Plant Domestication and Indigenous African Agriculture

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For some decades now considerations of plant domestication and agricultural origins have been permeated by two fundamental concepts: the "revolutionary" nature of agriculture and "centers of origin." Neither concept appears to have much application to Africa and may have generated more in the way of mental blocks than enlightenment elsewhere. The idea of an agricultural revolution as elaborated by V. Gordon Childe for the Near East was basically applied to the social and cultural consequences of food-producing economies. Food production, as opposed to hunting and gathering, was considered to be so superior that, once invented, no one would dream of returning to the old ways. The new system would spread rapidly at the expense of the more "savage" tribes. Civilization could arise only from agricultural societies because everyone else was too busy eking out a living by hunting and gathering to have the time to develop the cultural traits of "civilization," such as writing, metallurgy, specialized crafts, standing armies, priestly castes, professional classes, and so on. It was the food-producing economy that lifted man from "barbarism."

Revolutionary attributes were also applied to domesticated plants. The idea of growing food plants on purpose was thought of as having been "discovered" by some prehistoric genius, and the idea had such obvious merit that it would be adopted readily and diffused widely from its center of origin. Indeed, it seemed to be widely accepted that the concept of food production versus food harvesting required such brilliant insight and superior knowledge that it could only have been thought of once or at most a few times. While the term "agricultural revolution" has been gradually losing favor, the revolutionary nature
of plant and animal domestication permeates a good deal of current literature on the subject. As will become abundantly clear in this volume, plant husbandry is not a "Eureka!" type discovery (cf. John Pfeiffer, this volume). As we learn more about early agriculture it becomes more clear that it took a long time to develop and weld together the crops, technologies, and social practices necessary to build an effective agricultural system (cf. Higgs, this volume).

The center of origin concept, elaborated by the famous Russian geneticist Vavilov (1926), was first applied to individual crops. The geographic regions in which genetic variability was concentrated were supposed to correspond to the regions in which the crop originated. Vavilov did generalize to some extent in attempting to locate regions in which agriculture originated, but did not elaborate a great deal since his main interest was in sources of genetic variation for plant breeding. The geographer Sauer (1952) took the idea much further in postulating only a few or possibly one center for the origin of agriculture.

As more and more information has become available, the Vavilovian centers have become less clearly defined and centric concepts have been eroding. Zhukovsky, a colleague and follower of Vavilov, for example, enlarged the eight centers proposed by Vavilov until they fused over whole continents (Zhukovsky 1968). We suggest this modification is, indeed, closer to the real situation, but it weakens the center of origin idea. Our present understanding would hold that neither individual crops nor agricultural systems must necessarily originate in narrowly restricted geographic areas or centers. For our purpose, a more useful concept would be that of a temporally long, geographically widespread, and biologically intimate relationship between plants and man out of which domestication can proceed almost anywhere in temperate or tropical zones.

Massive data accumulated in the Near East point to what appears to be a center of agricultural innovation. The appearance may be an artifact due to the success of a particular agricultural complex. The complex was founded at first on barley and later on wheat, but what moved out of the nuclear area was a complete system including barley, emmer wheat, einkorn wheat, lentil, vetch, pea, chickpea, fava bean, rape, flax, vegetables, spices, tree and vine fruits, sheep, goats, cattle, and an array of agricultural techniques. The system spread, moving along the shores of the Mediterranean, up the Danube and down the Rhine, eastward to the Indus and North India, and southward across Arabia, the Yemen and into the Ethiopian plateau. It eventually reached China in the second half of the second millennium B.C. In this sense we can demonstrate a Near Eastern center. But were the Europeans, the Indians, and the Ethiopians completely devoid of domesticated plants at the time? Did the Near Eastern complex compete successfully against hunter-gatherers, or was the expansion against less efficient or transitional agricultural economies? We cannot answer these questions at the present time, but African agriculture appears to be basically noncentric in character. Not only do we fail to detect a particular center for the origin of indigenous African agriculture, but some African crops do not seem to have "centers" either (cf. Harlan and Stebler, this volume).

To be sure, centers have been proposed for African agriculture. Vavilov cited Ethiopia and ignored all the other African domesticates not originating there. Chevalier (1938), Portères (1951), and Murdock (1959) claimed a center in West Africa, focused on the Bend of the Niger. Our own analyses of the situation would call for a much more diffused view (Harlan 1971). We grant that teff, noog, ensete, and possibly finger millet were probably domesticated in Ethiopia and that African rice was probably domesticated in the Bend of the Niger region. Yet yam, oil palm, and cowpea more likely originated as crops in the ecotone between forest and savanna; sorghum, voandzeia, and fonio are savanna crops, and pearl millet is a product of the Sahel. The basic pattern is diffuse or noncentric rather than centric.

When one looks at the end products of agricultural evolution — the fully domesticated plant or the full-blown agricultural economy — it is evident that there have been radical changes. But at the outset, there is no clear advantage to food production versus food harvesting; the primitive cultivar differs little if at all from the wild progenitor. Studies of origins must involve studying initial and transitional conditions.

Africa may turn out to be the most useful laboratory of all for developing a fuller understanding of plant domestication and agricultural origins. The African scene is rich in "transitional" and "intermediate" situations — that is to say, in situations which we consider to be analogous to past situations out of which plant domestication and fully fledged agricultural economies have developed. Our studies are just beginning; they are fragmentary and unsystematic. Yet we have done enough to see fascinating and tantalizing vistas ahead. A serious and systematic multidisciplinary study of Africa would be of interest in its own right, but might also give us a much more mature view of what might have gone on in the Near East, the Far East, Oceania, and the Americas. The steps in the evolutionary process appear to be more evident in Africa than elsewhere.
DOMESTICATION

Domestication is a process, not an event. The process can be carried out over various ranges of time and at different intensities. The process continues for every crop actively being cultivated and will continue for an indefinite period into the future. How far it can go, no one yet knows. If operated at a sufficient intensity for a sufficient period of time, dramatic changes in morphology and ecological adaptation can be expected. Among African crops, for example, some yams have lost the ability to flower and, consequently, cannot be disseminated in the wild. In wild cereal grasses the inflorescence fragments at maturity by the formation of abscission layers, and seeds are dispersed. In domesticated cereals the abscission layers are suppressed, and seeds are retained at maturity. With the loss of the natural mode of seed dispersal, fully domesticated cereals are no longer able to survive without the aid of man.

Morphological changes may accumulate to the point that the differences between the wild and the more specialized domesticated races are astonishing. The wild progenitor of pearl millet (*Pennisetum violaceum*) has many inflorescences, ten centimeters or less in length. The domesticated *míl des Peules* may have single heads over two meters in length. Wild sorghum has open lacy heads with small covered seeds, while some of the most specialized domesticated types have dense compact ball heads with large exposed seeds. Similar differences may accumulate in other domesticated plants.

The process of domestication is one of genetic manipulation through human activity. In the case of seed crops much of the manipulation is automatic and comes from planting harvested seed. As long as seed is only harvested and not planted, there is likely to be little or no genetic effect on wild populations. It is seldom possible to harvest as much as half the seed produced by wild populations and ample seed remains to maintain the stand. If there is any selection pressure at all, it will be in favor of such wild-type characteristics as shattering (spontaneous seed release because of formation of abscission layers), seed dormancy, and indeterminate growth with maturation over a long period of time. It is the seed that escapes the harvester that will contribute to the next generation.

As soon as man starts to plant what he has harvested, strong selection pressures are set up. Now there are two populations, one maintained by nature and one maintained by man, with selection going in opposite directions. Outside the realm of human activity, natural selection proceeds as before, favoring wide dispersal of propagules. In the cultivator's field, however, all modifications that augment the "harvestability" of plants have a selective advantage. Mutants in which abscission layers do not form and, hence, do not naturally disperse their seeds should appear in the population rather quickly and automatically. These mutants (quickly eliminated from wild populations) are most likely to be harvested by man and sown the next year. As we shall show by the example of Ethiopian oats, deliberate selection for the trait is not necessary. Nonshattering (nondispersal of seeds) is one of the first domestic characteristics to appear in seed crops, and it is one of the most critical and diagnostic in separating wild from domesticated races. The character is usually rather simply inherited; in most cases either one or two genes are involved.

More subtle, but equally important is a selection trend toward more uniform maturity. A wild sorghum plant, for example, has many main stems which are often branched so that a large number of inflorescences are produced over a period of several weeks. This is adaptive for a wild plant because seed production continues as long as conditions permit. Seed production over a period of weeks is a disadvantage to a domesticated plant since only a fraction of the seed that can be produced is available at a single time for harvest. As soon as people begin harvesting and sowing, it is the plants which produce the most grain at a single time (rather than those which produce seed for the longest time) that make the greatest genetic contribution to the next generation. When seeds gathered in a single harvest are sown the next year, selection is automatic towards plants with a single terminal seed head, as in domesticated sorghums.

The morphological changes as a result of this selection trend are perhaps even more spectacular in pearl millet than in sorghum. Some crops have been more affected morphologically than others in the process of domestication, but the the trend toward greater uniformity of maturity is consistent and automatic in all cereals and most other seed crops.

A trend toward larger seeds is also common, although not entirely universal. Some of the increase may simply come through the selection for fewer and larger inflorescences, but most of the change is probably due to seedling competition in the seed bed. The seedling that comes up first and grows the fastest is the most likely to contribute offspring to the next generation. Seedling vigor is closely related to seed size and energy storage in the endosperm. We also know that large seeds can emerge from deeper planting better than small seeds. The depth of
planting under cultivation may, therefore, result in selection for larger seeds. Selection in the seed bed is very strong against prolonged dormancy. Most wild grasses produce at least some seeds so dormant that they will not sprout under natural conditions for several years. In domesticated races the dormant period is much reduced or eliminated altogether.

Other selection trends favor rather striking modifications in inflorescence morphology. These include “multiplication” and “condensation.” By multiplication, we simply mean an increase in the number of panicle branches or row number of the spike. This may come about in the course of selection for fewer and larger inflorescences. By condensation we mean a shortening of panicle branches or internodes in the inflorescence. This results in compact heads and more convenient harvestable “packages.”

Superimposed on the automatic selection pressures are those deliberately imposed by the cultivators. These may be in diverse directions and are likely to be biologically capricious, but can be genetically intense. Man selects for different colors, different flavors, for storage or nutritional quality, for culinary preference, and ease of processing in his equipment. Some sorghums are boiled like rice, some cracked for porridge, some ground to make flour for bread or dumplings. Different cultivars are used for different purposes.

A common procedure at harvest time is for the cultivator to go through his field and carefully select heads to be saved as stock seed for the next planting. The rest of the field is harvested for consumption. In this situation selection is total. The components of the population that contribute to the next generation are those chosen by the cultivator. The rest are eliminated from the gene pool. The fact that a cultivar makes good dumplings may confer no ecological advantage in the field, but the selection pressure may approach the absolute. It is this sort of human activity that has resulted in such a bewildering array of variation in most domesticated plants.

In this connection it should be pointed out that the part of the plant most used by man is the part most modified. In cereals it is the seeds and seedheads. In legumes it is the seeds and pods (or tuber in the case of the yampea). In yams it is the tuber, and in ensete the stem base. Fruits may be easily modified by selection. Some of the African Solanum species have fruits about as large and well developed as the American tomato, for example.

Among cereals and many other crops, weed races are produced as a by-product of domestication. These races are, in fact, continuously being formed through hybridization wherever wild and domesticated races are growing together. They can be very serious pests and cause substantial crop loss because they compete with crop plants for sunlight. They are usually identifiable by their intermediate morphologies and frequently mimic the local cultivated races in some particulars. The weed races may, in turn, interbreed with either or both parental types, and occasionally very complex populations are built up. As a rule, however, discontinuities are rather clear-cut. There are barriers of some sort to gene exchange and adaptation is either for the cultivated field or for a wild or wegetal habitat. The genes that control the differences in adaptation and morphology are usually tightly linked on the chromosomes so that nonadaptive recombinations are infrequent.

While domestication is a process of genetic manipulation through human activity, cultivation consists of those activities concerned with caring for the plants. A cultivated food plant can be defined as a plant deliberately established by man with the expectation of a later harvest. We shall show, however, that there are various intermediate states from indifference to tolerance, to protection, to encouragement, to full cultivation and that precise definitions are not always possible.

As we have seen, the process of domestication may be carried on to the point that some races of the crop are completely dependent upon man for survival. This state can be termed full domestication, but as with cultivation there are many intermediate and transitional states. We shall illustrate some of them with African examples.

**CEREALS**

Wild grass seeds are commonly harvested for food in Africa today. Jardin (1967) lists over sixty species reported to have been collected within recent years. Among these, the weedy grass *Paspalum scrobiculatum* suggests an example of incipient domestication. The species is common in the wetter parts of the Old World tropics from Japan to Indonesia and westwards across tropical Africa. It is often abundant along paths, ditches, and low spots, especially under disturbance, and frequently infests rice fields in West Africa. Should the rice crop fail or do poorly, the cultivator is usually not too concerned because his rice field is likely to be choked with *Paspalum scrobiculatum* which he will harvest for food. The grass has not been domesticated in West Africa, but domesticated races have been developed in south India,
probably through a long and intimate association with this useful weed.
An intermediate state between "wild" and "domesticated" is illus-
trated by Ethiopian oats. These oats are related to the weedy tetra-
ploid of the Mediterranean, *Avena barbata*, and were probably intro-
duced as weeds of emmer and barley when the Near East agricultural
complex arrived on the Ethiopian plateau. The oats are still weeds in
the sense that they are not grown as a pure crop, but the Ethiopian
cultivators do not object to them and make no effort to get rid of them.
The oats have responded to this toleration by producing both nonshat-
tering and semishattering races. The nonshattering races are harvested
along with the emmer and barley, and the mixture is sown as harvested
the next season. In the semishattering types, some of the seed falls to
the ground infesting the soil, and some are harvested and planted. Here
we have a plant that is not deliberately seeded with the expectation of
a later harvest, but which has, nevertheless, responded by the produc-
tion of nonshattering "domesticated" and semishattering "semidomesti-
cated" races.

The Guinea millet (*Brachiaria deflexa*) is wild over large areas of
tropical Africa and is harvested for food with some frequency. In the
Futa Djalon region of Guinea a domesticated race is grown. Typically
it is nonshattering and has much larger seeds than the wild races. The
area of culture is very limited and no other domesticated races are
known. The *Digitaria* millets are also endemic crops but not so limited
in distribution as *Brachiaria* (cf. Portères, this volume).

If the process of domestication is discontinued before full domes-
tication is achieved, the crop may revert partly toward the wild and be-
come a spontaneous weed. African rice, *Oryza glaberrima*, is a crop
rapidly declining in importance and acreage because of replacement by
Asian rice. In some areas, the African rice lingers on only as a weed of
Asian rice fields. Glaberrima rice is not fully nonshattering and sheds
eough seed that it can perpetuate itself provided the fields are
cultivated for rice production. The spontaneous glaberrimas are mor-
phologically the same as the domesticated ones and are not to be con-
fused with weed races that have developed during the course of domes-
tication through genetic interaction between wild and cultivated
races. The latter are identifiable morphologically and have been called
*Oryza stapfii*.

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Pearl millet is basically a fully domesticated plant, yet most West
African populations of the crop contain a certain percentage of *shibra*
or shattering types. These perpetuate themselves as weeds in the fields,
and since the crop is cross-fertilizing, the genes for shattering are
carried along genetically in the nonshattering forms. Again, these
shatter types can be separated morphologically from the hybrid swarms
produced when the wild progenitor crosses with the domesticated
forms.

**TREE AND TUBER CROPS**

Intimate relationships between man and selected tree species are wide-
spread in Africa. As with the cereals, we can arrange the examples in
a series illustrating increasing degrees of manipulation and genetic
response.

In many parts of the African savanna there is a close correlation
between village sites past and present and the occurrence of the baobab
(*Adansonia*). To what extent villages are located near baobabs by de-
sign or how frequently baobabs become established after the village is
founded we do not know. The tree has multiple uses; the bark is used
for fiber, the leaves are used as a pot herb, the fruits are eaten, and the
large hollow boles are often used as cisterns to store water for the dry
season. We have seen villages in Sudan that could not be occupied year
around without baobab cisterns, since there is no surface water in the
dry season. The baobab is not man dependent, but man can sometimes
be baobab dependent.

Among some peoples *Moringa* sp. is an important part of the diet.
In Konsoland, southern Ethiopia, the trees are grown in the villages
near the houses. Again, to what extent they may be actually planted we
do not know, but in that region they are confined to the villages. The
leaves are used as a pot herb. While the trees are abundant and often
quite large they are of little use for shade since the leaves are con-
tantly being picked.

In the West African savanna the karité or shea butter tree (*Butyro-
ssperrum*) is protected and encouraged. The original arborescent flora
probably contained a number of species, but selective cutting has been
practiced for a long time. The karité is protected and every other
species is cut for firewood, construction, or other uses. As a result vast
areas are covered with a uniform orchard-like savanna of nearly pure
stands of karité. The tree enjoys a nearly sacred status among the
people who refuse to cut it or allow it to be destroyed. The trees are
individually owned, and it is possible to transfer land without losing
ownership of the trees growing on it. An edible oil is extracted from
the fruit which is important in the diet of savanna peoples.
Extensive stands of *Acacia albida* may be built up by the same procedure. The acacia is not used by humans directly and does not enjoy the same status as the karité, but it is protected because it is believed that crops do better when grown between open stands of acacia trees. Some research has been conducted that indicates the belief to be correct (Dancette and Poulain 1968). This species of *Acacia* has the peculiar property of shedding its leaves at the beginning of the rains and remaining dormant through the rainy season. Therefore, it does not compete with interplanted crops. The leaves are eaten by sheep and goats which, in turn, deposit manure under the trees. Research has shown that both the nitrogen balance and water regime are better under acacia groves than without acacia although the reasons for the latter are not too well understood. At any rate, human activities have brought profound changes in the savanna flora without deliberately planting trees with the expectation of a later harvest. *Parkia* spp., *Tamarindus*, and the recently introduced mango are also protected trees of the savanna. In general, useful plants are not destroyed in Africa and, consequently, are encouraged through protection.

The African oil palm, *Elaeis guineensis*, presents a more complex transitional example. Since the plant does not tolerate deep shade, it is thought that its original habitat was the margins of the wet forest zone. The techniques of slash and burn agriculture have greatly expanded habitats suitable for the oil palm. In the process of slashing and burning, oil palm is spared; and after repeated cycles of crop and bush fallow, extensive stands may be built up without anyone deliberately planting a seed. Such subs spontaneous stands are often found well within the forest zones which would not be suitable for oil palm without agricultural disturbance.

In oil palm there is a gene that profoundly affects the fruit. One allele in homozygous condition produces the dura type which has a thick shell and relatively little pulp. The other allele in homozygous condition produces a pisifera type with lots of pulp but no kernel and, consequently, is female sterile. The heterozygote (tenera) is intermediate with a thin shell and good pulp yield. Presumably natural selection would favor the dura allele, but the other two types are preferred by the people for oil. The duras are more likely to be tapped for wine. Repeated tapping kills the trees. So there may be genetic manipulation of subs spontaneous populations. More than this, a survey of oil palm populations in Ivory Coast by Meunier (1968) revealed a strikingly close correlation between the distribution of particular oil palm varieties, on the one hand, and of certain ethnic groups on the other. Because

the distributions are disjunct, it seems possible that migrating groups of people may have taken seeds for planting in their new homes. However, we still have no conclusive evidence for deliberate planting of the tree in traditional agriculture.

African yams are treated in detail by Coursen (this volume), but we would like to point out here that protection of yam plants was important in early stages of domestication. The loss of natural protective devices (thorns, poisons, fibrous tubers, etc.) is compatible with survival only to the extent that natural devices can be replaced by human protection. Ultimately, in some varieties of yams the capacity to produce seeds was lost, and such clones became completely dependent upon man not only for protection, but for propagation and survival.

Altogether, Africa provides such a series of transitional and intermediate stages in plant domestication that the process is fairly well revealed. More detailed studies should be very rewarding in providing a still clearer understanding. We shall now turn our attention to the consequences of plant domestication, examining very briefly the characteristics of the African agriculture that emerged from these processes.

**GENERAL CHARACTERISTICS OF AFRICAN AGRICULTURE**

1. We have already indicated our opinion that African agriculture is basically noncentric. We cannot point to any one region and say: "This is where it all began." In a very broad and general way the botanical and archaeological evidence agrees that most of the activity took place north of the equator and south of the Sahara. But, where was the Sahara during the critical time range? Abundant evidence is presented in this volume for profound changes of climate over the millennia during which plant domestication is likely to have been underway. (See in this volume van Zinderen Bakker; Clark; and Wendorf and Schild.) It will be shown that the Sahara was occupied by people who undoubtedly harvested plants and who might have been manipulating them. The occupation near lake sites continued well after the onset of desiccation (cf. Munson, this volume).

It has been argued that the Sahara was once the "center of origin" and that it was wiped out by desiccation (Chevalier 1938; Munson, this volume). As we shall see, the argument has merit for some crops and some techniques, but could hardly apply to yam, oil palm, ensete, noog, tef, cowpea, or finger millet. Traditional African agriculture is a mosaic of crops, traditions, and techniques which does not reveal a center, a nuclear area, or a single point of origin.
2. African agriculture is characterized by a rather unusual number of dominant crops. In Arabic 'ašh means "life," and in the Sudanic savanna the word is applied to sorghum — the staff of life, the source of sustenance. Life without sorghum is unthinkable. To the north in the Sahel, 'ašh means "pearl millet." Life itself depends on pearl millet, and pearl millet alone, in that ecological zone. To the west around the Bend of the Niger, the word may be applied to rice by some Arabic speakers. Certainly in West Africa, from Senegambia to central Ivory Coast, a meal without rice is considered no meal at all. The same intense dependence of a people on a single crop is found in the yam zone. Existence itself depends on yams. In different parts of the continent other dominant crops are ensete, tef, and fonio.

It seems that African agricultural systems tend to become heavily dependent upon single crops. The dependence on bananas in some parts of Uganda must have developed since the crop was introduced into Africa. The current dependence of some people on maize and others on cassava indicates that dependence on single crops does not take long to establish. Whatever the reasons may be, we suggest that the number of dominant crops has contributed to the mosaic pattern just referred to.

3. While we cannot point to one geographic region as a center of agricultural innovation, the adaptation of the major crops and their wild relatives suggests some ecological clustering as indicated below:
   a. Forest — savanna ecotone: Oil palm (Elaeis guineensis), yam (Dioscorea sp.), cowpea (Vigna unguiculata), yampea (Sphenostylis stenocarpa), guinea millet (Brachiaria deflexa), black fonio (Digitaria iburua), Hausa potato (Plectranthus esculentus).
   b. Savanna: Sorghum (Sorghum bicolor), pearl millet (Pennisetum americanum), voandzeia (Voandzeia subterranea), rice (Oryza glaberrima), cotton (Gossypium herbaceum), fonio (Digitaria exilis), roselle (Hibiscus sabdariffa), watermelon (Citrullus lanatus), karité (Butyrospermum paradoxum), parkia (Parkia sp.), sesame (Sesamum indicum) (if African).
   c. East African highlands: Tef (Eragrostis tef), noog (Guizotia abyssinica), ensete (Ensete ventricosus), finger millet (Eleusine coracana), chat (Catha edulis).

   Most of the important crops grown in the forest zone appear to have been imported from the savanna or the forest-savanna ecotone. As we have indicated, the oil palm does not tolerate deep shade, and its original habitat was probably the forest-savanna ecotone. As will be elaborated by Coursey (this volume), yams with large tubers are native to the savanna, the tubers providing food storage which enables the plant to survive long dry seasons and periodic burning. The wild yams of the wet forest have less tuber development. Although African rice is now grown to the Guinea coast, it was domesticated from the annual Oryza barthii which is a savanna grass adapted to shallow water holes that dry up in the dry season. Only a few African crops are true forest species. They include coffee, cola, akee apple, and possibly a few others. The domesticated plants that provide food for peoples of the forest zone are almost all introductions from the savanna.

4. The present savanna agriculture of West Africa is strongly influenced by décru techniques. In French crue means "flood," and décru, "the period when the flood waters recede." Lacking an appropriate English word, we adopt the French for convenience. There is no space here to elaborate fully on the remarkably sophisticated décru agriculture that has evolved around the Bend of the Niger — Lake Faguibine area. The cultivators there have developed a number of options to help them deal with floods that are erratic in height and duration. The options include choice of crops, choice of cultivars, choice of seeding rates and hill spacing, time of sowing, and direct seeding versus transplanting. Cultivars are chosen for length of growing season, nutritional and storage qualities, adaptation to soil type, bird resistance, and ability to tolerate flooding before harvest. In some areas, sorghum and even pearl millet are harvested from a canoe because the waters rise before maturity. Some details are presented by Harlan and Pasquereau (1969).

   A décru crop must mature on moisture stored in the soil. Any device that will speed up the life cycle of décru crops can be useful. One of the most common is transplanting, and sorghum is the crop most often handled in this way. Seedlings are established in a bed of sandy soil. As the waters recede and land becomes available, the seedlings are uprooted and placed individually in deep dibble holes provided by ramming a stake into the soil. The transplant dibble is 1.5 to 2 meters in length and the holes are often 30 to 40 centimeters deep. Transplanted sorghum is grown not only on lands vacated by floodwaters, but in low spots in the savanna where water stands during the rains. Burning off the vegetation at the end of the rains may be the only land preparation other than making the dibble holes. The practice permits the use of land that is too soggy and wet during the rains for sorghum. Under special circumstances, pearl millet may also be transplanted.
Although we have no proof, it seems likely that the original décrue techniques were learned along the margins of the Sahara or in what is now the Sahara itself. We have ample evidence of villages located at the margins of shallow lakes, now dried up, but which at the time of occupation would enlarge during the rains and shrink during the dry season. This, we suggest was the ideal situation for learning décrue techniques, now practiced under more demanding situations along the flood plains of the Niger, Senegal, Benue, and other West African rivers.

5. African agriculture is a hoe and digging stick agriculture; the techniques of production, at least, are based on human labor. The plow and draft animals are hardly used in traditional agriculture except in Ethiopia and northern Sudan. Tsetse fly may be a contributing cause but can hardly explain the complete dependence on human energy in some areas. The labor expended is enormous. With incredible human effort the soil on millions of hectares is turned every year by hoes. In Senegambia a long-handled spade-like instrument is used to shape land and dig ditches for rice production. Mounding, ridging, and ditching are common in the wetter areas.

Other techniques also require a large expenditure of human energy. While grinding is common, the wooden mortar with pestle is the most universal equipment for reducing plant food materials for consumption. The sickle is used for harvesting rice and fonio in West Africa and for teff and small grains in Ethiopia, but little used elsewhere. Elaborate rock-walled terraces are or were constructed in widely separated regions on the continent.

6. Several practices have evolved to sustain or improve soil fertility. Most of them are found in some form elsewhere, but a few are characteristically African. The most general is shifting agriculture, bush fallow or slash and burn. The African procedures differ little from those developed in Southeast Asia, Oceania, or the Americas. The most specialized of the slash and burn techniques is the chitemene practiced in East Africa. In this system, branches are lopped from trees over a wide area and carried to the plot to be burned in order to produce a hotter fire and more ash.

Mounding and ridging are very general in the wetter zones. Both mounds and ridges tend to concentrate top soil as well as provide drainage and aeration. Soil burning is practiced on the higher parts of the Ethiopian plateau. Here the soils are so cold that organic matter accumulates to the point that clods of soil can actually be ignited. The practice of burning makes phosphorus more available (Wehram and Johannes 1965).

The use of Acacia and livestock for soil improvement has already been mentioned. In West Africa some sedentary villagers often arrange for the more nomadic Fulani to pasture stock on their fields after harvest for the benefits derived from manure. A few groups stall feed cattle in order to accumulate manure for their fields.

Thus, we conclude that: (1) African agriculture has a number of unique characteristics which appear to be indigenous and are not likely to have been derived from the Near Eastern system; (2) that African agriculture is far from homogeneous and consists of a mosaic of crop and technique combinations occupying different regions; and (3) there is a suggestion of a southward movement with décrue techniques infiltrating the savanna from the Sahara and savanna crops moving into the forest. These matters are covered in more detail in this volume by Harris, Shaw, and Purseglove.

CAUSES

The question of causes is treated by several contributors to this volume — especially Pfieffer, Higgs, and Smith. A number of points were also brought out in the discussions not covered in the papers. We can sum them up very easily by saying we really do not know what happened, but some factors were identified that were possibly preadaptive or that set the stage so that plant domestication could proceed. Other factors were suggested that might have triggered off the process.

Some factors that might be considered preadaptive are:

1. Protective attitudes toward plants. Useful plants are protected more or less throughout Africa and the attitude is often reinforced by ritual, belief, and "superstition."

2. Social systems that tend to favor larger group size and resist extreme fragmentation. This varies, of course, and some of the present hunter-gatherers seem to favor small groups to avoid quarrels. To the extent that larger group size is socially favored, agriculture may appear as an attractive option. Agriculture is a way to provide for large numbers of people living together in a small area.

3. Advanced hunting-gathering technologies may preadapt people for agriculture. Pottery, grinding equipment, sickles or reaping knives apparently were all available before we have evidence that plant domesti-
cates were actually being grown.
4. Productive habitats may provide opportunities for experimentation and innovation. The habitats identified in this connection were the shallow lakes of the Sahara before they dried up and the savanna-forest ecotone. The archaeological and ethnographic evidence suggests that good fishing was important to sedentism and stability.

Two demonstrable factors impinge on the African scene that might have triggered off domestication processes: the desiccation of the Sahara and the expansion of the Near Eastern agricultural system. As long as populations are comfortably in balance with their environments, radical innovations are not likely to occur although this may be a situation most fruitful for experimentation. As the lakes in the Sahara began to dry up, the hunting—fishing—herding—gathering people were forced to move southward into zones that might already have been rather intensely exploited by hunter-gatherers or even other agricultural economies. Contraction of the most favorable ecological zones might have applied stresses along the forest-savanna margins as well. The resulting imbalance may have stimulated more intense genetic manipulation of plant populations.

As to stimulus from the Near East, the evidence is equivocal to say the least. Livestock herding and pottery appear to have been widespread in the Sahara before they were found along the Nile. On the whole the stage seems to have been set in the Sahara and southward before clearly demonstrable connections with the Near East, but our evidence is too sketchy for definitive conclusions. The subject is treated in some detail in the papers by Clark and by Wendorf and Schild.

A third factor that could have been a triggering mechanism is simply a gradual increase in population density to the point that adjustments were required. The African savanna is exceptionally rich in food resources, and as long as population densities were low, there would always be room for people to exploit new ranges. Climatic stresses probably had little influence on basic hunting-gathering economies. With a rise in population density, however, stresses could become critical and a point of no return reached after which the man-plant relationship could only intensify. In due time man became as completely dependent on his crops as fully domesticated plants are dependent on man.

In this volume we have tried to assemble what evidence we could, and we have made the most reasonable interpretations we could. At this stage of our investigations, however, the evidence is so meager that we may find it necessary to revise our models radically as future studies provide new information.

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