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A Simplified Classification of Cultivated Sorghum[1]

J. R. Harlan and J. M. J. de Wet[2]

ABSTRACT

The simplified classification presented for *Sorghum bicolor* (Linn.) Moench is so easy that it requires no special knowledge of the crop to correctly identify mature heads and spikelets. Variation is partitioned into five basic races (bicolor, guinea, caudatum, kafir, and durra) and all combinations of their hybrid derivatives, for a total of 15 races. Intermediate races are designated, for example, as kafir-caudatum, durra-bicolor, etc. Subraces are the commonly used agronomic groups (feterita, kaura, sorgo, sudangrass, etc.) familiar to sorghum workers. None of these requires a formal Latin name.

Additional index words: ***Sorghum bicolor,*** **Races of sorghum.**

THE most complete and definitive classification of cultivated sorghum *Sorghum bicolor* (Linn.) Moench is that of Snowden (1936). All classifications since that time have been modifications or adaptations of the Snowden system. The "work groups" used by sorghum workers in India to classify the World Sorghum Collection (Murty et al., 1967) were based on it, as well as the system suggested by Jakushevsky (1969). In the classification proposed in this paper, we freely admit our debt to the monumental and exhaustive studies of J. D. Snowden.

On the other hand, people working with the crop in applied fields have found the Snowden classification extremely difficult to use. There are far too many names to memorize: 31 species, 158 varieties, and 523 forms, for a total of 712 taxa. A vast array of character combinations is required to separate so many units. Many sorghums are not recognizable on sight and must be keyed out. Some of the taxa are based on very few specimens and some appear to be hybrid derivatives. One can often find several taxa in a single segregating F2 population, and new ones are produced in breeding programs. The geographic distribution of some taxa is so widely scattered or disjunct as to cast at least some doubt on the validity of implied relationships.

The difficulties of Snowden's classification are more fundamental than the over-fine partitioning of the variability. A hierarchical system was used with more categories than the biological facts will support. We are dealing, we believe, with a vast amount of variation *within* a category. This lends itself better to a parallel arrangement than one of hierarchies.

An ideal classification would be one so simple that anyone could use it without special training or great experience with the crop. Identification should be positive and sure with few errors and should be reliable and repeatable. It should follow simple, logical rules so that one need not refer to keys, books, or notes nor need to memorize great numbers of character combinations or long lists of Latin names. The system should be so simple that one need only to look at an inflorescence to identify it by name. It should elucidate the variation patterns, reveal paths of evolutionary history, and make sense biologically. We do not claim that the classification proposed here is ideal, but we feel it is a step in the right direction.

MORPHOLOGICAL CHARACTERS

The characters traditionally used for the classification of sorghum can be classed as spikelet characters, inflorescence characters, and plant characters. We consider selected spikelet characters to be the most stable, the least influenced by environment, the most revealing with respect to relationships, and generally the most useful for our purpose. Inflorescence types are helpful and often correlate well with spikelet morphology. Plant characters are important agronomically, especially such items as height, tillering, juiciness of stalk, daylength response, stem size, etc., but these features vary enormously among related forms, are not easily represented in specimens, and are generally the least useful for our purpose. We have, therefore, based the classification on spikelet morphology, and the main races of sorghum can be identified from mature sessile spikelets alone.

We have found a number of characters used by Snowden to be of very little help in classification. Colors of grains and glumes, presence or absence of awns, persistence of pedicellate spikelets, juicy or dry stems, and membranaceous or papyrescent glumes are all characters that vary within related forms to the point that they have little taxonomic value. Hairiness of glumes and/or inflorescence branches is usually inconsistent, although there are some subraces that are consistently either hairy or glabrous. The striate nerving of the lower glume in *S. nervosum* Bess. ex Schult. seems to be less consistent than Snowden implied and the character has doubtful value. The overlarge, papery glumes of *S. membranaceum* Chiov. are due to a single gene (py) and can appear on any kind of sorghum. It is best to classify the sorghum on the basis of grain characteristics and ignore this glume character when it appears.

SPIKELET TYPES

Within the species *S. bicolor* (Linn.) Moench we recognize seven basic spikelet types: wild type, shattercane, bicolor, guinea, caudatum, kafir, and durra (Fig. 1).

Wild type: grain small linear-oblong, symmetrical dorso-ventrally, completely covered by the glumes; racemes fragile and spikelets deciduous.

Shattercane: similar to above, but grains decidedly larger and rounder, occasionally slightly exposed at the tip; spikelets deciduous.

Bicolor: grain elongate, sometimes slightly obovate, nearly symmetrical dorso-ventrally; glumes clasping

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the grain, which may be completely covered or exposed as much as 1/4 of its length at the tip; spikelets persistent.

Guinea: grain flattened dorso-ventrally, sublenticular in outline, twisting at maturity nearly 90 degrees between gaping involute glumes that are from nearly as long to longer than the grain.

Caudatum: grain markedly asymmetrical, the side next to the lower glume flat or in extreme cases even somewhat concave, the opposite side rounded and bulging; the persistent style often at the tip of a beak pointing toward the lower glume; glumes 1/2 the length of the grain or less.

Kafir: grain approximately symmetrical, more or less spherical; glumes clasping and variable in length.

Durra: grain rounded obovate, wedge-shaped at the base and broadest slightly above the middle; glumes very wide, the tip of a different texture from the base and often with a transverse crease across the middle.

HEAD TYPES

Since inflorescence characteristics vary continuously from the very open, loose panicles of the wild sorghums to very compact heads of some of the most highly derived forms, it is most convenient to partition the variation arbitrarily by a scoring system. We have found that a series of seven classes from wild-types to the most compact, ball-headed durras works very well. Head types can be easily assigned to an appropriate class with an error of no more than a half class interval. A numbering system is also convenient for computer recording of data.

Two additional classes are required to account for inflorescences in which the internodes are decidedly bunched as in broomcorn (type 9) and half broomcorns or subumbellate heads (type 8). A total of nine classes conveniently partitions the variation of head types although class No. 8 will include a few rather dissimilar types (Fig. 2).

Head types correlate in a general way with spikelet morphology. Bicolor and guinea spikelets are found on the more open panicles (types 2, 3, and 4); kafir and durra spikelets tend to be associated with more compact heads (types 5, 6, and 7). Caudatum spikelets are found on a wide range of head types, while broomcorn (type 9) has bicolor spikelets. The association is good enough that head type helps to classify races of sorghum when intermediate spikelet types are uncertain.

THE RACES OF SORGHUM

Following our own suggestions for the classification of cultivated plants (Harlan and de Wet, 1971), we partition the primary gene pool, *Sorghum bicolor* (Linn.) Moench, into the following races.

Cultivated races: *S. bicolor* ssp. *bicolor.*

Basic races:

Race (1)	bicolor	(B)
Race (2)	guinea	(G)
Race (3)	caudatum	(C)
Race (4)	kafir	(K)
Race (5)	durra	(D)

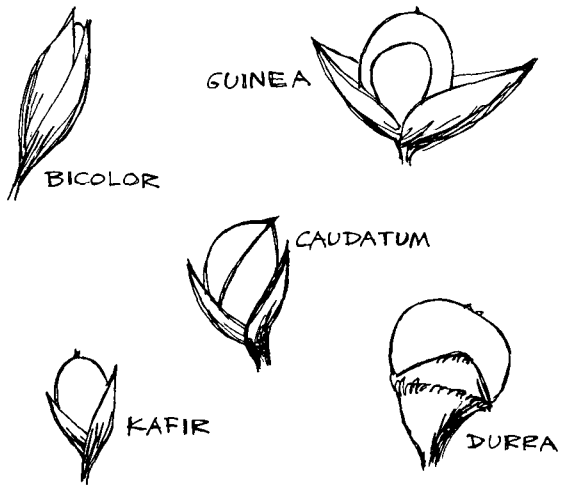

Fig. 1. Five basic spikelet types of cultivated sorghum; wild-type and shattercane not shown.

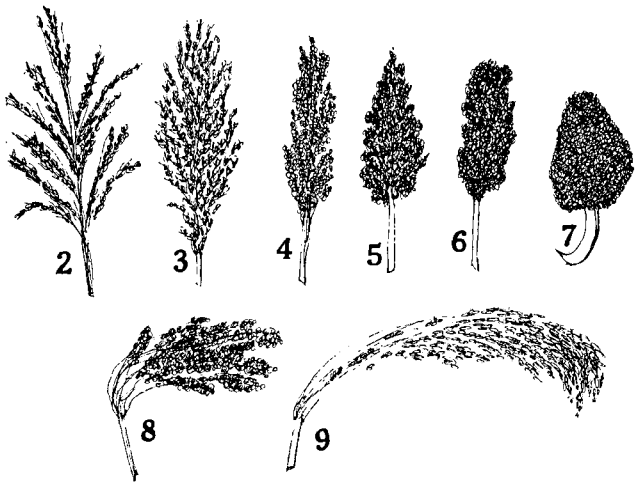

Fig. 2. Head types of cultivated sorghum. Type 1 is reserved for wild races and is considerably more diffuse than type 2.

Intermediate races: (all combinations of basic races)

Race (6)	guinea-bicolor	(GB)
Race (7)	caudatum-bicolor	(CB)
Race (8)	kafir-bicolor	(KB)
Race (9)	durra-bicolor	(DB)
Race (10)	guinea-caudatum	(GC)
Race (11)	guinea-kafir	(GK)
Race (12)	guinea-durra	(GD)
Race (13)	kafir-caudatum	(KC)
Race (14)	durra-caudatum	(DC)
Race (15)	kafir-durra	(KD)

Spontaneous races: *S. bicolor* ssp. *arundinaceum*

Race (1) arundinaceum	Race (4) verticilliflorum
Race (2) aethiopicum	Race (5) propinquum
Race (3) virgatum	Race (6) shattercane

The system is clear and simple. Practically all of the variation in cultivated sorghum can be accounted for by the five basic races and their intermediate combinations. The races are, for the most part, easily identifiable by spikelet morphology alone. Intermedi-

ate races involving guinea, for example, have glumes that open partially and seeds that twist noticeably, but not as much as in pure guinea. Intermediate races involving caudatum have asymmetrical seeds, but the character is not as fully expressed as in pure caudatum. Other intermediate combinations can be recognized in a similar manner. The method is so sensitive that even three-way and possibly four-way combinations can be recognized, but these are usually products of modern plant breeding and not part of the variation of indigenous varieties. If they occur in significant numbers, they could best be treated as subraces of the main races.

The chief advantage of the system is its simplicity. One need only look at the spikelets and ask a few questions. Are the grains flattened on the lower side (caudatum)? Are they flattened on both sides and twisted between the glumes (guinea)? Is the seed elongate with long glumes, usually associated with an open panicle (bicolor)? Is the seed broadest above the middle; are the glumes very wide, the tip of a different texture from the base (durra)? None of these (kafir)? The degree of expression of these characteristics and their combinations determine the race, and for the most part without equivocation. Identification can be made easily in the field or in the laboratory from head or even spikelet specimens.

Since the entire pattern of variation is based on five basic races as units of variation, we shall give brief descriptions of these and our understanding of them.

THE BICOLOR RACE

The bicolor race is based primarily on the subseries Bicoloria of Snowden. The long, clasping glumes, elongate seed, and open panicles are considered to be primitive characters and this group is thought to be the mostly closely related to the wild sorghums of all the cultivated races. This does not mean that the bicolors are necessarily the oldest, however, because bicolor can be reconstituted very easily. Hybrids between Sudangrass and grain sorghums, for example, are bicolor in all respects. It is common experience that the F2 of this cross does not segregate as extensively as could be expected and that the entire F2 population can usually be classed as bicolor, as well as the derivatives of subsequent generations.

Sudangrass itself is a nonshattering segregate from hybrid swarm materials produced in the Khartoum area of Sudan and involving a weedy form of the virgatum race. In the US the original Sudanese introduction has been crossed extensively with both sorgos and grain sorghums until modern Sudangrass differ in many respects from the original accession. They would be classed as race bicolor and it is likely that bicolor cultivars are repeatedly and recurrently reproduced wherever wild and cultivated sorghums occur together. We have recognized such productions in Sudan, Ethiopia, and South Africa and they are probably common and widespread in Africa.

The race is complex, heterogeneous, and consists of several distinct subraces. Sudangrass, sorgo, broomcorn, and bicolor are the main ones. The sorgos, in American usage, include sweet-stalked cultivars from which syrup or molasses can be extracted or which are used as forage for livestock. They enjoyed more popularity in America early in this century than they do now. Most of these are bicolors, although in some, the sweet-stalk character was introduced into modified material that would fall outside the range of the bicolor race. In Africa the sweet sorghums are widely grown but always on a small scale. Near many villages a small patch is grown for chewing, but the sorgos cannot be considered a major or even a very important crop in Africa. The ordinary bicolors are grown for the grain, which is often used in the manufacture of beer.

The bicolors, as a whole, are low-yielding with respect to grain and are not cultivated on vast acreages. They are grown on a small scale almost everywhere that sorghums are grown and consequently do not have a characteristic geographical distribution or ecological adaptation. Their primitive characteristics may be derived from either an ancient domestication or by recent and current introgression with wild or weedy sorghums. Intermediate races involving bicolor are mostly of minor importance, but durra-bicolor is grown extensively in the highlands of Ethiopia.

THE GUINEA RACE

The spikelets of the guineas are derived and specialized and there is nothing resembling them in the wild forms. The long glumes and the open panicles are considered primitive, but otherwise the guineas must be considered specialized and highly evolved. Our guinea race is based primarily on subseries Guineensia of Snowden.

It is basically a West African race, the dominant one of the savanna sorghum belt. In a general way, the larger-seeded types are grown in the drier zone, and the very small-seeded types, in the wettest zones at the fringe of the forest. A secondary center is found in East Africa, primarily in Malawi, and scattered examples may occur almost anywhere in Africa except in the driest zones.

We have found it most convenient to divide the race into three subraces based primarily on seed size: Conspicuum (large seeds), guinea (medium seeds), and margaritiferum (small seeds). Other characters used by Snowden to partition the race, such as hairiness, seed color, glume color, etc. seem to have little biological significance.

Since the guineas are often grown in high rainfall areas, there has evidently been considerable selection for good weathering and storage qualities. Seeds are often hard and corneous, keep their colors well, and are rather resistant to insect damage under primitive storage conditions. The open pendulous panicles and gaping glumes probably help reduce mold damage under wet conditions.

Many of the cultivars yield well and the race is of tremendous importance in West Africa, where it feeds millions of people. Some cultivars are remarkably tolerant of flooding (Harlan and Pasquereau, 1969) and basic to the specialized agriculture of the Niger *décrue*. Some intermediate races involving guinea are also important. Guinea-caudatum is a major race of Nigeria, Chad, and Sudan. Guinea-kafir is found to some extent in East Africa and is a major race in India

(*S. roxburghii* Stapf). The guinea-bicolor race is of minor importance, and guinea-durra is so rare that Snowden did not observe it.

THE CAUDATUM RACE

Our race caudatum is not based on a Snowden subseries as the other races are, but on material assigned by Snowden to a portion of *S. caudatum* Stapf and a portion of *S. nigricans* (Ruiz et Pavon) Snowden.

The pure caudatum race with its characteristic turtle-backed grains is dominant in parts of Sudan, Chad, Nigeria, and most of Uganda. Agronomically, it is one of the most important races of all, and the intermediate races involving it are also important. Caudatum spikelet types may be found on almost any head type, but the distribution is far from random. The more compact head types are confined to the drier zones and the open or unbellate head types are most common in areas of high rainfall.

The appropriate number of subraces has not yet been established, and there is some confusion due to problems of interpretation. In Sudan, for example, a common Arabic name for a kind of sorghum is "feterita." Included are cultivars that vary from guinea-caudatum through caudatum to durra-caudatum. Should the term "feterita" be used in the Arabic sense, or should it be restricted to the original material introduced to the US? The latter is a durra-caudatum, but probably most of the feteritas of the Sudan are of the caudatum race.

We have two kinds of dobbs in our collection. One is a caudatum, and the other, a guinea-caudatum. On the other hand, materials labelled hegari seem to be consistently caudatum. Considering these problems, it is probably premature to establish subraces of caudatum in a definitive way, but feterita, hegari, and dobbs are materials familiar to many sorghum workers.

The most important of the intermediate races by far is kafir-caudatum. Almost all of the modern American hybrid grain sorghums are of this race. The production in 1967 was estimated as 19 million metric tons. The durra-caudatum race is best known for its kaura subrace, dominant in northern Nigeria and a source of yellow endosperm and large seed size for American breeding programs. The guinea-caudatum race has already been mentioned as important from Nigeria to Sudan.

Caudatum apparently has the capacity to confer yielding ability, bright seed colors, and good seed quality to its hybrid derivatives. It has been a most important source of germ plasm for modern plant breeding programs around the world.

THE KAFIR RACE

Our race kafir is based on subseries Caffra with the caudatum materials omitted. It is a major race in East Africa from Tanzania southward and is not well represented north of the equator. The name is derived from the Arabic for "unbeliever" or pagan, referring to the blacks who grow it. Since agriculture came to this region relatively late, one would suppose that the race is of no great antiquity. The spikelet characteristics are, perhaps, less specialized than in guinea, caudatum, and durra, but the heads are usually semicompact to compact. The race is important agronomically, and its derivatives intermediate races, even more so.

The guinea-kafirs of India and the kafir-caudatums of the American sorghum belt have already been mentioned. The kafir-durras are not significant among indigenous African sorghums, but have been important as sources of breeding materials. The cytoplasmic male sterile system used in hybrid grain sorghum production involves durra (milo) cytoplasm and kafir derivatives as maintainers.

THE DURRA RACE

The race is based on subseries Durra. That the name durra is derived from the Arabic for sorghum (or millets in general) is appropriate. It is a Near Eastern race closely associated with Islam. The durras are dominant in Ethiopia, especially among the lowland tribes; it is virtually the only race in Turkey, Syria, Iraq, Iran, Arabia, North Africa, and along the fringes of the southern Sahara. Perhaps $^4/_5$ of the sorghums of India are durras (Ayyangar et al. 1942).

While many of the durras of Ethiopia and the Sudan are long-season cultivars, the durras do include the most ephemeral, short-season cultivars of all the sorghums. These are drouth resistant or at least drouth evading and can be grown in the driest regions where sorghum culture is possible. They were once important in the US and were called milo, but have largely been replaced by kafir-caudatum or at most kafir-caudatum-durra materials.

We are not able at this time to provide a useful partition of the race into subraces, but the milos of Africa and the nandyal types of India are familiar examples to many sorghum workers. Among indigenous sorghums, the most important intermediate races involving durra are durra-caudatum (Nigeria, Chad, Sudan) and durra-bicolor, the highland sorghums of Ethiopia. The durras are in many ways the most specialized and derived of all the sorghums and many useful characters are likely to be found in them.

Geographic distribution of the races lends support to the validity of our classification. Intermediate races appear in the expected places (de Wet and Harlan, 1971). In West Africa guinea is the dominant race of the savanna from Senegal to western Chad. To the eastward, it is replaced first by guinea-caudatum and then by caudatum. Guinea-kafir is found in East Africa where guinea and kafir are grown. Durra-caudatum is a major race in northern Nigeria with a belt of durra to the north of it in Niger and caudatum in abundance to the south and east. It is significant that guinea-durras are so uncommon that they were not in the Snowden collection. We have found a few in the world sorghum collection, but the ecological amplitudes of guineas and durras are so different that one would not expect them to come together except under special circumstances.

In order to compare our system with others most generally used, we provide classification of the Snow-

Table 1. Classification of the species used by Snowden.

Species	Race
(1) S. aterrimum	Shattercane
(2) S. drummondii	Shattercane
(3) S. nitens	Shattercane
(4) S. margaritiferum	Guinea
(5) S. guineense	Guinea
(6) S. mellitum	Guinea-bicolor
(7) S. conspicuum	Guinea
(8) S. roxburghii	Guinea-kafir
(9) S. gambicum	Guinea
(10) S. exsertum	Bicolor
(11) S. membranaceum	(various)
(12) S. basutorum	Kafir-bicolor
(13) S. nervosum	in part Bicolor in part Caudatum-bicolor in part Kafir-bicolor
(14) S. melaleucum	Guinea-bicolor
(15) S. ankolib	Durra-bicolor
(16) S. splendidum	Bicolor
(17) S. dochna	Bicolor
(18) S. bicolor	Bicolor
(19) S. miliiforme	Kafir-bicolor
(20) S. simulans	Kafir-bicolor
(21) S. elegans	in part Guinea-caudatum in part Kafir-bicolor
(22) S. notabile	in part Guinea-caudatum in part Caudatum-bicolor
(23) S. coriaceum	Kafir
(24) S. caffrorum	Kafir
(25) S. nigricans	in part Kafir-caudatum in part Caudatum
(26) S. caudatum	in part Caudatum in part Guinea-caudatum in part Durra-caudatum
(27) S. dulcicaule	Guinea-caudatum
(28) S. rigidum	Durra-bicolor
(29) S. durra	Durra
(30) S. cernuum	Durra
(31) S. subglabrescens	Durra-bicolor

den species, Table 1, and of the Indian work groups, Table 2. The Snowden collection at Kew has been examined as well as his descriptions. As for the work groups, it must be emphasized that we have classified only those specimens sent to us by the USDA and make no attempt to interpret what was intended by any work group designation. Some discrepancies are conspicuous, but there is a broad, general correspondence of the two systems.

The partitioning of the races into subraces is not complete at this time. In the flexible system we propose for cultivated plants (Harlan and de Wet, 1971) the subraces should be based on the experience of agronomists and plant breeders as to what comprises useful groupings of cultivars. This will emerge as the materials in the world sorghum collection become more familiar to professional sorghum workers.

Table 2. Classification of work groups according to specimens received from USDA and grown in Puerto Rico.

Work group	Race
(1) Roxburghii	Guinea*
(2) Roxburghii/Shallu	Guinea-kafir
(3) Conspicuum	Guinea
(4) Guineense	Guinea
(5) Margaritiferum	Guinea
(6) Membranaceum	Durra (py glumes)
(7) Kaoliang	Bicolor
(8) Nevosum-kaoliang	Kafir-bicolor
(9) Bicolor-broomcorn	Bicolor
(10) Bicolor-sorgos & others	Kafir*
(11) Bicolor/Kafir	Bicolor
(12) Dochna	Bicolor
(13) Dochna/Leoti	Bicolor
(14) Dochna/Amber	Bicolor
(15) Dochna/Collier	Caudatum-bicolor
(16) Dochna/Honey	Bicolor
(17) Dochna/Roxburghii	Guinea-caudatum
(18) Dochna/Kafir	Kafir
(19) Dochna/Nigricans	Caudatum
(20) Dochna/Durra	Durra
(21) Elegans	No specimen
(22) Caffrorum	Kafir-caudatum
(23) Caffrorum/Darso	Kafir-caudatum
(24) Caffrorum/Birdproof	Kafir-caudatum
(25) Caffrorum/Roxburghii	Guinea-kafir
(26) Caffrorum/Bicolor	Caudatum-bicolor
(27) Caffrorum/Feterita	Durra-caudatum
(28) Caffrorum/Durra	Kafir
(29) Nigricans	Caudatum
(30) Nigricans/Bicolor	Kafir
(1) Dobbs	Guinea-caudatum
(2) Nigricans/Guinea	Guinea-caudatum
(31) Nigricans/Feterita	Caudatum
(1) Dobbs	Caudatum
(32) Nigricans/Durra	Durra
(33) Caudatum	Durra*
(34) Caudatum/Kaura	Durra-caudatum
(35) Caudatum/Guinea	Bicolor*
(36) Caudatum/Bicolor	Caudatum-bicolor
(37) Caudatum/Dochna	Bicolor
(38) Caudatum/Kafir (Hegari)	Caudatum
(39) Caudatum/Nigricans	Caudatum
(1) Zera-Zera	Caudatum
(40) Caudatum/Durra	Caudatum
(41) Durra	Durra
(42) Durra/Roxburghii	Guinea-bicolor
(43) Durra/Membranaceum	Guinea-durra
(44) Durra/Bicolor	Durra-bicolor
(45) Durra/Dochna	Durra-bicolor
(46) Durra/Kafir	Kafir-caudatum
(1) Nandyal	Durra
(47) Durra/Nigricans	Caudatum
(48) Durra/Kaura and others	No specimen
(49) Cernuum	Guinea-bicolor*
(50) Subglabrescens	Durra-bicolor
(51) Subglabrescens/Milo	Durra
(52) Sudanense	Bicolor
(53) Grass-grains	No specimen
(54) S. halepense	Durra-caudatum*
(55) S. almum	Shattercane*
(60) S. plumosum	Shattercane*
(61) S. verticilliflorum	Shattercane*
(62) S. virgatum	Shattercane*

* Specimen does not agree with descriptive name of work group.

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