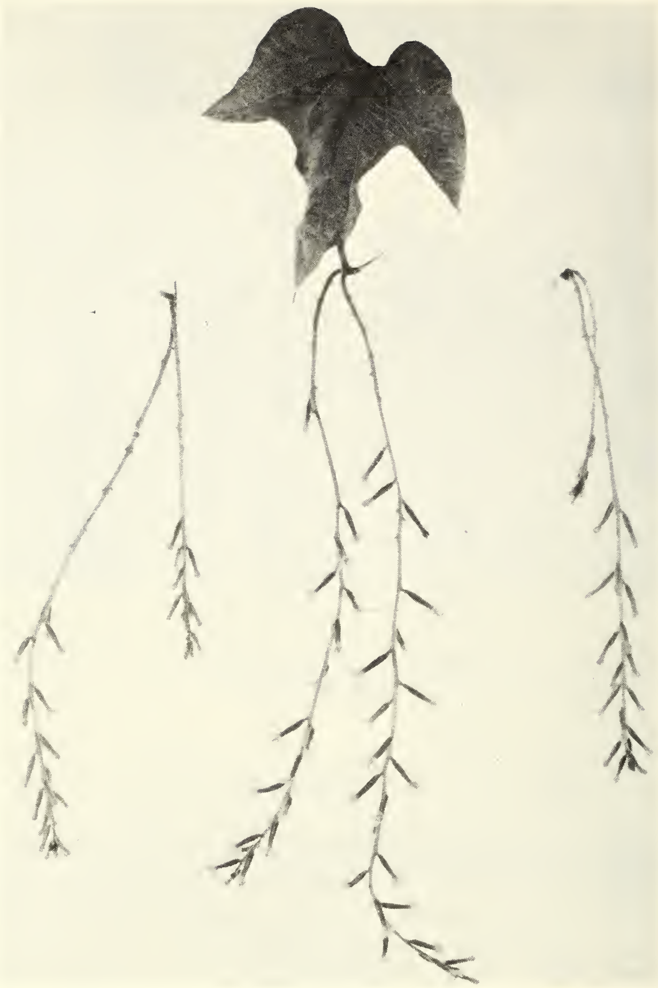

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FIGURE 4.—Female flowers of *D. trifida.*

Male and female flowers are produced on separate plants (dioecism), although monoic and hermaphroditic plants are rare (*8*). The male inflorescence, of which two usually occur at a node, consists of simple racemes or branched panicles, often complex, up to 80 centimeters in length. The flowers are only 4 to 6 millimeters in width and 6 to 7 millimeters in length. Each consists of six green perianth segments in two series, and six fertile stamens. The female flowers occur in racemes, usually paired, up to 20 centimeters in length. The flower is up to 14 millimeters in length because of the presence of a long, inferior ovary (fig. 4). The perianth resembles that of the male. The style is conical with three reflexed tubular stigmas. Six staminodes are present. Many different insects are suspected to pollinate the flowers, and hand pollination is also effective (*18*).

The fruit is a three-winged capsule, with one or two seeds in each wing. The seed is flat, somewhat rectangular in shape, and consists of a discoidal embryo and endosperm surrounded by a membranous wing.

The tubers are produced as terminal enlargements of stolons (runners) from the primary nodal complex (*5*). These runners are produced in successive rings from the crown, each ring higher than the previous ring, and are of stem origin. Although they resemble roots and are often covered with adventitious fibrous roots, they do not have the internal structure of roots. Runners with tubers vary from about 5 to 50 per plant. The tubers may be placed at various distances (0 to 75 centimeters) from the crown of the plant. In a good variety, it is convenient, if not almost essential, to have the tubers arranged compactly around the crown on short stolons.

Tubers vary in shape. A common form is the spherical or somewhat club-shaped tuber (fig. 5). The tuber can be compressed and somewhat discoidal, or shaped like a horsehoof (fig. 6). Those of other varieties are often elongated and narrow (fig. 7). The form of the tuber varies somewhat on a single plant because of the degree of enlargement that occurs and because of the malformations caused by hard ground or obstacles in the soil. The surface usually can be covered by a few fibrous roots. Some typical variations of tubers among the seedlings in Guadeloupe are shown in figure 8.

The cortex of the tuber is thin and smooth, with a few elongated cracks. The internal color ofter varies from white because of the presence of yellow (carotenoid) and purple (anthocyanin) pigments. Deeply purple-fleshed varieties are known and are sometimes especially appreciated. A wide range of intermediate and compound color forms has been seen, including tubers with brownish flesh and chimeras with white and purple sectors.

Cytology

The majority of the *Dioscorea* species of the New World are tetraploids and hexaploids with 36 to 54 chromosomes (*27*). According to Henry (*18*), the chromosome number of *D. trifida* is 72, although an unusual hermaphroditic plant with 81 chromosomes was seen, and a nonflowering plant contained only 54 chromosomes. Observations in Guadeloupe revealed chromosome numbers of 18 (diploid), 36 (tetraploid), and 54 (hexaploid). Henry found a distinct long chromosome in males and hermaphrodites, possibly a

(*Continued on page 10.*)

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Figure 5.—The clavate type of tuber of *D. trifida*.

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FIGURE 6.—The horsehoof type of tuber of *D. trifida*.

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FIGURE 7.—The elongate type of tuber of *D. trifida.*

sex-determining chromosome. The high numbers of chromosomes confound the sex determining mechanism and lead to the production of more males than females in some crosses (*26*). In Guadeloupe, 3.6 males were found to 1 female among 225 seedlings examined (*9*). In Trinidad, the sex ratio among seedlings was found to be five males to one female.

Cross-pollination is easily achieved when plants are grown close together or are allowed to intertwine. Small flies and other insects are believed to be responsible for pollen transfer in *Dioscorea.* Hand pollination is easily managed, and bagging the female flowers before and after pollination provides control. Male flowers open in the morning and begin to shed pollen about one-half hour later. Anthesis proceeds irregularly along the raceme over a period of 3 to 8 days. The female flower remains open and presumably susceptible to pollination for several days. The capsules mature in the dry season 3 to 4 months after pollination. Although most crossing combinations are fertile, a few appear sterile, possibly a result of differences in ploidy of the parents.

Seeds germinate irregularly after a post-maturation rest pe-

PN-5866

FIGURE 8.—Typical clusters of tubers from the collection in Guadeloupe, showing differences in tuber shape, size, and number, and length of stolons.

riod of about 2 months. After that, seeds will germinate uniformly in about 30 days. The viability can be preserved for about 1 year by dry, cool storage.

Open-pollinated seedlings have been produced in abundance, especially in Guadaloupe. These have been the chief materials used for the selection of new varieties.

The seedlings produce successively two to six stems, each of increased size. These stems form a rosette at first, until a climbing stem develops. A few seedlings remain for a prolonged period in the rosette stage. Meanwhile, the primary nodal complex forms and becomes the source of fibrous roots and stolons.

Seedlings grow rapidly to a normal size within the first year and exhibit from the beginning some of the physiological and morphological traits that clones derived from them will show. Because of high variability in growth rates and earliness, selections can be made at an early stage. Some seedlings do not bear tubers, and yield variations in tuber-bearing seedlings are obvious even at the first harvest. Seedlings can also be selected reliably for tuber type and color.

Plants also vary in stolon production, length of stolons, proportion of stolons that tuberize, time of initiation of tuberizations, distribution of roots on the tubers, smoothness of the tuber skin, shape of the tubers, and so forth. Most of these characters can best be judged from clones derived from individual seedlings.

Some data on inheritance have been produced (*7*). In Guadeloupe, crossing the long-stoloned 'Cousse-Couche Violette' (stolons 10 to 15 centimeters) with the short-stoloned 'INRA 40' (stolons less than 10 centimeters) produced the following distribution of mean stolon length among the progeny:

Stolon length (cm)	*Percentage of seedlings*
Less than 10	32.2
10–15	26.2
15–20	20.8
More than 20	20.8

In the same cross, the following tuber forms were found among the seedlings:

Shape	*Percentage of seedlings*
Spheroid (as in 'INRA 40')	17.3
Ovoid	20.2
Cylindrical	6.5
Club shaped (as in 'Cousse-Couche Violette').	32.3
Club shaped, branched	17.9
Fan shaped	5.8

The outer phelloderm color and flesh color segregated as follows:

Flesh colors	Skin colors (percent)				
	Deep purple	Purple	Light purple	White	Total
Deep purple	3.3	1.6	...	...	4.9
Purple	...	22.9	[1]18.0	...	40.9
Light purple	...	3.3	18.0	...	21.3
Very light purple	...	1.6	3.3	...	4.9
White	...	1.6	6.6	[2]19.6	27.8
Total	3.3	31.0	45.9	19.6	...

[1] 'Cousse-Couche Violette'.
[2] 'INRA 40'.

These data suggest complex inheritance based on a large number of segregating genes.

VARIETIES

Named varieties of *D. trifida* are not uncommon, but the majority have not been described. Henry (*18*) described 43 accessions from Trinidad, 3 from Guyana, and 1 from Jamaica. As variety-distinguishing characters, he emphasized leaf lobe number, the overlapping of basal leaf lobes, length of the central lobe, stem width, shapes of the immature and mature tubers, and the compactness of the cluster. On this basis, Henry was able to show that the Jamaican variety was distinct from any of the varieties from Trinidad.

Two botanical varieties have been distinguished. The variety *tuberosa* is the most favored because of its flattened, horsehoof, spheroidal to ellipsoidal tubers. These are always white in the West Indies, but may be purple in the Guyanas. Varieties include 'Patte a Cheval', 'IRAT 50', and 'Mapuey Largo'. The variety 'Genuina' includes the club-shaped and elongated, tubered types such as 'Cousse-Couche Violette', 'Cousse-Couche Rouge', and 'IRAT 24'.

At the INRA station in Guadeloupe a collection of 50 clones is maintained, including 22 from the West Indies, 18 from the Guyanas, and 10 developed locally (*9*). This collection is the most extensive ever developed of the species and marks Guadeloupe as the principal center of study and development. Some features of the collection are described below.

Among the varieties, the annual growth cycle lasts from 300 to 340 days, and flowering from 130 to 250 days. Female clones usually flower later and for a longer period than do male clones. There are more female than male clones in the collection.

Among leaf and stem characteristics, anthocyanin distribution and intensity are the best qualitative traits for distinguishing varieties. Presence or absence is noted on the upper and lower parts of the petiole, on the petiole wings and main body of the petiole, and on the wings of the stem and the interwing region. The intensity of the anthocyanin coloration varies from pink or light brown (caused by a mixture of anthocyanin and chlorophyll) to dark wine purple. Tuber skin or flesh color is not necessarily related to foliage color.

Important underground characteristics distinguish varieties. The diameter of the cluster in the soil varies from 20 to 80 centimeters. Actually, two modes occur: 40 to 50 centimeters and 70 to 80 centimeters. The fraction of the stolon that is not tuberized varies from less than one-fourth to more than three-fourths of the total length. Two modes are also observed with respect to this characteristic.

With respect to tubers, phelloderm and flesh colors are easy to judge and are useful in distinguishing varieties. Shape is harder to judge but includes at least two components, length and club shape (enlargement of the terminal extreme). About 84 percent of the varieties show at least some terminal enlargement, although in only 54 percent can the tuber be said to be club shaped.

Yields are varietal traits but are discussed in a later section.

Virus disease is an important factor limiting *D. trifida* growth and production. So far, no clear-cut resistance has been shown. Seedlings showing viral symptoms and yielding well have also been

TABLE 1.—*Some typical* D. trifida *cultivars from the INRA collection in Guadeloupe*

Name	Origin	Tuber type	Tuber number	Length/ width of tuber	Tuberized length/ length of stolon	Anthocyanin intensity[1] Tuber skin	Tuber flesh	Upper petiole	Lower petiole	Flowering class[2]	Sex	Yield
'Cousse-Couche Belfort'.	Guadeloupe	Club shaped	Low	3.5	0.50	0	0	0	0	III	M	Low
'Cousse-Couche Violette'.	do	do	High	1.7	.33	2	3	2	2	III	F	Good
'Indien St. Laurent'	Guyana	Cylindrical	Low	10.0	.75	2	2	2	2	II	F	Do.
'INRA 21'	Hybridization	Club shaped	Good	1.5	.67	0	0	0	0	III	F	Medium
'INRA 25'	do	do	Medium	2.0	.67	0	0	.5	.5	III	F	High
'INRA 40'	do	Spherical ovoid.	do	1.5	.33	0	0	0	0	III	M	Medium
'Macouria 3'	Guyana	Hoof shaped	do	.3	.25	1	2	2	2	(3)	M	Do.
'Marché St. Laurent 1'.	do	Club shaped	Very low	2.5	.75	0	0	0	0	III	F	High
'Marché St. Laurent 3'.	do	Fan shaped	do	1.5	.50	0	3	0	0	(3)	(3)	Good
'Régale Lounge'	Martinique	Branched fusiform.	High	5.0	.75	0	0	0	.5	(3)	(3)	Low
'Winceslas 1'	do	Double-fan shaped.	Very low	.8	.75	0	0	.5	.5	I	F	High

[1] Rated on a scale of 0 to 3, where 0=none, and 3=purple.
[2] I=150–175 days; II=175–200 days; III=200–225 days.
[3] Unknown.

obtained. Knowledge of the behavior of varieties when infected with virus is essential in comparisons or descriptions of varieties.

Some varieties of Guadeloupe are described in table 1.

CULTURE

Environmental Requirements

All yam species are limited by more or less rigid growth cycles that represent evolutionary adaptations to specific ecological situations. The tuber is a protective structure that guarantees continuance of the living plant during the adverse conditions of the dry season. *D. trifida* was apparently domesticated in the equatorial or subequatorial forest, where rainy seasons are long and day-length changes minimal. The growth season of *D. trifida,* although 10 to 11 months in length, is not as closely related to annual cycles as is the growth season of other species.

In Guadeloupe, experience with varieties from the Guyanas suggests that *D. trifida* tubers can be produced during two overlapping seasons, or even year round. The normal season begins from February to April and ends in December or January. Selected lines planted in October will mature in June. Suitable varieties for this purpose are now being developed. Successful two-season or year-round planting requires year-round rains or supplemental irrigation. Although tolerant of heavy rainfall, *D. trifida* plants do not tolerate flooding. Good drainage must be provided.

Land Preparation and Planting

Soil for *D. trifida* should be rich in organic material, or mineral fertilizer should be added. Little formal study of land-preparation methods has been made, and the techniques used for other yam species can be used without modification. Mixture of manure or other organic material into the soil followed by the formation of hills or ridges is an effective technique for hand or machine. Primitive methods include clearing of the forest, planting of the principal crops (maize and cassava), and intercalated plantings of yams and other minor crops. Yams are not normally planted twice in the same area.

Best yields have been obtained when high levels of fertilizer were applied to fields not previously planted to yam. Poor yields inevitably follow when the soil is impoverished and when little or no fertilizer is applied (*1*).

Trials done in Guadeloupe by Rouanet (*20, 21*), in lateritic soil and under high rainfall, showed the benefit of applying about 200–250–150 kilograms nitrogen-phosphorus-potassium, compared with an unfertilized or a manure treatment of 15 tons per hectare.

This formula, which has been used also in Trinidad by Henry (*18*), yielded 21 to 22 tons per hectare.

A yield of 15 tons per hectare was obtained in ferralitic acid soil (pH 4.3) of Guadeloupe with 120–120–150 kilograms N–P–K or a 120–120–300 kilograms N–P–K, whether or not lime was applied. But application of 4 tons of powdered calcareous rock per hectare the following year with the 120–120–300 N–P–K formula raised the yield to 32 tons per hectare.

The effect of type of planting material on vegetative growth and yields has been studied by Ferguson, Haynes, and Springer (*16*), Mathurin and Degras (*28*), and Degras, Mathurin, and Suard (*13*). Growth of the plant is closely related to the nature of the seed piece. The most common planting material is small, whole tubers, but these are the most likely to be affected by disease. Large tubers can be cut into several pieces.

When the pieces are large, a difference in sprouting behavior is observed, correlated with the part of the tuber used. Pieces taken from the upper portion of the tuber (head pieces) germinate more readily and produce more stems and tubers than do pieces from the lower portion or whole tubers. However, yields are not always affected by source of tuber piece, if sizes are equal. Tubers can be cut into pieces as small as 5 grams, and when protected by a fungicidal dip (benomyl),[3] can be germinated satisfactorily. These small pieces germinate late, in spite of differences in origin. Small pieces are useful for multiplying a stock rapidly.

Spacing trials in Trinidad (*18*) and Guadeloupe (*2*) showed that as spacing decreases, yields decrease proportionally. This result would be expected because closely spaced plants compete with each other. A spacing of 0.5 by 0.5 to 0.8 by 0.8 meters (40,000 to 15,000 plants per hectare) is recommended for maximum yields.

At the time of planting, the seed piece is buried in the loose soil of the hill or ridge to a depth several times its diameter. After planting, the hills should be kept somewhat moist. Unless the tuber piece is desiccated or small, germination occurs within a few weeks.

It is also possible to plant from seed. Seeds should be stored under dry, cool conditions and planted in clean soil with good drainage and aeration. The young plants are delicate and should be maintained in the nursery until twining stems arise. For convenience, such seedlings can be transplanted from the seedling flat to pots, for they transplant readily. When seedlings are transplanted to the field, they need some care until they become well established.

A variable degree of success has been achieved in the propagation of *D. trifida* from stem cuttings (*15*). Factors influencing success include clone, age of stem, and position of cutting on the

[3] Methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate.

the stem. The technique appears useful only for experimental purposes.

Once plants germinate, stakes are normally used. Because of the extreme vigor of the plants, long stakes (2.5 to 3 meters) are recommended. The vines then quickly establish a dense cover along the length of the stake. Staking systems developed for other yams should be equally suitable for *D. trifida,* but the amount of vines that need support is great, and weak stakes will be pulled to the ground.

Satisfactory field growth and exceptional yields of up to 55 tons per hectare have been obtained in Guadeloupe without staking. The comparative costs and yields of stakeless culture need further evaluation for this species.

Pest Control

In many areas of its distribution, *D. trifida* is remarkably free from pests and diseases. This condition probably would not hold true when the species is grown on a sufficient scale to permit insects and diseases to multiply. However, yams in general are relatively pest free.

Research in various parts of the world has shown that chemical pesticides effectively control certain pests in yam plantations. Most countries regulate the use of pesticides and establish the amount of pesticide residues permitted on raw agricultural commodities, including imported commodities. (In the United States, the Environmental Protection Agency is responsible for this activity.) In the following discussion, mention of a particular pesticide should not be construed to mean that its use on yams is legal in the United States or in any other country, or that residue tolerances have been established. The reader is cautioned to determine the status of every pesticide in the country where it is to be applied and to consult the appropriate authorities of an importing country concerning permissible residues.

Weeds

Weed control can be a problem from the beginning. Newly prepared clearings in the forest are not much troubled by weeds, and the minimum weed control necessary is achieved by pulling weeds. In Guadeloupe, atrazine[4] applied as a preemergence spray at the rate of 2.5 to 3 kilograms per hectare has successfully controlled weeds until tubers germinate. After germination, one or two hand weedings are necessary, or paraquat[5] can be applied care-

[4] 2-Chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine.
[5] 1,1′-Dimethyl-4,4′-bipyridinium ion.

fully with a shielded spray nozzle. When plants are grown without stakes, less weed control is possible.

Insects and diseases

A serious disease of yams believed to be caused by one or more viruses (*30*) debilitates and destroys *D. trifida* plants. An irregular mosaic of the leaves is followed by stunting and distortion that arrest growth of foliage and reduce or eliminate the tuber. This disease seems to occur throughout the Tropics and may have been introduced by another species of yam. Species differ in susceptibility, from least affected to worst, as follows: *D. bulbifera, D. esculenta, D. alata, D. cayenensis,* and *D. trifida.* In Puerto Rico, *Rajania cordata* L., a species with yamlike tuber, seems to be a reservoir of the disease in the wild, and it has been associated with outbreaks of the "virus."

Cushcush exhibits a well-defined mosaic pattern that can be associated with distorted, shortened, and aborted stems and leaves. In contrast to the viral leaf disease in *D. esculenta* and *D. alata,* the *D. trifida* symptoms have never been associated with internal tuber brown spot (*24*). Nevertheless, it seems that in all virused yams a flexuous long rod of 770 nanometers is found and can be attributed to the potato Y-virus family (*30*). Migliori, who confirmed this finding, has also observed "pinwheel" structures in virused *D. trifida* plants (*29*). He also observed, though rarely, 30-nanometer particles attributed to a type of cucumber mosaic virus (CMV). Until now, apical meristem culture, which could cure virused plants, has not succeeded. New efforts are in progress, based on stem axillary tissue culture as used by Mapes and Urata (*25*).

If varietal differences are observed in extensiveness and severity of symptoms, no clones can be said to be free from virus. Variation in severity seen in seedling progenies has to be confirmed. The virus is apparently not transmitted by seed; therefore, controlled infection of seedlings is needed to test for resistance. The growing and selection of hybrids isolated from contamination are needed to produce virus-free varieties.

Although roguing is sufficient to maintain plants virus free in less susceptible species, avoidance of the disease is recommended in the case of *D. trifida*. Complete destruction of infested plantings may be necessary to keep the disease from spreading. Seed material should never be taken from a diseased planting.

Nematodes can destroy cultures of *D. trifida.* In tubers, necrotic lesions are confined to epidermal and peridermal parenchyma tissue, but the ground parenchyma is not attacked, at least in the field (*12*). Cracks and pitting may be seen, and in heavy attacks (30,000 larvae per 100 grams of soil), gall formation resulting from *Meloidogyne incognita* has been observed in Martinique (*22*). In Jamaica, *Pratylenchus coffeae* is the main parasitic nematode of the *D. trifida* tuber. *D. trifida* seems to be resistant to the common yam nematode *Scutellonema bradys* (*19*). Roots can suffer from *Meloidogyne, Helicotylenchus, Pratylenchus,* and *Rotylenchus* (*19, 23*). Rarely, a foliage nematode, *Aphelenchoides besseyi* (the "white tip" rice nematode), is seen. Necrosis can cause death of the plant (*23*). No resistance against nematodes seems to exist in tested material. However, variation in tolerance is likely. Cultivation of cushcush after vegetable crops must be undertaken cautiously. Most nematicides are phytotoxic to yams.

At planting time, white mealy bugs are often found around the base of the growing stem and at the lower nodes. When numerous, they can kill the stem or occasionally an entire plant. On the adult plant, mealy bugs are found around the collar or upper part of the tubers. Pseudococcidae (*Planococcus citri, Planococcus gossypii, Planococcus citricus*) are the most injurious; some Diaspididae (*Gonaspidiotus hartii*) are also found. Clean or treated seed pieces at planting give good control of the disease. It must be noted that the world parasite of the yam, Diaspididae (*Aspidiotus destructor*) has not been found on *D. trifida* (*31*).

Harvest and Yields

In conventional plantings following normal cycles the harvest is made 10 or 11 months after planting when the foliage of the plant dies back. Special care must be taken when digging the tubers to avoid damaging the tender surface. Mechanized harvest has been studied in Guadeloupe and appears promising with varieties bred for this purpose.

Yields of *D. trifida* have tended to be low, compared to those of other yam species, one of the reasons this species has been neglected. Under conditions of a viral disease, yields can reach as low as 1 to 2 tons per hectare. Yields of 15 tons per hectare can be considered good for this species. Two years of cultivation of new hybrids in 20 locations in Guadeloupe resulted in yields from 4.6 to 37 tons per hectare. Weeding, staking, and appropriate soil-water relations, in addition to soil fertility, are the factors that most influence yields.

On an experimental basis, yields in Guadeloupe have reached 55 tons per hectare, a yield comparable to the best yields of other yam species. But current yields represent only one-half to two-thirds of that which would be expected under similar conditions from *D. alata*. The main reasons for this are probably the narrower ecological adaptation of *D. trifida* and its need for a more plentiful

TABLE 2.—*Yield of 45 clones as related to sex and chi-square analysis*[1]

Yield (g)	Male	Female	Total
0–1,000	2	2	4
1,000–1,500	5	11	16
1,500–2,000	8	3	11
2,000–2,500	2	5	7
2,500 or more	1	6	7
Total	18	27	45

[1] $X^2 = 7.89$; $P =$ about 0.5.

TABLE 3.—*Yield of 45 clones as related to geographical origin and chi-square analysis*[1]

Yield (g)	West Indies	Guyana	Hybridization	Total
0–1,000	3	1	0	4
1,000–1,500	11	5	0	16
1,500–2,000	3	4	4	11
2,000–2,500	2	2	3	7
2,500 or more	1	4	2	7
Total	20	16	9	45

[1] $X^2 = 13.20$; $P =$ about 0.5.

supply of water. More care is necessary to achieve maximum yields in *D. trifida,* but this effort pays in economic return.

In tables 2 and 3, chi-square tests are presented to test the relationship of yields of 45 clones to sex of clone and geographical origin. These data suggest that there is no reason to believe that either sex or geographical origin influences yields.

STORAGE

Yam varieties that need long growing seasons have been shown to have correspondingly short storage seasons. *D. trifida* is no exception. Varieties differ in storability from a week to 2 months. Normal ambient-temperature storage is then terminated by sprouting. Although sprouting can be suppressed by eliminating sprouts, the quality and food value of sprouted tubers decline rapidly. Some year to year (environmental) conditions also affect storage time. The storage time for 'Cousse-Couche Violette' is about a month; that of 'Cousse-Couche Belfort' is 50 days. Up to 20 percent of the dry weight of the tuber can be lost during storage.

Injury at harvest, especially the breaking of the stolon, results in a fungus infection. *Penicillum oxalicum* is an especially trouble-

TABLE 4.—*Effects of two temperatures on storage rot, mealy bug infestation, sprouting of tubers, and dry-weight loss of cushcush yams*

Type of deterioration		18° C			26° C	
	1 mo	2 mo	3 mo	1 mo	2 mo	3 mo
Storage rot .... mm	...	23	34	...	12	16
Mealy bug infestation .. %	7	22	22	11	80	86
Sprouting of tubers .... %	38	90	100	92	100	100
Dry-weight loss .... %	...	16	24	...	21	38

some pest. From 10 to 30 percent of the tubers are usually affected by rot.

Mealy bugs (*P. citri, P. gossypii*), which migrate from stems to stolons and tubers when maturation occurs, form mixed colonies on stored cushcush. With as a few as 1 or 2 percent contaminated tubers at harvest, mealy bugs can multiply during storage and infest 80 percent of tubers within 2 months. Infection during storage is often related to the appearance of sprouts, which they colonize and sometimes destroy.

The mealy bug endoparasite *Leptomastix dactylopii* (Encyrtide) attacks *P. citri* and *P. gossypii* but not enough to give natural biological control. Chemical control is obtained by a 10-minute dip in 0.5 gram malathion[6] per liter of water, but such pesticide must be limited to seed tubers. Storage at cool temperatures in the dark partially controls mealy bugs (table 4). Cool storage also reduces sprouting and loss of dry weight, but can increase rotting. P. Ricci (personal communication, 1976) has found that respiratory intensity increases sharply after infection by *P. oxalicum*. Curing, as done with other yams, is not effective for control of *P. oxalicum* rot. Complete protection can be achieved by a fungicidal dip of 1 milliliter thiabendazole[7] suspended in 4 liters of water in the first days after harvest. Benomyl has been successfully used at 0.1 gram per liter of water (*32*).

A final source of storage decay in cushcush tubers is nematodes. High populations of *P. coffeae* have been found in Jamaica, associated with dry rot of the flesh, which is reduced to a dark-brown powder. The skin, at first firm, becomes brittle and flakes off. At this stage saprophytic nematodes (*Aphelenchus* sp., *Aphelenchoides* spp.) can be also found (*19*). It appears that incidences of nematode infestation can be limited in the field, but nematodes may cause heavier potential loss in storage.

In summary, storage in a dark, cool room (16° to 18° C) of

[6] Diethyl mercaptosuccinate *S*-ester with *O,O*-dimethyl phosphorodithioate.
[7] 2-(4-Thiazolyl) benzimidazole.

cushcush tubers treated against mealy bugs and *P. oxalicum* has been widely tried in Guadeloupe. Even without the malathion treatment, good keeping for as long as 1 year has been observed, and acceptable culinary performance in this case has been verified.

CULINARY CHARACTERISTICS

The tubers of *D. trifida* are of convenient size for home use. They may be baked whole or peeled and cut into convenient pieces for boiling. The variety 'INRA 40' can be successfully peeled by machine. The cooked flesh is smooth in texture, attractive even when colored with anthocyanin, and of an unusual rich flavor that is readily appreciated and is sufficiently moist in the mouth. Fibrous and pasty textures are observed in varieties from Guyana, when cooked.

COMPOSITION

Apparently, few analyses have been made of *D. trifida* tubers. The starch percentage is high (38 percent); free carbohydrates and fat are low. Starch granules are large (10 to 65 micrometers in length). The ascorbic acid content of 5.5 milligrams per 100 grams could be significant in some diets. This vitamin is reported to be lost rapidly during storage.

The protein content was measured in a few cases by the senior author and was found to be from 6.7 to 7.6 percent (dry-weight basis), somewhat low for yams in general. But, these cases may not represent the best potential of *D. trifida,* because the plants were infected by a virus. The protein content of the variety 'INRA 25' was observed to be 7.6 percent. The amino acid composition of one variety in Puerto Rico is given in table 5, compared to that of several other yams and the Food and Agriculture Organization (FAO) reference protein. Important deficiencies are seen in the case of the sulfur-containing amino acids, and with respect to tryptophan. Breeding and selection should result in better protein contents and more balanced amino acid distribution.

POTENTIAL USE

Because of its sexual fertility, *D. trifida* seems to have the potential for improvement. Breeding work, already begun in Guadeloupe, shows that it should be possible to obtain hybrids of this species with high yields, acceptable tuber shape, good quality, virus tolerant, and with the capacity to produce without the need for staking. Some of these characteristics are already incorporated into selected varieties.

On the other hand, the relatively small size of the individual

TABLE 5.—*Essential amino acids in cultivars of several yam species compared*

[Grams amino acid per 100 grams protein]

Amino acid	FAO reference protein[1]	Species and cultivar				
		D. alata 'Sweet'	*D. rotundata* 'Negro'	*D. esculenta* 'Spindle'	*D. trifida* 'Mapuey Largo'	*D. bulbifera* 'Hawaiian Poison'
Leucine	4.8	7.5	7.6	8.6	8.6	10.0
Lysine	4.2	5.2	5.4	4.0	4.6	4.3
Methionine	2.2	1.9	1.5	1.6	1.3	.8
Cysteine	2.0	.5	1.8	.5	1.6	2.2
Phenylalanine	2.8	5.8	6.1	5.9	5.2	6.2
Threonine	2.8	4.2	3.9	3.9	5.0	5.0
Tyrosine	2.8	3.2	2.8	3.0	3.1	2.4
Valine	4.2	4.2	4.6	5.3	5.1	6.3
Isoleucine	4.2	3.7	4.2	4.3	3.9	4.8
Tryptophan	1.4	.6	.3	1.1	.2	.2

[1] FAO Nutritional Studies 24 (*17*).

tubers, the frequently large number of tubers that are too small, and the relatively narrow adaptation of the species are negative features perhaps more difficult to eliminate. Recent hybrids produced in Guadeloupe suggest that the problems are not insurmountable.

In order to realize the potential of *D. trifida,* a comprehensive effort to obtain a full range of germplasm would be desirable. This germplasm should then be evaluated carefully under several environments, and could serve as a basis for improvement of the species for a wide range of environments. *D. trifida* must be distributed much more widely, preferably as seed so that selections could be made in each environment. The junior author now distributes seeds of *D. trifida* on request so that breeding can be initiated in many localities.

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