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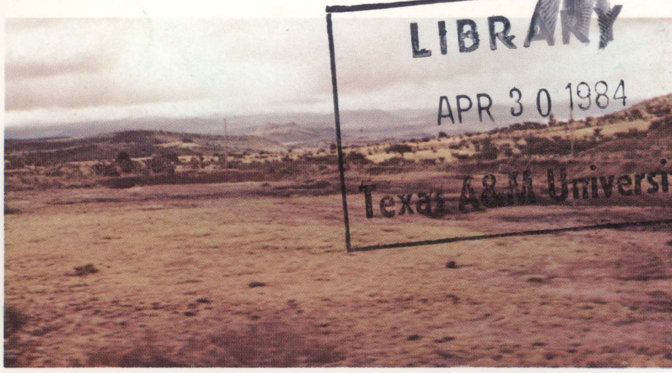
The Origin and Early Cultivation of Sorghums in Africa



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The Origin and Early Cultivation of Sorghums in Africa

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Major physical features of Africa identified in the text.

National boundries and locations of archiological sites mentioned in the text.

Foreword

Sorghum is a major food and feed crop throughout the world. It is a species of tropical origin, but in recent history it has been adapted, through selection, to the temperate regions of the world. Sorghum remains the staple food of many countries in Africa and Asia. It is now a major feed grain crop in the United States, Mexico, Argentina, Australia, and South Africa.

Because of drought resistance found in the species, sorghum is important in marginal rainfall areas of the world. The ability of sorghum to perform well under limited moisture and high temperature conditions where other crops often fail makes it an extremely important commodity in providing the necessary food and feed for millions of people in both developing and developed countries.

The improvement of any species depends largely upon an accumulated knowledge of the species and the efficient utilization of its genetic diversity. Africa is either the center of origin, or a major site of diversification of much of the sorghum germplasm available in the world. Knowledge of where types originated and how they might have moved within Africa is very important to our efficient utilization of the germplasm in our breeding programs. If we know more about the history of Africa, and can draw from that knowledge sound inferences about how, where, and when sorghum was domesticated and diversified, it will help explain the adaptation of sorghum to specific climatic zones, and what traits various types are likely to possess.

Thus, a better knowledge of sorghum history will allow breeders to more accurately forecast what traits might exist in materials presently used, and also to forecast where we might collect materials with particular traits needed in germplasm collections. This publication presents several alternate hypotheses on origin and domestication of sorghum in Africa, in consideration of archeological findings. A new look at ancient events should lead us to new or expanded concepts. This treatise primarily expands on previous theories of the origin of sorghum and suggests that domestication of sorghum may well have occurred much earlier than previously thought. It is not the purpose of the authors to dispute or discredit previous concepts on the origin of sorghum, but to present in a concise manner the various theories of domestication of sorghum.

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The Origin and Early Cultivation of Sorghums in Africa

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Introduction

The origin, domestication and early distribution of sorghum (*Sorghum bicolor* (L.) Moench) in Africa is of interest to those concerned with the origins of agriculture, but it has a special importance to those who deal directly with the crop today as agriculturists. The historical geography of sorghum's origins gives clues as to why the crop exists in its present form, and also provides valuable insights into where exploitable germplasm of a given type might exist, and what characteristics relate to sorghum's adaptation to different ecological zones within the general area of origin.

The interaction of early sorghums and man may well have come about far earlier than current evidence suggests (56,57). Alternatives will be explored from a human ecology viewpoint based on changing physical environments.

Climate

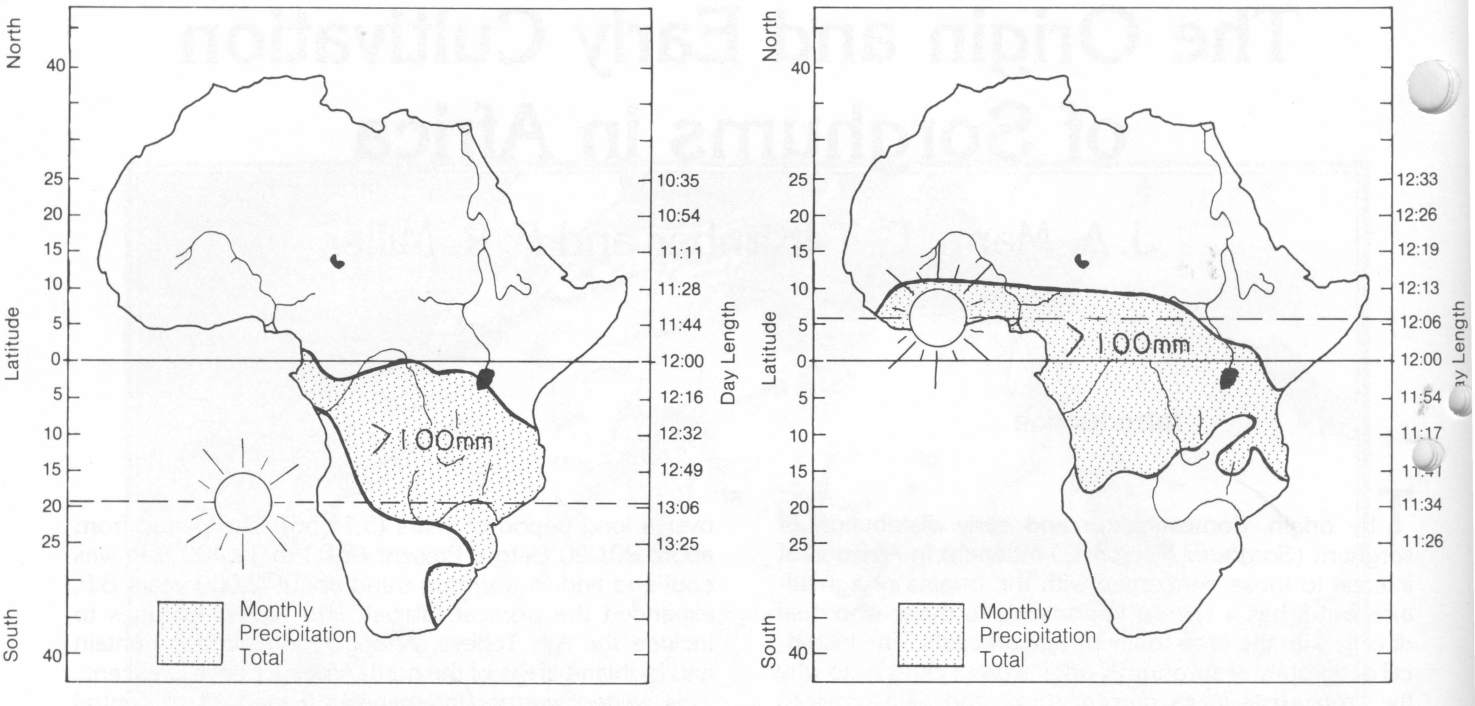
The climate of central Africa from the Tropic of Cancer in the north to the South African plateau in the south is largely controlled by the position of the Intertropical Convergence Zone, associated with the shifting of the high sun throughout the year (Figure 1) and the equatorial trough (35). The tropical marine air mass originating over the Atlantic contributes the moisture for most of Africa as far east as the Rift Valley. The monsoon, another system from the Indian Ocean, influences the areas from the Rift eastwards (79). The relationship of temperature to precipitation in this tropical rain belt is opposite to that in the extreme north and south of the continent. At these extremes, rainfall is inversely correlated to temperature, so that more rain falls in the cooler seasons. Within the central tropical belt, rain is more likely in the warmer seasons. Because this central belt across Africa is the main area of concern for this publication, a knowledge of long term temperature and rainfall patterns in the area will be useful in looking for times which may have been propitious for the cultural/biological events of domestication to occur.

The general pattern in northern Africa (south of 15-20 degrees N) has been one of dessication and revegetation over a long period of years (5,17,56). The period from about 20,000 Before Present (B.P.) to 12,400 B.P. was cool and arid. A warming trend about 12,000 years B.P. expanded the tropical rainbelt into higher latitudes to include the Aïr, Tebesti, Ahaggar and other mountain and highland areas of the north African 'Fertile Crescent'. This wetter, warmer interpluvial affected all of central Africa from Mauritania to Ethiopia and south to Tanzania (4) for much of the period from 12,000 to 4,500 B.P. The period 8,000 to 7,000 B.P. was drier, however. From 4,500 B.P. until present much of central Africa has been in a cooling and drying phase (35,56).

The cycles of cool, dry to warm, wet weather which have characterized this area for so many thousands of years may have played a role in the domestication event(s) of sorghum and other crops (12). During the warm, wet periods, the Sahara, Sahel and Sudanic belts were mostly savanna occupied by plains game, and containing numerous streams and waterfilled depressions (4,53). It is likely that among the evolving flora of these areas were the wild ancestors of today's African cereal grains. As the weather cycle turned dryer, the true desert and its sahelian fringe would have expanded southward. Within this area, changes in altitude are equivalent to changes in latitude, such that the mountains would have dried from the bottom upwards at the same time and in the same way the lowlands dried from the southern desert fringes southward. As the true desert moved both southward and upward, the semi-desert steppe and savanna contracted (11,44,56). This meant a gradual drying of permanent lakes, streams and other features likely to have been food source foci for early hunters and gatherers. The two major rivers, the Nile and the Niger, would have varied in both level and volume as the climate changed.

The shrinking of habitable areas might have decreased food supplies to the point that the inhabitants turned to agriculture and domestication of crops. It is also likely that during some of the following wet periods they abandoned agriculture as it became unnecessary for their sustenance.

The kind of variation possible in vegetation due to the aforementioned wet and dry cycles is shown in Figures 2 and 3. Of special interest is the dramatic contraction of



Position of the sun on January 15.

Position of the sun on April 15.

Figure 1. The climates of central Africa from the Tropic of Cancer in the north to the South African plateau in the south are controlled by the high sun position and the location of the Equatorial Trough. Day length, moisture, and temperature provided the framework for cultural adaptation of crops.

the savanna and semi-desert steppe regions from the wet situation of 5,000 B.P. (Figure 2) to the dry situation today (Figure 3), and the enormous expansion of true desert. It should be noted that as livestock herding became more common, environmental degradation due to overstocking may have confounded the effects of climatic change. What in the record looks like climatic change may have been desertification caused by overgrazing.

As the expansion and contraction of the savanna and semi-desert steppe regions north of the equator took place, the most advantageous habitats would have also moved north and south, and thus been in slightly different day length patterns over time. These critical few minutes in day length would have affected the adaptation and distribution of wild plants as they came under selection and domestication pressure. Wild and early domesticated sorghums were photoperiod sensitive, and required short days to flower.

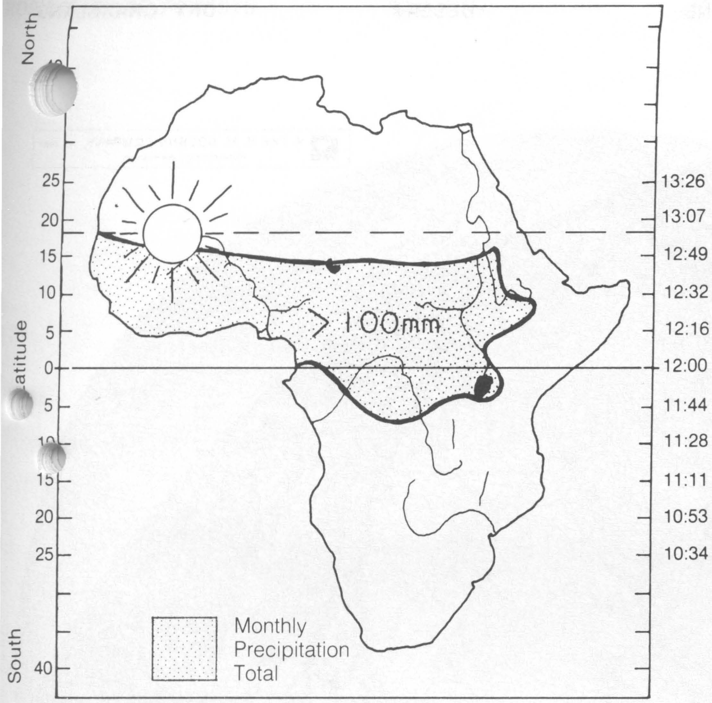
Migration

Other events or processes which may have been important in the origin, dispersal, and domestication of sorghum are movements of people around the continent (migration) and trade routes which might have carried sorghums or ideas about agriculture from one place to another (Figure 4). The archeological records to document such movements are rare for Africa, especially south of the Sahara.

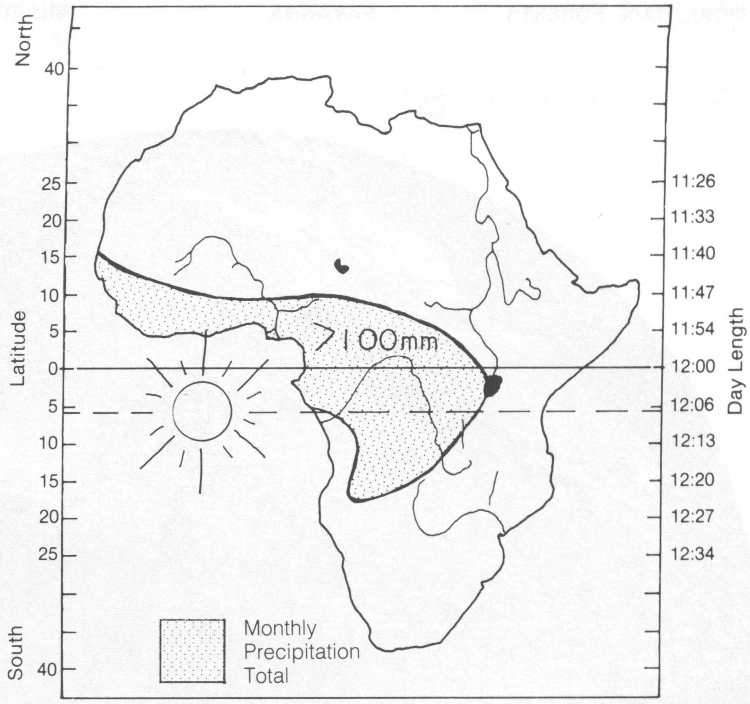
Modern man seems to have replaced Neanderthal man some forty to thirty thousand years ago (11,31). Probably well before 9,000 B.P., the present races in Africa had differentiated, with Koisan or Bushmanoid peoples in the south and east, Negroid peoples in the west, north and central parts, and Afro-Mediterranean/Afro-Asiatic (Caucasoid) peoples along the Mediterranean coast and in northeastern Africa (11,63).

During the Makalian Wet phase (about 7,000 B.P. to 4,500 B.P.) there was likely considerable movement of peoples north and south across the Sahara and Sahel (9,10) as well as a number of at least semi-permanent habitations in that region (11). Further east there is evidence of Caucasoid pastoralists moving into East Africa from Ethiopia/Sudan as early as 12,000 B.P. (63). More importantly for this discussion, the Cushites, after being driven out of Egypt into the Sudan, may have filtered down into Kenya and Tanzania as early as 5,000 B.P. At some point they possibly introduced eleusine millets (*Eleusine* spp.) and sorghums into the area, which were later adopted by the Bantu (45,62).

Another migration of great importance is that of the Bantu (or proto-Bantu) from the area of eastern Nigeria and northern Cameroon through the forests to Katanga, and later on to East Africa. The proto-Bantu were a Negroid stock closely related to the Niger-Congo people (if not actually of that stock). While originally thought to have been due to the movement south of a war-like Iron Age people bent on conquest (78), the accepted view now is that the 'Bantu Expansion' was a slow movement of an expanding populace into the forest as their technology permitted and their population size demanded



Position of the sun on July 15.



Position of the sun on October 15.

(61,62). The movement of the proto-Bantu may have begun after the introduction of iron tools and Southeast Asian food crops such as banana (*Musa sapientum* L.), taro (*Colosasia esculentum* (L.) Shott), yam (*Dioscoria* spp.), etc. into West Africa about the turn of the Christian era (61). Newer evidence indicates that the forest was penetrated by people using indigenous yams and stone tools much earlier (57). McIntosh argues for acquisition of Southeast Asian crops via the Zambezi valley after about 1,400 A.D. (55). The reason for the Bantu move is difficult to guess, although increased population pressures due to a contracting forest/savanna may be one reason (c.f. 17, 85). The route of the migration is disputed, but a 'cultivation belt' cuts through the humid forest from present Kinshasha to Katanga, indicating a slow migration with concurrent agriculture (34) south through the forest, then southeast along its margin (66). Others speculate the course may have been east along the northern margin, then south just west of the Rift Valley (30). In any case, the migration seems to have stopped temporarily in the light woodlands of Katanga, a region of similar ecological nature to the homeland they had left (55,61). By 700 to 800 A.D. a Bantu Kingdom had been established there (62), and linguistic evidence indicates that Katanga was the center of origin of the Bantu languages.

The food production complex of sorghum and millets (*Eleusine, Panicum, Pennisetum* and *Setaria* spp.), the banana and Asian yam, and iron tools set the stage for the rapid increase in population. This resulted in the expansion of the Bantu to the Atlantic and Indian Ocean coasts, then into the higher rainfall areas of East and central Africa (i.e. the highlands and coastal belt) and finally the drier areas of the savanna (55,61). By the middle of the present millennium, the expansion of the Bantu into eastern, central, southern and southwestern Africa was complete (55).

The last migration of concern was the movement of several Caucasoid peoples out of the central Sudan after the Muslem invasions and collapse of the Christian Kingdom of Nubia. In the subsequent unrest, about 1,300 to 1,500 A.D., the Lwoo (now Luo) moved south and occupied areas north and east of Lake Victoria, evidently carrying their sorghums with them (9,16,18,25,61, 62,86).

Trade

The other process which may have played a role in the dispersal of sorghum is trade, both intercontinental and intra-African (Figure 5). There is no firm archaeological evidence for trade across the Sahara before Roman times. Law, however, describes earlier trade routes from Egypt to the Fezzan then southwest via Tassili and Ahaggar to the Niger (51). A more complete network developed in the first millennium A.D. (58), which included routes from Sudan/Ethiopia across the Sudanic belt to Lake Chad and on into Niger, Upper Volta and Mali. By 500 A.D. there was trade between areas of central Sudan and East Africa down the Western Rift (52). This may have connected the proto-Bantus with the Nilotes of Sudan.

In the first millenniun A.D., most of the trade in East and northeast Africa was with Arabic, Indian, and Indonesian traders. They brought in a variety of manufactured goods and other products (including foods and food

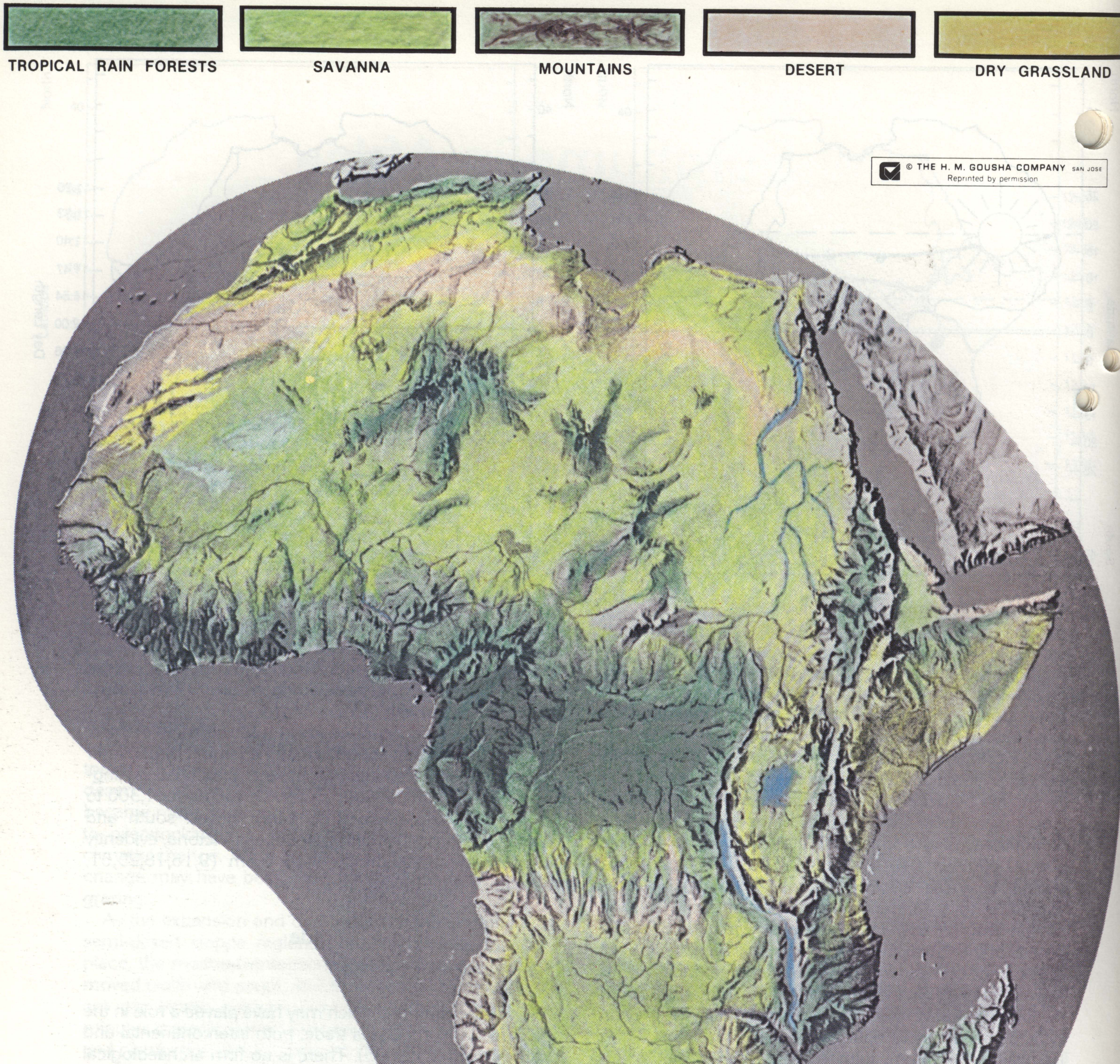


Figure 2. Five thousand years ago the temperature regimes, rainfall patterns, and resultant vegetation were markedly different from today. These different environmental conditions made much of northern Africa a more hospitable environment for sorghum.

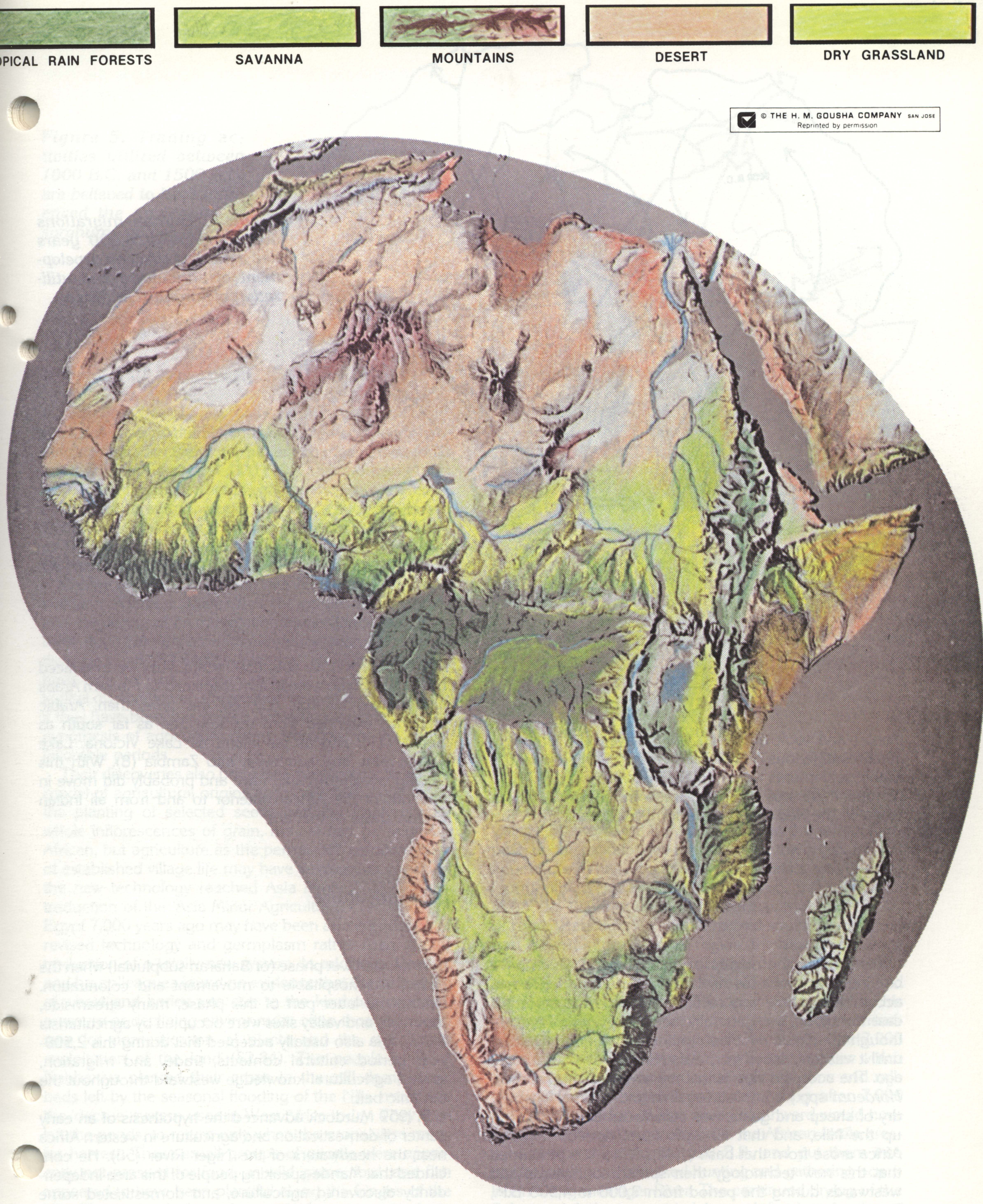


Figure 3. Drier climate resulted in an expansion of the deserts and contraction of savanna and tropical vegetation (3,000 B.P. to present).

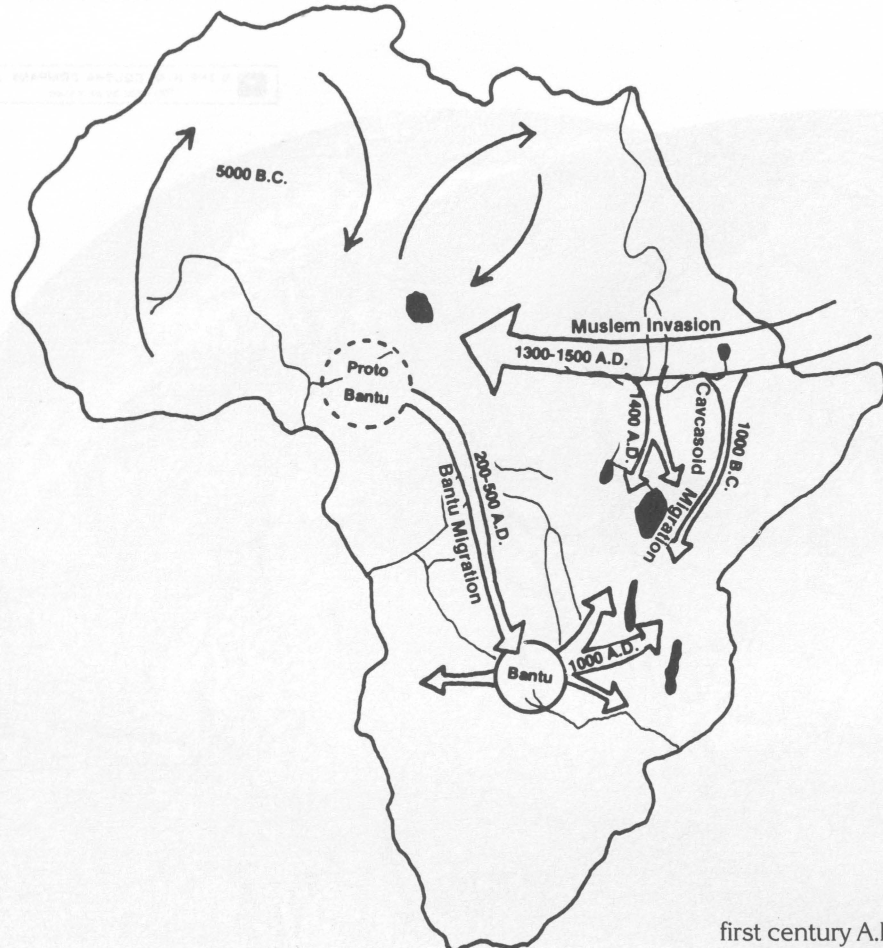


Figure 4. Human migrations over a period of 6,500 years had a marked effect on development of agriculture and utilization of sorghum in Africa.

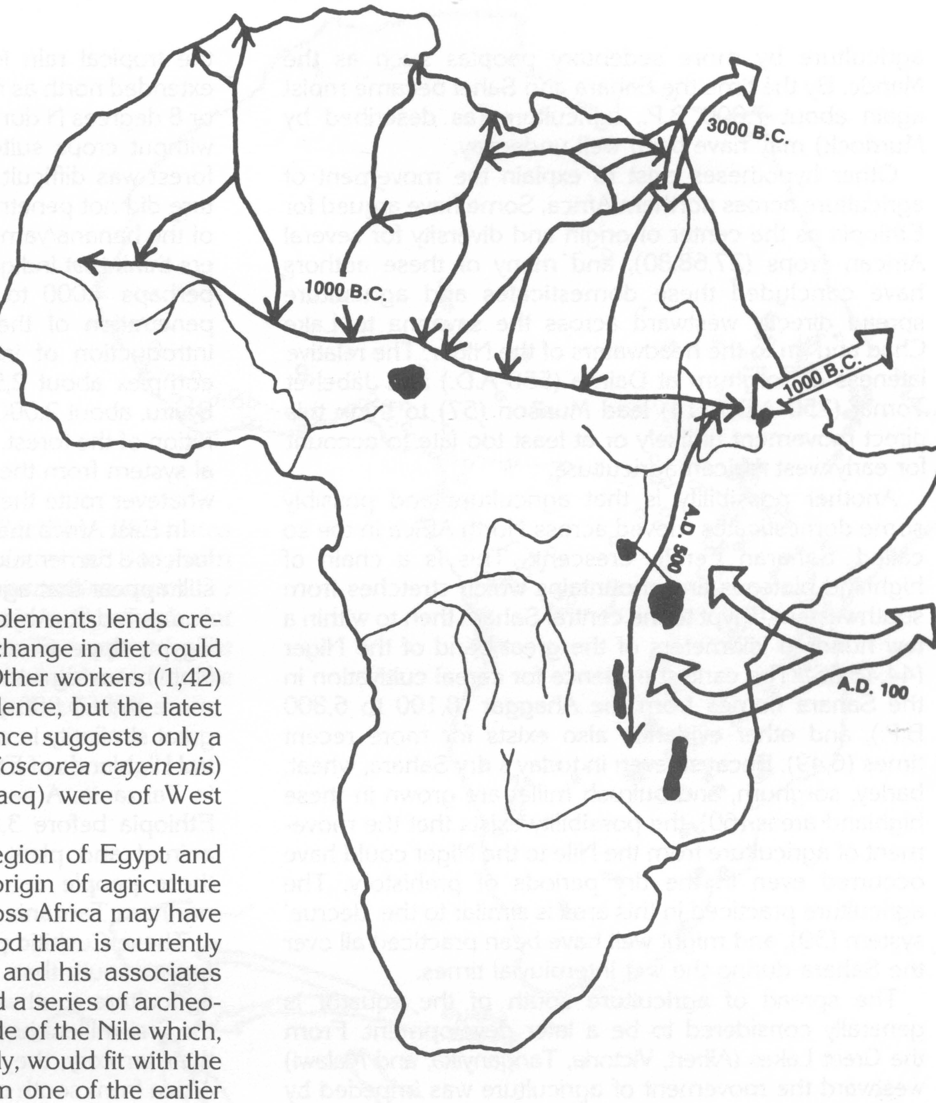
plants) and took out gold, ivory, slaves and probably certain indigenous African food crops (2,40). Permanent Arabic settlements were in place in Zanzibar by 107 A.D. (2) and there was extensive trade from Pate south to Kilwa. In the Red Sea, Egypt dominated trade from the first century A.D. for about 500 years. They were replaced by Persians, who were in turn displaced by Muslem Arabs and Indians by 700 A.D. By this time, then, Arabic influence extended from the Red Sea as far south as Sofala (19), and as far inland as Lake Victoria, Lake Tanganyika, and southwest into Zambia (8). With this trading, sorghum could have and probably did move in and out of the African interior to and from all Indian Ocean states of that era.

The Origins of African Agriculture

Ideas about the origins of agriculture in Africa have continued to evolve as new archeological evidence has accumulated. Until very recently, no evidence existed to cast doubt on the generally held view that Africa, although the oldest peopled continent, had no agriculture until it was introduced from Asia Minor about 7,000 years ago. The accepted view is that the wheat/barley (*Triticum/Hordeum* spp.) complex, together with animal husbandry of sheep and goats, was introduced about this time up the Nile, and that all agricultural developments in Africa arose from that base (1,42,58,71). It is presumed that this new technology then spread southwards and westwards during the period from 7,000 to 4,500 B.P., first south up the Nile and then into the Sahara during the Makalian wet phase (or Saharan subpluvial) when the desert was hospitable to movement and colonization. During the latter part of this phase, many streamside, mountain and valley sites were occupied by agriculturists (9,42). It is also usually accepted that during this 2,500-year period cultural contacts, trade, and migration, spread agricultural knowledge westward throughout the Sudanic belt.

In 1959 Murdock advanced the hypothesis of an early center of domestication and agriculture in western Africa near the headwaters of the Niger River (58). He concluded that Mande-speaking people of this area independently discovered agriculture, and domesticated some thirty African crops. While not proving domestication, the

Figure 5. Trading activities utilized between 1000 B.C. and 1500 A.D. are believed to have influenced the movement of sorghums across Africa.



presence of agricultural/cooking implements lends credence to the idea that a permanent change in diet could have taken place about 7,000 B.P. Other workers (1,42) have given the theory botanical credence, but the latest botanical and anthropological evidence suggests only a few of these thirty such as yam (*Dioscorea cayenenis*) and oil palm (*Elaeis guineensis* Jacq) were of West African origin (42,66).

Recent evidence from the Nile region of Egypt and northern Sudan suggests that the origin of agriculture and the timing of its movement across Africa may have been during an earlier climatic period than is currently thought (75,81,83,84,85). Wendorf and his associates have, over the past 12 years, reported a series of archeological discoveries on the western side of the Nile which, if they have been interpreted correctly, would fit with the hypothesis of agriculture dating from one of the earlier favorable periods.

Their discoveries also bring into question the accepted model of agricultural origins and dispersals. Agriculture, the planting of selected seeds and the harvesting of whole inflorescences of grain, may in fact be originally African, but agriculture as the permanent resource base of established village life may have developed only when the new technology reached Asia Minor (71). The introduction of the 'Asia Minor Agricultural Complex' into Egypt 7,000 years ago may have been an introduction of revised technology and germplasm rather than the introduction of a totally new system. In addition, Wendorf and his colleagues found no evidence that the cultivation of wheat and barley was due to the kind of population pressure or declining environment often thought necessary for domestication of plants and the agricultural exploitation of the land (82,84). The people of Wadi Kubbaniya planted their crops in the still damp pond beds left by the seasonal flooding of the Nile, much like the 'decrue' system used in West Africa today. They then left the ponds, to return only when the crops were ready for harvest. These small groups of people were apparently not pressed for food, as wild game, fowl, and fish appeared to have been plentiful along the fringes of the Nile. Thus, a kind of transient agriculture seems to have developed there without the kind of crisis often deemed necessary for such change (85).

On the other hand, because of the hospitable environment in the Sahara and the Sahel during the wet interpluvial (12,000 to 8,000 B.P.) it seems that this would have been an auspicious time and place for the beginnings of agriculture. These incipient agriculturists would have found wild cereals adapted to the region, and agriculture might have sprung up in the Sahara as much as 10,000 or more years ago. As people moved south to north and east to west in the Saharan region, the basic technology of agriculture and domestication could have spread across sub-Saharan Africa. It would seem possible and even probable that while Murdock was wrong in his conception about a center of domestication at the headwaters of the Niger, he may have been right that 7,000 years ago there developed an agricultural center which grew a number of crops (including sorghums and millets) currently thought domesticated long after 7,000 B.P. The expansion of true desert southward would have forced the 'casual' agriculturist in the African fertile crescent southward around 8,000 B.P., and put them into contact with an established hunting and gathering population along the Niger River. The continued drying of the Sahara might have provided the push for the adoption of agriculture by more sedentary peoples such as the Mande. By the time the Sahara and Sahel became moist again about 7,000 B.P., agriculture (as described by Murdock) may have been well underway.

Other hypotheses exist to explain the movement of agriculture across northern Africa. Some have argued for Ethiopia as the center of origin and diversity for several African crops (27,68,80), and many of these authors have concluded these domesticates and agriculture spread directly westward across the savanna to Lake Chad and on to the headwaters of the Niger. The relative lateness of sorghum at Daima (550 A.D.) and Jabel et Tomat (250 A.D.) (14) lead Munson (57) to think this direct movement unlikely or at least too late to account for early west African agriculture.

Another possibility is that agriculture and possibly some domesticates moved across North Africa in the so called 'Saharan Fertile Crescent'. This is a chain of highland plateaus and mountains which stretches from southwestern Egypt to the central Sahara then to within a few hundred kilometers of the great bend of the Niger (44,48,66). The earliest evidence for cereal cultivation in the Sahara comes from the Ahaggar (8,100 to 6,800 B.P.), and other evidence also exists for more recent times (6,49). Because even in today's dry Sahara, wheat, barley, sorghum, and bulrush millet are grown in these highland areas (60), the possibility exists that the movement of agriculture from the Nile to the Niger could have occurred even in the dry periods of prehistory. The agriculture practiced in this area is similar to the 'decrue' system (39), and might well have been practiced all over the Sahara during the wet interpluvial times.

The spread of agriculture south of the equator is generally considered to be a later development. From the Great Lakes (Albert, Victoria, Tanganyika, and Malawi) westward the movement of agriculture was impeded by the tropical rain forest. During wet periods the forest extended north as far as 13 degrees N, and receeded to 7 or 8 degrees N during the dryer periods (56). In any case without crops suited to such areas, penetration of the forest was difficult. Some authorities think that agriculture did not penetrate the forest belt until the acquisition of the banana/yam complex from Malaysia (58,66). Others think that indigenous yam agriculture is much older, perhaps 4,000 to 5,000 years (58,66), but that deep penetration of the forest was possible only after the introduction of iron implements into the agricultural complex about 2,500 B.P. (15). The expansion of the Bantu, about 2,000 B.P., finally accomplished the penetration of the forest, and moved an established agricultural system from the Cameroon highlands to Katanga, via whatever route they followed.

In East Africa the situation was different because of the lack of a barrier such as the tropical forest. While it would still appear that agriculture was late developing there, as compared to Abyssinia (Ethiopia), Nubia (Sudan), and Egypt, there is evidence of agricultural peoples from Nubia moving into the Rift Valley of Kenya and Tanzania more than 5,000 years ago (27,28). Doggett notes the great similarity in agricultural systems found in the Central Highlands of Ethiopia and the area near Lake Victoria in Tanzania. A second wave of Caucasoid peoples left Ethiopia before 3,000 B.P. and with them came both animal and plant domesticates. Apparent vestiges of these people can still be found in the Rift Valley of northern Tanzania (58).

These Cushitic peoples probably did not move much further south than northern Tanzania, and the spread of agriculture southwards probably waited until the end of the first millennium after Christ. As the Bantu expanded their territory, they spread agriculture through much of Africa from south of the tropical forest to Cape Province.

The Origins and Domestication of Sorghum

Domestication of plants is a process which has drawn a considerable amount of attention from a number of geographers, historians, archeologists and botanists (1,9,12,42,43,50,70,71,80). In sorghum, domestication is initiated by allelic changes at only two loci resulting from different selection pressures when harvest techniques change. This initial simple change has resulted in dramatic changes in the plants themselves and how they are used.

The basic distinction between a wild and domesticated cereal is the presence or absence of an abscission zone at the rachis, panicle, or spikelet nodes (65). The wild type progenitors of all cereals disperse their seeds by the breakage of these nodes and subsequent shattering of the seeds. As long as these wild grasses were collected by threshing the inflorescences while still on the plant, this character was maintained (even reinforced) by this type of selection. Even if these seeds were later sown, no progress was made towards domestication in this narrow sense. Selection for other characters such as seed size or quality or inflorescence size might well have been successful without completing domestication. The essential step in the domestication was the harvest of whole inflorescences, and the utilization of this grain for seed. This change in harvest technique makes shattering a strongly negative character, and those mutant types in which the rachis, panicle branch, or spikelet node remained intact suddenly had the selective advantage.

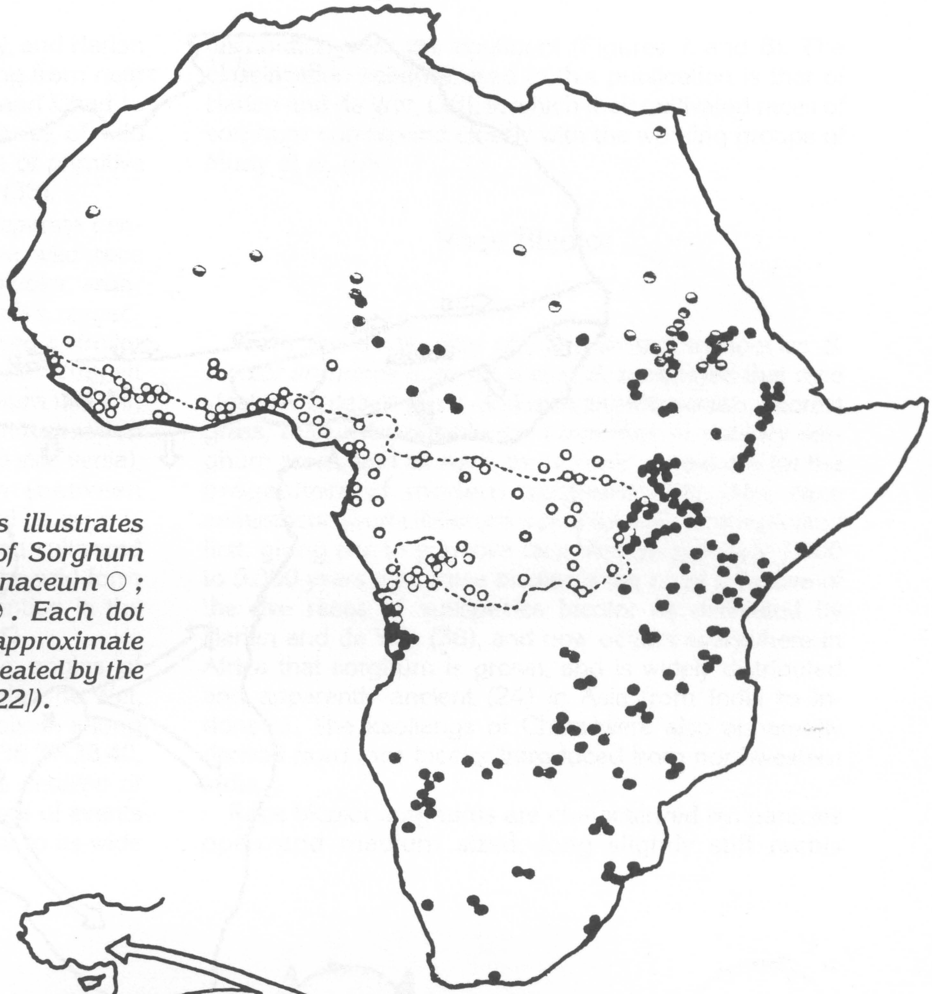


Figure 6. Mapping sorghum collections illustrates the distributions of the wild varieties of Sorghum bicolor: var. aethiopicum ◒ ; var. arundinaceum ○ ; var. verticilliflorum ● ; var. virgatum ◓ . Each dot represents one or more collections. The approximate limit of present day tropical forest is delineated by the dashed line. (From de Wet and Harlan [22]).

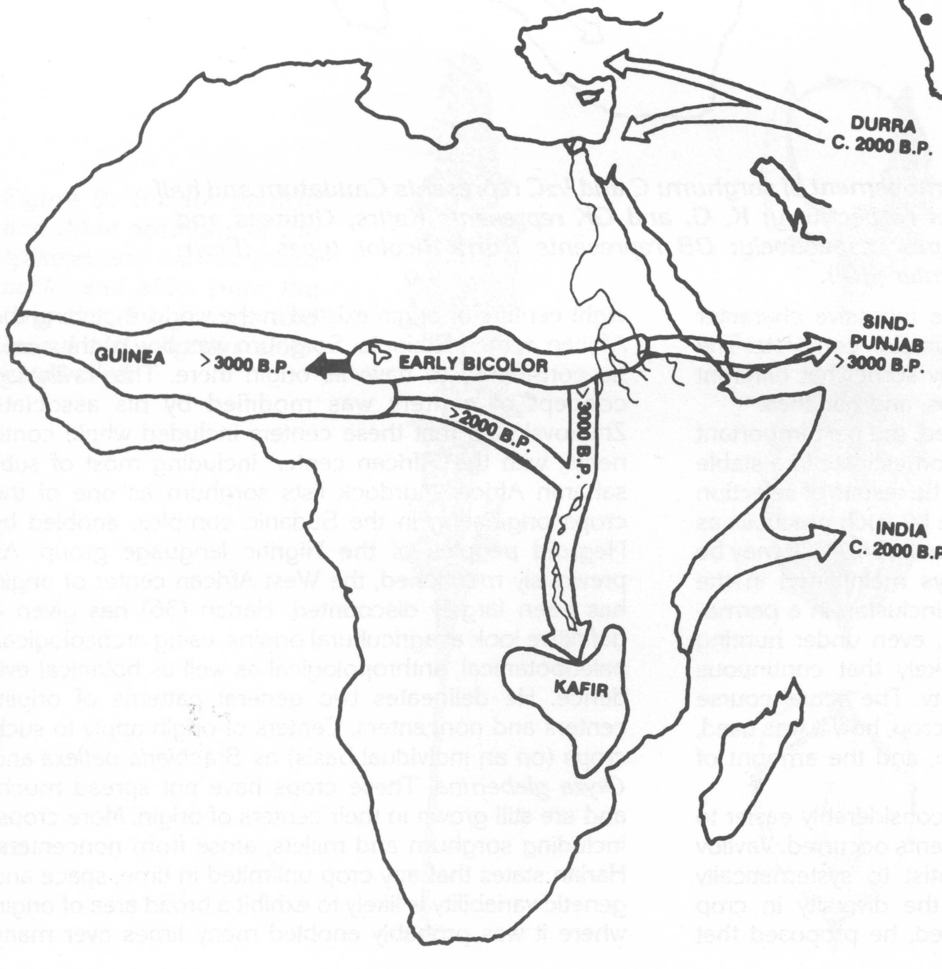


Figure 7. Presumed souce region of domesticated sorghum and early diffusion to secondary centers. (From Harlan and Stemler [40]).

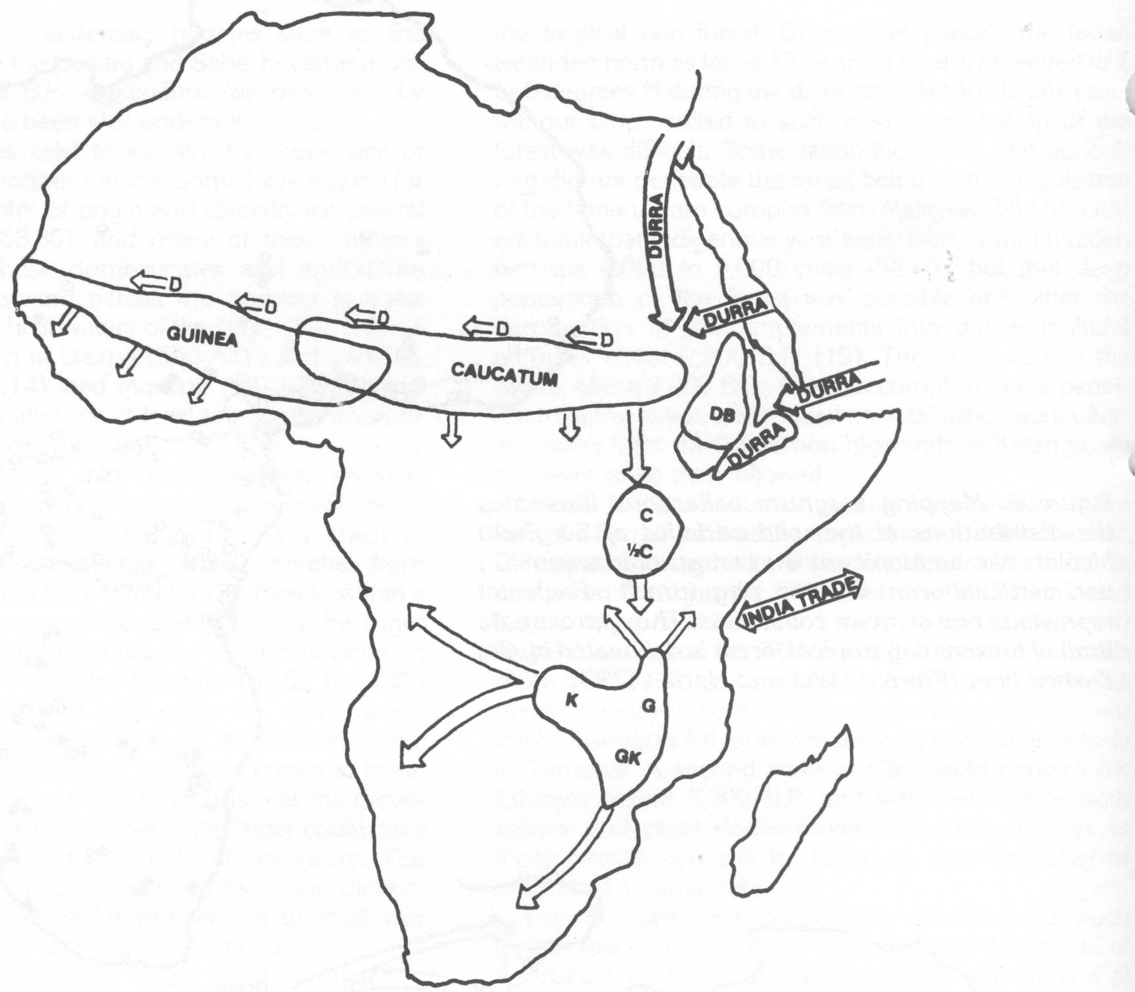


Figure 8. Later movement of sorghum: C and ½C represents Caudatum and half Caudatum types respectively; K, G, and GK represents Kafirs, Guineas and Guinea-Kafir types respectively; DB represents Durra-Bicolor types. (From Harlan and Stemler [40]).

Within a very few generations, this recessive character would have been fixed, and domestication complete. The domestication process is obviously somewhat different for tree crops, root and tuber crops, and bananas.

Once domestication has occurred, the next important step may be the inclusion of the domesticate in a stable 'village agriculture' setting, so that the results of selection and domestication are not undone by such practices as the use of wild seeds as planting stock (54,71). It may be that domesticates were not always maintained in the years between domestication and inclusion in a permanent agricultural system. However, even under hunting and gathering conditions, it is likely that continuous selection increased genetic diversity. The actual course of diversification depended on the crop, how it was used, the pollination system of the crop, and the amount of diversity present (42,50,71).

The hows of domestication are considerably easier to define than where and when the events occurred. Vavilov (80) was perhaps the first scientist to systematically examine, on a worldwide basis, the diversity in crop plants. From the evidence gathered, he proposed that eight centers of origin existed in the world, including the African center, Ethiopia. Sorghum was one of the crops he considered to have its origin there. The Vavilovian concept of centers was modified by his associate Zhukovsky so that these centers included whole continents, with the 'African center' including most of subsaharan Africa. Murdock lists sorghum as one of the crops originating in the Sudanic complex, enobled by Negroid peoples of the Nigritic language group. As previously mentioned, the West African center of origin has been largely discounted. Harlan (36) has given a definitive look at agricultural origins, using archeological, paleobotanical, anthropological as well as botanical evidence. He delineates two general patterns of origin, centers and noncenters. Centers of origin apply to such crops (on an individual basis) as *Brachiaria deflexa* and *Oryza glaberrina*. These crops have not spread much, and are still grown in their centers of origin. More crops, including sorghum and millets, arose from noncenters Harlan states that any crop unlimited in time, space and genetic variability is likely to exhibit a broad area of origin where it was probably enobled many times over many years (37). Sorghum fits this definition nicely, and Harlan envisions a noncenter for sorghum stretching from near the Ethiopian border west through Sudan and Chad to near Lake Chad. The diversity and abundance of wild and weedy species, as well as the presence of primitive race bicolor lead Harlan to this conclusion (38).

Snowden considered sorghum to have separate centers of origins for different types, with the wild race aethiopicum giving rise to races durra and bicolor, arundinaceum to guinea, and verticilliflorum to kafirs, respectively (68). De Wet and Huckaby (26) proposed a similar scheme, with durras arising from the race kafir. Doggett (27) says, given the distribution of wild sorghum races in Africa (Figure 6) and the known amount of introgression of genes from wild to cultivated species (and visa versa), the similarities observed by Snowden (between aethiopicum and durras, for example) should be expected because of mutual modification of wild and cultivated forms. In other words, the diversity seen in the wild form may, to some degree, reflect man's intervention in the selection of domesticated types.

The most widely published view of the origins of sorghum comes from the work done by Harlan, de Wet, Stemler, and others at the University of Illinois. In a long series of publications (20,21,22,23,24,25,36,37,38,40, 41,70,71,73,74,75,76) the general outline is detailed of what they find to be the most logical sequence of events from the time of sorghum's first enoblement to its wide distribution over the continent (Figures 7 and 8). The classification scheme used in this publication is that of Harlan and de Wet, (38), in which their cultivated races of sorghum correspond closely with the working groups of Murty et al. (59).

Race Bicolor

From the distribution of races in the subspecies *S. bicolor arundinaceum*, de Wet et al. concluded that race vigatum, a desert grass, and race arundinaceum, a forest grass, both exist outside the boundries of primary sorghum areas, and as such are unlikely candidates for the progenitors of modern sorghum (24). The race aethiopicum/verticilliflorum complex was domesticated first, giving rise to primitive race bicolor, probably 3,000 to 5,000 years ago. Race bicolor is the most primitive of the five races of subspecies bicolor as deliniated by Harlan and de Wet (38), and now occurs everywhere in Africa that sorghum is grown, and is widely distributed and apparently ancient (24) in Asia from India to Indonesia. The kaoliangs of China were also apparently derived from race bicolor introduced from northwestern India.

Race bicolor sorghums are characterized by: panicles open and medium sized; long slightly stiff rachis

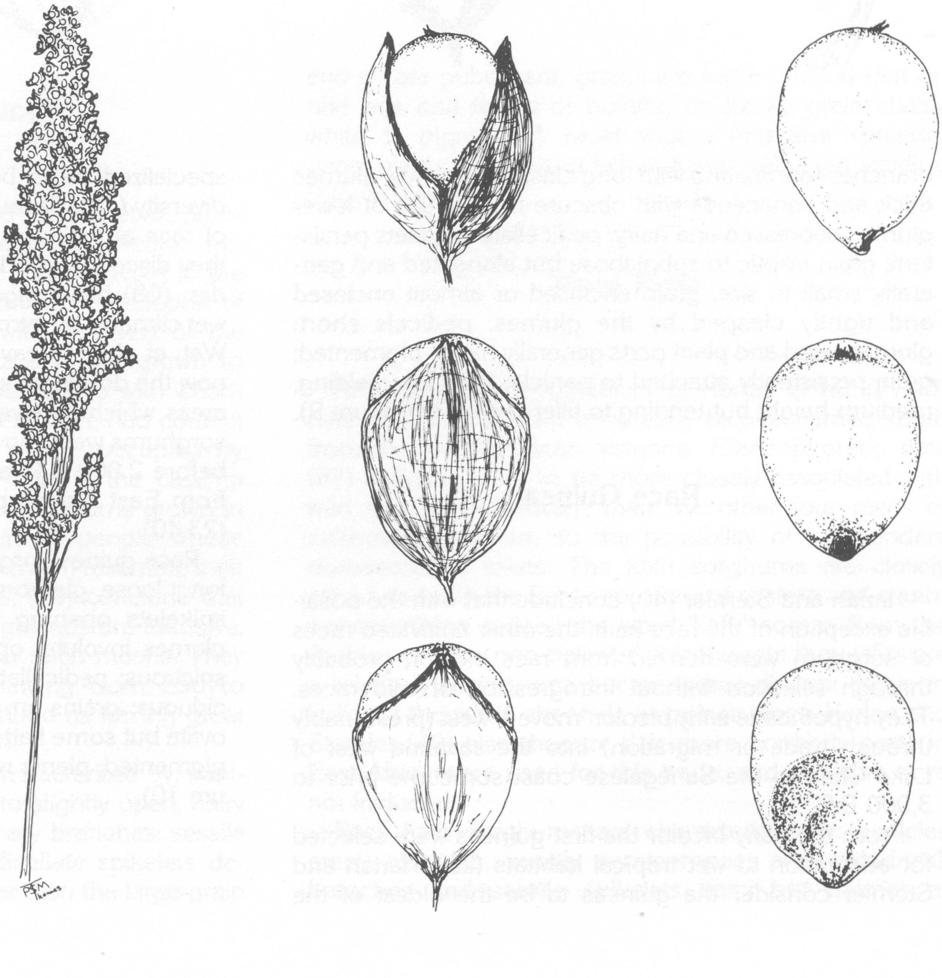


Figure 9. Bicolor panicle and three positions of the spikelet and kernel; front, back, and side. Note the long clasping glumes and round but slightly elongated seed.

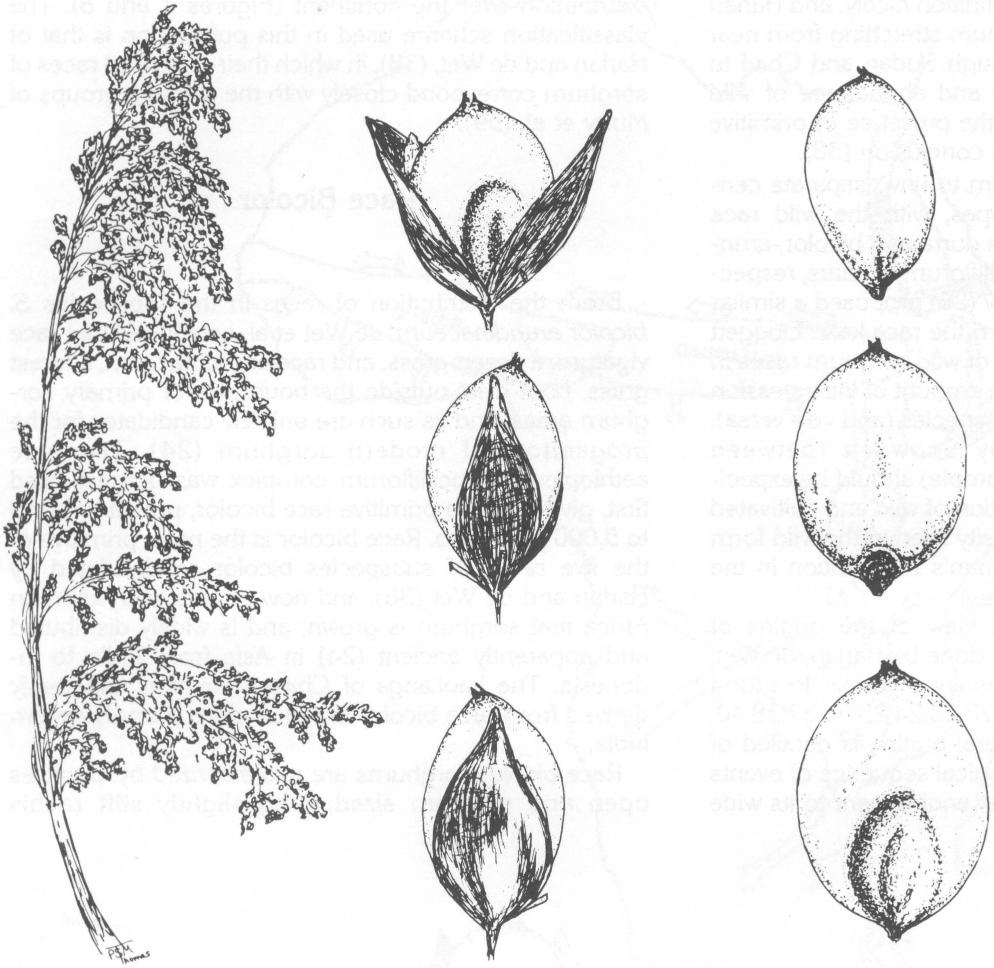


Figure 10. Guinea panicle and three positions of the spikelet and kernel. Note the long loose and pendulous panicles as well as exposed grain in the involute glumes.

branches terminating with long clasping glumes; glumes thick and coriaceous with obscure nerves; tips of lower glumes depressed and hairy; pedicellate spikelets persistent; grain elliptic to subglabose but elongated and generally small in size; grain enclosed or almost enclosed and tightly clasped by the glumes; pedicels short; glumes, seed and plant parts generally highly pigmented; grain persistently attached to panicle; fairly low yielding, medium height but tending to tiller profusely (Figure 9).

Race Guinea

Harlan and Stemler (40) conclude that with the possible exception of the race kafir, the other cultivated races of sorghum were derived from race bicolor, probably through selection without introgression of wild races. They hypothesize early bicolor 'moved' west (presumably through trade or migration) into the savanna west of Lake Chad to the Senegalese coast sometime prior to 3,000 B.P.

From the early bicolor the first guineas were selected for adaptation to wet tropical habitats (23). Harlan and Stemler consider the guineas to be the oldest of the specialized races because of its wide distribution and diversity (40). Because, they claim, the ecological niches of race arundinaceum and race guinea do not overlap, they discount arundinaceum as a direct ancestor. Snowden (68) has suggested guineas gained adaptation to wet climates by introgression with arundinaceum, and de Wet, et al. (24) leave it as a possibility. The guineas are now the dominant sorghums of western Africa, grown in areas which receive up to 5,000mm of rainfall. Guinea sorghums were moved into east and southeastern Africa before 2,000 B.P. and were then transported, probably from East African ports, to the Malabar Coast of India (23,40).

Race guinea sorghums are characterized by: panicles long, loose, glabrous and pendulous at maturity; sessile spikelets opening when mature exposing the grain; glumes involute, opening widely, hairy and awns conspicuous; pedicellate spikelets both persistent and deciduous; grains small to medium, biconvex and nearly ovate but some flattened; grain color light or only slightly pigmented; plants medium to tall and low yielding (Figure 10).

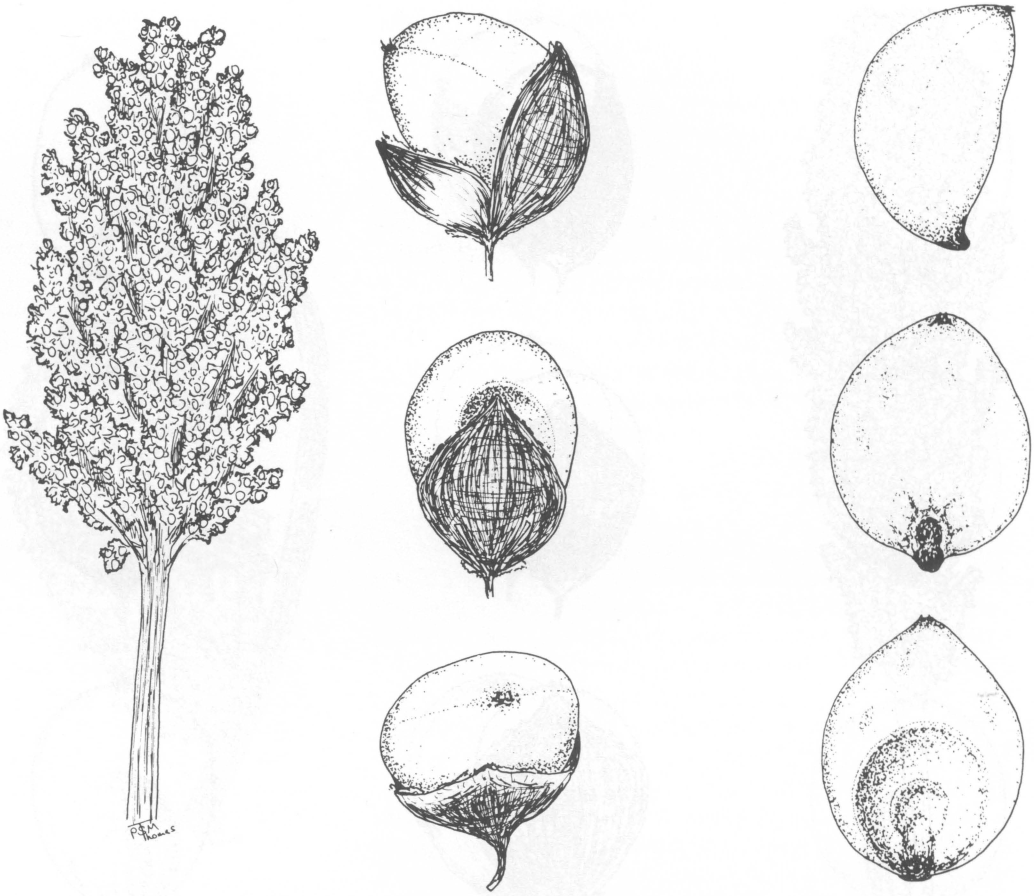


Figure 11. Caudatum panicle and three positions of the spikelet and kernel. Note the shorter glumes and longer grain which is turtle backed (flat on one side and bulging on the back).

Race Caudatum

Race caudatum was, according to Stemler et al., probably also selected directly from early race bicolor, because caudatums are for the most part restricted to the area of early bicolor domestication. The distribution of caudatums is closely associated with speakers of the Chari-Nile language group. Caudatums are grown to some extent outside of the areas associated with Chari-Nile speakers, but usually these areas have had contact with traders of Chari-Nile origin or are occupied by immigrants from the core area. This is the case in Cameroon and Ethiopia (74). The caudatums grown in the Ethiopian lowlands are grown by people whose traditions and farming systems very much resemble their Sudanese neighbors. Stemler et al. (76) conclude that the caudatums of the Ethiopian highlands are intrusive, probably acquired by trade or other such means. They are most common in areas receiving from 250 to 1300mm of rainfall, and are described as having great adaptation to harsh conditions (74).

Race caudatum sorghums are characterized by: panicles medium large oblong, dense to slightly open, hairy with stout peduncle and rigid primary branches; sessile spikelets obovate to elliptical; pedicellate spikelets deciduous; glumes coriaceous, shorter than the large grain and all are pubescent; grains are turtle backed (flat on one side and round or bulging on back); grain chalky white or pigmented, most with a recessive spreader gene; plants medium to tall and generally high yielding (Figure 11).

Race Kafir

According to the construct of Harlan et al., (21,40) race kafir was derived from early bicolor carried south from the north African savanna. Electrophoretic data (67) indicate kafirs to be more closely associated with wild race verticilliflorum than the other four races of cultivated sorghum, so the possibility of independent domestication exists. The kafir sorghums are closely associated with the Bantu speakers of eastern and southeastern Africa; indeed the word 'kafir' comes from the Arabic word for 'non-believer'. It is thought that kafirs are a relatively recent race because they did not move to India via the same channels as guinea types. Harlan and Stemler (40) also theorize that more northerly ports in East Africa were used for this trade, and so kafirs were not included.

Race kafir sorghums are characterized by: panicles erect, elongate, mostly semicompact and cylindrical; branches and sessile spikelets hairy but glumes at

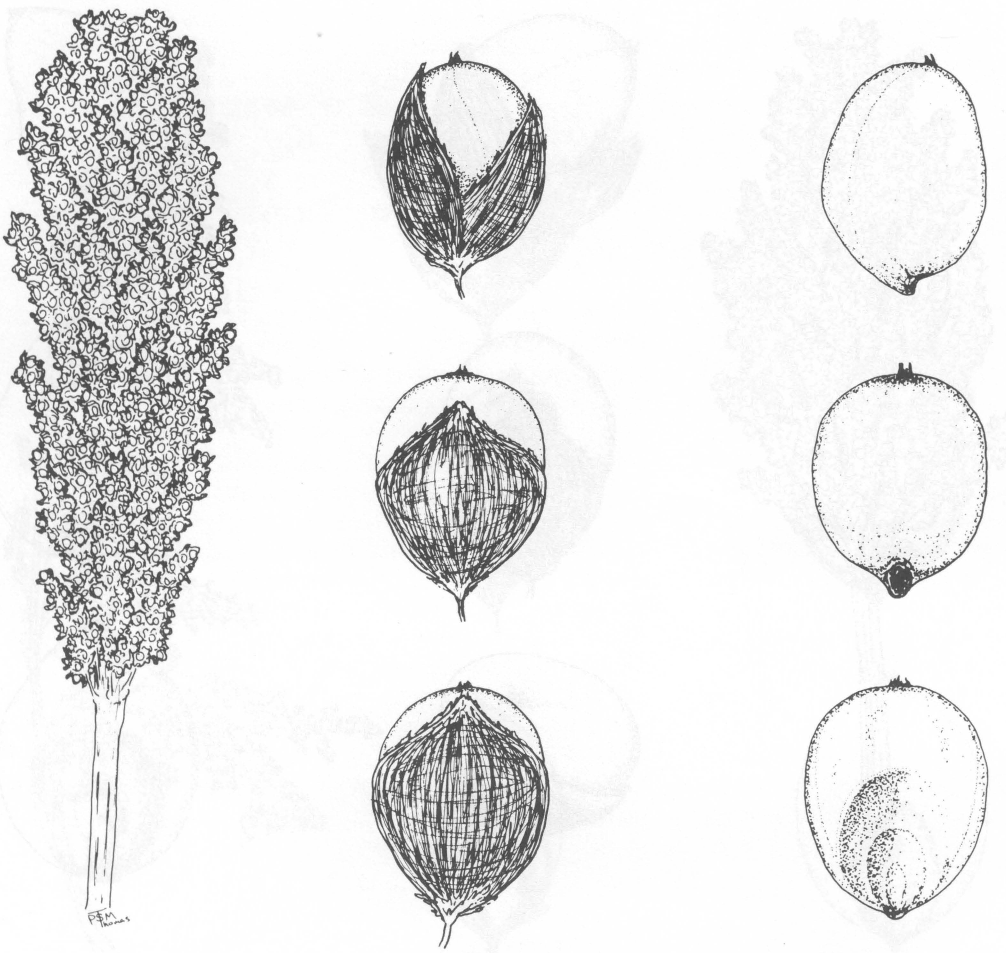


Figure 12. Kafir panicle and three positions of the spikelet and kernel. Note the erect mostly semi-compact cylindrical panicle containing elliptical and sometimes compressed but almost round grain.

maturity almost glossy; glumes moderately coriaceous and much shorter than grain; grain is broadly elliptical, sometimes compressed, flattened or biconvex (almost round); plants medium height and high yielding (Figure 12).

Race Durra

Because of its compact panicle and predominantly white grain, race durra is adapted to areas of low rainfall and low grain mold risk. It is the most important sorghum type in Ethiopia and is restricted in distribution to areas of Africa north of the equator. It is also an important type in India. According to Harlan and Stemler (40) and Stemler et al. (76), durra sorghums were selected from early bicolors which had been carried to India before 3,000 B.P. They were acquired by Arabs from India by trade or invasion before the sixth century A.D., and established in Arabia and parts of Africa that the Arabs invaded. During the migration of Arabic Muslems into Ethiopia around 615 A.D., durra sorghums were introduced and these sorghums were the economic base of those Muslem states. Harlan et al. base their hypothesis on the fact that durras are primarily grown by Muslem Africans and Arabic peoples in Ethiopia, while they are grown in both Islamized and Hindu areas of India. They indicate that the main growers of durra sorghum in Ethiopia today are the Muslem Oromo (Galla), who settled the fertile warm highlands about 450 years ago, and adopted race durra sorghums as the basis of their agricultural system.

Durras are grown today in the mid-altitude highlands of Ethiopia, the Nile Valley of Sudan and Egypt, and in a belt across Africa between 10 and 15 degrees N. latitude from Ethiopia to Mauritania.

Race durra sorghums are characterized by: panicles stiff, dense and compact (often very compact), ovate to oblong shaped or rhomboidal and covered with dense velvety pubescence; peduncle often recurved but occasionally erect; panicle branches short, semi-erect and hairy; rachis varies from elongate to hidden; pedicellate spikelets large and persistent; sessile spikelets obovate elliptic to rhomboidal with glumes coriaceous on lower half and slightly to strongly depressed with a central transverse wrinkle, the lower half of the glume strongly nerved with tip papery; glumes lightly pigmented; grain generally medium to large, biconvex, broad top and wedge shaped base; plants medium to tall and good quality (Figure 13).

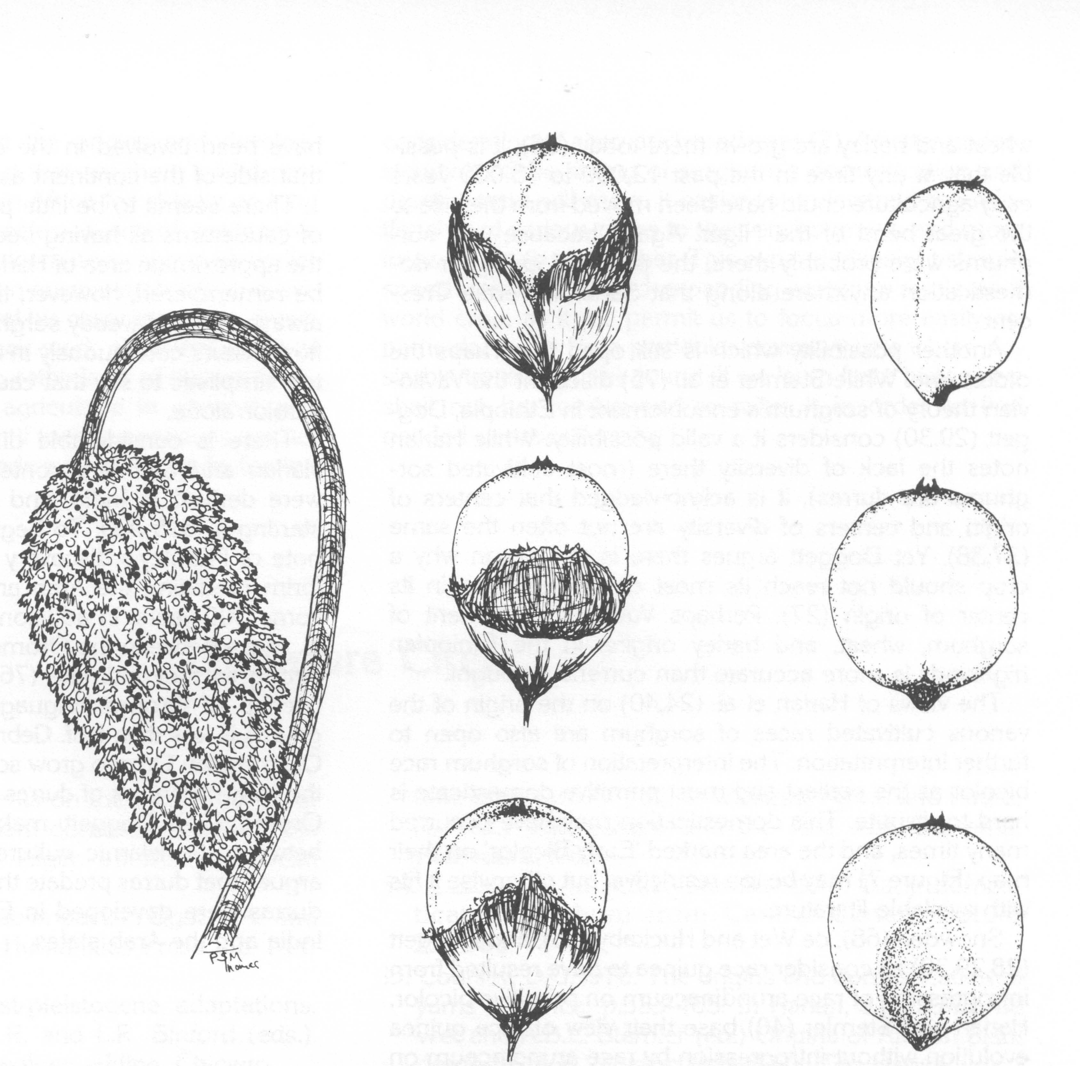


Figure 13. Durra panicle and three positions of the spikelet and kernel. Note the often recurved peduncle and mostly rhombidal panicle as well as the central transverse wrinkle on the lower half of the glume.

Alternate Hypotheses for the Timing and Placement of the Origins of Sorghum Cultivation

There is no archeological evidence for the existence of wild sorghum species in northern Africa in prehistoric times, but there is no reason to suspect they did not exist. If in fact the four wild races of subsp. *arundinaceum* were present in the Sahara during the wet interpluvials (about 11,500 to 8,000 and 7,200 to 4,000 B.P.) then it would seem logical that early agriculturists might have cultivated these wild sorghums.

Races aethiopicum and verticilliflorum both exist today nearly all the way across the African savanna, and in those times of major weather modification, surely coexisted and freely intercrossed (21,24,26). In addition, in western Africa, race arundinaceum overlaps and intercrosses with both of the other two now (26) and surely did in times of greater rainfall.

To initiate the domestication of sorghums, early man would have had only to harvest the whole inflorescence of the wild sorghums. In spite of Stemler's feeling that sorghum's domestication came late in African prehistory because of the lack of tools adequate to harvest whole panicles, it seems likely that Paleolithic stone tools would have easily cut the relatively small peduncles of sorghum's progenitors, if indeed, tools were required at all.

This process of domestication may have happened once and diffused throughout northern Africa, or more likely it happened many times in many places. With the entire region south of the Sarharan highlands habitable (13,56,58), and given movement of people east to west and south to north, both the technology and the cultigens of early sorghum could have spread across Africa from the Nile to the headwaters of the Niger before the dry period about 8,000 B.P. If MacNeish (54) and others are correct, this period of ecological pressure may have resulted in the inclusion of sorghum into agricultural systems ranging from the Sudan to Senegal.

Another possibility for the early domestication of sorghum involves the movment of 'casual' agriculture through the Saharan highlands. Because sorghum, wheat and barley are grown there today (66), it is possible that at any time in the past 12,000 to 13,000 years early agriculture could have been moved from the Nile to the great bend of the Niger. Again, because wild sorghums were probably there, the potential exists for domestication anywhere along that Saharan Fertile Crescent.

Another possibility which is still open is perhaps the oldest one. While Stemler et al. (75) discount the Vavilovian theory of sorghum's ennoblement in Ethiopia, Doggett (29,30) considers it a valid possibility. While Harlan notes the lack of diversity there (most cultivated sorghums are durras), it is acknowledged that centers of origin and centers of diversity are not often the same (37,38). Yet Doggett argues there is no reason why a crop should not reach its most developed form in its center of origin (27). Perhaps Vavilov's placement of sorghum, wheat, and barley origins in the Ethiopian highlands is more accurate than currently thought.

The views of Harlan et al. (24,40) on the origin of the various cultivated races of sorghum are also open to further interpretation. The interpretation of sorghum race bicolor as the earliest and most primitive domesticate is hard to dispute. This domestication may have occurred many times, and the area marked 'Early Bicolor' on their map (Figure 7) may be too restrictive, but otherwise it fits with available literature.

Snowden (68), de Wet and Huckaby (26), and Doggett (28,29,30) all consider race guinea to have resulted from introgression of race arundinaceum on primitive bicolor. Harlan and Stemler (40) base their view of race guinea evolution without introgression by race arundinceum on mutually exclusive habitats. This view discounts the vastly different environments which have existed in northwest Africa the past 12,000 years. During the interpluvial of 12,000 to 8,000 years B.P., the forest extended as far north as 13 degrees N. latitude. Surely arundinaceum, a forest grass, and bicolor sorghums would have been in contact as these vegetation belts moved north and south. In addition, de Wet and Huckaby (26) speak of the ranges of verticilliflorum and arundinaceum overlapping today, and interbreeding occurring. De Wet (21) also notes that weeds which are the result of introgression between race arundinaceum and race guinea are very troublesome in the northern fringe of the tropical forest today, hardly a case of mutually exclusive ecological adaptation zones. It seems more logical that guineas gained access to the wet environments of the tropical forest by introgression with a forest grass (race arundinaceum) than strictly by selection from a progenitor selected for in semi-arid savannas perhaps for thousands of generations.

In contrast to the view of West African origins for race guinea, Doggett (30) now hypothesizes that guineas were selected in East Africa and moved west via the 'aqualithic' agriculture described by Sutton (77). Doggett speculates that the notable characters which evolved in the guineas may have been present in the primitive sorghums in East Africa (29). Also, in contrast to reports in the literature, the wild race arundinaceum is present in East Africa as observed by the second author, and could have been involved in the development of guineas on that side of the continent as well.

There seems to be little problem with the description of caudatums as having been selected from bicolors in the approximate area of Harlan's 'Early Bicolor'. It should be remembered, however, that in these areas there are always wild and weedy sorghums present, and that gene flow occurs continuously in all directions (28). It may be too simplistic to say that caudatums were selected from bicolor alone.

There is considerable dispute in the literature with Harlan and Stemlers contention that durra sorghums were derived in India, and later brought into Ethiopia starting in 615 A.D. To begin with, de Wet (21) makes note of Plumley's discovery of durra sorghums at Qasr Ibrim predating the Arab arrival in Ethiopia by at least some 300 years. In addition, the connection Stemler et al. make between the Oromo and durras may not be as strong as they intimate (76). Even on their maps, the overlap of Oromo language speakers and durra sorghums is less than half. Gebrekidan notes that more non-Oromo than Oromo grow sorghum in Ethiopia, and that the early cultivators of durras in the north are entirely non-Oromo (33). Doggett makes the connection as well between the Islamic culture and durra sorghums, but argues that durras predate the Arab arrivals (30), and that durras were developed in Ethiopia and later moved to India and the Arab states.

Conclusions

Sorghum is an important crop worldwide in part, at least, because of the vast diversity in its germplasm. This diversity is a result of the climate and geography in which it and its wild ancestors evolved, and the selection pressure applied by man and environment down through the centuries. The evidence is strong that sorghums evolved and were first domesticated in northeastern Africa, in the area north of the equator and east of 10 degrees E longitude. Present distribution patterns of wild and cultivated races give strong clues as to the pattern of evolution and domestication and to the environments within which these processes and events took place (87). An understanding of the scope of these factors is important for those who work as breeders, agronomists, and cultivators of sorghum.

While there are prehistoric and historic facts that we know about sorghum, probably that which is most certain is the knowledge that we will never know the whole story of sorghum's evolution. As has been the case with most crops, new archeological findings are likely to push back the time factor to even earlier dates, and widen the area of prehistoric use. Because of the large gaps in the archeological record, and the especially scant information on sorghum in its presumed area of origin, a better understanding of domestication and the development of agriculture (3,32,46,47,64) will be necessary to make reasoned judgements about the origins and development of sorghum. Assuming that sorghum's wild progenitors have been present in Africa for at least as long as those of other crop species, a set of reasonable hypotheses can be drawn concerning a very much earlier development of sorghum than current archeological evidence permits. If Wendorf and his associates have drawn correct conclusions from their work, then the seeds of Wadi Kubbaniya force us to rethink all of our assumptions about the origins of agriculture in general, and sorghums in particular. Even if their conclusions are not correct, they will have still made a contribution by forcing consideration of alternate hypotheses (7). A better understanding of the timing of sorghum's domestication and development will make it easier to understand the relationship of various races to their environment, and more importantly, to each other. This expanded insight should speed our work toward expanding sorghum's role as a world crop, as it will permit us to focus more easily on particular races from particular environments where desirable traits might be found. If we learn from history, we shall not be condemned to relive it in order to find needed genetic diversity.

Literature Cited

1. Baker, H.G. 1962. Comments on the thesis that there was a major center of plant domestication near the headwaters of the River Niger. Journal of African History 3(2):229-233.
2. Bennett, N.R. 1968. The Arab Impact. *In* Ogot, B.A., and A. Kieran, (ed.) Zamani. Humanities Press Inc. New York.
3. Binford, L.R. 1968. Post-pleistocene adaptations. p.313-341. *In* Binford, S.R. and L.R. Binford (eds.). New perspectives in archeology. Aldine, Chicago.
4. Butzer, Karl W. 1968. Climatic change in the arid zones of Africa during early to mid-Holocene times. p.72-83. *In* World climate from 8,000 to 0 B.C. Royal Met. Soc. Symp.
5. Butzer, Karl W. 1980. Adaptation to global environmental change. Professional Geographer 32(3):269-278.
6. Camps, G. 1969. Amekni: Neolithique ancien du Hoggar. Memoire du Centre de Recherches Anthropologiques, Pre'historiques et Ethnographiques 10. Arts et Metiers Graphiques. Paris. Flammarion.
7. Chamberlin, T.C. 1965. The method of multiple working hypotheses. Science 148:754-759.
8. Chittick, N. 1968. The coast before the arrival of the Portuguese. p.100-118. *In* Ogot, B.A., and J.A. Kieran, (ed.) Zamani. Humanitis Press Inc. New York.
9. Clark, J. Desmond. 1962. The spread of food production in sub-Saharan Africa. Journal of African History 3:211.
10. ______. 1964. Prehistoric origins of African culture. Journal of African History 5:161.
11. ______. 1970. The prehistory of Africa. Praeger Publishers. New York.
12. ______. 1976. Prehistoric populations and pressures favoring plant domestication in Africa. p.67-106. *In* Harlan, J.R., J.M.J. de Wet, and A.B.L. Stemler (ed.) Origins of African plant domestication. Mouton Publishers. The Hague.
13. ______. 1980. Human populations and cultural adaptations in the Sahara and the Nile during prehistoric times. p.527-582. *In* Williams, M.A.J. and Faure, H., (ed.) The Sahara and the Nile. A.A. Balkema. Rotterdam. 1980.
14. ______, and A.B.L. Stemler. 1975. Early domesticated sorghum from Central Sudan. Nature 254:588.
15. Coursey, D.G. 1976. The origins and domestication of yams in Africa. p.383-408. *In* Harlan, J.R., J.M.J. de Wet and A.B.L. Stemler (ed.) Origins of African plant domestication. Mouton Publishers. The Hague.
16. Cohen, D.W. 1968. The river-lake Nilotes from the 15th to the 19th century. p.142-157. *In* Ogot, B.A. and J.A. Kieran (ed.) Zamani. Humanities Press Inc. New York.
17. Cohen, M.N. 1977. The food crisis in prehistory. Yale University Press. New Haven.
18. Cole, Sonia. 1963. The prehistory of East Africa. The MacMillan Company. New York.
19. Davidson, Basil. 1969. A history of East and Central Africa. Doubleday and Company, Inc. Garden City, New York.
20. de Wet, J.M.J. 1977. Domestication of African cereals. African Economic History 3:15.
21. de Wet, J.M.J. 1977. Systematics and evolution of Sorghum Sect. Sorghum (Gramineae). Amer. J. Bot. 65:477-484.
22. ______, and J.R. Harlan. 1971. The origination and domestication of *Sorghum bicolor*. Economic Botany 25:128-135.
23. ______, and B. Kurmarohita. 1972. Origin and evolution of guinea sorghums. East African Agriculture and Forestry Journal 38:114-119.
24. ______, and E.G. Price. 1976. Variability in *Sorghum bicolor*. p.453-464. *In* Harlan,J.R., J.M.J. de Wet , and A.B.L. Stemler (ed.) Origins of African plant domestication. Mouton Publishers. The Hague.
25. ______, and A.B.I. Stemler. 1975. Caudatum Sorghums and Chari-Nile Languages. Journal of African History 16:161-183.

26. ______, and J.D. Huckaby. 1967. The Origin of Sorghum bicolor II. Distribution and Domestication. Evolution 21:787- 802.
27. Doggett, H. 1965. The development of cultivated sorghums. p.50-69. *In* Sir Joseph Hutchinson (ed). Crop Plant Evolution. Cambridge Univ. Press. London.
28. Doggett, H. 1970. Sorghum. Longmans, Green and Co., Ltd. London.
29. ______. 1976. Sorghum. p.112-117. *In* Simonds, N.W. (ed.) Evolution of crop plants. Longman. New York.
30. ______. 1982. Personal communication.
31. Ehret, C. 1968. Cushites and the highlands and plains Nilotes. p.153-176. *In* Ogot B.A., and J.A. Kieran (ed.) Zamani. Humanities Press Inc. New York.
32. Flannery, K. 1968. Archeological systems theory and early MesoAmerica. p.67-87. *In* Anthropological Archeology in the Americas. Anthropological Society of America. Washington, D.C.
33. Gebrekidan, B. 1979. Sorghum genetic resources in Africa. Ethiopian J. of Agri. Sci. 1(2):108-115.
34. Gray, R. 1962. Report on the third conference on African history and archeology. J. of African History 8: 184.
35. Griffiths, J.F. 1972. Climates of Africa. *In* Landsberg, H.E. et al. (ed). World survey of climatology. V 10. Elsevier Publishing Co. Amsterdam.
36. Harlan, J.R. 1971. Agricultural origins: center and noncenters. Science 174:468-474.
37. ______. 1975. Geographic patterns of variation. The Journal of Heredity 66:182.
38. ______ and J.M.J. de Wet. 1972. A simplified classification of cultivated sorghum. Crop Science 12:172-176.
39. ______, and J. Pasquereau. 1969. 'Decrue' agriculture in Mali. Economic Botany 23(1):70-74.
40. ______, and Ann Stemler. 1976. The races of sorghum in Africa. p.465-478. *In* Harlan, J.R., J.M.J. de Wet, and A.B.L. Stemler, (ed.) Origins of African plant domestication. Mouton Publishers. The Hague.
41. ______, J.M.J. de Wet, and Ann Stemler. 1976. Plant domestication and indigenous African agriculture. p.3-19. *In* Harlan, J.R., J.M.J. de Wet and Ann Stemler (eds). Origins of African plant domestication. Mouton Publishers. The Hague.
42. Harris, D.R. 1967. New lights on plant domestication and the origins of agriculture: A review. The Geographical Review 57:90-107.
43. ______. 1981. Breaking ground: Agricultural origins and archeological explanations. p.1-20. *In* Bulletin of the Institute of Archeology. V 18. Univ. of London.
44. Hester, James J. 1968. Comments on 'The Origin of African Agriculture'. Current Anthropology 9 (5):497-498.
45. Hiernaux, Jean. 1968. Bantu Expansion: The evidence from physical anthropology confronted with linguistic and archaeological evidence. Journal of African History 9 (4):505.
46. Higgs, E.S. (ed.). 1972. Papers in economic prehistory. Cambridge Univ. Press. Cambridge.
47. ______. 1974. Paleoeconomy. Cambridge Univ. Press. Cambridge.
48. Hobler, P.M. and J.J. Hestor. 1969. Prehistory and environment in the Libyan Desert. S. African Archaeological Bulletin 33:120-130.
49. Hugot, H.J. 1968. The origins of agriculture: Sahara. Current Anthropology 9(5):483-488.
50. Hutchinson, Sir Joseph. 1965. Essays on crop plant evolution. Cambridge Univ. Press. Cambridge.
51. Law, R.C.C. 1967. The Garmantes and trans-saharan enterprise in classical times. Journal of African History 8:181-200.
52. Leakey, L.S.B. 1931. The stone age cultures of Kenya Colony. Cambridge Univ. Press. Cambridge.
53. Maley, J. 1977. Analyses polliniques et paleoclimatologie des douze derniers millenaires du bassin du Tchad (Afrique centrale). Recherches française sur le Quaternaire hors de France, Comite' Trimesriel Ethographique National Français. 1 (50):187-197.
54. MacNeish, R.L. 1982. Lecture. October 29, 1982. Texas A&M University, College Station, Tx.
55. McIntosh, B.G. 1968. The eastern Bantu peoples. p.198-215. *In* Ogot, B.A., and J.A. Kieran, (ed.) Zamani. Humanities Press Inc. New York.
56. McIntosh, S. K. and R. J. McIntosh. 1981. West African prehistory. American Scientist 69:602-613.
57. Munson, Patrick J. 1976. Archeological data on the origins of cultivation in the southwest Sahara and their implications for West Africa. p.187-210. *In* Harlan, J.R., J.M.J. de Wet, and A.B.L. Stemler (ed.) Origins of African plant domestication. Mouton Publishers. The Hague.
58. Murdock, G.P. 1959. Africa, its peoples and their cultural history. McGraw Hill, London.
59. Murty, B.R., V. Arunachalam, and M.B.L. Saxena. 1967. Classification and catalogue of a world collection of sorghum. Indian Journal of Genetics and Plant Breeding. 27:(Spl. No.):1-394.
60. Nicolaisen, J. 1963. Ecology and the culture of the pastoral Tureg. National museets Skrifter, Ethnoiatisk Roekke 9. National Museum. Copenhagen.
61. Oliver, Roland. 1967. The problem of the Bantu explosion. Journal of African History 7(3):361.
62. Posnansky, Merrick. 1968. Bantu Genesis. Archeological reflections. Journal of African History 9 (1):1-11.
63. ______. 1968. The prehistory of East Africa. p.49-68. *In* Ogot B.A., and J.A. Kieran, (ed.) Zamani. Humanities Press Inc. New York
64. Renfrew. C. (ed.) 1973. The explanation of cultural change: Models in prehistory. Duckworth. London.
65. Schwanitz, F. 1966. The origin of cultivated plants. Harvard Univ. Press. Cambridge, Mass.
66. Shaw, T. 1976. Early crops in Africa: A review of the evidence. p.107-153. *In* Harlan, J.R., J.M.J. de Wet and A.B.L. Stemler. (ed.) Origins of African plant domestication. Mouton Publishers. The Hague.
67. Shechter, Yaakow and J.M.J. de Wet. 1975. Comparative electrophoresis and isozyme analysis of seed proteins from cultivated races of sorghum. American Journal of Botany 62(3) :254-261.
68. Snowden, J.D. 1936. The cultivated races of sor-

ghum. Adlard and Son, Ltd. London.
69. Stanton, W.R. 1961. Analysis of the present distribution of varietal variation of maize, sorghum and cowpeas in Nigeria as an aid in the study of tribal movement. Journal of African History 3:251.
70. Stemler, A. 1978. Comments on the evidence for a relatively late transition from food collecting to food production in sub-Saharan Africa. American Anthropology Association Symposium. Causes and consequences of food production in Africa. Los Angles, Calif. Nov. 1978.
71. ______. 1980. Origins of plant domestication in the Sahara and the Nile Valley. p.503-526. *In* Williams M.A.J., and H. Faure (ed.) The Saraha and the Nile. Balkema. Rotterdam.
72. ______. and R.H. Falk. 1980. A scanning electron microscope study of cereal grains from Wadi Kubbaniya. p.299-306. *In* Wendorf, F., R. Schid, and A.E. Close (ed.) Loaves and Fishes: The prehistory of Wadi Kubbaniya. Dept. of Anthropology. Southern Methodist Univ. Dallas.
73. Stemler, A.B.L. and R. Falk. 1980. A scanning electron microscope study of cereal grains from Nabta Playa. p.393-399. *In* Wendorf, F. and R. Schild. 1980. Prehistory of the Eastern Sahara. Academic Press. New York.
74. ______, J.R. Harlan, and J.M.J. de Wet. 1975. Caudatum sorghums and speakers of Chari-Nile languages in Africa. Journal of African History l6:161-183.
75. ______, ______, and ______. 1975. IV. Evolutionary history of cultivated sorghums (*Sorghum bicolor* (Linn.) Moench) of Ethiopia. Bulletin of the Torrey Botanical Club 102 (6): 325-333.
76. ______. 1977. The sorghums of Ethiopia. Economic Botany 31:446-460.
77. Sutton, J.E.G. 1968. The African aqualithic. Antiquity 51:25-34.
78. Sutton, J.E.G. 1968. The settlement of East Africa. p.69-99. *In* Ogot, B.A., and J.A. Kieran, (ed.) Zamani. Humanities Press Inc. New York.
79. Van Zinderen Bakker, E.M. 1976. Paleoecological background in connection with the origin of agriculture in Africa. p.43-66. *In* Harlan, J.R., J.M.J. de Wet, and A.B.L. Stemler (ed.) Origins of African plant domestication. Mouton Publishers. The Hague.
80. Vavilov, N.I. 1951. The origin, variation, immunity and breeding of cultivated plants. *In* Selected writing of N.I. Vavilov, K. Starr Chester, translator. Chronica Botanica Vol. 13. Waltham.
81. Wendorf, F., R. Said, and R. Schild. 1970. Egyptian prehistory: Some new concepts. Science 169:1161-71.
82. ______, R. Schild, N. El Hadid, A. Close, M. Kobusiewicz, H. Wieckowska, B. Issawi, and H. Hass. 1979. Use of barley in the Egyptian late Paleolithic. Science 205:1341.
83. Wendorf, F. and R. Schild. 1980. Prehistory of the eastern Sahara. Academic Press. New York.
84. Wendorf, F., R. Schild, and A.E. Close (eds) 1980. Loaves and Fishes: The prehistory of Wadi Kubbaniya. Dept. of Anthropology. Southern Methodist Univ. Dallas.
85. ______, ______, and ______. 1982. An ancient harvest on the Nile. Science 82. 3(9)68-73.
86. Were, G.S. 1968. The western Bantu peoples from A.D. 1300 to 1800. *In* Ogot, B.A., and J.A. Kieran, (ed.) Zamani. Humanities Press Inc. New York.
87. Wilson, D. 1978. Science and archeology. Penguin Books. Harmondsworth.

Additional Bibliography Dealing with the Origins of Agriculture in Africa

Archeological Evidence

1. Binford, L.R. (ed.). 1977. For theory building in archeology. Academic Press. New York.
2. Churcher, C.S. and P.E.L. Smith. l972. Kom Ombo: Preliminary report on the fauna of late Palaeolithic sites in Upper Egypt. Science 177:259-261.
3. Connah, G. l968. Radiocarbon dates for Benin City and further dates for Daima, N.E. Nigeria. Journal of the Historical Society of Nigeria. 4(2):313-320.
4. ______. 1976. The Daima sequence and the prehistoric chronology of the Lake Chad region of Niger. Journal of African History l7:321-352.
5. Fagan, B.M. l969. Radiocarbon dates for sub-Saharan Africa. Journal of African History 10:150-151.
6. Gifford, D.P., G.I. Isaac and C.M. Nelson. 1981. Evidence for predation and pastoralism at a pastoral neolithic site in Kenya. Azania 15: 40-196.
7. Harlan, J.R. and J.M.J. de Wet. l973. On the quality of the evidence for origin and dispersal of cultivated plants. Current Anthropology 14:51-62.
8. Higgs, E. l976. Archeology and Domestication. p.29-42 *In* Harlan, J.R., J.M.J. de Wet and A.B.L. Stemler (eds.) Origins of African Plant Domestication. Mouton Publishers. The Hague.
9. Munson, P.J. l968. Recent archeological research in the Dar Tichitt region of south central Mauretania. W. African Archeology. Newsletter 10:6-13.
10. Sasson, H. l967. New views on Engaruka, northern Tanzania. Journal of African History 7:201-217.
11. Vogel, J.O. 1969. On early evidence of agriculture in southern Zambia. Current Anthropology 10:524.
l2. Wendorf, F. 1968. The prehistory of Nubia. Two volumes. Southern Methodist Univ. Press. Dallas.

Domestication/Origins

l. Alexander, J. 1969. The indirect evidence for domestication. p.123-129. *In* Ucko, P.J. and G.W. Dimbleby (ed.). The domestication and exploitation of plants and animals. Duckworth. London.

2. Anderson, E. 1952 (revised 1967). Plants, Man and Life. University of California Press. Berkley.

3. Brunken, J.N., J.M.J. de Wet and J.R. Harlan. 1977. The morphology and domestication of pearl millet. Economic Botany 31:163-174.

4. Burkill, I.H. 1953. The habits of man and the origins of cultivated plants in the Old World. Proc. of the Linn. Soc., London. 164:12-24.

5. Carter, G.F. 1977. A hypothesis suggesting a single origin of agriculture. p.89-134. *In* Reed, C. (ed.). Origin of Agriculture. Mouton Publishers. The Hague.

6. Chang,Kwan-Chin. 1970. The beginnings of agriculture in the Far East. Antiquity 44:175-185.

7. Davies, O., H.J. Hugot and D. Seddon. 1968. The origins of African agriculture. Current Anthropology 9(5) 479-509.

8. de Candolle, A. 1884. The origin of cultivated plants. Kegan Paul. London. (Second ed. 1959. Hafners. London.)

9. de Wet, J.M.J. 1975. Evolutionary dynamics of cereal domestication. Bulletin Torrey Botany Club 102:307-312.

10. Epstein, H. 1971. Origins of the domestic animals of Africa. Africana Publishing Corp. New York. 2 Vols.

11. Greenway, P.J. 1944. Origins of some East African food plants. E. African Agricultural Journal 10:34-39, 115-119,177-180, 251-256.

l2. ________. 1945. Origins of some East African food plants. E. African Agricultural Journal 11:56-63.

13. Harlan, J.R. 1969. Ethiopia: a centre of diversity. Economic Botany 23(4):309-314.

14. Harris, D.R. 1972. The origins of agriculture in the tropics. American Scientist 60(2):180-193.

15. ________. 1976. Traditional systems of plant food production and the origins of agriculture in West Africa. p.311-356. *In* Harlan, J.R., J.M.J. de Wet, and A.B.L. Stemler. Origins of African Plant Domestication. Mouton Publishers. The Hague.

16. Hawkes, J.G. 1970. The origin of agriculture. Economic Botany 24: 131-133.

17. Higgs, E.S. and M.R. Jarman. 1969. The origins of agriculture: a reconsideration. Antiquity 43:31-41.

18. Lee, R.B. and I. DeVore (eds.). 1968. Man the hunter. Aldine. Chicago.

19. MacNeish, R.S. 1965. The origin of American agriculture. Antiquity 39:87-94.

20. Posnansky, M. 1969. Yams and the origins of West African agriculture. Odu 1:101-107.

21. Sauer, C.O. 1952. Agricultural origins and dispersals. American Geographical Society. New York.

22. Seddon, D. 1968. The origins and development of agriculture in east and southern Africa. Current Anthropology 9(6):489-494.

23. Ucko, P.J. and G.W. Dimbleby (eds.). 1969. The domestication and exploitation of plants and animals. Duckworth. London.

24. Wilke, P.J., R.Bettinger and T.F. King. 1972. Harvest selection and domestication in seed plants. Antiquity 46:203-208.

Climatalogical/Environmental

l. Burke, K., A.B. Durotoye and A.J. Whiteman. 1971. A dry phase south of the Sahara 20,000 years ago. West African Journal Archaeology 1:1-18.

2. Butzer, K.W. 1975. Patterns of environmental change in the Near East during the late Pleistocene and early Holocene times. p.389-410. *In* Wendorf, F. and A.E. Mark(eds.). Problems in Prehistory: North Africa and the Levant. Southern Methodist Univ. Press. Dallas.

3. ________. and C.L. Hansen. 1968. Desert and river in Nubia. University of Wisconsin Press. Madison.

4. ________, G. Isaac, J.L. Richardson, and C. Washbourn-Kamau. 1972. Radiocarbon dating of East African lake levels. Science 175:1069-1076.

5. Grove, A.T. and A. Warren. 1968. Quaternary land forms and climate on the south side of the Sahara. Geographical Journal 134(2): 194-208.

6. Smith, A.B. 1977. Saharan and Sahel zone environmental conditions in the upper Pleistocene and early Holocene. *In* Pan-African Congress of Prehistory and Quaternary Studies, Nairobi, Nov. 1977.

7. Street, F.A. and A.T. Grove. 1976. Environmental and climatic implications of late Quaternary lake-level fluctuations in Africa. Nature 261:385-390.

8. Van Zinderen Bakker, E.M. 1967. Upper pleistocene and holocene stratigraphy and ecology on the basis of vegetation changes in sub-Saharan Africa. p.125-146. *In* Bishop, W.W. and J.D. Clark (eds.). Background to evolution in Africa. University of Chicago Press. Chicago.

9. Wright, H.E. 1977. Environmental change and the origin of agriculture in the old and new worlds. p.281-320. *In* Reed, C. (ed.). Origins of Agriculture. Mouton Publishers. The Hague.

Cultural

1. Clark, J.D. 1967. The problem of neolithic culture in sub-Saharan Africa. p.600-627 *In* Bishop, W.W. and J.D. Clark. Background to evolution in Africa. University of Chicago Press. Chicago.

2. ________. 1972. Mobility and settlement patterns in sub-Saharan Africa: A comparison of late prehistoric hunters/gatherers and early agricultural occupation units. *In* Ucko, P.J. and G.W. Dimbleby (eds.). Man, settlement and urbanization. Duckworth. London.

3. Greenberg, J.H. 1972. Linguistic evidence regarding Bantu origins. Journal of African History. 13:189-216.

4. Guthrie, M. 1962. Some developments in the prehistory of the Bantu languages. Journal of African History 3:273-282.
5. Higgs, E.S. 1972. Papers in economic prehistory. Cambridge Univ. Press. Cambridge.
6. Oliver, R. 1966. Bantu genesis. African Affairs 65:245-248.
7. Simoons, F.J. 1965. Some questions on the economic prehistory of Ethiopia. Journal of African History 6:1-12.

Botanical/Paleobotanical

1. Anderson, E. 1967. The bearing of botanical evidence on African cultural history. p.169-180. *In* Giabel, C. and N.R. Bennett (eds.). Reconstructing African History. Boston Univ. Press. Boston.
2. Bishop, W.W. 1980. Paleogeomorphology and continental taphonomy. *In* Behrensmeyer, A.K. and A.P. Hill (eds). Fossils in the making. University of Chicago Press. Chicago.
3. Gifford, D.P. 1981. Taphonomy and paleoecology: A critical review of archeology's sister discipline. *In* Schiffer, M.B. (ed.). Advances in archaeological method and theory. Academic Press. New York.
4. Harlan, J.R. 1975. Crops and man. American Society of Agronomy. Madison.
5. ______, J.M.J. de Wet and E.G. Price. 1973. Comparative evolution of cereals. Evolution 27:311-325.
6. ______, and D. Zohary. 1966. Distribution of wild wheats and barley. Science 153:1074-1080.
7. Porteres, R. 1976. African Cereals Eleusine, Fonio, Black Fonio, Teff, *Brachiaria paspalum*, Pennisetum and African rice. p.409-452. *In* Harlan, J.R., J.M.J. de Wet, and A.B.L. Stemler (ed.) Origins of African plant domestication. Mouton Publishers. The Hague.
8. Shaw, T. 1977. Hunters, gatherers and first farmers in West Africa. *In* Megaw, J.V.S. (ed.) Hunters, gatherers and first farmers beyond Europe. Lester Univ. Press.

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