A Review of Sexual Propagation for Yam Improvement

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The development of methods to germinate seeds now make it possible to improve white yam (*Dioscorea rotundata*) through sexual propagation. Previous difficulties in seed germination resulted from the failure to recognize a 3–4 month dormancy period, and because many seeds lack well developed embryo and endosperm. At the end of dormancy, seeds germinate in 3 weeks. Since 1973, about 40 000 genotypes have been produced through sexual propagation. This provides a wide range of genetic diversity to improve yam by selection for desirable characteristics.

Genetic diversity in white yam (*Dioscorea rotundata*) has been narrow and hopelessly inadequate for plant improvement. This has resulted primarily from lack of hybridization, and continuous vegetative propagation. Yam breeders have long recognized this limitation and its adverse effect on yam improvement. As a result, all improvement efforts have been devoted to selection among the small number of existing cultivars. Attempts to improve the crop by selection, however, have proven futile,

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judging by the slow rate of improvement and the resulting decline in yam production during recent years.

Lack of hybridization and its adverse consequences were recognized as the most important limiting factor for yam improvement through breeding at the International Institute of Tropical Agriculture (IITA), when the Root and Tuber Improvement Program was initiated 6 years ago. It was believed then that unless hybridization could be accomplished, little contribution could be made over what previous breeders had done.

With that in mind, research on yam improvement at IITA was set out to identify and solve the problems and overcome the constraints that prevent yam hybridization.

Constraints

Many factors contribute to lack of hybridization. The following, however, are the most important:

Flowering — Many of the important yam species cultivated for their edible tubers do not flower, and among plants that flower, there is a high male-to-female ratio. In West Africa, only a small number of *D. rotundata* plants established through vegetative propagation flower. In other regions, such as the Caribbean, flowering has not been reported although it may exist. Some *D. alata* cultivars flower abundantly and produce both male and female plants, but fruit production according to Martin (personal communication, 1975) is extremely rare and none of the fruits contain seed. Work by Rao et al. (1973) suggests that although *D. alata* flowers, fruits and seeds are not obtained because of hexaploidy. Flowering of *D. esculenta* has not been reported in West Africa or elsewhere. *D. cayenensis*, an important yam in West Africa, flowers occasionally, but produces only male flowers. *D. dumetorum* produces both male and female plants and abundant fruiting, however seed germination is yet unknown and requires investigation. *D. bulbifera* and *D. trifida* flower profusely and produce viable seed (Henry 1967).

Pollination, fertilization, and incompatibility — Because of the dioecious nature of yam and the smallness of flowers, pollen transfer from male to female plants can be a problem. Hand pollination is possible, but not practical. Due to the sticky nature of pollen grains and their strong adherence to anthers, wind pollination is not possible, and therefore it is believed that pollen is transferred by night insects (Coursey 1967) or by small insects such as thrips, *Larothrips dentipes* (Pitkin 1973). In addition to the physical difficulty of pollen transfer from male to female plants, the viability of pollen grains is poor and certain inter- and intraspecific barriers may exist that result in pre- or post-ovular breakdown and embryo abortion (Rao et al. 1973).

Seed germination — Despite flowering scarcity and difficulties encountered during pollination, fertilization, and seed development, a small number of fruits with fertile seeds can be found occasionally on *D. rotundata* plants in farmers' fields in West Africa and elsewhere. Many attempts over the years to germinate such seed to produce plants with greater genetic diversity were only partially successful and were abandoned because of the common belief that the seeds were not viable. Such belief almost became accepted as fact and researchers were discouraged from pursuing further research on seed germination after the work of Waitt in 1959.

Since 1973, however, Sadik and Okereke (1975) have germinated *D. rotundata* seeds on a large-scale basis and have produced more than 40 000 genotypes. Other workers, since then, have successfully germinated seeds and their progenies have been used for selection (Doku 1973; Okoli 1975).

Seed Germination and Seedling Establishment

Sadik and Okereke (1973) discovered two major factors limiting seed germination of *D. rotundata*. First, a large number of seeds are not viable because they lack well developed embryo or endosperm; and second, seeds have a dormancy period of about 3–4 months following harvest. The nature of the dormancy period has not been identified, but preliminary studies suggest that it is an after-ripening rest period. Methods for breaking the dormancy period have not been found and therefore storage of seeds at room temperature for 3–4 months is the only available way to overcome dormancy.

The method adopted for seed germination and seedling establishment can be summarized as follows: Fruits are collected from plants after maturation, during November–December in West Africa. Fruits are air-dried and split to

Table 1. Fruit and seed production of *D. rotundata* plants.

Family	Number of plants	Fruit per plant	Estimated number of seeds[a]
1974 Harvest			
Ihobia	13	40	2068
Boki	140	180	100632
Mixed	66	127	33636
Total	219	156	136336
1975 Harvest			
Umidike	143	368	210664
Boki	71	207	58900
Iwo	147	167	97908
Mixed	45	140	25148
Ihobia	7	81	2264
Ihobia (Veg.)	93	44	16324
Total	506	203	411208

[a]Based on 4 seeds per fruit.

release seeds. Seeds are dewinged and stored at room temperature until the end of dormancy. Seeds are then lightly and uniformly coated with a suitable fungicide and germinated on water-soaked filter paper in Petri dishes. Seed dewinging is not necessary, but reduces the amount of planting space needed in Petri dishes and prevents browning of filter paper during germination. Germination usually starts after 3 weeks and continues for 5 weeks. Germinated seeds are transplanted to peat pots following the appearance of the first leaf and grown until 2–3 leaves develop before they are transplanted in the field.

This method can be simplified by sowing seeds directly in peat pots or in germination boxes filled with soil-mix rich in organic matter. Seedlings established in this way can be transplanted later in the field.

Where laboratory and greenhouse facilities are not available, seeds can be planted directly in elevated seed beds. The seed bed should be protected from heavy rains by a 1 m high bamboo canopy covered with palm leaves. Seeds are planted densely in rows 10 cm apart and lightly mulched to avoid soil crusting. Seedlings are later thinned to 5 cm spacing between plants. Sufficient planting material for one hectare of land can be produced from a 100 m^2 area.

Seeds can also be planted directly in the field, eliminating the need for transplanting. However, special care must be taken to mulch and protect seeds and young seedlings from heavy rains and soil crusting.

It is important to treat seeds with a suitable fungicide before planting. Six disinfectants (Demosan, Demosan T, Vitavax, Argosan, Arasan, and calcium hypochlorite) were evaluated by Sadik (1975) to find a suitable chemical for treating seeds before planting. All chemicals other than calcium hypochlorite inhibited seed germination. A 10% w/v calcium hypochlorite solution produced 85% germination with only 5% rot (root and shoot development in the seedlings was good). Agrosan, a systemic fungicide prevented seed rotting and germination as well. The most effective method is to soak seeds for 20 minutes in calcium hypochlorite solution. However, because wet seeds are difficult to work with, fungicides that can be applied in powder form are preferable and require further investigations.

Flowering

A low degree of flowering (47%) and a high male-to-female ratio (32/15) characterize plants produced through continuous vegetative propagation. In contrast, second-generation plants produced from seed are characterized by a higher degree of flowering (80%) and a lower male-to-female ratio (41/35). Whereas plants produced through continuous vegetative propagation are normally dioecious, lines originating from seed produce a large number of monoecious plants (4%), which are a useful addition to any yam breeding program. There is also an increase in the number of flowers produced by sexually propagated,

second generation plants. Sexually propagated plants usually produce 500–90 000 flowers per male and 500–11 000 flowers per female plant, whereas 185 female flowers is the common maximum on vegetatively propagated plants.

Fruit and Seed Production

The formation, development, and retention of fruits on vegetatively propagated female plants are low. Studies during 1972 revealed that the number of retained fruits on vegetatively propagated plants did not exceed 24 per plant with a potential production of 5–7 filled seeds per plant. The number of fruits retained on sexually propagated plants, studied during 1974 and 1975, was greater, and exceeded 2000 fruits on some plants (Table 1).

Tuber Yield

Because of seed dormancy it is impossible during the first year to produce seedlings ready for field transplanting at the normal April planting time. During 1975, seedlings were transplanted in the field between June 15 and July 15, which only allowed a 4–5 month growing period, too short to produce large tubers. Despite that, tubers up to 1 kg were produced. It would be interesting to find the yield potential of plants grown from seed if the seedlings could be transplanted in April. An answer to that should be possible in the future when old seeds that have passed their dormancy are germinated in time to be transplanted in the field during April.

Yields of sexually propagated, second-generation plants ranged from 0.1–8.7 kg/plant during 1974, whereas some plants yielded up to 25 kg/plant during 1975. During both years, flowering plants outyielded nonflowering plants, and female plants outyielded male plants.

Genetic Diversity

Sexually propagated plant populations exhibited a wide spectrum of genetic diversity during the first year. Further intercrossing between such plants increased the genetic diversity even more. Some of the most important genetic variabilities observed are as follows:

Plant height and vigour — Yams are vine plants with poor stem structures that necessitate staking. In West Africa, staking accounts for almost 20% of production inputs. The advantage of selecting short and sturdy yam plants that do not require support is obvious. As a result of sexual propagation, about 4% of the plants were dwarf and did not require mechanical support. These plants produced many stems and small tubers with a maximum weight of 200 g/tuber. Small tubers are commercially undesirable at present, but such plants can be used in breeding programs to change plant height and canopy structure.

Table 2. Vigour and canopy structure among plants of *D. rotundata* derived from seed.

Canopy	Number of plants	Percentage
High vigour	4685	32.5
Medium vigour	2909	20.1
Low vigour	6235	43.2
Dwarf	586	4.1
Semidwarf	13	0.1
Total	14428	100.0

Plants produced through sexual propagation exhibit a high degree of variability in vigour (Table 2), which presents opportunities for selection within and among families.

Vegetative variability — A wide range of leaf and stem shapes, sizes, colours and other minor characteristics was observed. Variability in tuber size, shape, furcation, hairiness, rugosity, and flesh colour was also observed. It is difficult to determine the desirable characters for plant improvement before obtaining basic information on the importance of these genetic characters and their contributions to yield.

Reproductive variability — Sexually propagated plants presented a wide spectrum of variability in date and degree of flowering, sex expression, inflorescence shape and length, fruit size, shape, and colour, and seed size, colour, and dormancy.

Disease resistance — Sexually propagated plants manifested marked variability in resistance to major diseases present at IITA.

Seed Storage

Seed viability deteriorates during storage at ambient temperatures, and germination drops to 30–40% one year after harvest. During 1975 a study to find suitable conditions to store seed for at least 3 years without appreciable loss of viability was started.

Seed germination was tested monthly during the first 8 months of storage at six conditions. Cold-storage treatments especially, when combined with desiccation, reduced the percentage of germination and increased the number of days to the onset and to 50% germination. Storage at 25 °C without silica gel resulted in the highest germination rate and the least number of days to the onset and to 50% germination, whereas storage at 25 °C over silica gel resulted in opposite results. Although germination of seed stored at 25 °C for 8 months is superior to that at cold storage, the long-term effect of cold storage is not yet known.

Research Needs

The opportunities to improve yams through hybridization have been greatly enhanced by increasing flowering and by achieving seed germination. However, many problems remain before further advancements can be made. Although flowering has been improved quantitatively and qualitatively, methods for inducing flowering in nonflowering plants and species must be found before the genetic resources of such plants can be utilized. Studies of the barriers that prevent inter- and intra-specific hybridization are also urgently needed.

Conserving yam germ plasm in tuber form is difficult and undesirable because of the great bulk, poor storability, and the possibility of disease- and pest-transmission from one crop to another. Because of these factors, quarantine regulations restrict the movement and exchange of germ plasm among research workers. Germ plasm can be conserved and exchanged through seeds that are less bulky, not restricted by quarantine regulations, and contain more genetic diversity for selection. However, before this can be recommended, work should be conducted to find suitable conditions for storing seed, to develop methods to break seed dormancy, and to present strong evidence that disease and pests are not seed-borne.

These are some of the problems that need urgent attention to maximize opportunities to improve yams through hybridization and sexual propagation.

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