UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 981
Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER December 21, 1921

SUDAN GRASS AND RELATED PLANTS

By

H. N. VINALL, Agronomist, and R. E. GETTY, Assistant Agrostologist
Office of Forage-Crop Investigations

CONTENTS

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By H. N. VINALL, *Agronomist*, and R. E. GETTY, *Assistant Agrostologist*,[1]
Office of Forage-Crop Investigations.

CONTENTS.

INTRODUCTION INTO THE UNITED STATES.

Sudan grass was introduced into the United States from Africa in 1909, through the efforts of C. V. Piper, Agrostologist in Charge of the Office of Forage-Crop Investigations, Bureau of Plant Industry, United States Department of Agriculture. Eight ounces of seed were obtained in the original importation (fig. 1), and a portion of this was planted that year at the forage-crop field station at Chillicothe, Tex.[2] From this small beginning has come practically all of the

[1] Many of the data here recorded were contributed by the following members of the staff of the Office of Forage-Crop Investigations, who personally conducted the experiments at the points indicated: R. W. Edwards, at Chillicothe, Tex. (resigned Feb. 25, 1918); A. B. Cron, at Amarillo, Tex.; Roland McKee, at Chico, Calif.; Samuel Garver, at Redfield, S. Dak.; and H. R. Reed, at Bard, Calif. Acknowledgment is made of their assistance and of the cooperation of the agronomists of the State Agricultural Experiment Stations and the superintendents of the field stations of the United States Department of Agriculture.

[2] The field station at Chillicothe, Tex., is maintained as a cooperative project in conjunction with the Texas Agricultural Experiment Station. From its inception, in 1905, up to 1916 the expenses were borne largely by the United States Department of Agriculture. In 1915, 100 acres of land 5 miles southwest of Chillicothe were purchased by the State of Texas and designated "Texas Substation No. 12." The cooperation between the Office of Forage-Crop Investigations of the United States Department of Agriculture and the Texas Agricultural Experiment Station has been continued at the new location. The administration of the station since January 1, 1916, has been in the hands of the Texas station, and the State of Texas has made liberal financial contributions to support the work.

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Sudan grass now being grown in the United States. The value of this crop in 1918 was estimated at $10,500,000.

The first importation of Sudan grass seed, which was received in the United States on March 16, 1909, was presented to the United States Department of Agriculture by R. Hewison, then Director of Agriculture and Lands, Sudan Government, Khartum, Sudan. This shipment was assigned S. P. I. No. 25017. A second importation was received on July 12, 1912, from W. A. Davie, Inspector of Agriculture, Khartum, Sudan, and assigned S. P. I. No. 34114. A third lot was re-

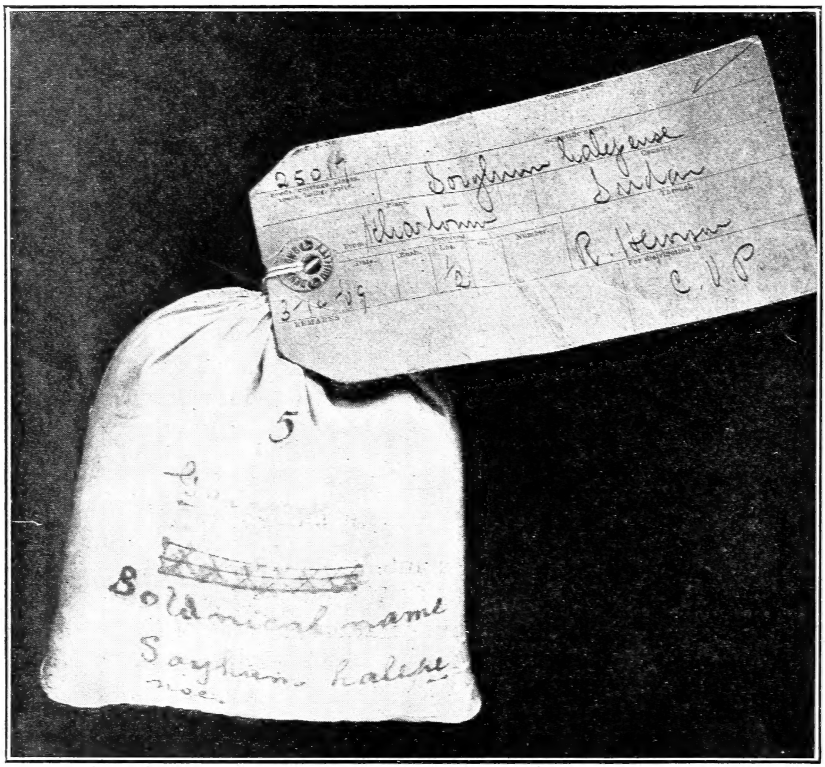

FIG. 1.—The original package of Sudan grass seed just as it came from Mr. R. Hewison, Khartum, except for the attached inventory tag of the Office of Foreign Seed and Plant Introduction.

ceived on January 24, 1918, from W. Carl McQuiston, Cairo, Egypt, and numbered 45773 in the Seed and Plant Introduction Inventory. The first two importations, Nos. 25017 and 34114, were to all appearances identical in value, but No. 45773 was less vigorous and was therefore not used in growing seed for experimentation or distribution.

In addition to the shipments received by the United States Department of Agriculture, there were at least two known importations of Sudan grass seed from Africa by private parties, one by L. T. Shoemaker, Camden, Ohio, in 1914, and the other by W. E. Mountain,

Pilot Point, Tex., in the same year. None of these later importations had any appreciable effect on the spread of Sudan grass in the United States, because practically all of the seed distributed by the United States Department of Agriculture to State agricultural experiment stations in 1912 and to farmers in 1913 originated in the importation of 1909 grown in the increase plats at the Chillicothe (Tex.) Field Station in that and the following years (fig. 2). The Texas Agricultural Experiment Station obtained a considerable quantity of the seed from the Department of Agriculture in 1913 and distributed it to farmers in the State, enthusiastically urging its propagation.

FIG. 2.—The first row of Sudan grass grown in the United States. Photographed at the Chillicothe (Tex.) Field Station, July 17, 1909.

The success of the Sudan grass was immediate and phenomenal, and in order to encourage its propagation the Office of Forage-Crop Investigations has carried on a great many tests in cooperation with the State agricultural experiment stations. It is the purpose of this bulletin to describe the results of these tests more fully than was possible in the former publication, Farmers' Bulletin 1126, in order to establish definitely the status of Sudan grass in different sections of the United States and to furnish a more complete basis for the recommendations given in the bulletin mentioned. Other grass sorghums closely related to Sudan grass are considered also and their probable value indicated.

DESCRIPTION AND BOTANICAL RELATIONSHIPS.

Sudan grass is an annual hay plant belonging to the sorghum family, with slender stems 4 to 6 feet high, numerous, rather soft leaves, a loose, open panicle, numerous tillers, only occasional

branches, and no rootstocks. Johnson grass (*Andropogon halepensis*), on the other hand, is a perennial under favorable conditions, with stems more slender than those of Sudan grass, 3 to 4 feet high, few, narrow, rather harsh leaves which have thick white midribs, loose, open, often drooping panicles, few to many tillers, branching somewhat after maturity, and with numerous aggressive rootstocks which make it difficult to eradicate from cultivated fields. The seed characters of the two grasses will be considered in detail under "Seed production."

According to the classification of Piper in his "Forage Plants and Their Culture," Sudan grass belongs to his proposed new agronomic group called "grass sorghums," and its technical name is *Andropogon sorghum sudanensis* (19, pp. 33–34)[3] and not *Andropogon halepensis*, under which name it was obtained from Africa.[4] The dividing line botanically between *Andropogon sorghum* and *Andropogon halepensis* has been determined by Piper as the presence or absence of rhizomes, or rootstocks. This characteristic provides a very definite line of demarcation, and a study of the map of Africa and the Mediterranean region of Europe and Asia (fig. 3) leaves little doubt that the range of natural distribution conforms with this indicated classification. The halepensis, or rootstock, forms are confined to Asia Minor, Turkey, Greece, Italy, southern France, and the northern parts of Africa, the distribution extending eastward through southern Asia to the Himalayas, while farther south in the interior of Africa all the wild forms of Andropogon seem to lack rootstocks and to be more closely related to the true sorghums.

Rather strong evidence of a specific difference between Johnson grass and the sorghums is the difficulty attending their cross-pollination. It has long been known that Johnson grass crosses very rarely with the sorghums, even though the two species have been intermingled in the same fields for the last 30 years. A letter of inquiry was sent in 1912 to each agronomist of the agricultural experiment stations of our Southeastern States where Johnson grass was known to be abundant, asking him if he had ever personally observed an undoubted hybrid of Johnson grass and sorghum. The replies revealed the astonishing fact that only one of these men so intimately in touch with agricultural conditions in these States was willing to say that he had observed even what he suspected might be a cross between these two crop plants. Since that time a definite search for such hybrids has resulted in the discovery of three or four undoubted natural crosses between sorghum and Johnson grass, one of which is

[3] The serial numbers in parentheses refer to "Literature cited," at the end of this bulletin.

[4] The technical name of Sudan grass used in Department Bulletin No. 772, entitled "The Genera of Grasses of the United States," by A. S. Hitchcock, p. 267, is *Holcus sorghum sudanensis* (Piper) Hitchc., while its allies are known as *Holcus sorghum drummondii* (Nees) Hitchc., and *Holcus sorghum exiguus* (Forsk.) Hitchc.

shown in figure 4. Attempts to cross these two species artificially in the greenhouse have been successful in only a very small percentage of the trials, most of the attempts resulting in failure even under fa-

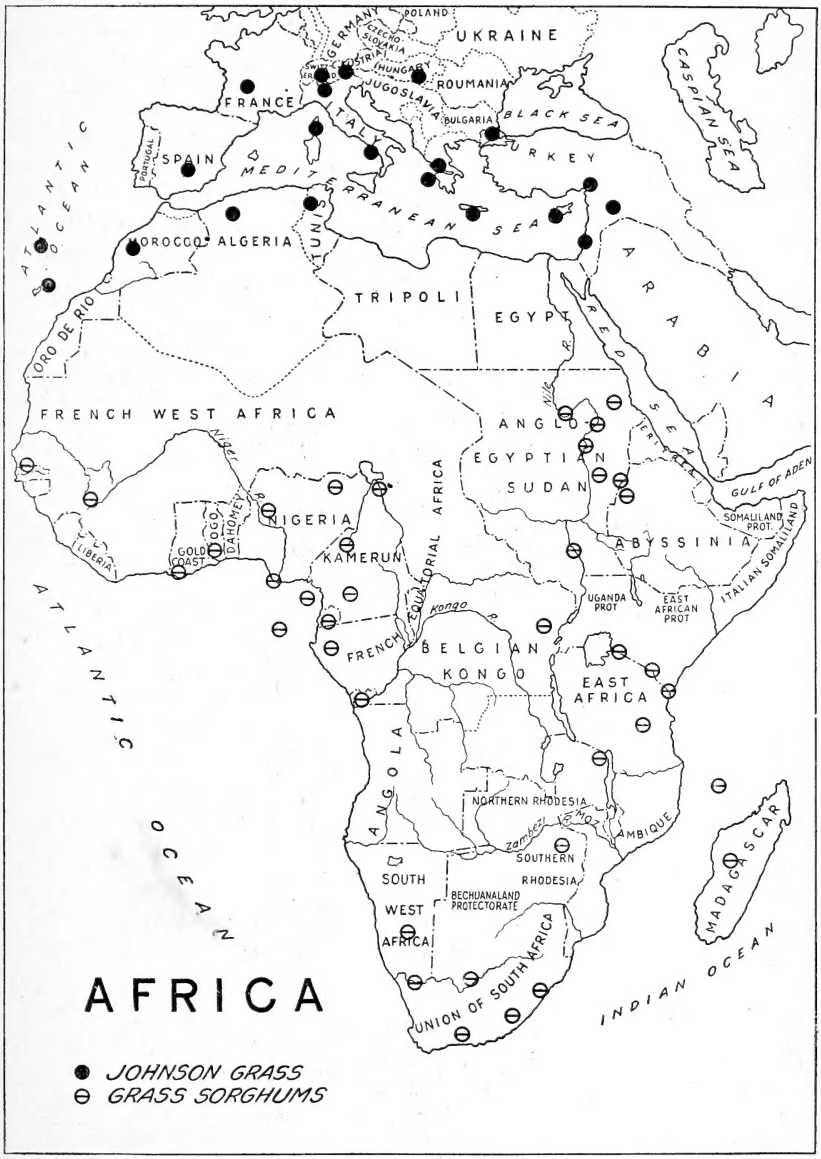

FIG. 3.—The natural distribution of Johnson grass and the grass sorghums.

vorable conditions. There is apparently an antagonism or unfavorable reaction between the reproductive organs of these two plants, which is rather decided evidence of their specific differences.

Several other grass sorghums discovered in Africa and near-by islands since the introduction of Sudan grass into the United States indicate the possibilities which exist in this comparatively unexplored

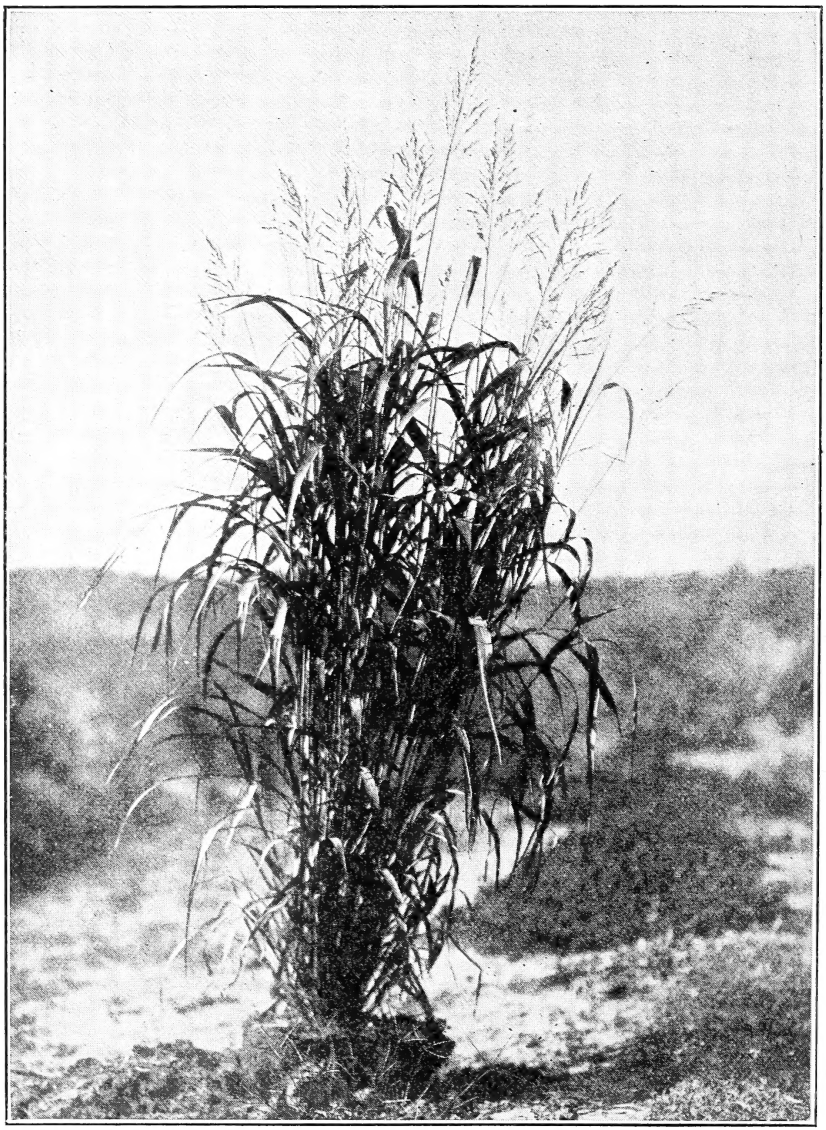

FIG. 4.—A typical plant of the Sumac sorgo-Johnson grass hybrid, F. C. I. No. 5846. Photographed at the Arlington Experimental Farm, Va., October 12, 1913.

continent. Among these introductions are Tunis grass, toura, Kamerun grass, and tabucki grass.

A discussion of these different grass sorghums has been introduced in order to show the very easy and natural gradations in forms already

known to exist between Sudan grass and the cultivated varieties of sorghum. Others, no doubt, will be found in Africa when that continent is more carefully explored. No one can foretell the possibilities of improvement through the careful hybridization of these new forms with our cultivated sorghums.

TUNIS GRASS.

There have been at least two distinct importations of Tunis grass (*Andropogon sorghum virgatus* (Hack.) Piper) through the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry. The first, S. P. I. No. 26301, was received from Dr. L. Trabut, Algiers, Algeria, December 2, 1909. In a letter received at a subsequent date from Doctor Trabut he says regarding Tunis grass: "This grass has been accidentally introduced at the botanic station with seeds from Egypt, berseem, sorghum, cereals, etc. It has meanwhile become naturalized here." The second importation, S. P. I. No. 38108, was received May 4, 1914, from Alfred Bircher, of the Middle-Egypt Botanic Station, Matania el Saff, Egypt, who described it as "a fodder grass growing spontaneously in Egypt."

Evidently Tunis grass, like Sudan grass, has been introduced into Egypt and no doubt is found growing spontaneously where it has escaped from cultivation. It is native, however, in Anglo-Egyptian Sudan, where it is found growing wild. The Kew and Berlin herbaria contain specimens of Tunis grass from Kordofan, Khartum, El Egeda, between Old Dongola and Merowat, between Khartum and Berber, and at Matama in northern Abyssinia. Hackel cites a specimen from Senegal also.

Tunis grass has never been tested so extensively as Sudan grass, because it has always appeared less desirable. It is not as leafy as Sudan grass (fig. 5), and its seeds shatter so easily that a great deal of care is required to obtain a sufficient quantity for field plantings. Scar tissue forms at the base of the seed, and it breaks from the rachis branch clean, like Johnson grass. Much of the seed falls from the top of the panicle before that at the bottom is ripe and while the leaves and stem of the plant are yet green.

At the Fort Hays Experiment Station, Hays, Kans., in 1914 and 1915 Tunis grass made an average yield of 8,360 pounds and Sudan grass 8,840 pounds of cured hay to the acre. The difference in yield is not very large, but the quality of the Tunis grass hay was so inferior to that of the Sudan grass hay that further tests were not considered necessary. R. E. Karper, superintendent of substation No. 8, Lubbock, Tex., says in Bulletin No. 219 of the Texas Agricultural Experiment Station: "Comparisons of Sudan grass and Tunis grass for forage in 1914 resulted in Sudan grass outyielding the latter in every case, showing a total average increase of yield of 0.85 ton

per acre." Tests at the field stations at Chillicothe and Amarillo, Tex., have always shown that Sudan grass is superior to Tunis grass in those localities.

Tunis grass seems best adapted to a region where the period of heaviest rainfall coincides with that of the higher temperatures. It is possible that it might have some value in a locality having wet and dry seasons. If the temperatures were high enough during the wet part of the year Tunis grass might make a good pasture grass and reseed itself indefinitely.

Tunis grass crosses freely with the sorghums, and some of these natural crosses appear more valuable than the pure strain. This

FIG. 5.—Tunis grass grown in rows 40 inches apart at the Arlington Experimental Farm, Va. Photographed August 26, 1915.

grass apparently has only two points of superiority over Sudan grass; it is a few days earlier in reaching maturity and is less subject to the attacks of red-spot, or sorghum blight. These two characters if they are transmitted to the hybrids with sorghum may give to such hybrids a superiority over the Sudan-sorghum crosses.

KAMERUN GRASS.

The first introduction into the United States of Kamerun grass (*Andropogon sorghum effusus* Hackel) was S. P. I. No. 38005, received April 13, 1914. This was obtained by P. H. Dorsett, near Bahia, Brazil, in which country it is rather widely distributed. A second shipment of seed, S. P. I. No. 38670, was received on July 1, 1914, from Dr. T. A. Argolla Ferrão, Bahia, Brazil. In Brazil

this grass bears the vernacular name "capim de boi," which means grass of the ox or cattle. Kamerun grass is undoubtedly a native of the Kongo and Guinea coast regions of Africa, where numerous travelers have found it growing wild, usually along watercourses. It was no doubt introduced into Brazil by the slave trade and by the same agency into Cuba, another place where it is now found.

Besides the importations obtained by P. H. Dorsett, of the Office of Foreign Seed and Plant Introduction, several other collectors, including Burchell, Blanchet, and Gardner, found Kamerun grass in Brazil (18). The Kew and Berlin herbaria contain specimens from the islands of St. Thomas and Fernando Po, from Kamerun, the Spanish Guinea Hinterland, Togo, and Boma on the Kongo River and Nupe on the Niger River. Most of the specimens, it will be noted, are from the Guinea coast region, but Shantz[5] found Kamerun grass in abundance along the Lualaba River and in other parts of eastern Belgian Kongo. It would therefore seem to be widely distributed in the interior of equatorial Africa, as well as along the Guinea coast.

FIG. 6.—Kamerun grass, S. P. I. No. 38005. Planted April 22. Photographed October 19. Plants ripening at a height of 7 feet. Chula Vista, Calif., 1916.

Under cultivation in the United States, Kamerun grass reaches a height of 6 to 9 feet, with erect stems somewhat larger than a lead pencil; narrow, rather harsh leaves with thick midribs; and a large, loose, drooping panicle. (Fig. 6.) The individual spikelet is about the same shape as that of Sudan grass, but smaller and pubescent,

[5] Dr. H. L. Shantz, of the Bureau of Plant Industry, United States Department of Agriculture, spent about 14 months, from July, 1919, to September, 1920, on a collecting trip in eastern Africa for the Office of Foreign Seed and Plant Introduction.

whereas that of Sudan grass is nearly glabrous. The seed shatters easily, but not so readily as seed of Tunis grass or tabucki grass. A study of Kamerun grass in row plantings at various field stations has indicated that it can not compete successfully with Sudan grass in the United States. It may have some value, however, for crossing with Sudan grass or the sorghums.

TABUCKI GRASS.

Seed of tabucki grass (*Andropogon sorghum verticilliflorus* (Steudel) Piper) was obtained as S. P. I. No. 38866 from I. B. Pole Evans, Pretoria, South Africa, in 1915. It is a variable grass which appears indigenous to southeastern Africa from Mount Kilimanjaro to the Cape. Numerous specimens are also recorded from adjacent islands in the Indian Ocean.

Later importations of tabucki grass were received as follows: S. P. I. No. 39377, from H. G. Mundy, Department of Agriculture, Salisbury, southern Rhodesia, November 9, 1914 (the seed of this lot was immature and none of it germinated); S. P. I. No. 40773, from P. R. Dupont, curator of the Botanic Gardens, Seychelles Islands, May 19, 1915; S. P. I. No. 40832, from I. B. Pole Evans, Department of Agriculture, Pretoria, South Africa, June 7, 1915 (the seed of this lot was collected at Tzaneen in northern Transvaal); and S. P. I. No. 40897, from F. A. Stockdale, Director of Agriculture, Reduit, Mauritius, July 6, 1915. The seeds from Mauritius produced plants which resembled toura more than they did tabucki grass.

Under cultivation in the United States tabucki grass resembles Kamerun grass very closely. The stems are erect or slightly spreading, 6 to 9 feet high, somewhat larger than a lead pencil, with 9 or 10 leaves which are rather narrow and harsh. The panicle is large and spreading, like that of Kamerun grass, but the spikelets are a little smaller, more turgid at the base, and shatter from the stem almost as freely as the seed of Tunis grass.

Another form of *Andropogon sorghum verticilliflorus* is the toura, of Tahiti. A small sample of this was obtained by the United States Department of Agriculture in 1903 from William F. Doty, United States consul, Tahiti, Society Islands, but it was identified as Johnson grass (*Andropogon halepensis*), and no attempt apparently was made to test the seed at that time. Later, when trials of Sudan grass had indicated the possible differences which might exist in these so-called halepensis forms, the seed was brought out and tested. These tests showed that it was not halepensis, being entirely without rootstocks. The description of tabucki grass answers for toura except that toura is somewhat earlier and smaller than tabucki grass and the stems ascend at a trifle wider angle. (Fig. 7.)

Mr. Edouard Ahnne, president of the Chamber of Agriculture, Tahiti, Society Islands, who presented an additional supply of toura seed to the United States Department of Agriculture under S. P. I. No. 42278, sends the following information about it: "This grass grows in Tahiti in a wild state, all along the creeks, on the roadside, and on the uncultivated lands. The horses and cattle seek for it willingly when it is young; later, the stem becomes woody and hard."

Tests of the different forms of *Andropogon sorghum verticilliflorus* indicate that they are of little value in the United States.

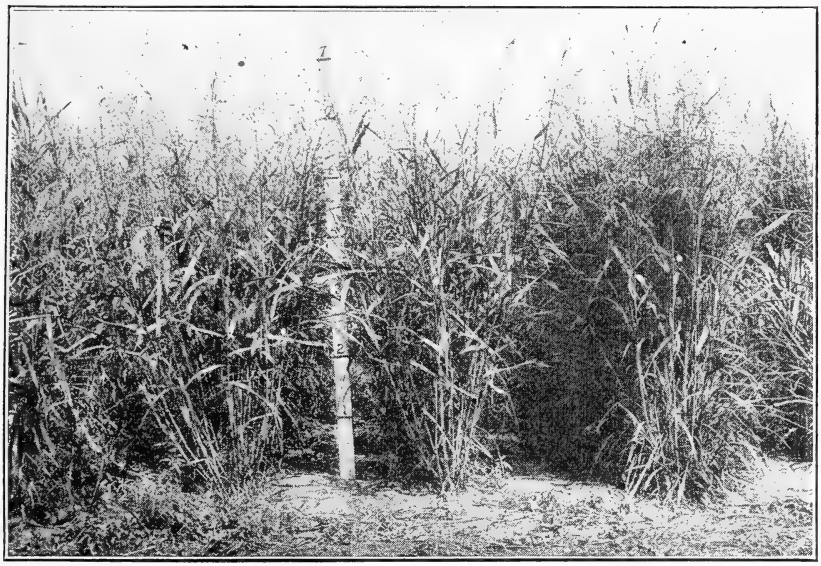

FIG. 7.—Two rows of toura grass (on the left) and a row of Sudan grass (on the right)Chillicothe, Tex., September 16, 1915.

HEWISON GRASS.

Seed of a wild sorghum (*Andropogon sorghum hewisoni* Piper) was obtained as S. P. I. No. 33739 from Sennaar Province, Sudan, through R. Hewison, Esq., in 1912. It has stout, rather pithy, slightly sweet stems five-eighths of an inch in diameter and 8 to 10 feet high; many rather broad leaves; a compact panicle, the base of which is inclosed in the sheath; and spikelets which are decidedly pubescent and usually reddish in color. This wild sorghum is more limited in distribution than the others mentioned and is more nearly like the cultivated varieties. (Fig. 8.) It is quite possible that a more complete knowledge of this form will show it to be a cross between some other wild sorghum and durra.

In the United States *Andropogon sorghum hewisoni* is found to require a very long season in which to mature and it seems to be of little value.

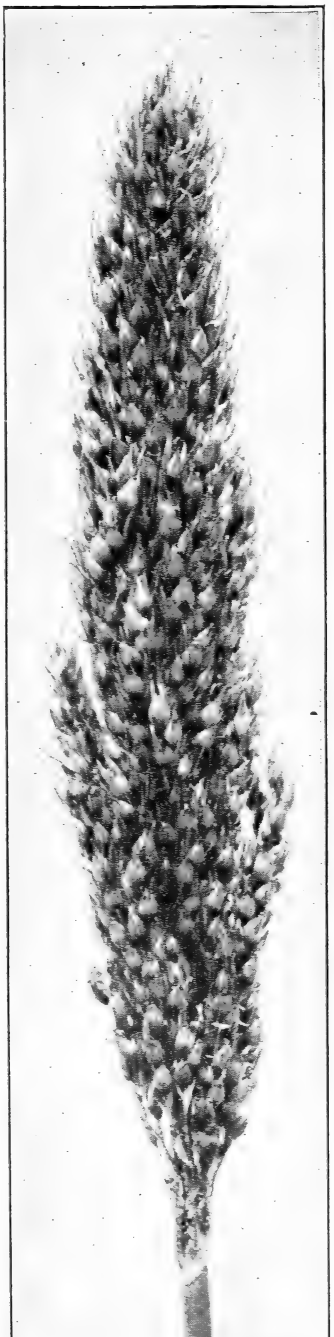

FIG. 8.—Panicle of *Andropogon sorghum hewisonii*, S. P. I. No. 33739, from a plant grown in the greenhouse of the Department of Agriculture.

CHICKEN CORN.

Seed of this sorghum (*Andropogon sorghum drummondii* (Nees) Hackel) was first collected by Drummond at New Orleans in 1832. It is widely distributed in Louisiana and Mississippi, being known locally as "chicken corn," and occurs as far north as Kentucky, growing spontaneously in cultivated ground. This wild sorghum was undoubtedly introduced from Africa by Negro slaves, as it has been found in northern Nigeria and at other points along the Niger River. Specimens have been collected from the Carolinas, Mexico, Yucatan, and Guatemala. This sorghum apparently has been modified by cultivation, and in its present form it resembles the cultivated varieties much more closely than does any other wild-grass sorghum. At one time it appeared to have been abundant and rather highly prized in the Southern States, but it is now somewhat scarce, owing probably to the attacks of the sorghum midge.

In cultivated plantings at the Arlington Experimental Farm and other field stations of the United States Department of Agriculture *Andropogon sorghum drummondii* grew to a height of 8 to 10 feet, with pithy stems five-eighths to three-fourths of an inch in diameter; rather broad, fairly abundant leaves; panicle barely exserted from the last leaf sheath, open and spreading like that of Amber sorgo (fig. 9); and spikelets about the same size as those of Black Amber, with smooth black or reddish brown glumes. A careful comparison with other sorghums indicates that this form, though interesting historically, adds little of value to the crop plants of the United States.

SORGHUM-JOHNSON GRASS HYBRIDS.

Consideration of some of the natural and artificial hybrids of sorghum and Johnson grass indicates the wide possibilities in this comparatively untouched field. The first natural hybrids to be studied

FIG. 9.—Typical panicle of chicken corn (*Andropogon sorghum drummondii*). Grown at the Arlington Experimental Farm, Va., 1914.

by the Office of Forage-Crop Investigations were found in September, 1912, in a field of Sumac sorgo on the farm of Mrs. Flynn, near Chillicothe, Tex. This field was badly infested with Johnson grass, and a number of plants were discovered which showed evidences of hybrid origin. Seed was gathered from these plants, and two of them were dug up and transplanted at the field station. One of these plants had elementary rootstocks, and the other, though it lacked any well-developed rootstocks, had a panicle that clearly showed a relationship with Johnson grass.

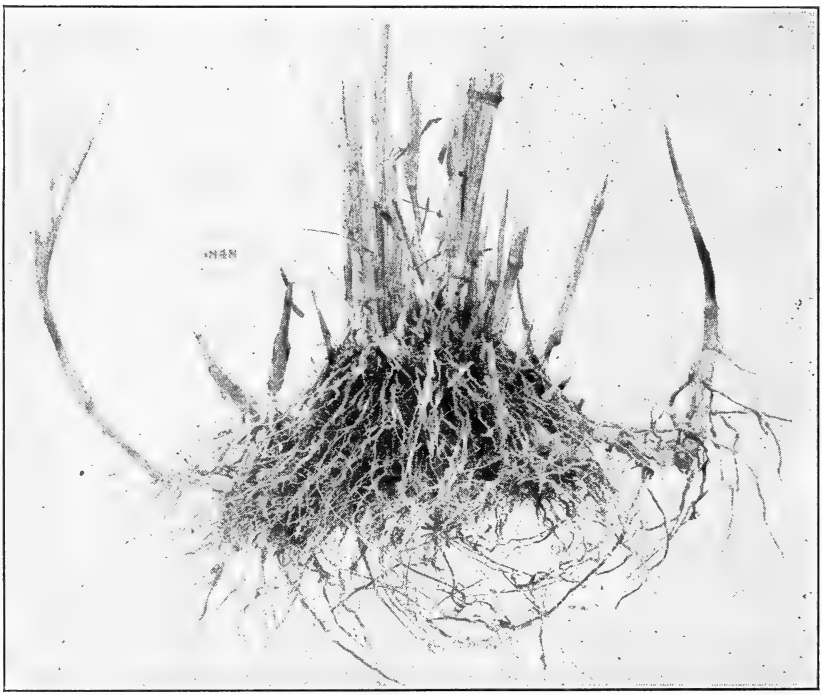

FIG. 10.—Root of a hybrid between Sumac sorgo and Johnson grass, F. C. I. No. 5848, showing the development of rhizomes.

Neither of the plants which had been reset at the field station lived over winter, but the seed from these and other hybrid plants was sown at the Chillicothe Field Station and at the Arlington Experimental Farm, Va., in the spring of 1913. In the resulting crop there were at least four distinct forms. Some had well-developed rootstocks (fig. 10), while others, even though they resembled Johnson grass more closely in stem and leaf characters, had no rootstocks at all. There was also a wide variation in the juiciness and sweetness of the stems, one form being quite as juicy and sweet as Sumac sorgo, while other forms had pithy stems.

A second natural cross between sorghum and Johnson grass was discovered on September 16, 1913, on the farm of J. W. Austin, Pilot Point, Tex. This was located in a field of Honey sorgo, and is quite surely a cross between Honey sorgo and Johnson grass. Mr. Austin has applied to this cross the name "Johnsorgo." This hybrid has abundant and very large rootstocks and will probably not become popular in the South except as a hay and pasture crop on fields already

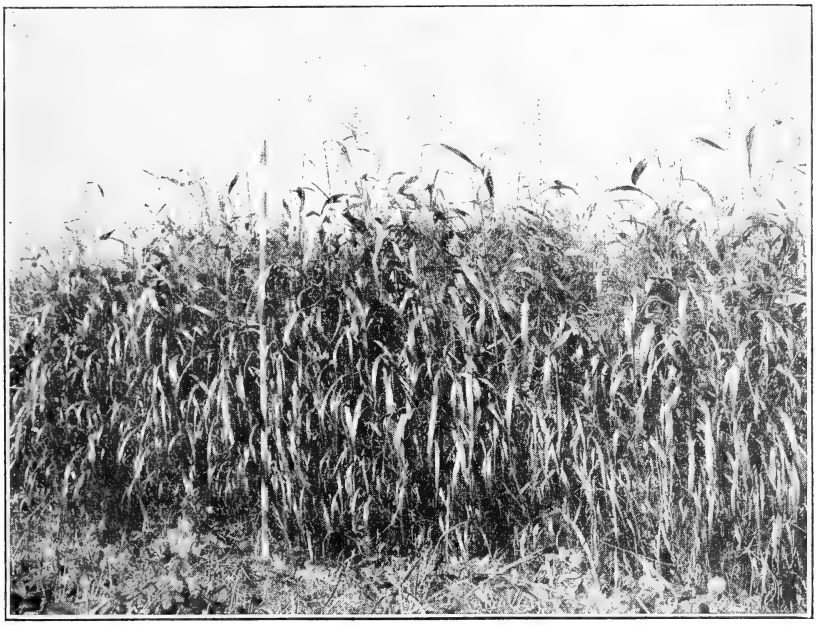

FIG. 11.—A row of "Johnsorgo," F. C. I. No. 8557, 8 feet tall, at the Arlington Experimental Farm, Va., October 11, 1915.

infested with Johnson grass. Johnsorgo is remarkably like Sudan grass in appearance (fig. 11), but is much less subject to the attacks of the red-spot, or sorghum blight, a disease which is very destructive to Sudan grass in warm, moist climates. Johnsorgo is the most promising of all the hybrids between sorghum and Johnson grass yet tested.

In order to provide material for a more definite study of these hybrids several artificial crosses of sorghum and Johnson grass were made. The first of these, F. C. I. No. 6573, a cross between Black Amber sorgo and Johnson grass, was made at the Arlington Experimental Farm, Va., in September, 1912. The first-generation plant, which was grown in the greenhouse that winter from a hybrid seed which developed on the Black Amber sorgo, looked more like Johnson grass than sorgo, but had no rootstocks. Seed from this F_1 plant was

sown at Arlington on June 3, 1913, and the F_2 proved to be quite vigorous, about 90 inches tall, and almost as coarse as its sorgo ancestor. The panicles, however, were intermediate in character, and a few plants in the row developed rudimentary rootstocks. Trials of the progeny of this cross were continued, and several promising selections were made. One of these selections growing in a row at Biloxi, Miss., in 1917 was cut twice, first on July 17 and the second time on October 2. Each time the plants were about 7 feet tall.

Other artificial crosses between sorghum and Johnson grass have been made, but their history is very similar to that of F. C. I. No. 6573 and will not be given here.

Selections from the different sorghum-Johnson grass hybrids have been grown each year in the tests at Chillicothe, Tex., and at other points, but nothing superior to Sudan grass has been obtained. Some of the selections resemble Sudan grass very much, however, (see figs. 4 and 11), and if this valuable grass sorghum had not been discovered previously a fairly good substitute for it could have been developed in this way.

DISTRIBUTION AND IMPORTANCE OF SUDAN GRASS IN AFRICA.

Sudan grass is being cultivated sparingly under the name "garawi" along the Nile in lower Egypt, mostly on military hay farms. It has not, however, gained any great popularity there such as it has attained in the United States. That this grass originated farther south in Africa is now fairly well established. Botanical specimens of it are on file from upper Egypt; also from Senegambia, a British possession on the west coast of Africa, and from a point near the northern end of Lake Nyasa in northern Rhodesia. Besides these more or less authentic specimens, a plant very similar to Sudan grass has been collected in the Katagum district of northern Nigeria.

The fact that Sudan grass is found only under cultivation in lower Egypt and that it is known to be growing spontaneously along the upper Nile and in the Sudan farther west indicates that the grass must be native in that region of comparatively low rainfall just south of the Sahara Desert. (See the map, fig. 3.) It is more difficult to understand just how the grass came to be found south of the equator on the shore of Lake Nyasa. British colonial troops may have carried the seed with them in hay shipments from Egypt to their more southern possessions, or it may have been carried south by natives from the headwaters of the Nile along the chain of interior lakes which form an almost continuous waterway from Lake Albert Nyanza on the north to Lake Nyasa on the south. These, however, are only speculations. We are sure that Sudan grass is found growing wild in a part of Africa

having a rainfall of 20 to 40 inches and a mean temperature during the growing season of 80° to 90° F., climatic conditions very similar to those in our southern Great Plains, where Sudan grass has done so well.

SUDAN GRASS IN OTHER COUNTRIES.

Since its introduction by the United States Department of Agriculture, Sudan grass has been tested in many parts of the world. It has, perhaps, been most successful in Australia, where it is being grown at the different experiment stations, and is recommended highly, especially in New South Wales (3). It has done well where tested in Brazil and Argentina (fig. 12), and no doubt will become a valued forage crop in the stock-producing sections of South America.

FIG. 12.—Sudan grass on the Estado do Maranhão, 2 degrees south of the Equator in Brazil. Planted February 26 and photographed on May 3 by Edward C. Green, Superintendente, Servico do Algodão, Brazil.

The Philippine Islands, Hawaii, and Porto Rico all report success with Sudan grass, and in Cuba it is highly prized as forage (12). Although it is not adapted to the climate of Canada, good crops of it have been grown in southern Alberta. Sudan grass is sure to prove valuable in all semitropical regions and in the warmer parts of the temperate zones.

SOIL RELATIONS.

FERTILITY.

Sudan grass thrives best, of course, in a good soil. Rich clay loams produce the best growth, but it makes better yields on poor soils than most hay crops. A good many farmers are now using it as a supplementary pasture on poor hill lands in the dry summer

season, and not a few have reported success with it on sandy lands. On sandy land at Valentine, Nebr., it made the following yields of hay to the acre: In rows 42 inches apart, 0.61 ton; in rows 21 inches apart, 0.83 ton; and in drilled seedings, 0.87 ton.

At Grand Rapids, Mich., it grew to a height of 5 feet on sandy soil and made a better yield than any other annual hay plant on trial.

DRAINAGE.

A wet, muggy, or seepy soil is disastrous to Sudan grass, and thorough drainage must be provided for such soils before one can hope to succeed with this grass. Soils not naturally well drained should be tile-drained at least one year previous to seeding, so that the ground will have an opportunity to become warm. Cold, wet soils are particularly unsuited to Sudan grass, and this is the chief reason why early seedings are so often failures.

ACIDITY AND ALKALI.

Sudan grass is not as susceptible to injury from acid soils as the legumes. Applications of lime are required only when the soil is too acid for the ordinary cereals.

Several tests of Sudan grass on alkali soils have been made, and its behavior under such conditions is about the same as that of the sorghums. A number of other crops are far more resistant to alkali than is Sudan grass.

CLIMATIC ADAPTATIONS.

TEMPERATURE REQUIREMENTS.

Sudan grass grows best in a warm climate with a comparatively good rainfall. During germination and early growth it will endure as much cold as other sorghums, but not quite as much as corn. Numerous reports from the Northwestern States show that Sudan grass a few inches high withstood late spring frosts which killed other tender plants. In many of these instances the grass remained practically dormant during the period of low temperatures, but made a vigorous growth when warm weather arrived. In other cases frost killed the young Sudan grass. Still other reports have been common from cold regions to the effect that the crop lived through the season but was of a yellowish color and did not grow more than 6 to 18 inches high even after warm weather came.

Because of the untimely frosts and the cold growing season Sudan grass does poorly at the higher altitudes. The farther south, the higher the altitude limit. The profitable limit for hay production seems to be from 6,000 to 8,000 feet in New Mexico, Arizona, California, Nevada, Colorado, and Utah, and 4,000 to 5,000 feet in Wyoming, Montana, Idaho, Oregon, and Washington. In several tests reported

from Apache County, Ariz., in 1915, this grass produced a hay crop 4 to 5 feet high and sometimes matured seed without irrigation at an altitude of 6,000 to 6,800 feet, and in 1916 it grew 5 to 6 feet high and yielded 2 tons to the acre under irrigation at Eagar, Apache County (7,600 feet). At Currie, Elko County, Nev. (7,380 feet), 1 ton per acre without irrigation was reported in 1916. At Santa Fe, N. Mex. (7,000 feet), one satisfactory cutting was secured on dry land, but two or three farmers in that State report entire failure at 8,000 feet. In southwestern Colorado at altitudes of 6,500 to 7,000 feet, Sudan grass grew 3 to 5 feet high and made satisfactory hay cuttings. It attained a height of 2 feet at Placerville, San Miguel County (9,000 feet), and did equally well at Grand Valley, Garfield County, which is over 8,000 feet high. Many failures, however, have been reported from Colorado, especially in 1915, at altitudes above 6,000 feet. In Wyoming Sudan grass has been a failure at Laramie (7,000 feet), has sometimes grown 3 to 5 feet high at Cheyenne and other points at 6,000 feet, but has appeared to be valuable only in the northeastern part of the State at the lower altitudes (4,000 to 5,000 feet). In Utah in 1916 Sudan grass grew but 2½ feet high at 6,500 feet in Grand County, made 1¼ tons per acre at 7,000 feet in San Juan County, but froze at 8,300 feet in Carbon County when 4 inches high. In Montana under irrigation Sudan grass produced 4 tons of hay per acre in 1914 and 3 tons in 1916 at Bozeman (4,887 feet), but has been satisfactory in less than half the dry-land tests in Fergus County (4,000 feet). In Idaho and Oregon the crop has been successful only in the lower altitudes, frost having killed or injured many plats on the dry lands of those States above 3,000 or 4,000 feet high. In both Oregon and Washington Sudan grass has been found valuable only at the lower altitudes. It can be planted with a reasonable chance of success in the valleys, both to the east and to the west of the Cascade Range. In the Willamette Valley, Oreg., and along the coastal plain in Washington other forage crops, such as alfalfa and the small grains, which will outyield Sudan grass, are available, but even in these localities it can be profitably used for soiling and as an emergency hay crop.

The limit of altitude for seed production is at least 1,000 feet lower than for hay, because under cool conditions it takes a month or more to mature seed after the crop has reached the proper stage of maturity to cut for hay.

MOISTURE REQUIREMENTS.

The drought endurance of Sudan grass is equal but not superior to that of the best sorghums. Its extensive fibrous root system enables the crop to grow as long as there is any available moisture in the soil. It has repeatedly shown ability to discontinue growth but continue alive during a period of drought and then revive quickly and grow vigorously when rain comes. It must have moisture, however, and

crops reported to have grown without rain are usually found to have used soil moisture previously stored or to have been favored by the natural run-off from adjoining areas.

Sudan grass has sometimes given good returns under dry farming in the Southwest at places where the normal annual rainfall is but 8 to 15 inches. It yields much more, however, in the southern Great Plains area, where the annual rainfall is between 20 and 30 inches. Growth is abundant in the Southeast, where the rainfall is 40 to 60 inches, but this humidity permits the sorghum midge to thrive, which, as explained elsewhere, prevents seed production. Where the rainfall is about 60 inches and the altitude mostly below 100 feet, as in Florida and other Gulf and Atlantic coast points, Sudan grass production is usually not profitable, owing to the disease known as red-spot, or sorghum blight. Heavy rainfall, in addition to cold, accounts for the failure of Sudan grass reported within 10 or 20 miles of the Pacific coast in northern California and Oregon. The crop has shown ability, however, to survive inundation for several days as well as corn or any of the sorghums if the soil is drained well.

TABLE I.—*The water requirements of Sudan grass and other staple crops, as determined by experiments at Garden City, Kans., and Akron, Colo.*

[The data under "Ratio" show the number of pounds of water required to produce 1 pound of dry matter.]

Crop plant.	At Garden City, Kans., 1915 (16, pp. 483–484).			At Akron, Colo., 1912 (4, pp. 50–51).	
	Varieties.	Period of growth.	Ratio.	Varieties.	Ratio.
Corn	Pride of Saline	May 22 to Aug. 25	267± 2	Average of 8	286
Kafir	Dwarf Blackhull	May 22 to Sept. 11	221± 2	Blackhull	259±5
Milo	Dwarf	May 22 to Sept. 3	244± 3	Dwarf	273±4
Sorgo				{Minnesota Amber	239±2
				{Red Amber	237±4
Millet				{German	248±7
				{Kursk	187±2
Feterita		May 22 to Sept. 6	249± 2		
Sudan grass		May 22 to Sept. 14	306±15		359±2

The water requirements of Sudan grass and several other crops were determined on the basis of the total dry matter, exclusive of that in the roots, by Briggs and Shantz in 1912 at Akron, Colo., and by Miller in 1915 at Garden City, Kans., as shown in Table I. These results indicate in a general way that Sudan grass uses more water in the production of a pound of dry matter when the supply of soil moisture is abundant than the other sorghums, the millets, or corn. In the tests at Garden City, Kans., and Akron, Colo., the plants were grown under optimum soil-moisture conditions; that is, the soil was supplied regularly with all the water the plant could use. This condition, of course, did not simulate in the least degree the soil conditions ordinarily found in a semiarid region, where drought endurance is an important factor in crop production. It is impossible

to predict what the results would be if the plants were grown in soil with a limited or suboptimum soil-moisture content. The careful work of these investigators can not be used, therefore, as a basis for estimating the value of Sudan grass under dry conditions.

RELATIVE IMPORTANCE OF THE CROP.

Texas, Oklahoma, and Kansas are now the leading States, respectively, in Sudan grass acreage, and will be likely to remain so. Statistics are available for Kansas only, where, according to reports of the State board of agriculture, 79,166 acres were grown in 1918. So far, the leading locality is in northwestern Texas, around Lubbock (29), where the crop has been grown in large acreages for seed and forage since 1913. The acreage in other States is still small,

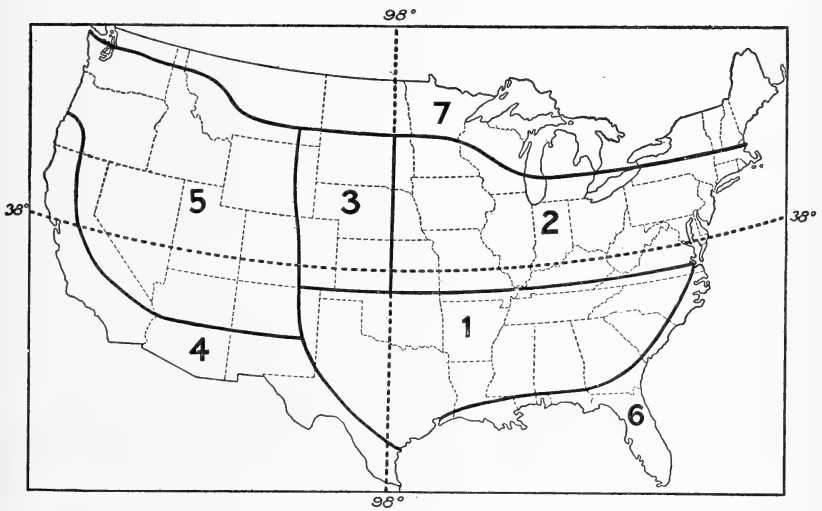

FIG. 13.—Outline map showing the forage value of Sudan grass in different parts of the United States.

but the crop has been widely grown experimentally all over the United States since 1912, and its use is increasing.

The principal regions of production in the United States are shown on the map (fig. 13) as follows:

Region 1.—Two or three good cuttings of hay are obtained without irrigation in this region, the yields varying from 2 to 4 tons to the acre. This is the region of its greatest importance because of the need for a better hay grass in these States. Profitable seed yields are obtained west of the ninety-eighth meridian only, the sorghum midge usually preventing seed formation in the more humid district east of this meridian.

Region 2.—Sudan grass thrives here almost as well as in region 1, making good yields both of hay and of seed. Timothy, clover, and alfalfa, however, meet the hay requirements of this region so fully that Sudan grass is valued chiefly as a catch crop or for limited culture on soils not suited to these forage crops.

Region 3.—This comprises the region west of region 2, where the rainfall is too low for the successful cultivation of timothy and clover. Sudan grass commonly makes

one cutting under such conditions, and in favorable seasons two, yielding 1 to 3 tons of hay to the acre. Its chief competitors in this region are alfalfa, sorghum, and millet. Alfalfa is preferred to Sudan grass only in the more favored locations, such as river and creek valleys or where irrigation is possible. The better varieties of sorghum, such as Red Amber and Orange, will outyield Sudan grass, but the latter is better suited for pasture purposes, produces a better quality of hay, and is easier to handle with haying machinery. Seed production, though possible in most of this region, is profitable only in the southern part.

Region 4.—Sudan grass yields abundantly both in hay and in seed in all irrigated localities in this region; yields of 4 tons of hay to the acre are not uncommon on good soils. It is used chiefly to supplement alfalfa in the rations of horses and dairy cattle, as a pure alfalfa hay ration seems to result in digestive disturbances, especially in dairy cows.

Region 5.—In this part of the United States Sudan grass is successful only in limited areas. Its failure except in these localities is due either to low temperatures caused by high altitudes or to insufficient rainfall.

Region 6.—In this region, including Florida and the Coastal Plain along both the Atlantic and Gulf coasts, Sudan grass is usually a failure, largely on account of the injury to the foliage caused by red-spot, or sorghum blight.

Region 7.—This is a region 100 to 200 miles wide along the northern border of the United States. Sudan grass is not profitable here, because of the cool summers and the short growing season.

The Office of Forage-Crop Investigations of the Bureau of Plant Industry, United States Department of Agriculture, sent seed to numerous State agricultural experiment stations in 1912 and succeeding years. In 1914 the Office of Congressional Seed Distribution sent out 1-pound packets of Sudan grass seed to 2,800 farmers, in 1915 to 75,751, and in 1916 to 97,392. Reports as to the success of Sudan grass and its probable value, as compared with other forage crops, were called for from several thousand of these farmers in 1915 and 1916. Their answers have been examined and their opinion of the crop, expressed in the percentage of favorable reports for each section of the United States, is shown on the map, figure 14, which indicates in more detail than figure 13, the relation of Sudan grass to climatic factors.

This map (fig. 14) is based upon Weather Bureau Bulletin W and shows for each section of the United States (1) the average length of the growing season, i. e., the time elapsing between the last killing frost in spring and the first killing frost in the fall; (2) the mean temperature for the growing season; (3) the normal rainfall for the entire year; and (4) the adaptation of Sudan grass to these conditions, as shown by the percentage of favorable reports from farmers who received seed through the Office of Congressional Seed Distribution.

The rather complete agreement between this map and the outline map, which was prepared largely from reports secured through State agricultural experiment stations, is worthy of note. There are several slight inconsistencies in the results, but on the whole the

maps show that the successful production of Sudan grass is correlated with high temperatures during the growing season and to a less extent with rainfall.

USE AS A CATCH CROP.

Sudan grass will be widely grown as an emergency hay crop in much the same manner as millet. As a means of overcoming a threatened shortage in the supply of hay required to carry the farmer's live stock through the winter, Sudan grass is fully as good as millet. (Fig. 15.) The growing season is short, the quality of the hay is very good, and the yields of Sudan grass are usually higher than millet yields. Millet in the North and sorgo (sweet

FIG. 14.—Outline map, showing by States and other indicated geographic divisions (1) the average length (in days) of the growing season or frost-free period, (2) the mean temperature (in degrees F.) of the growing season, (3) the normal annual rainfall (in inches), and (4) the percentage of success with Sudan grass grown in different sections, as reported by several thousand farmers who received trial packages of seed from the United States Department of Agriculture in 1915 and 1916. Frost is likely to occur any month of the year in the western section of Wyoming (marked with an asterisk).

sorghum) in the South have been the most popular catch crops. A comparison of these two crops with Sudan grass is presented in Table II.

Table II shows that millet is equal or superior to Sudan grass in the northern Great Plains and that it yields about the same in the timothy and clover belt if only one cutting is considered in the yield of both crops. In the southern Great Plains Sudan grass yields much more than millet. Sweet sorghum grown in cultivated rows or in drilled or broadcasted seedings outyields both Sudan grass and millet, but the hay is coarse and unsuitable to handle with a fork. The aftermath or second growth of sorghum is not as safe to pasture as that of Sudan grass, and none of the millets make sufficient second

growth to afford appreciable pasturage. These facts indicate a wider utilization of Sudan grass as a catch crop in the future.

TABLE II.—*Comparative yields of Sudan grass, millet, and sorgo, seeded broadcast or in close drills.*

Location of test.	Years of test.	Plats.		Yields of cured hay per acre (tons).		
		Size (acres).	Replications.	Sudan grass.	Millet.	Sorgo.
Southern Great Plains:						
Big Spring, Tex.	1916 to 1919.	0.10 to 3.0	1 to 4	2.54	1.23	4.85
San Antonio, Tex.	1912 to 1916.		2	5.86		6.35
Chillicothe, Tex.	1913 to 1918.	.05	2	2.04	.94	3.00
Lubbock, Tex.	1914 and 1915			3.81	3.33	4.88
Lawton, Okla.	1917 to 1919.	.10	1 to 2	2.40		4.14
Average.				3.33	1.83	4.64
Central Great Plains:						
Amarillo, Tex.	1912 to 1917.	.05	2	1.65	1.44	2.70
Dalhart, Tex.	1917 to 1919.	.10	1 to 2	1.66	.46	2.08
Tucumcari, N. Mex.	1913 to 1917.	.10	1	1.33	.93	2.70
Woodward, Okla.	1914, 1917 to 1919.	.04 to .10	1 to 2	1.70	1.34	3.77
Garden City, Kans.	1912	.05	2	1.69	2.23	3.25
Hays, Kans.	1914 to 1919.	.05	2	2.72	2.18	3.66
Akron, Colo.	1915 to 1919.	.05	3	1.69	2.01	2.10
Average.				1.78	1.51	2.89
Northern Great Plains:						
Archer, Wyo.	1914 to 1915.	.10	1	.82	1.61	1.41
Sheridan, Wyo.	1917 to 1919.	.05	3	.67	.57	1.37
Ardmore, S. Dak.	1915 to 1916, 1918, 1919	.10	3	2.04	2.04	3.05
Newell, S. Dak.	1915 to 1918.	.05	3	1.40	2.09	2.33
Redfield, S. Dak.	1915 to 1919.	.04	2	3.34	3.18	4.15
Mandan, N. Dak.	1915 to 1919.	.05	3	1.40	2.09	2.33
Moccasin, Mont.	1915, 1916.	.05	2	.74	1.62	1.05
Average.				1.49	1.89	2.24
Timothy and clover region:						
Manhattan, Kans.	1914, 1915.			4.02	2.81	3.99
Lincoln, Nebr.	1915 to 1917.	.05	2	3.60	3.40	5.50
Madison, Wis.	1916	.025	2	2.79	3.08	
Jackson, Tenn.	1914		2	2.21	.77	
Knoxville, Tenn.	1914, 1915, and 1917.	.02	2	3.08	2.31	
Wooster, Ohio.	1912 to 1918.			3.70	3.70	8.30
New London, Ohio.	1912, 1913.	.05	2	1.29	2.52	
Ithaca, N. Y.	1913	.012	3	.73	1.65	
State College, Pa.	1913, 1915.			2.64	2.13	
Blacksburg, Va.	1912	.02	2	5.00		6.43
Do.	1917	.02	8	1.69	2.85	
Average.				2.80	2.52	6.06

The acreage of millet has been on the decline since 1899 (24, p. 5), and except in the irrigated regions of the Southwest any increase in the acreage of Sudan grass will mean a further decrease in the millet acreage. On the other hand, there has been a steady growth in the acreage of forage sorghums, which are likely to continue to be the chief competitors of Sudan grass as emergency hay crops.

USE IN ROTATIONS.

Although Sudan grass is an annual and therefore can be introduced easily into any rotation, its extensive use as a staple crop in regular rotations is not to be expected. To fill such a position, the crop

must be either a money crop or a soil improver. In certain Southern States where good prices are to be obtained for hay, Sudan grass may be used like the corn or wheat of our Northern States as one of the money crops, but in other States it is not likely to supplant the well-known plants of our common rotations. It probably exhausts the fertility of the soil as rapidly as corn or cotton. Sorghums are popularly supposed to be "hard on the soil," and this reputed deleterious effect on fertility is frequently mentioned by farmers in the timothy and red clover region as their reason for not growing Sudan grass.

FIG. 15.—Growth of Sudan grass (at left) compared with that of millet, 48 days from planting.

A 4-year rotation for the cotton belt which has been suggested by the Texas Agricultural Experiment Station (29, p. 9) is, for the first and second years, cotton; third year, corn or grain sorghum, with cowpeas interplanted, to be pastured or plowed under for green manure; fourth year, Sudan grass. In such a rotation the grain sorghums should be used only in those regions where they are not subject to attacks of the sorghum midge. It is quite likely that such a rotation would require the application of some fertilizer, preferably barnyard manure, at least once in four years, since the small quantity of humus added by the legume would hardly be sufficient to maintain fertility.

HAY PRODUCTION.

PREPARATION OF THE SEED BED.

On account of its small seed and slow early growth, Sudan grass requires a seed bed that is well prepared, warm, moist, and free from weeds. For surface planting either in rows or with a grain drill, soil prepared as for wheat or oats is usually satisfactory. It is best to plow the ground in the spring, about two or three weeks before it is intended to sow the Sudan grass. Plowing at this time warms and aerates the soil and turns under the early crop of weeds. After plowing, the field should be harrowed to pulverize the clods and settle the soil. After two or three weeks the second crop of weeds will have started, and these can be killed with the disk or drag harrow.

In the dry regions row plantings are sometimes made with a lister. Where this method of seeding is practiced, it usually pays to blank list the ground in the fall or early spring and follow this with sufficient spring tillage to destroy the weeds at seeding time. Disking or some other form of cultivation should precede listing whenever it is planned to list and plant in the same operation.

USE OF FERTILIZERS.

In the Central and Western States fertilizers for Sudan grass are not necessary, but in the Southeastern States, on the poorer soils, moderate applications of some fertilizer, chiefly combinations of phosphorus and nitrogen, will be found profitable. Sudan grass is not adapted to infertile soils, and profitable crops of hay should not be expected unless a reasonably good soil is chosen for growing it. A legume of some kind, such as vetch, cowpea, or clover, should be used on worn-out soils which need building up.

Tests of acid phosphate applied at the rate of 200 pounds to the acre were made in Kentucky, and in only two cases out of ten did it fail to give profitable increases in the hay yields. The average increase attributable to the fertilizer was 68 per cent. In experiments on gray sandy soil at Calhoun, La., in 1915 Sudan grass yielded 0.75 ton of dry hay per acre on unfertilized plats. With an application of 315 pounds of cottonseed meal per acre the yield was 1.66 tons per acre, an increase of 121 per cent due to the fertilizer. An application of cottonseed meal and acid phosphate in equal parts at the rate of 315 pounds per acre resulted in a yield of 2.13 tons per acre, an increase of 184 per cent over the check plats. These plats were planted in rows 3 feet apart. In broadcasted plats on the same soil the yield was considerably larger. These experiments, though limited in number, indicate the wisdom of using fertilizers in the Southeastern States.

Barnyard manure nearly always increases the yields of Sudan grass. It is generally more profitable, however, to apply the manure

to some money crop, such as corn, and allow the Sudan grass to benefit by the residual effect, which is usually noticeable for two or three years after the manure has been applied.

DATE OF SEEDING.

Like other plants of the sorghum family, Sudan grass must not be seeded until the soil is warm. A large number of the failures with this grass can be attributed directly to early planting, especially in the northern part of the Sudan grass region. In South Dakota the spring is usually cold and backward and seedings made by farmers in the early part of May have often been unsuccessful. During the same years, however, good crops have been grown at the experiment station at Redfield, S. Dak., by planting about June 1 (fig. 16).

FIG. 16.—Sudan grass 4 feet tall and not yet headed at the Redfield (S. Dak.) Field Station, August 10, 1915.

Sudan grass has frequently withstood light frosts, but a frost of any severity is likely to injure the young plants materially. A good rule is to sow this grass from two to four weeks after the normal date for planting corn. Experimental data on this subject are presented in Table III.

Table III shows that in regions from 30° to 35° north latitude the earlier dates are best, but that good yields may be expected from seedings made at any time between April 1 and June 15. The maximum hay yields were obtained from seedings on April 1.

In the middle section of the United States, approximately between 35° and 40° north latitude, it is usually safe to sow at any time be-between May 1 and July 1. There is no decided optimum date, although June 1 gave a slightly higher average yield at the eight stations where tests were made.

In the Northern States, above 40° north latitude, the safest rule is to withhold planting until the ground is thoroughly warm and the weather settled. Not enough data were obtained from northern stations to decide the question of the best date for planting. Unfavorable weather conditions prevented seeding on the earlier dates in most years. It is worth mentioning, however, that seedings on June 1 have been uniformly successful at Redfield, S. Dak.

TABLE III.— *Yields of Sudan grass hay from different dates of seeding in various parts of the United States.*

Location of test.	Plats.		Seasons under test.	Yields of cured hay (per acre) from plantings made on—							
	Size.	Replications.		Apr. 1.	Apr. 15.	May 1.	May 15.	June 1.	June 15.	July 1.	July 15.
Southern section:	*Acres.*			*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Bard, Calif.	0.05	2	2	3.82	3.84	4.15	3.80	3.55	2.91	.....	.....
Chillicothe, Tex.	.05	2	7	2.07	1.95	1.97	2.05	1.55	1.67	1.58	.....
Baton Rouge, La.	.....	.....	1	4.70	3.85	3.60	3.15	3.00	.....	.....	.....
Agricultural College, Miss.	.05	1	1	5.38	5.58	3.60	3.45	3.05	2.63	2.58	.....
Athens, Ga.	.....	1 or 2	5	1.98	2.05	2.11	2.05	2.29	2.05	1.32	1.33
Gainesville, Fla.	.05	2	1	1.31	1.81	1.54	2.04	.....	.....	.....	.....
Average	.....	.....	.....	3.21	3.18	2.83	2.76	2.69	2.32	1.83	1.33
Middle section:											
Davis, Calif.[1]	.05	2	2	5.66	6.80	4.87	5.02	3.98	.....	.....	.....
Do.	.05	2	2	4.96	7.02	4.70	4.98	3.20	.....	.....	.....
Hays, Kans.	.05	2	6	.....	.37	1.51	1.84	1.84	1.87	1.61	1.30
Tribune, Kans.	.02	2	2	.65	1.10	2.06	2.80	3.76	2.98	2.40	1.27
Stillwater, Okla.	.10	1	1	.....	2.23	2.94	2.70	.68	1.18	.43	.88
Amarillo, Tex.	.05	2	5	.....	1.52	1.68	1.71	1.70	1.81	1.99	1.37
Knoxville, Tenn.	.02	1	1	1.10	1.25	1.05	1.10	1.70	1.05	1.05	1.37
Jackson, Tenn.	.....	.....	2	1.66	2.23	2.28	2.55	2.48	2.58	2.28	1.02
Blacksburg, Va.	.05	2	3	.....	.....	3.52	2.73	2.74	2.30	1.85	.....
College Park, Md.	.05	2	1	.....	.....	2.17	2.69	3.32	3.85	.....	2.25
Average[2]	.....	.....	.....	1.14	1.45	2.15	2.27	2.28	2.20	1.66	1.35
Northern section:											
St. Paul, Minn.	.015	2	1	.....	.....	4.74	4.54	4.59	4.49	.....	.....
Redfield, S. Dak.	.05	2	5	.....	.....	2.75	2.87	3.05	2.77	.....	.....
Average	.....	.....	.....	.....	.....	3.75	3.71	3.82	3.63	.....	.....

[1] Irrigated.

[2] The data for Davis are excluded from the averages.

The latest date at which it is advisable to sow Sudan grass may be considered roughly as 70 to 90 days before the normal date of the first killing frost in the fall. The high price of seed makes it advisable to postpone seeding several weeks rather than sow in dry, cold, or weedy soil. If conditions for planting continue bad during the season, it may be found practicable to substitute for Sudan grass a forage crop the seed of which is cheaper, such as sorghum or millet.

METHOD OF SEEDING.

The method of seeding found best for sweet-sorghum hay production in any region should be followed in seeding Sudan grass. This means that it may be sown broadcast, in close drills, or in any con-

venient width of cultivated rows. Moisture, seed, and cultural equipment are the chief factors to be considered in deciding upon the exact method.

Because of its smaller size Sudan grass seed should be planted shallower than sorghum; usually from half an inch to 1½ inches deep is best on moist or heavy soils, while from 1 to 3 inches is better on dry or lighter land. Planting deep in loose or dry soil often secures better conditions for germination, but does not seem to have any appreciable effect on the depth at which the Sudan grass plant forms its root system. In some tests at the Arlington Experimental Farm, Va.,

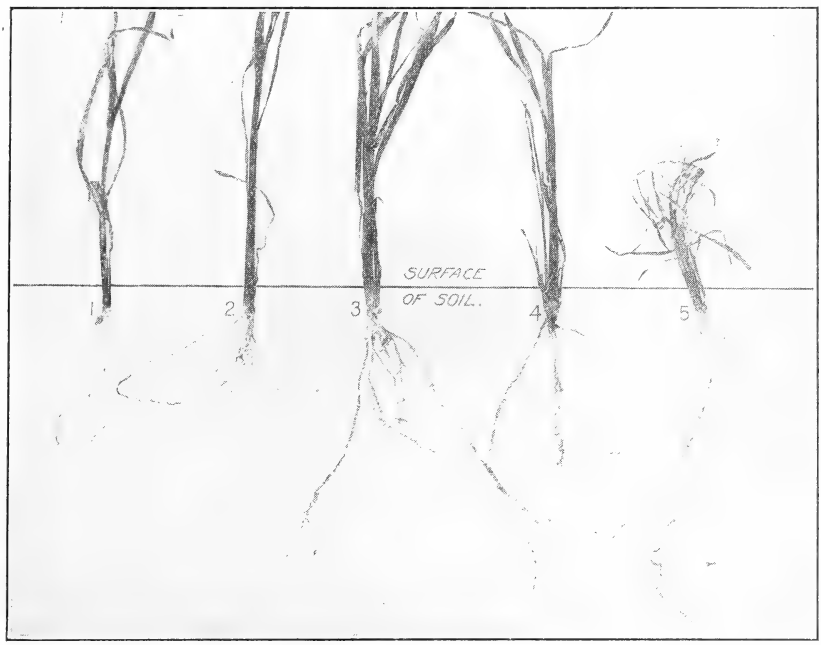

FIG. 17.—The effect on the seedling of planting Sudan grass seed at different depths. From left to right (1) half an inch, (2) 1 inch, (3) 1½ inches, (4) 2 inches, (5) 3 inches.

seeds planted from half an inch to 3 inches deep all produced plants with the crown just beneath the surface of the ground. (Fig. 17.)

Experiments to permit exact comparisons of results from different planting methods under widely varying conditions were begun in 1913. Data for work extending over one to four years at each of 23 agricultural experiment stations are presented in Table IV.

Table IV shows that no one method has given uniformly superior yields in any region. The plant's vigorous root system exhausts so completely the available plant food and moisture in rows of any width here reported that yields usually bear a definite relation only to factors of climate, soil, and culture.

TABLE IV.— *Yields of cured Sudan grass hay from different methods of seeding.*

Location of test.	Years of test.	Plats.		Number of cuttings.	Yields per acre.		
		Size.	Replications.		Close-drilled or broadcasted.	18 to 24 inch rows.	34 to 44 inch rows.
Humid regions:		*Acres.*			*Tons.*	*Tons.*	*Tons.*
Angleton, Tex.	1913 to 1916		1	2–3	2.39	3.29	2.05
Beeville, Tex.	1913		2		4.70	5.21	5.63
Nacogdoches, Tex.	1914				1.52	1.80	1.51
Temple, Tex.	1913		2			1.48	1.03
Stillwater, Okla.	1914	0.10	2		.60	.35	2.29
Lincoln, Nebr.	1915 to 1917	.05	2	2	3.80		3.70
Lexington, Ky.	1915			2	7.95	9.39	6.96
Nine farms in Kentucky	1915	.05	18		1.77		1.18
Wooster, Ohio	1916 to 1918				3.04	2.86	2.74
State College, Pa.	1915	.065	1	1	2.59		2.55
St. Paul, Minn.	1913	.015	2	1	3.76	3.69	4.10
Average [1]					3.42	3.80	3.61
Dry regions (not irrigated):							
Davis, Calif.	1913 to 1915	.05	1	3	3.79	4.49	3.65
Chillicothe, Tex.	1913 to 1919	.05	2	2–3	1.99	1.98	2.19
Amarillo, Tex.	1913 to 1917	.05	1 or 2	1–3	1.68	2.04	1.88
Lubbock, Tex.	1913		3 or 4			3.00	2.14
Woodward, Okla.	1917 and 1918				1.58		2.08
Hays, Kans.	1913 to 1919	.05	2	1–2	2.40	2.74	2.55
Garden City, Kans.	1914		1	1	.43	2.41	1.36
Tribune, Kans.	1914		1	1	1.95	1.66	1.00
Dodge City, Kans.	1914			2	3.57		1.15
Colby, Kans.	1914			1	0	0	1.00
Akron, Colo.	1914 to 1919	.05	3	1	1.77		1.70
Valentine, Nebr.	1913	.10	1	1	1.19	.83	.61
Archer, Wyo.	1914 to 1915	.10	1	1	1.35	.78	.82
Sheridan, Wyo.	1917 to 1919	.05	3	1	.67		.61
Ardmore, S. Dak.	1914, 1916, 1918, 1919.	.10	3	1	1.26		1.40
Redfield, S. Dak.	1915 to 1919	.05	2	1	3.34	2.54	2.15
Newell, S. Dak.	1914 to 1918	.05	3	1	1.91		1.64
Mandan, N. Dak.	1914 to 1919	.05	3	1	1.43		1.52
Huntley, Mont.	1914	10	1	1	.60	.42	
Average [1]					1.81	1.95	1.72
Dry regions (irrigated):							
Bard, Calif.	1914, 1915	.05	2	3	3.12	3.99	2.77
Davis, Calif.	1913, 1914, and 1916.	.05	1	2–3	6.15	6.23	5.99
Chico, Calif.	1913 to 1915	.05	1 to 4	2–3	5.52	5.50	5.17
Bozeman, Mont.	1914	.10	1	1	4.35		3.60
Average [1]					4.93	5.24	4.64

[1] Averages include only the stations where data for all three methods are presented.

CLOSE DRILLS AND BROADCASTING.

In humid regions and under irrigation, drilling with a grain drill is the most satisfactory method of seeding Sudan grass for hay except when seed is very expensive. Even in the dry regions this method gives nearly as good results as the cultivated-row plan. Sudan grass seeded in close drills requires no cultivation, the plants mature more uniformly and have finer stems, the roots are less troublesome later on, and the hay is not as dusty as that grown in cultivated rows.

The ordinary wheat drill is the best machine for this work. It distributes clean Sudan grass seed uniformly and covers it evenly. Most wheat drills sow this seed at about the same speed as wheat; for example, when set for 2 pecks of wheat per acre the drill may be

expected to sow 2 pecks of Sudan grass seed (15 to 20 pounds). If the drill feed can not be set to sow thinly enough, bran or some other inert substance may be mixed with the Sudan grass seed. Alfalfa and grass seed drills or attachments have been used by some farmers for sowing Sudan grass. Although such machines work in some cases, their general use is not recommended because the seed of Sudan grass is so much larger than that of alfalfa, clover, and timothy that it stops up the feeds frequently, and as a result the seed may be sown too thinly and not covered deeply enough.

Broadcasting is recommended only when the area to be sown is small, the seed not well cleaned, or no suitable drill is available. About 25 per cent more seed should be used in broadcasting than in drilling, and it should be harrowed in well at once. The objections to broadcasting are that it distributes and covers the seed so unevenly that more seed is required, and a good stand is not as certain as when the crop is drilled.

CULTIVATED ROWS.

In the dry regions west of the 98th meridian, cultivated rows frequently show a greater superiority over drilled seedings than is indicated by the comparative yields of hay. During drought periods, as at Hays, Kans., in 1916, intertilled plats produced nearly normal plants, while adjoining close-drilled Sudan grass failed to head out and produced an inferior quality of hay, though the yield per acre was nearly equal to that from the rows. When seed is very scarce and expensive, wide rows are preferable, because they require much less seed per acre.

On the other hand, as the row width increases the hay becomes enough coarser to lower its market value somewhat. The actual feeding value, however, is not reduced much, if any; for when row plantings are harvested at the proper stage of maturity and fed intelligently the stems as well as the leaves are practically all consumed.

Hay from cultivated rows mowed and raked in the usual way is sometimes objectionable because of the clods and dust gathered up with it. This condition is seldom troublesome except in seasons of drought or in fields cultivated deeper or later than usual. Cutting row plantings with a binder solves the dust problem.

The bunchy root system developed by Sudan grass in wide rows sometimes makes soil preparation for the next crop expensive and difficult. Fields, after being in 40-inch rows at the Fort Hays Experiment Station, Hays, Kans., in 1915, were placed in condition for cropping the next year with great difficulty. (Fig. 18.) After plowing, it required two double diskings and several harrowings to fit the land for 1916 crops. Close-drilled fields at the same station that year and 24-inch row plantings the preceding year left roots so much

finer and more evenly distributed that later tillage was not difficult, and in some cases the soil seemed lighter and more mellow than before.

Sudan grass may be surface planted in rows with either a grain drill or corn planter. It may be planted in furrows directly with a lister, or, more safely but less economically, with the corn planter following blank listing. Surface planting is more likely to give a good stand and rapid early growth, because the soil is warmer and the plants are not exposed to being washed out, covered up, or drowned, as in listed furrows. Listing has the advantage in dry regions of putting the seed down into moist soil, often resulting in good stands where the surface soil is too dry for seed to sprout. Listed fields may be cultivated easily and rapidly with the special

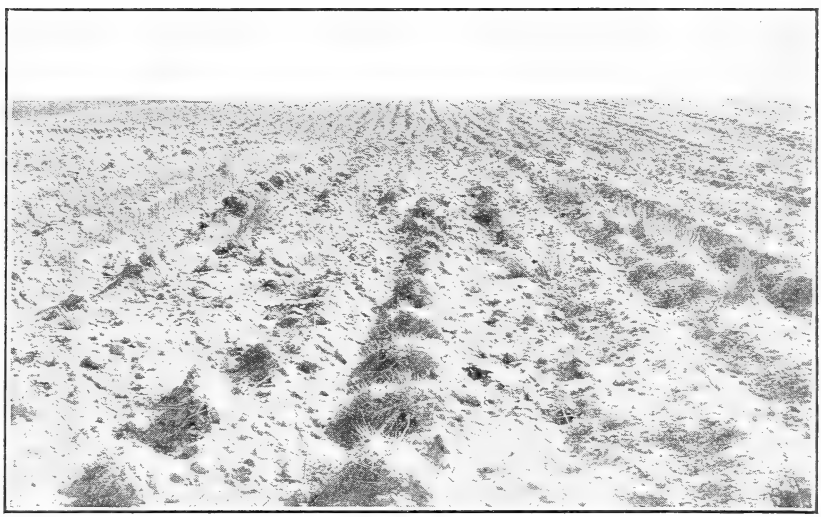

FIG. 18.—The difficulty of putting a field in condition for cropping the year following a crop of Sudan grass seeded in 40-inch rows is shown in this illustration.

2-row machine commonly used for listed corn and sorghums in the Great Plains area. It is much easier to cover up weeds in cultivating listed fields, but, on the other hand, surface-planted Sudan grass properly handled grows so rapidly that weeds give very little trouble and are soon overcome by the shade.

Rows may be spaced any distance desired with a grain drill by stopping up the holes not needed. In drills with the vertical disk feed, rags tightly inserted serve this purpose, but in drills with the horizontal corrugated-cylinder feed it is usually necessary to tack a material like tin or wood over the holes. The grain drill used in this way is especially useful for rows less than 3 feet apart. For example, a drill with 10 holes 7 inches apart sows four 21-inch rows at once by seeding through the first, fourth, seventh, and tenth holes; or the

first, fifth, and ninth holes may be used to sow three 28-inch rows. Rows 36 to 48 inches apart are better suited to the corn planter. The planter may also be used to sow 18-inch to 24-inch rows by straddling, but this is slower and does not space the rows as uniformly as the drill. The lister is best adapted to rows 40 or 42 inches apart. One may use either a single-row lister, requiring three or four horses, or a 2-row lister with six or eight horses.

RATE OF SEEDING.

IN DRILLED OR BROADCASTED SEEDINGS.

Rates varying from 10 to 40 pounds per acre have been tested for from one to four years at 24 widely distributed points. Table V presents the yield reported to the Office of Forage-Crop Investigations from these stations.

TABLE V.— *Yields of cured hay from different rates of seeding broadcast or in close drills.*

Location of test.	Years of test.	Plats.		Hay yields when seeded at following rates per acre.				
		Size.	Replications.	10 pounds.	15 pounds.	20 pounds.	25 to 30 pounds.	35 to 40 pounds.
Humid regions:		*Acres.*		*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Athens, Ga.	1914		1		0.42	0.91	1.63	
Agricultural College, Miss.	1913	0.05	1		1.93	2.06	2.45	2.50
Do	1915	.10	2	3.12	4.09	4.34	4.22	3.56
Baton Rouge, La.	1913	.05	2		2.05	1.73	2.20	
Beeville, Tex.	1913		2		4.84	4.84	5.03	5.01
Blacksburg, Va.	1913 to 1917	.05	2		1.46	1.62	1.58	2.00
College Park, Md.	1913 to 1915	.05	2		3.32	3.33	3.41	3.62
Fayetteville, Ark.	1913	.10	1		1.12	.87	.95	.88
Jackson, Tenn.	1913 to 1915		1	2.32	1.90	2.14	1.97	2.01
Knoxville, Tenn.	1913	.025	2		2.94	3.26	3.29	2.69
Lexington, Ky.	1915		1	6.72		7.95	8.85	
Lincoln, Nebr.	1915 to 1917	.05	2		3.40		3.30	3.60
Madison, Wis.	1915	.025	2	3.37	3.24	3.11	3.06	2.42
St. Paul, Minn.	1913	.015	2		4.25	3.97	4.28	4.05
Average [1]					2.91	2.95	3.02	2.87
Dry regions (not irrigated):								
Davis, Calif.	1913 to 1915	.05	1 or 2	5.04	4.99	4.31	3.91	4.37
Amarillo, Tex.	1914 to 1917	.05	2	2.30	2.51	2.18	2.49	
Chillicothe, Tex.	1913 to 1919	.05	2	1.94	2.28	2.24	2.23	2.13
Lubbock, Tex.	1913 to 1916				3.18	3.43	3.30	3.18
Pecos, Tex.	1913		2		1.25	1.89	2.20	2.58
Spur, Tex.	1914		2		5.14	5.02	5.02	5.04
Hays, Kans.	1913 to 1918	.05	2	2.48	2.50	2.43	2.40	2.45
Tribune, Kans.	1914 and 1915	.02	2	3.62	4.22	3.95	3.28	2.81
Redfield, S. Dak.	1916 to 1919	.04	2	2.53	2.58	2.49	2.71	
Average [1]					3.37	3.32	3.19	3.22
Dry regions (irrigated):								
Bard, Calif.	1914 and 1915	.05	2	2.66	3.02	2.68	3.02	2.76
Davis, Calif.	1914 to 1916	.05	1	8.02	6.74	7.28	5.90	6.16
Average				5.34	4.88	4.98	4.46	4.46

[1] Only the stations where data are presented for all rates of seeding of 15 pounds or more are included in the averages.

The yields reported in Table V, as in the width-of-row tests, show no decided superiority for any rate of seeding. Sudan grass tillers so freely in thin stands that the final number of stems per square

foot has been about the same for all the rates in these experiments. In general, 20 pounds per acre under favorable seeding conditions has been just as satisfactory as thicker rates. In several cases, 10 to 15 pounds have given maximum returns. A farmer near Goodland, Kans., obtained an excellent yield in 1915 on a 4-acre field by broadcasting only 5 pounds of seed per acre. The stand averaged one plant to each square foot, but each plant tillered profusely and grew to a height of 6 to 8 feet.

A pound of the average Sudan grass seed contains 50,000 seeds. As there are 43,560 square feet in an acre, it follows that a Sudan grass field would have as many plants per square foot as there were pounds sown per acre if 87 per cent of the seeds grew. But one can not expect more than 40 or 50 per cent of the seeds to produce plants.

Taking all factors into consideration, 20 to 25 pounds per acre are recommended for close-drilled seedings in humid regions and 15 to 20 pounds in dry sections. Owing to the more favorable conditions for germination under irrigation, 15 to 20 pounds are sufficient. These quantities should be proportionately increased if the seed is poor, the soil in poor physical condition, or if broadcasting is practiced.

CULTIVATED-ROW PLANTING.

Few tests of different rates of seeding in row plantings have been made. These trials show that it makes little difference in the forage yield whether 3 or 6 pounds of seed per acre are used in the 36-inch to 44-inch rows. The plants in the thinner seedings tiller so abundantly that the lack of original plants is usually overcome. Thin seeding results in coarser stems, however, and unless seed is scarce or very expensive it is advisable to sow 4 pounds per acre in the dry regions and 6 pounds in the more humid areas.

A grain drill, a corn planter, or a lister may be used in planting these rows, as described under "Methods of seeding." If the planter or lister is not equipped with suitable plates, blank ones may be bought and fitted with holes as desired. The ordinary milo plate works well. In any case, the holes should be well reamed out on the under side and large enough to let three or four seeds through at once. About 15 seeds per foot of row space should be dropped; this requires 3 to 4 pounds per acre in 40-inch rows and correspondingly more for closer widths.

HARVESTING.

TIME OF CUTTING.

Like timothy, Sudan grass allows considerable latitude in the time of cutting. It makes good hay if cut at any time from the appearance of the first heads until past full bloom. If mowed before heading, the plant is quite succulent and more cuttings during the

season can be made, but usually no appreciable increase in yield of hay results. (Fig. 19.)

Sorghum when very young is 90 per cent water; just before heading, 87 per cent; when first heads are appearing, 85 per cent; in full bloom, 80 per cent; and when ripe, 75 per cent. Sudan grass is so nearly like sorghum that it is safe to estimate the percentage of moisture in Sudan grass by that found in sorghum at like stages of maturity. It is apparent, therefore, that if the crop is cut quite young, practically 90 per cent of the total weight will be made up of water. This means that only 10 per cent of the crop is dry matter and effective as feeding material. Where

FIG. 19.—Sudan grass in drilled seedings at the Fort Hays Experiment Station, Hays, Kans. Both plats were seeded on June 14; the plat on the left shows the second growth after a first cutting made on August 3 before the grass headed. Photographed September 4, 1915.

the crop is cut when in full bloom or with the seeds in the soft-dough stage, approximately 20 per cent of the total weight is dry matter and possesses feeding value.

The percentages of protein, ash, and fat are highest in young plants and lowest in mature ones. The yield of these elements in pounds per acre is larger, however, when the grass has been allowed to head. Early cutting is not justified, therefore, either from the standpoint of total yield or food value. The wisdom of allowing Sudan grass to grow at least until it has headed is indicated by the results presented in Table VI.

The question of palatability affects the decision regarding the time of cutting. Sudan grass leaves remain green and new shoots keep

coming until the seed ripens. The stems, however, become woody after seed has set; therefore the hay from cuttings made about the time the grass heads is somewhat more palatable than later cuttings.

TABLE VI.—*Composition and yield per acre of the principal food elements in Sudan grass when cut at different stages of maturity.*

Stage of maturity.	Number of samples.	Total dry matter.	Ash.	Ether extract.	Protein.	Crude fiber.	Nitrogen-free extract.
Computed on the basis of actual dry matter:							
Very young, 18 to 24 inches tall	24	*Per cent.* 100	*Per cent.* 10.77	*Per cent.* 1.52	*Per cent.* 13.58	*Per cent.* 25.54	*Per cent.* 48.59
Just before heading	19	100	9.26	1.98	12.89	27.05	48.82
First heads appearing	12	100	8.74	1.72	11.54	28.38	49.62
Beginning to bloom	10	100	8.19	1.68	9.82	31.15	49.16
Seed in milk or soft-dough stage	8	100	7.20	1.64	8.73	29.26	53.17
Seed fully mature	2	100	7.35	1.38	6.03	36.71	48.53
Yields per acre at Hays, Kans., 1915 to 1918:							
Just before heading, two cuttings		*Pounds.* 3,235	*Pounds.* 355	*Pounds.* 62	*Pounds.* 471	*Pounds.* 923	*Pounds.* 1,424
Cut as first heads appeared and again at frost		3,952	422	65	506	1,173	1,786
Cut when beginning to bloom and again at frost, in 1915 and 1916		3,802	373	60	421	1,196	1,752
Seed in soft-dough stage; only one cutting		4,093	361	62	352	1,336	1,982

Local conditions should largely govern the time of cutting. When insect pests threaten or drought or frost checks growth, it frequently pays to mow Sudan grass if it is 2 or 3 feet high whether it is headed or not. Scarcity of hay or the approach of a very busy season may also justify such early cutting. Rush of work and the desire to harvest seed are valid reasons for late cutting, for even thrashed Sudan grass is a fairly good roughage.

MACHINERY.

The mowing machine is usually employed in harvesting Sudan grass hay, especially that less than 4 to 5 feet high. If the crop is fed green, a little at a time, an ordinary scythe may well be used.

Grain binders work well on both rows and broadcast Sudan grass 3 to 6 feet high. Cultivated rows more than 5 feet high are best handled with a corn binder. (Fig. 20.) In 1915 some Kansas growers cut very tall broadcasted Sudan grass and sweet sorghums with a corn binder by attaching an extension arm on one side to make it gather in and cut a swath 2 to 3 feet wide. Though loose Sudan grass hay is much easier to pitch than the coarser sorghums, many farmers consider that the added cost in binding tall grass is more than offset by the convenience of handling. In humid regions the hay may spoil in the bundle if bound green.

CURING AND STORING.

In dry windy regions the crop, if bound, may be set up at once in substantial shocks. If mowed, the hay usually should be raked within

two or three days, for the leaves dry very rapidly. It may then be cured in windrows or cocks until the stems are dry and it becomes safe to bale or stack the hay. On account of the slow drying of the stems, Sudan grass hay should rarely be stacked, baled, or piled in a haymow until two weeks after cutting. At the Fort Hays Experiment Station, Hays, Kans., Sudan grass 5 to 6 feet high was cut in July, 1914. After three or four good drying days the hay looked cured, and about 30 tons of it were stacked in a large rick. Small samples taken at stacking time lost 30 per cent of their weight upon further air drying. When the stack was fed out, much hay in the center showed injury from heating. In September, 1914, at the same station, some apparently cured hay was placed in a barn on a damp day. A week

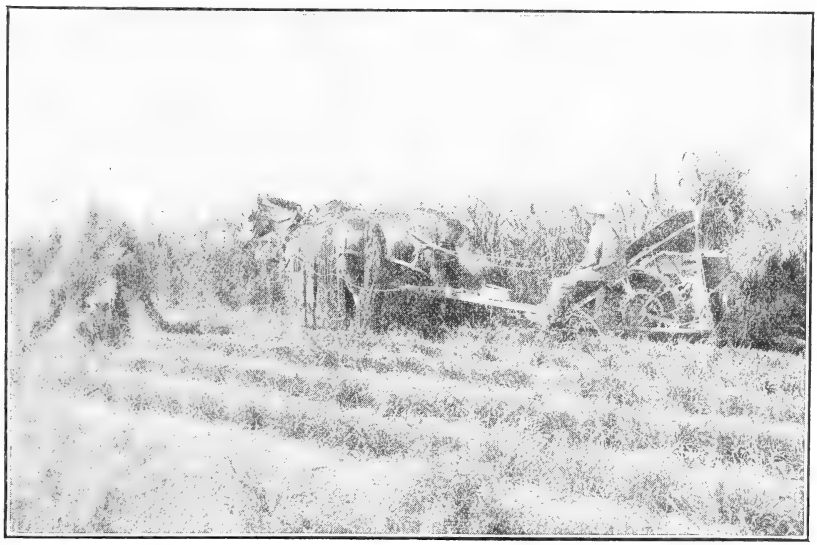

FIG. 20.—Cutting Sudan grass seeded in rows 40 inches apart at Dalhart, Tex.

later this Sudan grass was found to be heating. The temperature 1 foot below the surface was 128° to 130° F., though there were but a few tons of hay in the center of a large well-ventilated haymow.

In humid regions, a proportionately longer time is required for curing. The leaves do not shatter easily, however, and a few rains do not materially injure the quality of the hay. The crop should be removed from the field as soon as safe, in order to avoid injuring the next cutting, or so that the aftermath may be pastured.

SUDAN GRASS AND LEGUME MIXTURES.

The growing of legumes in mixtures with nonlegumes is a very old practice in agriculture. In the United States this practice of mixed seedings is not common except with hay crops, because the harvesting is done by machinery, and unless the two crops mature at the same

time and the separation of grain from the legume seed is easy, growing grain crops in mixtures will be found impracticable. This objection does not apply with equal force to hay crops, because uniformity in maturity is not so essential. Several notable examples of such mixtures are found in American agriculture, the most common of which is timothy and red clover. Rye and vetch, oats and vetch, oats and field peas, and barley and field peas are other combinations illustrating this practice.

Cowpeas or soy beans are often sown with millet or sorghum by southern farmers, and the combination of these legumes with Sudan grass has been found equally promising in the humid regions. (Fig. 21.) Table VII shows in detail the results of mixed plantings of

FIG. 21.—A mixed planting of Sudan grass and soy beans at the Arlington Experimental Farm, Va., 1914.

these forage crops in the Southeastern States. Tests of the same mixtures were made in the semiarid regions, but in regions of limited rainfall the practice was found unprofitable. The Sudan grass almost invariably started growth quicker and overcame the legume plants by exhausting the available soil moisture before the legumes had become well rooted, or the grass increased in height so rapidly that they were shaded out, the result usually being that at harvest time only the Sudan grass was present in any quantity.

The data in Table VII indicate that so far as the yields are concerned it makes little difference whether cowpeas or soy beans are used in the mixtures. The quality of the hay is first-class in both cases, but it is generally conceded that the soy bean, on account of

its more upright habit of growth, is better suited for these mixed plantings than the cowpea. Nearly as much hay is obtained from the Sudan grass alone as from the mixed seedings, but the addition of a legume to the hay adds to its value by increasing the protein content.

TABLE VII.—*Yields of hay from mixtures of Sudan grass and legumes compared with yields from Sudan grass when seeded alone.*

Location of tests.	Years of test.	Plats.		Rate of seeding in mixtures.		Yields of cured hay per acre.		
		Size.	Replications.	Sudan grass.	Legumes.	Sudan grass and soy beans.	Sudan grass and cowpeas.	Sudan grass alone.
		Acres.		*Lbs.*	*Lbs.*	*Tons.*	*Tons.*	*Tons.*
Baton Rouge, La.	1913	0.05	2	12	60	.....	2.05	2.00
Do.	1913	.05	2	20	60	.....	2.95	2.00
Do.	1913	.05	2	12	40	.....	2.30	2.00
Do.	1914	.05	2	.....	.....	.....	3.15	4.50
Agricultural College, Miss.	1913	.05	1	12	60	1.85	1.90	2.45
Do.	1913	.05	1	20	60	2.38	2.38	2.45
Do.	1913	.05	1	12	40	2.25	1.80	2.45
Knoxville, Tenn.	1913	.05	2	12	60	2.13	1.72	1.70
Do.	1913	.05	2	20	60	1.38	1.66	1.70
Jackson, Tenn.	1914	.....	.....	24	60	.....	1.39	1.80
Do.	1914	.....	.....	40	60	.....	1.96	1.80
Do.	1915	.....	.....	15	60	.....	2.36	1.94
Do.	1915	.....	.....	20	60	.....	1.63	2.93
Do.	1915	.....	.....	25	60	.....	1.96	2.49
Do.	1915	.....	.....	30	60	.....	2.80	2.09
Do.	1915	.....	.....	35	60	.....	1.78	2.39
Lexington, Ky.	1915	.....	.....	.....	.....	5.70	5.30	4.60
Blacksburg, Va.	1913 to 1917	.05	1	12	60	2.27	2.24	1.46
Do.	1913 to 1917	.05	1	20	60	2.51	2.20	1.62
Do.	1913 to 1917	.05	1	12	40	2.29	1.72	1.46
Arlington Farm, Va.	1912	.10	1	20	30	4.40	4.60	3.50
Do.	1913	.05	2	12	60	1.24	.98	.97
Do.	1913	.05	2	20	60	1.32	1.11	.97
Do.	1915	.05	2	12	40	1.10	1.07	.97
College Park, Md.	1913	.05	2	12	60	3.26	3.48	3.58
Do.	1913	.05	2	20	60	3.47	3.09	3.90
Do.	1913	.05	2	12	40	3.38	3.67	3.58
Do.	1914	.05	1	15	90	4.51	4.09	3.64
Do.	1914	.05	1	15	120	3.77	4.34	3.64
Do.	1914	.05	1	20	120	3.72	4.10	3.98
Do.	1914	.05	1	15	40	4.04	4.19	3.64
Do.	1914	.05	1	15	60	4.60	4.76	3.64
Do.	1914	.05	1	20	60	.....	4.34	3.98
Do.	1915	.05	1	15	90	3.10	3.04	2.75
Do.	1915	.05	1	15	120	3.24	3.25	2.75
Do.	1915	.05	1	20	120	3.06	3.39	2.59
Average[1]						2.96	2.93	2.67

[1] The averages include only the stations and years where data are presented for all methods.

The proper proportion of Sudan grass and legumes in the mixtures has not been determined, but a mixture containing three plants of Sudan grass to one plant of the legume is theoretically obtained by sowing 10 pounds of Sudan grass with 50 pounds of cowpeas, 12 pounds of Sudan grass with 60 pounds of cowpeas, or 16 pounds of Sudan grass with 80 pounds of cowpeas. The total weight of seed used can be regulated according to the wishes of the planter and the fertility of the soil. The proportions of Sudan grass and soy-bean seed can be made the same as those with cowpeas. Generally speak-

ing, the seed of soy beans is somewhat larger than that of cowpeas, but there is a wide variation among varieties in this respect. The Peking and the Arlington are two varieties which have exceptionally small seed. These varieties average 6,800 seeds per pound, while four other well-known varieties, Wilson, Guelph, Ito San, and Mammoth, average only 2,600 seeds to the pound. This difference in the size of the seed should be taken into consideration in determining the proportions of grass and legume seed. The varieties mentioned above are all very well adapted for use in mixtures, because all of them make a luxuriant growth of vines.

The greatest drawback to the use of mixtures lies in the difficulty of seeding the two elements uniformly. This can be accomplished most easily by broadcasting the mixture. If a drill is used, great caution is required to keep the Sudan grass and legume seed thoroughly mixed in the drill box. Experimental plantings have been made most successfully by going over the ground twice with a drill in which alternate holes have been closed. In this way rows of the legume can be made to alternate with rows of Sudan grass. This method is too expensive, however, for extensive use by farmers. With drills which have a grass-seeder attachment it is possible to run the Sudan grass seed through the seeder and the cowpeas or soy beans through the grain feed.

General experience indicates that it is usually more practicable, except in localities where cowpeas or soy beans succeed especially well, to sow the Sudan grass and legumes on separate fields. The greater ease of seeding and harvesting the crops is likely to overcome the advantages which might be derived from a mixed seeding.

Another feature of mixed plantings of annual crops which has received little attention is the effect on the chemical composition of the Sudan grass produced by its association with the legumes. Lyon and Bizzell (13, pp. 365–368), of New York, found a marked increase in the percentage of protein in nonlegumes when grown in association with legumes; e. g., timothy with alfalfa and oats with field peas. Westgate and Oakley (27), on the contrary, could detect no effect of this nature.

TABLE VIII.—*Proportions of protein and ash in Sudan grass when grown alone and when grown with legumes at the Arlington Experimental Farm in 1913.*

Crop.	Protein.	Ash.
Sudan grass alone.....per cent..	6.63	7.46
Do.....do....	6.59	7.56
Sudan grass with cowpeas.....do....	6.40	8.60
Sudan grass with soy beans.....do....	7.30	10.46
Sudan grass with bonavist beans.....do....	7.66	9.11
Average, Sudan grass alone.....do....	6.61	7.51
Average, Sudan grass with legumes.....do....	7.12	9.39

In 1913 Sudan grass grown at the Arlington Experimental Farm, Va., in mixtures with cowpeas, soy beans, and the bonavist bean (*Dolichos lablab*) was analyzed with the results shown in Table VIII.

UTILIZATION OF SUDAN GRASS.

HAY.

Sudan grass is essentially a hay crop, its slender leafy stems making it easy to handle with the ordinary haying machinery. It yields well in most parts of the United States, as shown by Tables II to V, and the hay is relished by cattle, horses, and sheep.

The feeding value of Sudan grass hay is practically equal to that of millet, Johnson grass, timothy, and other nonlegume roughages. This is shown both by chemical analyses and by practical feeding tests. A statement of the percentages of the different food elements in Sudan grass hay and other common hay and fodder crops is given in Table IX. These percentages are given on a water-free basis, because there seems no other way at the present time to make them comparable for the different feeds. It is realized that hay and fodder when fed to live stock contain an appreciable quantity of water and that this necessarily means a lower percentage of the other nutrients such as protein, carbohydrates, and fat. In order to be ready for use in computing balanced rations, the composition of feeds should be stated on the basis of their average moisture content at the time they are being fed. The data now available, however, on the moisture content of hays and fodders at the time they are removed from the stacks and barns are very limited (1, 25, 26). It is impossible, therefore, to estimate accurately the average percentage of moisture in the different kinds of roughage as they are fed.

TABLE IX.—*Average composition of hay made from Sudan and other grasses and legumes and of corn and sorghum fodder.*

Feed.[1]	Number of analyses.	Average constituents.				
		Ash.	Protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
Hay:		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sudan grass	71	8.6	10.2	29.5	49.9	1.8
Johnson grass	77	7.7	9.0	32.6	47.7	3.0
Timothy	226	6.2	7.8	32.3	50.6	3.1
Millet	40	8.8	9.8	30.1	48.3	3.0
Alfalfa	247	9.7	17.4	29.6	40.5	2.8
Red clover	99	7.9	15.6	27.7	44.9	3.9
Cowpeas	78	14.3	19.4	22.7	40.5	3.1
Fodder:						
Corn	45	6.6	8.4	26.1	56.2	2.7
Sorghum	18	10.1	10.1	28.4	49.4	2.0

[1] These analyses were supplied by the Cattle Food and Grain Investigation Laboratory, Bureau of Chemistry, United States Department of Agriculture.

The remarkably close similarity in the composition of Sudan grass, Johnson grass, timothy, and millet hay is shown by Table IX. The legume hays, of course, show a high percentage of protein, and this must be taken into consideration in feeding. Corn fodder and sorghum fodder are very similar in composition, and each is of lower feeding value than any of the hays because there is more waste in feeding them.

Only a few determinations of the digestibility of Sudan grass hay have been made, but these show that its rank in digestibility, as in composition, is practically equal to that of millet and timothy hays. One of the tests was carried out at the Maryland Agricultural Experiment Station in 1915 with a young bull, another at the Iowa Agricultural Experiment Station in December, 1916, with two Guernsey heifers, and the third with two sheep at the Texas Agricultural Experiment Station. (Table X.)

TABLE X.—*Coefficients of digestibility of Sudan grass, millet, and timothy hays.*

Constituents.	Digestion coefficients.				
	Sudan grass.			Millet.[4]	Timothy.[4]
	Iowa.[1]	Maryland.[2]	Texas.[3]		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Dry matter	64.9	60.6	.....	65	59
Protein	47.4	35.4	61.3	60	57
Crude fiber	67.8	63.3	47.2	68	57
Nitrogen-free extract	70.6	67.1	59.4	67	63
Ether extract	58.4	41.2	53.2	64	48

[1] Data from Gaessler (9, p. 73).
[2] Data from Schmitz (20, p. 62).
[3] Data from Fraps (7, p. 10); average of digestion experiments 60 and 62.
[4] Data from Henry and Morrison (10, p. 649); Hungarian millet and timothy cut when in bloom.

The digestion experiments at the Texas station showed that sheep, as compared with cattle, will digest a much larger percentage of the protein but considerably less of the carbohydrates of Sudan grass. A larger number of tests are necessary to determine accurately the digestibility of Sudan grass.

A peculiar feature of the effect of climate on the composition of Sudan grass is shown in Table XI. The grass when grown in regions of light rainfall, such as the Great Plains, has a higher percentage of ash and protein than when grown in the more humid regions farther east.

The differences apparent in the averages shown in Table XI very fairly represent the actual differences in the composition of the grass, it is believed, when grown in different sections of the United States; that produced in the semiarid regions has a higher percentage of all the really essential food elements except fat and must therefore be a better feed.

TABLE XI.—*Comparison of the composition of Sudan grass when grown under different climatic conditions.*

Locality where grown.	Number of samples.	Constituents.				
		Ash.	Ether extract.	Protein.	Crude fiber.	Nitrogen-free extract.
Humid regions:		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Arlington Farm, Va.	7	7.07	1.47	6.25	34.85	50.36
College Park, Md.	1	4.74	1.87	6.57	34.83	51.99
Ames, Iowa	1	7.35	3.53	6.57	32.36	50.19
Average[1]	9	6.85	1.74	6.32	34.57	50.52
Dry regions:						
Hays, Kans.	8	9.85	1.55	10.65	29.68	48.27
Chillicothe, Tex.	20	7.61	1.75	9.06	27.93	53.65
Average[1]	28	8.25	1.69	9.52	28.43	52.11

[1] These averages are weighted according to the number of samples.

Actual feeding tests furnish the best measure of the value of Sudan grass hay. The Kansas Agricultural Experiment Station (22, pp. 21–27) in 1914 and 1915 conducted a series of feeding tests which furnish a direct comparison between Sudan grass hay, alfalfa hay, and kafir stover. One of these tests was made at the Fort Hays Experiment Station during the winter of 1914–15 to determine the value of Sudan grass hay as a roughage for wintering work animals. The 12 horses and 6 mules used in this test were taken from a normal grain and hay ration when work ceased in the fall and fed a daily ration of 20 pounds of roughage alone, with the results outlined in Table XII. Each lot consisted of 4 horses and 2 mules. The animals had warm stalls at night and ran in an open corral during the day.

TABLE XII.—*Comparison of Sudan grass hay with alfalfa hay and kafir stover as a roughage for wintering idle work stock.*

Items of comparison.	Test weighings.					
	Jan. 11.	Jan. 21.	Jan. 31.	Feb. 10.	Feb. 20.	Mar. 3.
Sudan grass hay:	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Total weight	7,436	7,270	7,300	7,513	7,419	7,387
Loss (−) or gain (+) from initial weight.		−166	−136	+77	−17	−49
Alfalfa hay:						
Total weight	7,753	7,630	7,590	7,801	7,817	7,783
Loss (−) or gain (+) from initial weight.		−123	−163	+48	+64	+30
Kafir stover:						
Total weight	8,241	7,945	7,840	8,022	7,918	7,941
Loss (−) from initial weight.		−296	−401	−219	−323	−300

As would be expected, all the animals when deprived of the grain ration lost weight at first, the loss being greatest in the lot fed upon kafir stover. At the end of the period of seven weeks the lot fed alfalfa had recovered this loss and made a gain of 5 pounds a head over the initial weight. The lot fed upon Sudan grass, after recovering the initial loss, ended the feeding period only 8 pounds per head lighter than at the beginning; while the lot fed kafir stover never

regained their original weight and averaged 50 pounds lighter at the end of the period than at the beginning.

Farmers in western Kansas report that horses and mules stand plowing and other hard work in the hot summer months better when fed upon Sudan grass hay than when their hay ration consists of alfalfa.

A second feeding test at the Fort Hays Experiment Station showed that Sudan grass hay was an efficient feed for carrying stock cattle through the winter. When "long-yearling" heifers were fed Sudan grass hay with a small supplementary ration of silage and linseed meal, steady gains in weight were obtained at a reasonable cost. The results of this test are given in Table XIII.

TABLE XIII.—*Comparison of Sudan grass hay with alfalfa hay, kafir stover, and sorgo stover as a roughage for wintering stock cattle.*

[Feeding period 120 days, Dec. 17, 1914, to Apr. 15, 1915, 25 heifers in each lot.]

Items of comparison.	Lot 1.	Lot 2.	Lot 3.	Lot 4.
Daily ration per animal:				
Silage.....pounds..	10.00	10.00	10.00	10.00
Sudan grass hay.....do....	7.54			
Kafir stover.....do....		12.89		
Alfalfa hay.....do....			8.14	
Sorgo stover [1].....do....				10.24
Straw.....do....	2.64	3.78	3.10	2.60
Linseed meal.....do....	1.00	1.00	1.00	1.00
Results of weighing:				
Average initial weight.....do....	620.8	650.6	661	653.6
Average final weight.....do....	701.2	733.2	740	736.4
Gain per head.....do....	80.4	82.6	79	80.8
Gain per head per day.....do....	.670	.688	.658	.673
Cost comparisons:				
Cost per head per day	$0.057	$0.058	$0.063	$0.057
Cost per pound of gain	.085	.084	.096	.085

[1] The supply of sorgo stover was exhausted on March 6. After that date Sudan grass hay was substituted for the sorgo stover in feeding lot 4.

In this test the feeds were evaluated as follows: Silage, $3; alfalfa hay, $6; kafir stover, $3; sorgo stover, $3; Sudan grass hay, $5; straw, 50 cents a ton; linseed meal, $1.54 a hundredweight. These prices are all much lower than the present market rates, but are representative of farm values in 1914. The alfalfa hay had been damaged considerably in curing, and its feeding value was no doubt less than that of good hay. This perhaps accounts for the rather poor showing of the animals fed upon alfalfa. This lot, despite its handicap, had smoother coats and a better general appearance than any of the other lots. The different lots received all the Sudan grass hay, kafir stover, alfalfa hay, and sorgo stover that they would eat up clean and were allowed all the straw they would eat in addition to 10 pounds of silage and 1 pound of linseed meal a head daily. The proportion of silage in the ration was small, but it no doubt had much to do with the good showing made by the different roughages other than alfalfa. Without the silage the results would probably have been much more favorable to alfalfa.

The third test, which was designed to ascertain the value of Sudan grass hay as a feed for dairy cows, was made at Manhattan, Kans. Six cows were separated into two lots of three each, as nearly alike as possible in regard to the period of lactation. The ration consisted of corn silage, a grain mixture of 4 parts of ground corn, 2 parts of bran, and 1 part of oil meal, in addition to chopped Sudan grass hay in one case and chopped alfalfa hay in the other.

In lot 1 the cows were fed alfalfa hay with the above supplementary ration for a 15-day preliminary period and a 30-day actual test. At the end of this time Sudan grass hay was substituted for the alfalfa hay in the ration, and during a 10-day change period and a 30-day test period they were fed upon Sudan grass hay and the same supplementary ration as in the first period.

In lot 2 the cows were fed upon Sudan grass hay, with the supplementary ration during the first period and alfalfa hay during the second period, under the same conditions as in lot 1.

The results are given in detail in Table XIV.

TABLE XIV.—*Comparison of alfalfa and Sudan grass hay for milk production.*

Lot.	Hay ration.	Production.		Body weight.
		Milk.	Butter fat.	
		Pounds.	*Pounds.*	*Pounds.*
Lot 1	Cow No. 1:			
	Alfalfa	597.0	31.01	884
	Sudan grass	527.4	26.14	877
	Difference	69.6	4.87	7
	Cow No. 2:			
	Alfalfa	633.3	29.76	929
	Sudan grass	597.0	29.01	921
	Difference	36.3	.75	8
	Cow No. 3:			
	Alfalfa	1,291.6	55.91	942
	Sudan grass	1,082.6	46.41	887
	Difference	209.0	9.5	55
Lot 2	Cow No. 4:			
	Sudan grass	603.2	22.33	1,032
	Alfalfa	576.3	21.36	1,024
	Difference	26.9	.97	8
	Cow No. 5:			
	Sudan grass	663.5	22.98	1,203
	Alfalfa	530.2	20.38	1,248
	Difference	133.3	2.6	−45
	Cow No. 6:			
	Sudan grass	547.8	21.44	1,402
	Alfalfa	483.5	19.88	1,429
	Difference	64.3	1.56	−27
Lots 1 and 2	Total (comparison):			
	Alfalfa	4,111.9	178.30	6,461
	Sudan grass	4,021.5	168.30	6,319
	Difference	90.4	10.00	142

Although an attempt was made to separate the cows into practically equal groups from the standpoint of milk production, the quantity of milk produced by the different cows varied considerably, and this affected the results. Cow No. 3 in lot 1 produced twice as much milk as either of the other cows, and this made the difference in the milk produced in the alfalfa period and the Sudan grass period proportionately great. Since the alfalfa was fed earlier in the lactation period of this cow, the large yield of milk resulted in a disadvantage to the Sudan grass. Notwithstanding this fact, the cows produced 97.8 per cent as much milk on Sudan grass as on the alfalfa hay, though the Sudan grass hay was coarse and poorly cured, while the alfalfa hay was first-class.

Testimonials of hundreds of farmers who have fed Sudan grass hay to all classes of live stock confirm the results of these more or less definite experiments, indicating the high value of Sudan grass hay as a roughage for work animals, stock cattle, and dairy cows. The consensus of these reports from farmers is that cattle, horses, and sheep all relish Sudan grass hay and eat it with no derangement of the digestive processes and with good results when measured in gains of flesh and ability to work or to produce milk.

Experts in feeding live stock claim that Sudan grass gives the best results only when fed in connection with other forage. It is not well adapted to use as the sole roughage in rationing any kind of animals.

PASTURE.

Sudan grass is perhaps most important as a hay grass, but it is used more and more widely as a summer pasture. A number of tests, more or less well arranged, have been made in pasturing Sudan grass at the different agricultural experiment stations throughout the United States. These have been described briefly in Farmers' Bulletin 1126, copies of which may be obtained free, on request, from the Division of Publications, United States Department of Agriculture.

At the experiment farm at Dodge City, Kans., Sudan grass furnished abundant pasturage at the rate of one milk cow per acre for a grazing period of 125 days, and the cows made a daily average of 3.2 pounds more milk per cow on the Sudan grass than on native grasses. At the Chillicothe (Tex.) substation, horses, mules, and cows all showed a decided preference for Sudan grass over millet and Amber sorgo. At the Arizona experiment farm, near Prescott, Sudan grass maintained 20 sheep to the acre continuously for 100 days. No irrigation was given the grass during this period, yet the sheep fattened perceptibly and did much better than those grazing on Amber sorgo. At the California Agricultural Experiment Station, Davis, Calif. (14, pp. 215–216), Sudan grass seeded on silt loam maintained approxi-

mately 22 head of sheep per acre and produced gains of about one-third pound a day during the pasture period. This flock of sheep was composed of 16 lambs and 6 ewes. The land was irrigated before seeding the grass but not afterwards. The field was pastured intermittently from July 24 to October 29, and 2.32 tons per acre of hay were obtained in addition to the pasturage.

As a pasture on irrigated lands Sudan grass probably ranks next to alfalfa, and has an advantage over the latter crop in not causing bloat in cattle and sheep, as alfalfa sometimes does. At the Yuma experiment farm, Bard, Calif., in the summer of 1915, a field of Sudan grass maintained an average of three head per acre of work horses and milk cows over a period of six months. The field was divided in halves and the halves pastured alternately in periods of two to three weeks. The grass was irrigated in each case as soon as the stock were removed and left unpastured until the ground became firm and the growth was 4 or 5 inches high.

A comparison of Sudan grass with Dallis grass (*Paspalum dilatatum*) on the Murrumbidgee irrigation areas of New South Wales is also of interest (3, p. 14). Cows to the number of 28 which had been grazing on the Dallis grass were transferred to a field of Sudan grass, with the results shown in Table XV.

TABLE XV.—*Comparison of the milk and butter produced daily by 28 cows when grazing on Sudan grass and on Dallis grass.*

Kind of pasture.	Daily production (pounds).		
	Milk.	Butter fat.	Commercial butter.
Sudan grass	574	28.24	34.50
Dallis grass	518	24.03	28.31

Although the cows pastured the Sudan grass later in their lactation period than they did the Dallis grass, the results showed an increase of 56 pounds of milk and 4.21 pounds of butter fat, or 6.19 pounds of butter, in the daily output of the 28 cows when they were changed from the Dallis grass to the Sudan grass. The records were made just before the cows were taken off the Dallis grass and again after they had been on the Sudan grass two weeks.

In addition to the foregoing experiments some very conclusive results have been obtained by the Kansas Agricultural Experiment Station in pasturing milk cows on Sudan grass (5). An upland field containing 5.4 acres was seeded to this grass on June 6, and 6 Holstein cows, which had previously been fed on alfalfa hay, silage, and grain, were turned into the field on July 10. The grass was then 3 or 4 feet high, lack of labor preventing the inauguration of the experiment earlier, when the grass was at the proper height for pasturing.

The cows had free access to salt and water, and a shelter was provided for them where they were fed and milked. In addition to the pasturage, the cows received daily 1 pound of a grain mixture for each 4 pounds of milk produced. This mixture was made up of corn, bran, and oil meal in the proportion of 4 to 2 to 1.

The cows were weighed before being turned on the pasture and again each 10 days thereafter. Composite samples of the milk were taken every 10 days and tested for butter fat by the Babcock method. On account of the rank growth it was found advisable to mow the grass after the cows were turned into the field. Half the field was first mowed, and two weeks later the other half was cut. A total of 7.33 tons of hay was obtained, and after these cuttings the cows had no trouble in keeping the grass eaten down. Notwithstanding the fact that the rainfall for July, August, and September was light, the pasturage proved sufficient for the cows until frost. The cows were taken off the pasture on October 11. Table XVI shows in detail the results obtained from the Sudan grass pasture.

TABLE XVI.—*Results obtained in pasturing Sudan grass with dairy cattle at Manhattan, Kans.*

Cow.	Weight.						Values.		
	At start.	At close.	Gain or loss.	Milk produced.	Butter fat produced.	Grain fed.	Butter fat and skim milk.	Grain.	Pasture above cost of feed.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*			
No. 19	1,343	1,302	−41	2,658.5	82.08	684.00	$60.54	$20.52	$40.03
No. 16	1,325	1,267	−58	2,473.9	92.19	656.50	65.82	19.69	46.14
No. 102	1,175	1,200	25	1,104.3	37.92	366.25	27.44	10.98	16.46
No. 114	1,248	1,185	−63	3,334.5	93.87	870.75	70.49	26.12	44.37
No. 106	1,375	1,397	22	2,104.8	64.01	595.00	47.35	17.85	29.51
No. 112	1,391	1,380	−11	587.2	19.11	263.25	14.46	7.89	6.58
Total	7,857	7,731	−126	12,263.2	389.18	3,435.75	286.14	103.05	183.09

Table XVI shows an average loss in weight of 21 pounds a head, but this is not as much as milk cows ordinarily lose while on pasture during dry summers. The low average production of milk and butter fat was due to the poor performance of cows 102 and 112. This fact is attributed not so much to the feed as to the lack of persistency of these two cows in maintaining their milk flow late in the lactation period.

In arriving at the values given in Table XVI, the butter fat has been rated at 60 cents a pound and the skim milk at 50 cents a hundred pounds, assuming that 85 pounds of skim milk would remain after the cream was separated from 100 pounds of fresh milk. If the value of the 7.33 tons of Sudan grass hay at $10 a ton is added to the value of the butter fat and skim milk that the cows produced, the Sudan grass pasture must then be credited with a net

return of $47.47 an acre above the value of the grain fed. With the whole milk valued at 30 cents a gallon, each acre of pasture returned $73.55 above the cost of the grain consumed by the cows.

Hogs provided with Sudan grass pasture make good gains with 60 to 70 per cent of the customary grain ration. Some experiment stations have found that Sudan grass is not equal to alfalfa as a pasture for brood sows during the summer months. The alfalfa pasture is ready earlier in the spring and continues growth later in the fall. Sudan grass can not be sown until the soil becomes warm and it is generally killed by the first frost in the fall.

The most serious drawback to the use of Sudan grass as pasture for cattle, horses, and sheep is the danger of prussic-acid poisoning. All sorghums contain small amounts of this acid, and under certain conditions, such as an acute drought, the quantity is likely to reach dangerous proportions. Both Sudan grass and Johnson grass are less likely to contain injurious amounts of prussic acid than the larger sorghums. This has been definitely proved by Menaul and Dowell (15), who found by careful analysis only one-third as much prussic acid in Sudan grass as in the grain sorghums. Very few cases of poisoning due to pasturing Sudan grass have been reported to the United States Department of Agriculture, but at least three authentic cases are known. In each of these instances the trouble occurred while pasturing the grass after it had been injured by drought or frost. Caution and good judgment are therefore required in pasturing Sudan grass with any kind of live stock other than hogs, which do not appear susceptible to this form of poisoning.

SOILING AND SILAGE.

Green feed for dairy cattle and work animals can be supplied as needed during the summer from a field of Sudan grass. It is well adapted to soiling, because the growth is renewed quickly after cutting, and it is relished by both cattle and horses in the green state. The cost of labor prevents any very extended use of soiling crops in the United States, although the return per acre of land is much larger by this method of furnishing a succulent feed than it is by pasturing.

Sudan grass silage has been used very little, for three reasons: (1) Sudan grass can be easily made into hay; (2) there is little waste in feeding it as hay; and (3) both sorghum and corn, which can be grown in the same regions as Sudan grass, make larger yields of silage. Because of these facts there have been very few experiments with Sudan grass silage. The Oklahoma Agricultural Experiment Station (6, 8) has done some work along this line. Its earliest publication (Bulletin 115) is concerned chiefly with chemical analyses and temperatures. In the 1918 work reported by Dowell and Friedemann,

(6) the acids, sugars, and alcohols present in the silage were also determined.

In 1917 Sudan grass was stored in a steel silo 25 feet high and 9 feet in diameter, having an approximate capacity of 75 tons. Because the grass was somewhat dry when placed in the silo it was found necessary to run considerable water in with it. Under these conditions the resulting spoilage of 10 per cent does not seem excessive. Sheep seemed to relish the silage less than they did corn silage, but ate it fully as well as the silage made from grain sorghums.

TABLE XVII.—*Composition of Sudan grass and corn silage compared on a water-free basis.*

Kind of silage.	Constituents.				
	Ash.	Ether extract.	Protein.	Fiber.	Nitrogen free extract.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sudan grass (fresh)	7.21	2.33	9.38	30.55	50.53
Corn (fresh)	6.58	2.16	8.39	23.39	59.48
Sudan grass (near top, 122 days)	5.60	2.17	8.20	33.53	50.50
Corn (near top, 148 days)	6.80	2.60	9.56	23.62	57.42
Sudan grass (from middle, 140 days)	6.51	2.77	10.36	33.57	46.79
Corn (from middle, 182 days)	6.20	2.96	8.85	22.84	59.15

It appears from Table XVII that the composition of Sudan grass silage is practically the same as that of corn silage. The experiments in 1918 showed that the density of the former was only 54 per cent of that of the latter. Notwithstanding the fact that the grass silage always seemed fluffier than corn silage, the spoilage was not unreasonably great in either year.

The silo used in the experiments in 1918 was a cylindrical iron structure 4 by 9 feet. The acidity of Sudan grass silage, as determined by the average of two samples, one taken near the top and the other near the bottom of the silo 245 days after it was filled, was as follows: Lactic acid, 1.16; acetic acid, 0.39; propionic acid, 0.03; total acids, 1.58 per cent. As determined at the Kansas Agricultural Experiment Station, the acidity of corn silage was 2.03; sorgo silage, 1.46; and kafir silage, 1.43 per cent. It will be seen, therefore, that Sudan-grass silage is less acid than corn silage but slightly more acid than sorgo or kafir silage. The Sudan grass silage made in 1918 was fed to cattle, and they seemed to relish it very much, eating it much more freely than they did the Sudan grass hay.

The feeding value of Sudan grass silage was compared with that of corn silage at the California Agricultural Experiment Station in a test with 21 dairy cows (28, pp. 33–36). The experiment covered three periods of four weeks each, the test period in every case being preceded by a preliminary feeding period of one week. In addition to silage, the cows were fed alfalfa hay and a grain mixture of dried-

beet pulp, coconut meal, wheat bran, and rolled barley in the proportion of 4 to 1 to 1 to 1 by weight. The cows received 1 pound of this grain mixture for each 5 pounds of milk they produced. Corn silage was fed in the first and third periods, Sudan grass silage in the second period.

The results were slightly in favor of the corn silage. The average daily production of milk in periods 1 and 3 was 19.6 pounds; in the second period it was 18.9 pounds. Butter fat, periods 1 and 3, 0.916 pound; period 2, 0.879 pound. If the production is indicated on the basis of dry matter fed in the different periods, it is found that the production of milk was 10 per cent larger and the fat 11 per cent larger for the corn-silage periods than it was for the period when Sudan grass silage was fed.

Some experimental work with Sudan grass as a silage crop has been carried on at the Nevada Agricultural Experiment Station and also at the Manitoba Agricultural College. The yields, however, are sure to be the determining factor as to whether Sudan grass will be used in making silage. The best yield that can be expected from Sudan grass in most localities is 6 to 10 tons per acre. Corn in the real corn States and sorghum in the semiarid regions will yield nearly double that quantity; hence, there seems little chance for Sudan grass to be widely used as a silage crop.

SUDAN GRASS AS A GRAIN CROP.

The yields of the seed are so small (see Table XX) that Sudan grass has never been seriously considered as a grain crop. If, however, a strain of Sudan grass or a hybrid between Sudan grass and sorghum could be developed which would produce seed more abundantly and retain the vegetative characteristics of Sudan grass as well as its ability to withstand drought, it might be a good substitute for oats in the semiarid region. Such a grass sorghum would become popular on account of the ease of harvesting and thrashing, even though the average yield of seed were somewhat less than that of kafir or milo. A grass sorghum the height of Sudan grass could be harvested easily with a grain binder and thrashed like bundle grain. The straw would be much superior to that of the ordinary small grains; in fact, practically equal to prairie hay as a roughage for live stock.

In so far as the composition of the seed is concerned, Sudan grass seed is equal in feeding value to most other cereals. A comparison of the composition of Sudan grass seed with that of the common cereal grains of the United States is given in Table XVIII.

The presence of a slight amount of tannin in the seed of Sudan grass would perhaps lower its feeding value somewhat. This objectionable feature may be overcome by the development of a white-seeded strain.

TABLE XVIII.—*Comparison of the composition of Sudan grass seed with that of the common cereal grains.*

Grain.	Constituents (per cent).					
	Moisture.	Ash.	Ether extract.	Protein.	Crude fiber.	Nitrogen-free extract.
Sudan grass seed [1]	10.47	3.09	3.81	13.62	5.38	63.63
Oats	9.20	3.50	4.40	12.40	10.90	59.60
Barley	9.30	2.70	2.10	11.50	4.60	69.80
Wheat	10.20	1.90	2.10	12.40	2.20	71.20
Corn	10.50	1.50	5.00	10.10	2.00	70.90
Kafir seed	11.80	1.70	3.00	11.10	2.30	70.10

[1] The analysis of Sudan grass seed was made by Dr. G. S. Fraps, of the Texas experiment station; all other analyses were taken from Henry and Morrison (10, p. 633–635).

SEED PRODUCTION.

The production of Sudan grass seed in the United States is a matter of considerable importance, not only because most of the acreage will always be cut for hay, but because good, pure seed is obtained only when care is used in its production.

LOCALITIES ADAPTED TO SEED PRODUCTION.

Ever since Sudan grass became a crop of importance, northwestern Texas has been the center of production for the seed. The total production of Sudan grass seed in the United States in 1914 was estimated at 5,000,000 to 6,000,000 pounds, approximately 3,000,000 pounds of which were produced in the vicinity of Lubbock, Tex. There have been almost no failures of Sudan grass in this part of Texas. East of the ninety-eighth meridian in Texas, seed production is uncertain, however, owing to the presence of the sorghum midge (17).

Kansas and Oklahoma rank next to Texas in the production of Sudan grass seed. (See the map, fig. 22.) The sorghum midge is not troublesome in either of these States, but drought often causes a short seed crop. In the irrigated regions of Colorado, New Mexico, Arizona, and California the seed yields are heavy and the quality of the seed first class, but only limited quantities are grown under these conditions, owing to the high price of the land and the profitable returns from other crops. Yields of more than 2,000 pounds of seed per acre have been reported from California and Arizona, and 1,700 pounds from the vicinity of Lubbock, Tex., but the average in both regions is much less. In other parts of the United States 300 to 500 pounds of seed per acre is all that should be expected, as will be observed in Table XX. The results in the growing of Sudan grass for six years indicate that the seed can be produced successfully in all but the States farthest north, where the seasons are too short, and the Southeastern States, where the sorghum midge is present.

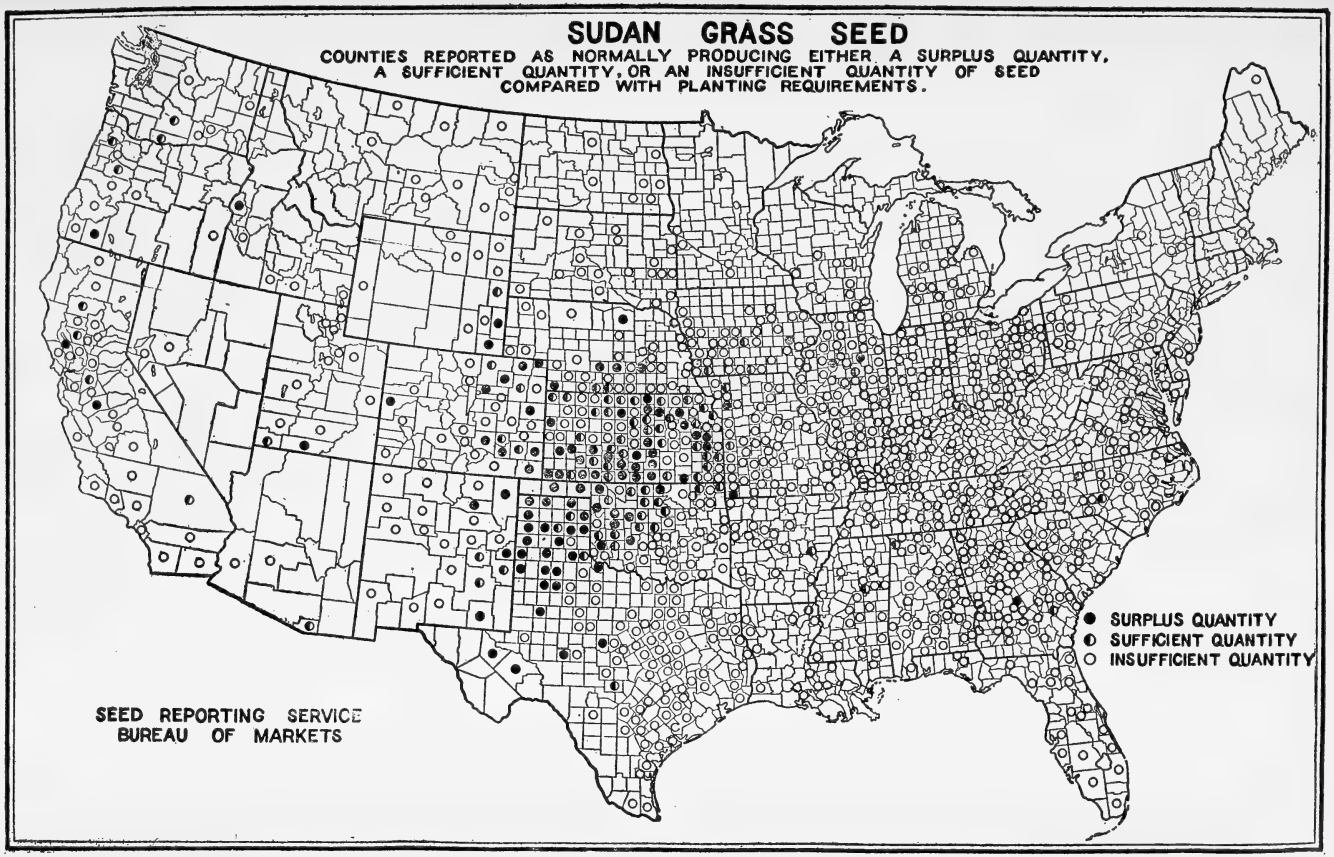

FIG. 22.—The production o Sudan grass by counties in 1918. From the Seed Reporter, Bureau of Markets, April 5, 1919.

Table XX shows yields of 350 to 400 pounds of seed in the humid corn-belt States, while the average yield in the semiarid regions is only 250 to 300 pounds per acre. Seed produced in the latter region, however, is likely to be of better quality than that from the more humid regions. In arid regions where irrigation is practiced, yields of 1,200 to 1,400 pounds of good seed per acre are to be expected. An increased acreage of Sudan grass devoted to seed production in these irrigated sections would appear justified as soon as a reliable market for the seed has been developed.

Only a small acreage was planted in 1913, and owing to extensive advertisement of the crop the seed sold readily at retail for $1 a pound. Prices as high as $2.25 a pound were recorded near the close of the 1914 planting season. These prices stimulated seed production in 1914 and resulted in the large crop of that year. Unreasonableness on the part of certain growers and seed dealers in expecting 1913 prices for the large crop of 1914 caused a surplus to be carried over into 1915 and that winter the price dropped to 4 cents a pound wholesale. The producers of the seed received much less than this, and their discouragement resulted in a marked decrease in the acreage devoted to Sudan grass seed production in 1916 and 1917. A price to the farmer of 5 or 6 cents a pound for the seed is necessary to make seed production worth while under ordinary conditions, if the yields given in Table XX are representative of what may be expected in different parts of the United States.

In determining the suitability of any given locality for Sudan grass seed production, the presence of Johnson grass (*Andropogon halepensis*) should be taken into account. The seeds of Johnson grass are very much like those of Sudan grass in size and general appearance. No mechanical method for separating the two kinds when mixed is known. It is highly important, therefore, that pure Sudan grass seed be used on farms in the South where Johnson grass is not present. Johnson grass is a dangerous pest only where it behaves as a perennial. That portion of the United States where Johnson grass ordinarily lives over winter is shown on the map (fig. 13). Broadly speaking, the region in which it perennates lies south of 38° north latitude except for that area west of the Cascade and Coast Ranges in California, Oregon, and Washington. Outside of the district described Johnson grass behaves normally as an annual and can be easily killed out. Admixtures of Johnson grass seed in Sudan grass seed sown north of 38° north latitude is not a matter of any great importance when the crop is to be harvested for hay, because it can be easily controlled and it does not injure the Sudan grass hay crop appreciably.

It is well for those living in that section of the United States where Johnson grass perennates to remember: (1) That a farmer

may grow sufficient seed for his own plantings and thus be assured of its purity; (2) that if the farmer finds it necessary to buy Sudan grass seed and his land is free from Johnson grass, he should purchase only seed grown outside the Johnson grass region or from responsible growers in the South who are willing to guarantee its purity; (3) and that if the Sudan grass is to be seeded on land already foul with Johnson grass the presence of seed of the latter is a matter of small importance.

The southern planter can afford to pay a slight advance in price for seed produced north of 38° north latitude or by responsible growers south of that parallel. (See the map, fig. 13.) It must be remembered, however, that some of the Sudan grass seed handled by northern seedsmen is purchased by them in the South, so that to be absolutely safe the seed must be registered as northern grown, and even then it will not be pure unless the grower has sown seed free from Johnson grass seed and other impurities.

The Texas Agricultural Experiment Station has done more to safeguard the production of Sudan grass seed than any other agency in the United States. Through the Texas Experiment Association, an organization intended to assist in all movements to improve agricultural conditions, a campaign was launched in 1914 to require each bag of Sudan grass seed to be labeled with the name and address of the grower, together with information as to the grade of the seed and whether it had been inspected in the field by a representative of the association. Instructions regarding the proposed grades of seed and the methods of tagging the package offered for sale were issued by the secretary of the association on August 3, 1914. Much good was accomplished by this effort in stimulating the production of pure seed and in acquainting farmers with the extreme care required in such work.

DESCRIPTIONS OF THE SEEDS OF SUDAN GRASS AND JOHNSON GRASS.

The seeds of Sudan grass and Johnson grass resemble each other so closely that it becomes a matter of extreme difficulty to detect the presence of small numbers of Johnson grass seeds in the seed of Sudan grass. Bulk lots of Sudan grass seed are easily distinguished from Johnson grass seed on account of their uniformly larger size (fig. 23), but the variations in size, color, and other factors of appearance are so slight that individual seeds may be indistinguishable except under very close examination and with the aid of a magnifying glass. Certain points of difference in the seeds of these two grasses were pointed out, first by Oakley in 1912 (18, p. 504) and later by the senior writer (23). No critical investigation of this rather important question was attempted, however, until it was necessitated by the action of horticultural inspectors in certain California counties, who refused to allow the importation of Sudan grass seed, claiming that

it was impossible to ascertain by seed inspection whether it was adulterated with Johnson grass seed. F. H. Hillman, after a critical study of the seeds of the two grasses, published (11) complete instructions for their identification. The method is based chiefly on the character mentioned by Oakley, that of the attachment of the seed to the rachis branch, but this was amplified and explained by drawings in a way which now makes it possible, at least for a trained seed analyst, to identify the two seeds with reasonable certainty. (Figs. 24 and 25.)

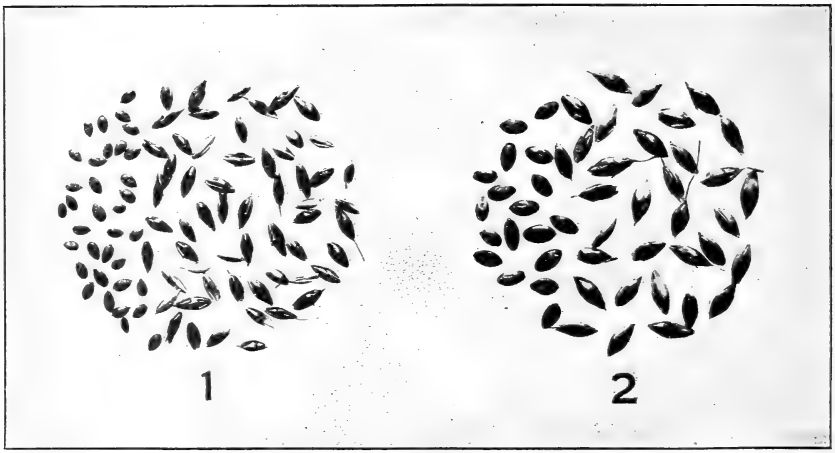

FIG. 23.—Seeds of Johnson grass (1) and Sudan grass (2). Hulled grains appear at the left of each group. (Natural size, from a photograph.)

TABLE XIX.—*Distinguishing characters of the seeds of Sudan grass and Johnson grass.*

Kind of seeds.	Length of seeds.		Prevailing color.	
	Unhulled.	Hulled.	Hulls.	Hulled seeds.
	Inches.	*Inches.*		
Sudan grass	0.18 to 0.25	0.13 to 0.18	Straw or light tawny, some reddish and some blackish brown.	Light reddish brown.
Johnson grass	0.15 to 0.22	0.08 to 0.12	Blackish brown, some reddish and some straw color.	Dark reddish brown.

Kind of seeds.	Character of the—		Apex of the seed appendages.	Shape of the hulled seed.
	Attachment of seeds.	Embryo.		
Sudan grass	No distinct suture or scar tissue; portion of rachis segment usually adhering.	Relatively large.	Jaggedly broken, not expanded.	Elliptical in outline.
Johnson grass	Distinct suture or scar; usually no rachis segment adhering.	Smaller and narrower than that of Sudan grass.	Smooth, expanded, cup shaped.	Usually oval or oval-elliptical.

The contrasting characters of the two seeds, as described by Hillman, are set forth in Table XIX.

It will be noticed that there is an overlapping in several of these characters, particularly in the size and color of the unhulled seeds; also that a small percentage of Sudan grass seeds has no portion of the rachis adhering and an equally small percentage of Johnson grass seeds is found in which a portion of the rachis adheres. In all such cases, however, Hillman declares that an examination of the seed surface at the point of attachment, the size of the seed, together with the size, form, and color of the grain, should suffice to distinguish the seed of one grass from that of the other. Most States now have seed laboratories in connection with their agricultural experiment stations. By referring samples of all Sudan grass seed importations to the analysts in these laboratories the seed dealer may ascertain whether these samples are free from Johnson grass seed.

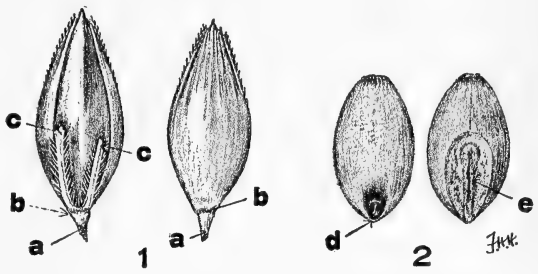

FIG. 24.—Sudan grass seeds, enlarged. Unhulled seeds, spikelets (1); hulled grains (2): *a*, *a*, Seed stem; *b*, *b*, construction at the junction of seed and stem; *c*, *c*, appendages of the seed with broken apexes; *d*, scar of the grain; *e*, embryo.

CULTURAL METHODS FOR SEED PRODUCTION.

Most Sudan grass seed is produced in cultivated rows, because this method of planting with its accompanying cultivation more nearly assures a crop, especially in regions subject to drought. Table XX shows the yields obtained in both wide and narrow rows, as compared with broadcast or close drills.

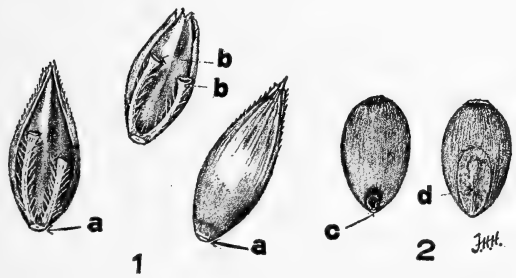

FIG. 25.—Johnson grass seeds, enlarged. Unhulled seeds, spikelets (1); hulled grains (2): *a*, *a*, Scar of the hull; *b*, *b*, appendages of the seed with expanded, cup-shaped apexes; *c*, scar of the grain; *d*, embryo.

Table XX shows that cultivated rows give better yields of seed in the humid regions and also in the semiarid regions if the crop is not irrigated. Under irrigation the results are reversed, the broadcasted or close-drilled seedings being markedly superior. Narrow rows, 18 to 24 inches apart, give larger yields than the wide rows, 36 to 44 inches apart, but it is hardly advisable for a farmer to plant in narrow rows unless he has on hand machinery adapted for their cultivation. Wide rows can be

cultivated with an ordinary corn cultivator, but narrow rows require some such tools as are used for sugar beets. Specific directions for the planting, cultivating, and harvesting of row plantings have been given under "Hay production." The method of planting and cultivating the rows is the same whether they are intended for hay or for seed. The rate of planting in rows or close drills should be about the same as for hay, because the seed matures more uniformly in thick stands. The usual practice has been to sow rather thinly for seed production, but this has been warranted only by the scarcity and high price of seed.

TABLE XX.— *Yields of Sudan grass seed under different methods of seeding.*

Location of test.	Years of test.	Plats.		Yields of seed per acre.		
		Size.	Replications.	Broadcast or in close drills.	Cultivated rows.	
					18 to 24 inches apart.	36 to 44 inches apart.
Humid regions:		*Acres.*		*Pounds.*	*Pounds.*	*Pounds.*
Beeville, Tex	1913		1	380	360	400
Temple, Tex	1913		1		556	361
Stillwater, Okla	1914	0.10	1	195		324
Manhattan, Kans	1914					640
Jackson, Tenn	1913			293	320	245
Arlington Farm, Va.	1912	.45	1	118	457	
Blacksburg, Va	1913, 1914, 1916	.05	1 or 2	258	398	274
College Park, Md	1914	.05	2	339	228	142
Madison, Wis	1916, 1918	.025	2	484		754
St. Paul, Minn	1913	.015	2	370	778	708
Average				328	417	354
Dry regions (not irrigated):						
Davis, Calif	1913 to 1915	.05	1 or 2	908	919	784
Chillicothe, Tex	1913 to 1919	.05	2	86	141	158
Amarillo, Tex	1913 to 1917	.05	2	211	223	228
Spur, Tex	1914		12	1,026		
Lubbock, Tex	1913, 1914		4 or 5			633
Dalhart, Tex	1912	.10	1	460		540
Hays, Kans	1913 to 1919	0.05 to .10	2	28	116	111
Garden City, Kans	1914	.10 to 5.5	1	0	311	243
Dodge City, Kans	1914				252	335
Colby, Kans	1914			0	0	100
Ritzville, Wash	1914, 1915					910
Wenatchee, Wash	1915	.25	1			500
Average				206	285	271
Dry regions (irrigated):						
Bard, Calif	1914, 1915			518	466	494
Davis, Calif	1913, 1914, 1916	.025 to .05	1	1,292	1,183	1,010
Chico, Calif	1914, 1915	.05	2	1,560	1,250	1,210
Phoenix, Ariz	1913		1			2,254
Reno, Nev	1915, 1916					1,506
Umatilla, Oreg	1914		1			508
San Antonio, Tex	1911, 1913, 1914	.20	1			627
Average [1]				1,123	966	905

[1] These averages include only those stations where data are given for all three methods of seeding.

Harvesting for seed is nearly always done with a row binder or a grain binder rather than a mower. The grass when tied in bundles can be thrashed more efficiently and is easier to care for in the field. The shockers should follow closely after the binder, because the seed will become discolored if the bundles are allowed to lie on the ground

for any length of time. In humid regions it is profitable to protect the grass with shock covers; otherwise the seed will be damaged by wet weather.

The proper time for harvesting must be decided very largely by the grower. Sudan grass tillers freely, and this gives rise to a progressive ripening of seed panicles; those on the main stem ripen first and those on the tillers mature successively in the order of their age. The period of ripening is thus continued almost indefinitely. Sudan grass seed does not shatter easily. Harvesting, therefore, may de delayed for several days after the panicles on the main stems are mature without any particular loss unless high winds prevail, birds are abundant, or the stems become so weakened by red-spot that they break down. Because of these risks it is well not to wait too long after the first heads are ripe, and in addition the gain in seed from the ripening tillers will not be sufficient to balance the loss of hay or pasture from the aftermath. Obviously, the earlier the seed crop is taken off the larger will be the aftermath.

It is best, then, to watch the crop carefully and harvest as soon as the main stems have fully ripened their seed unless the seed crop from the main stems promises to be small as compared with that from the tillers. Immature heads usually ripen considerably in the shock.

The crop is ready for thrashing after it has been in the shock for two or three weeks, if good curing weather has prevailed. There is danger in stacking the seed crop unless it is thoroughly cured. Sudan grass has a large amount of sap in the stems and will often heat in the stack and injure the germination of the seed even if stacked when the leaves are fully cured. It is usually safer to use shock covers to protect the seed from rain and birds and leave the crop in the field until it is thrashed.

CARE NECESSARY TO PREVENT HYBRIDIZATION.

Sudan grass crosses very freely with all sorghums, but especially with the sweet sorghums, such as Minnesota Amber. Extreme care is necessary, therefore, to prevent the hybridization of Sudan grass and sorghum in field plantings where a seed crop is to be harvested. There is usually little danger of cross-pollination if the Sudan grass field is 100 yards from any sorghum, but on the Great Plains, where the atmosphere is usually in motion, pollen may be carried for a greater distance. Under such conditions 60 to 80 rods is not too far to have fields of these two crops separated.

Another source of cross-pollination is the volunteer sorghum growth sometimes found in Sudan grass fields. This trouble can be avoided by seeding the grass on a field which has been planted to some crop other than sorghum the preceding year, or by careful roguing before the Sudan grass or sorghum has headed. The sor-

ghum plants can be easily distinguished by their broader leaves and heavier stems.

Johnson grass does not cross-pollinate as freely with Sudan grass as the sorghums do, but natural crossing does occur when the two grasses grow in mixtures or in adjoining rows. It is important, therefore, to see that no Johnson grass is allowed to bloom in the Sudan grass field, because of the possibility of hybridization.

ROGUING THE FIELDS.

If pure seed is to be produced, every grower must remove from his Sudan grass field all sorghum and Johnson grass, and also hybrids between these crops and Sudan grass. Sorghum plants and sorghum-Sudan grass hybrids are coarser and usually taller than the Sudan grass. Some growers have found that the most effective way of locating these rogues is to ride through the field on horseback. This places the rider's vision above the tops of the Sudan grass and enables him to discover, from a considerable distance, plants which are off type.

Johnson grass and Johnson-Sudan grass hybrids are much more difficult to discover in a Sudan grass field. The only way to be sure there are no such plants in the field is to sow absolutely pure seed on land which is known to be free from Johnson grass. Roguing a field infested with Johnson grass, unless it be done with more than ordinary care, will not insure the removal of all the plants. It is well, then, for both buyer and producer to remember that preventing contamination is the only safe plan for dealing with Johnson grass, because it is so much like Sudan grass in appearance.

All rogues should be removed before the Sudan grass has come into bloom, in order to preclude any chance of cross-pollination.

THRASHING AND CLEANING THE SEED.

Sudan grass can be thrashed in an ordinary grain separator if care is used in regulating the air blast so that seed will not be blown over into the straw pile. The sieves which are used in thrashing wheat or sorghum can be used for Sudan grass. If dry, the straw will run through the machine without clogging, but when not well cured or somewhat moist at thrashing time it may be desirable to top the bundles, so that only the heads need to be run through.

Prices paid in 1920 for thrashing in Oklahoma and Texas varied from 50 cents to $1 per hundredweight, depending on whether the crew is furnished with the machine and on the quantity of grass to be thrashed. The thrashed Sudan grass makes a good roughage for either horses or cattle. Many stockmen believe it equal to prairie hay in feeding value.

A farmer may flail out small quantities of Sudan grass for his own seeding. If this is done, the grass should be thoroughly dry before it is placed on the canvas. Seed thrashed in this way has to be

separated from the chaff, either by passing it through a fanning mill or winnowing it in a breeze. Machine-thrashed seed usually has to be recleaned in a fanning mill before it is ready for sale.

Good recleaned seed weighs 36 to 40 pounds per bushel. Seed grown in the humid sections where the vegetative growth has been luxuriant and the conditions for ripening not particularly favorable is not often plump, and only a small percentage is hulled in thrashing. Such seed with the glumes attached usually weighs 30 to 36 pounds per bushel.

Sudan grass seed if stored in good condition, either bagged or loose in a bin, keeps much better than seed of the larger sorghums, like kafir, milo, or feterita. No trouble need be anticipated if the seed is dry and well cured when placed in storage.

SEED GRADES.

The quantity of Sudan grass seed handled by the trade has not been large enough yet to call for the establishment of grades. Certain seed grades based primarily on color were suggested by the Texas Agricultural Experiment Association in August, 1914. These grades have not been generally accepted, because they did not indicate the quality of the seed, as seed grades should, but attempted to establish values for different strains of the grass. According to the proposed Texas standards, seed might be classed as grade 1 only when it was "pure creamhul"; that is, absolutely free from seeds with black or purple glumes. Grade 2 was described as "creamhul with not to exceed 5 per cent blackhul" and grade 3 as "creamhul with more than 5 per cent blackhul." The chief idea in the advocacy of such grades was that the detection of Johnson grass seeds would be much easier if the Sudan grass seeds were uniformly light colored. This is true, because more than 90 per cent of the Johnson grass seeds are black or purple.

The general effect of the Texas grades was to put a premium on strains of Sudan grass with light-colored ("creamhul") seeds. No superiority in forage value attached to or was claimed for these strains. The impracticability of such grades was realized when it became known that climate had much to do with the coloration of the seed. Seed produced in the arid regions was more often "pure creamhul" than that grown in the humid regions. Even in the arid regions seed harvested early in the season might be without color, while that from the same field harvested later in the fall would contain a large percentage of black and purple seeds. Mr. R. E. Blair (2, p. 16) reports from the experiment station at Bard, Calif., as follows:

> As the cool nights of autumn set in, Sudan grass seed has a tendency to become highly colored in red and black shades * * *. The fields producing a second crop of highly colored seed produced a first crop of excellent light-colored seed.

It is quite probable that in time we shall have recognized grades of Sudan grass seed, applying equally well to all strains of the grass, if differing strains are actually developed. Stipulations such as were adopted by the Chicago Board of Trade June 20, 1916, for timothy seed might be applied to Sudan grass seed. These require "prime" seed to be "good average color, clean, sound, not too much hulled, and reasonably free from foul or foreign seed." Descriptions of the grades of Sudan grass seed would need to be more definite, but these descriptions would necessarily have to be similar to those already found satisfactory for other grass seeds by the trade.

When grades are established they should indicate, in addition to more closely defining the color requirements, the definite percentages of inert matter and foreign seed allowable in each grade. Sudan grass seed grades, to be useful, must be based on some such specifications as follows:

(1) Condition of seed.
  (a) Color: Bright and free from discolorations due to weathering or disease.
  (b) Plump, sound, and dry. In condition for storing.
(2) Purity of seed.
  (a) Inert matter: Reasonably free from dirt, broken stems, etc., the percentages allowable in different grades to be specified.
  (b) Foreign seed: The percentages of weed seed allowable in different grades to be given and certain dangerous weeds, like Johnson grass, to be specifically named, the presence of such seeds to be considered cause for classing the sample as "No grade."

BREEDING FOR CROP IMPROVEMENT.

Considerable work has been done at the different agricultural experiment stations in breeding Sudan grass; but so far little progress has been made in producing a new strain that seems likely to prove more valuable than the Sudan grass as it came direct from Africa. Dwarf strains with finer, more leafy stems have been segregated from the parent variety, but these dwarf strains yield less than the pure Sudan grass. Larger, coarser strains were obtained by crossing Sudan grass with sorghum. These coarse-stemmed hybrids make higher yields than pure Sudan grass, but the hay therefrom is poor in quality, and such forms are not able to compete with sorghum and corn as fodder and silage crops.

Considering these facts, one of the best opportunities for success seems to lie in the development of a grass sorghum like Sudan grass, able to resist the attacks of red-spot, or sorghum blight. In attempting to develop such a strain many crosses of Sudan grass with Tunis grass, tabucki grass, and Kamerun grass have been made. Not enough work with these hybrids has been done to warrant a statement as to their value. Several of these hybrids look promising from a forage standpoint, but the work so far has been done in southern

California, and the selections will have to be tried in the Gulf coast region before their disease resistance can be determined.

Another opportunity for success in breeding operations lies in the production of a grain-bearing strain of grass sorghum, as discussed under the section "Sudan grass as a grain crop." The difficulties in the way of producing such a strain of Sudan grass seem to be less than those connected with the production of a disease-resistant strain. It is an easy matter by crossing with the Freed sorghum, feterita, or kafir to obtain intermediate forms with nearly pure-white seeds. These hybrids yield much more seed than Sudan grass, but none have been found as yet which will compete with the grain sorghums. The present results, however, make it seem worth while to continue work along this line.

DISEASES OF SUDAN GRASS.

The most destructive disease of Sudan grass is the red-spot, or sorghum blight, a bacterial disease which in its effect on the plant resembles the rust on small grains. Red-spot is present wherever Sudan grass is grown, but is a limiting factor in the production of Sudan grass only in the warm, humid regions along the South Atlantic and Gulf coasts.

The kernel smut of sorghums, *Sphacelotheca sorghi* (Link) Clinton, also attacks Sudan grass, but this can be controlled by treating the seed with formaldehyde.[6]

Besides the two rather important diseases named above, Taubenhaus (21, p. 22) declares that a rust caused by the organism *Puccinia purpurea* Cooke was prevalent in Texas during the season of 1919 and lists the anthracnose caused by *Colletotrichum cereale* Manns as present on Sudan grass. The causal fungus of the anthracnose is carried over in the seed and in the stubble or straw. Rotation of crops and treatment of the seed with formaldehyde, as suggested for grain smut, are the most effective methods of control. Taubenhaus states that little is yet known about methods for controlling rust, but that it is destructive only in wet seasons.

INSECT ENEMIES OF SUDAN GRASS.

The same insects which interfere with the culture of sorghum also attack Sudan grass. Grasshoppers are fond of it and do considerable damage in localities where they are abundant. The most effective method of controlling their depredations is by scattering poisoned bran mash about the edges of the Sudan grass fields. Chinch bugs are troublesome at intervals when the seasonal conditions are favorable for their multiplication in other crops. The sorghum midge

[6] For methods of seed treatment with formaldehyde, see Farmers' Bulletin 939, entitled "Cereal Smuts and the Disinfection of Seed Grain."

(*Contrarinia* (*Diplosis*) *sorghicola* Coq.) usually prevents the profitable production of Sudan grass seed in the Southern States east of central Texas.

The diseases and insect enemies of Sudan grass and methods for their control are discussed in Farmers' Bulletin 1126, entitled "Sudan Grass." A full account of the insects which attack Sudan grass is given in Circular No. 7 (new series) of the Texas Agricultural Experiment Station (17).

WEEDS.

There are but few weeds which cause any considerable trouble in Sudan grass fields. The preparation of the seed bed usually destroys the spring crop of weeds, and if the soil is warm the grass starts off quickly and grows so rapidly that as a rule weeds are not able to compete with it. Sudan grass probably ranks next to millet in its ability to overcome weeds.

The common weeds, such as the pigweeds, Russian thistle, foxtail, and the sand burs, are sometimes found in fields of Sudan grass. They rarely occur in sufficient numbers, however, to affect the yield of hay. The worst weed pest is undoubtedly Johnson grass, which behaves as a perennial south of the thirty-eighth parallel of north latitude and is widely distributed on the better soils of that region. Its relation to the seed production of Sudan grass has been discussed under that topic.

The presence of Johnson grass in a field of Sudan grass being cut for hay is of little consequence except for the very slight reduction in yield that it entails. The quality of the hay when Sudan grass is mixed with Johnson grass is fully as good as that of Sudan grass alone. The immediate effect, therefore, of Johnson grass in Sudan grass fields is not especially objectionable, but the aggressive rootstocks of Johnson grass make it difficult to eradicate and cause it to persist and interfere with the following crop. The succeeding crop, especially if it is corn or cotton, will be injured appreciably by the Johnson grass, and this fact causes farmers to resist its incursion into any of their cultivated fields. Because of its tendency to persist on the land after another crop has replaced the Sudan grass, extreme care should be exercised by the farmer to avoid introducing Johnson grass in the Sudan grass seed with which he plants his fields.

SUMMARY.

The value of the 1918 crop of Sudan grass in the United States was estimated at $10,500,000. Practically all this crop was derived from the 8 ounces of seed obtained in 1909 by the United States Department of Agriculture from R. Hewison, Director of Agriculture and Lands, Sudan, Africa.

Sudan grass is technically known as *Andropogon sorghum sudanensis* and belongs to the agronomic group known as grass sorghums.

Several other grass sorghums have been obtained from Africa and one from South America, but none of these has proved as valuable as Sudan grass.

After its introduction into the United States Sudan grass was tested and is now being grown successfully in Australia, South America, the Philippines, Hawaii, Porto Rico, and Cuba.

Sudan grass is most successful in the southern half of the Great Plains in the States of Texas, Oklahoma, and Kansas. It does not succeed well at high altitudes nor within 200 miles of the northern boundary of the United States.

Sudan grass, although it has a high water requirement, is able to withstand protracted periods of drought and recover quickly when rain comes.

This grass is of most value as an emergency hay crop. It is now being used to replace millet as a catch crop in many localities and is also suited for use as a summer pasture.

For hay production it is best to drill or broadcast 20 to 25 pounds of seed per acre in the humid regions and 10 to 15 pounds per acre in the drier portions of the United States; for seed production 3 to 4 pounds of seed drilled in rows 36 to 42 inches apart is best.

Sudan grass should not be cut for hay until it has headed. Very little difference in yield or feeding value of the hay is occasioned by cutting any time between the date when the grass is fully headed and when the seed is in the soft-dough stage.

Sudan grass cures slowly on account of the juicy stems, and considerable time must be allowed for it to cure before placing it in a stack or hay mow, especially when a seed crop is being stored.

Mixed plantings of Sudan grass and legumes, such as cowpeas or soy beans, are profitable only in the more humid regions where the legumes and Sudan grass both grow successfully.

The composition of the hay of Sudan grass is very similar to that of Johnson grass, timothy, and millet; in digestibility it ranks somewhat above timothy but slightly below millet hay.

Sudan grass grown in the humid regions has a lower percentage of protein and ash than that grown in the semiarid regions.

Feeding experiments show that Sudan grass hay is an effective roughage for work stock, dairy cows, and stock cattle.

A large number of tests have shown Sudan grass to be a valuable summer pasture, but care must be observed in pasturing it with cattle, on account of the danger of prussic-acid poisoning.

Sudan grass is useful as a soiling crop, but it is not of much value for silage, because other crops, such as corn and sorghum, make larger yields.

Seed production at present is very often unprofitable on account of low yields and uncertainty as to price. Seed yields are highest in western Texas and the irrigated regions of New Mexico, Arizona, and California.

The greatest difficulty attending the production of Sudan grass seed is the danger of the admixture of Johnson grass seed. Extreme care is required to prevent such mixtures, because it is practically impossible to separate the seed of the two grasses by mechanical means.

A method of identifying the seed of Johnson grass when mixed with Sudan grass has been developed and described by F. H. Hillman (11), of the United States Department of Agriculture.

Great care is necessary in growing Sudan grass for seed to prevent its hybridization with the sorghums. Sudan grass intended for seed production should never be sown on a field which has produced sorghum the previous year, and the field ought to be situated at least 80 rods from any field of sorghum.

The same diseases and insects that attack sorghums also injure Sudan grass. The most important diseases are red-spot and kernel smut; the most destructive insects are grasshoppers, chinch bugs, and the sorghum midge.

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