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GRAIN SORGHUM NURSERY MANAGEMENT HANDBOOK WITH SELECTED PROCEDURES FOR ESTIMATING GRAIN QUALITY AND QUANTITY

D.L. Oswalt

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GRAIN SORGHUM NURSERY MANAGEMENT HANDBOOK

WITH SELECTED PROCEDURES FOR ESTIMATING GRAIN QUALITY AND QUANTITY

D. L. Oswalt[1]

INTRODUCTION

The consideration of the significant factors that limit production of high yields and high quality material is essential in the establishment of a breeding nursery. This outline is an attempt to provide a guide for planning work at a sorghum improvement nursery or test site. Factors that can limit yield and reduce quality have been listed with preventative or control measures, and selected procedures to estimate quality are detailed later in the booklet as *MANAGEMENT PROCEDURES* (MP). Lists of selected terminology (MP-22), equipment suggestions (MP-24), and general references (MP-25) are also included.

[1] Support provided by the United States Agency for International Development through Contract csd-1175 entitled " Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (L.) Moench " Purdue University, W. Lafayette, Indiana 47907.

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SITE SELECTION

1. Whe possible select a unii rm soil type, dra nage pattern and slope with a known uniform cropping and fertilization history. If the cropping or fertilization history or the internal drainage characteristics of the soil are unknown, plant a one-year uniformity trial (MP-1) using one variety to identify spots to avoid when placing yield and quality tests in the succeeding year or cycle. This will enable one to collect more reliable data from small plots.

2. Locate in an area with adequate air and water drainage which is not subject to surface erosion or flooding.

3. Consider the direction of the slope, wind and light as well as protection from high wind velocity and frequent storm areas.

4. Study rainfall patterns and water management to maximize the water holding capacity of the soil and insure that irrigation water is available if drought conditions exist during critical times of the growing season. Consider planting on ridges or in furrows to allow for aeration or accumulation of water, control the run-off damage, and water losses from rainfall or from irrigation sources.

5. Fertilize according to soil type, previous cropping pattern and fertility treatments in reference to soil tests (MP-2). Consult your soil specialists on the amount of lime that your soil requires to insure availability of adequate levels of all plant nutrients (pH 5.8 - 6.8). It is noted that for an 8,000 kg/ha grain yield the sorghum plant requires approximately 195 kilos of nitrogen, 37 kilos of phosphorus (85 kilos P_2O_5), and 240 kilos (273 kilos K_2O) of potassium per hectare for normal growth (MP-3). Other fertility problems may be associated with a

deficiency in iron, boron, zinc, manganese or magnesium and also toxicity due to aluminum or accumulated salts.

6. Beware of potential disease, insect, weed, pest, and weed pollen contamination problems by studying the past cropping history related to weed plants of your area and location in reference to bird populations (plots near buildings, trees, and water usually attract more birds) and prepare to control each (MP-4).

7. Locate site on all-weather roads to facilitate supervision by workers and observation by visitors.

8. Arrange for a flexible supply of labor as work loads change seasonally to provide for timely planting, thinning, weeding, irrigation, observations, crossing, selections, harvest, analyses, and storage.

PLOT DESIGN

1. Place row direction across slope and direction of wind to control erosion (wind and water), to make maximum use of light (perpendicular to path of sun when the site is away from the equator) and allow for surface drainage and irrigation, if it is needed or to be used.

2. Establish the required number of rows per plot (minimum of three rows harvesting the center row only) for chemical and yield data, four to six rows are preferred (harvesting center two rows) with a minimum of six rows when height differences of more than 50 centimeters exist. Insure at least one border row on each side of an experiment and a border of 75-100 centimeters on the end of each row to avoid path, height differences, and variety interactions with harvested area. If heights of specific entries or genotypes are known, entries should be grouped into uniform height

blocks (maximum range of heights in one block of less than 50 cm) for planting and evaluation purposes. Variety, height, and alley-way interactions of up to 50 percent differences on height and yield have been noted, if plants were not bordered by at least one row of the same height material.

3. When testing for yield and similar quantitative characters randomize entries in blocks according to height and replicate each a minimum of three times (four to six preferred when soil and environmental conditions are not uniform). Rows of four-meter length are desirable, as only the center two meters of a row would be left if one meter border is left on the end of each row. If a closed canopy is desired for most lines, rows should be 60-75 cm in width depending on fertility level, type of planting equipment, moisture availability, and varieties in trials. Adjust plant spacings or seed rate to moisture and soil fertility levels (40 to 300 thousand plants per hectare).

4. Determine the amount of seed required (MP-5) and the amounts available for each variety desired for all experiments. Adjust amounts according to known germination and plant populations. It is advisable to overplant yield trials 25-30% and thin the stand to the desired spacing. This will insure a more uniform stand.

5. Determine the harvest(s) to be made and the space, plus drying, threshing, and storage equipment required and available.

6. Arrange to place lines to be crossed near each other or near genetic male sterile sources. Male lines can be placed end to end or adjacent to female lines to facilitate pollination and harvesting procedures. Consider adjacent rows of A and B lines for maintenance of

cytoplasmic male sterile phenotypes. This will facilitate getting pollen of many fertile plants to their sterile counterpart and to do the back-crossing (MP-6).

7. A procedure to establish male sterile random-mating populations by the use of the male sterile or other genetically controlled sterility mechanism is outlined in MP-7.

8. Establish isolation requirements considering direction of wind, (open-pollinated adjacent rows can be expected to show about 3-50% out-crossing), saturation with desirable pollen, staggering of planting to stagger flowering dates, and weed pollen sources (Johnsongrass and other grassy-type sorghum pollen can travel many kilometers).

PREPARATION FOR PLANTING

1. Detailed maps with known varieties planted on a regular and definite scheme should be made. It is important that a system be developed that will allow for each row to be specifically numbered and for the con-tinuation of the system from location to location and year to year (MP-8). The system must be clearly recognized and understood by the workers in a given project.

2. Planting instructions should include number of rows, row width, row length, direction of rows, alley widths, and borders.

3. Packet the correct amount of seed for each row and make a definite arrangement of the packets. Fasten the packets together according to map plans (MP-9).

4. Treat the seed with a fungicide and insecticide to prevent damage to young seedlings. Possible fungicides to use are Captan or Thiram type

used as a slurry or as a dry powder coating of seed. Possible insecticides are Lindane, Aldrin, Dieldrin, and Heptachlor, if sale is permitted. Follow manufacturer's instructions for safe use.

5. Fertilize according to soil test results to a level that will insure normal plant growth (MP-3). Lime to about a pH of 5.8 - 6.8, depending on soil type. Make applications of nitrogen, phosphorus and potash as determined by soil tests and plant requirements. It will be noted that it is important to recognize the phenotypes that will respond to fertilizer. This cannot be done at a low level of fertility. It is further noted that it is often desirable to apply nitrogen in more than one application (one-half at planting and one-half at the early boot stage). Banding, hill placement, or use of foliage spray applications may be considered as more efficient methods of fertilizer application for maximum availability for plant usage.

PLANTING

1. Select simple equipment capable of spacing rows up to 75 cm apart and uniformly planting seed to a depth of two to four centimeters. Firmly compact the soil around the seed to help conserve moisture for germination. If soil moisture is low, then seeds may be planted deeper, but not more than six centimeters.

2. Overplant seed (five to six grams per six meter row) to provide an adequate number of plants which can be thinned from five or up to 38 plants per meter in 75 cm rows (MP-5).

3. Maximum seed yields per plant can be obtained by space-planting individual seeds (25-30 cm between plants) to permit maximum tiller

production.

4. Plan for rapid rate of germination when the soil temperature (at 10 cm depth) is above 20°C. Most varieties germinate very slowly at temperatures lower than 20°C.

5. Timeliness of planting is essential to maximize rainfall, obtain optimum germination temperature, desired length of season, provide some insect control, limit undesirable pollen and limit bird damage. It may be necessary to irrigate at planting, if the seedbed is dry and the rainfall patterns are not conducive to good germination within four to five days. This would insure uniformity of stand and minimal germination losses. (MP-10).

WEED CONTROL

1. Weeds must be controlled very early to insure uniform and comparable data. Weeds should never be allowed to reach heights of 10 cm. Propazine at two to three kilos per hectare or five to eight kilos of Atrazine/Ramrod are chemicals applied pre-emerge that control most weeds in many soil conditions (MP-4). For broad leaf plants, 2,4-d (two to four kg/ha) and Atrazine (four to seven kg/ha for grasses) can be used as a post-emergent spray. 2,4-d should be directed away from sorghum plants to avoid reduced root growth and lodging. Atrazine should be applied when weeds are 5-10 cm tall. In all cases follow the manufacturer's instructions regarding rate and time of application for the soil type and rainfall pattern of your site (Note: Sorghum is damaged by some chemicals recommended for maize).

2. Rogue outcrosses and off-types early to prevent undesirable plant competition due to height differences and contamination of plots and soil.

Be extra careful to rogue out all shattercane types prior to their maturity to reduce seed drop and soil contamination with their seed.

PEST CONTROL

1. Birds of various species can cause serious damage to small plots and particularly small areas in times of shortage of other sources of food. Various bird control measures can be undertaken such as:

a) Bag and protect all selected panicles.

b) Cover plots with netting (must be high enough that tall plants are all covered).

c) Use labor to watch plots.

d) Arrange planting times to coincide with availablity of alternate and preferred sources of bird food.

e) Use mechanical noise devices (MP-24).

f) Use chemical sprays to ward off birds (Arasan M in water-soluble paint (equal volumes of liquids) or other special bird repellants. Note: Manufacturer's recommendations must be followed regarding control and use of any seed produced which contains chemicals.

2. Fencing is a requirement in most areas to prevent damage from domestic and/or wild animals. Small plots can be potentially destroyed in minutes if not fully protected.

THINNING

1. Thin before plants reach a height of 10 cm if tillering is to be permitted and evaluated. Disturb the plants that are being left as little as possible as you remove the excess plants. It is important that

germination be uniform so that the entire plant population is up by the time that the thinning is undertaken, otherwise the plots may need to be thinned a second time. Select the number of plants required per meter of row for the row width in your plot at the desired plant population (MP-11). When thinning, space the required number of plants within a meter of row as evenly as possible, even if some may be slightly closer or farther apart than recommended.

DISEASE AND INSECT CONTROL

1. Study the potential sources (MP-4 and 12) of insect and disease damage (MP-25 suggests more detailed sources of information) and identify potentially available control measures. Study the symptoms of the disease and insect damage so that they will not be confused with physiological discoloration of sorghum plants.

2. Control grasshopper damage to pollinating bags by treating bags prior to field use with an available insecticide (e.g., Dieldrin).

3. The application of an insecticide inside pollinating bags may be essential to control aphids, webworm, corn earworm or other insect damage to bagged panicle grain prior to field harvest (e.g., Dieldrin or Lannate).

NOTE-TAKING

1. Use a consistent number scoring system to facilitate averaging replications and/or computer calculations. It is important to observe frequently enough to utilize maximum differences or development (most timely period) to identify limiting or most desirable factors. See the suggested scale for ratings as listed in MP-12.

POLLINATING

1. For test crosses uniformally bag cytoplasmic male sterile plants with dated bags when panicle is one-half exerted from the flag leaf.

2. Use dated bags to allow for more rapid location of receptive panicles when actually making crosses on cytoplasmic materials. Face date on bags or identification all one direction (toward sun until cross is made, then away from sun to avoid fading).

3. Collect pollen by bagging the male plants in late afternnon with marked bags (striped or colored), the next morning collect pollen from under the bagged panicles and transfer it to the receptive female plants. Always use dry bags for collecting or transporting pollen. Pollen can be carefully collected from open dry panicles in the early morning with minimum contamination, if you work the nursery toward the prevailing wind. Pollen remains viable under most conditions for 15-30 minutes. You should test your procedure, if longer time is required for pollen transportation.

4. If sufficient plants are available entire panicles may be cut insuring a larger supply of viable pollen over a longer period of time. Cut panicles can be placed in vials of water on receptive female selections under pollinating bags at time of first pollination and be shaken the next morning to release pollen and thus increase the volume of pollen available. This increases the time available for pollinating and reduces the chances of contamination from windblown pollen and this prevents loss of pollen due to brisk winds after pollen starts shedding. It also allows for double application of pollen to one female from the same male (increases seed set).

5. Identify male sterile plants (plants which do not shed pollen) in population isolation plantings by tagging them in order to harvest only

male sterile plants grown in association with selected male entries, thus assuring cross pollination in isolation plantings.

6. Plants can be emasculated to remove or inactivate the anthers or pollen (MP-13). Large numbers of florlets may be male sterilized by hot water emasculation where a plastic bag is tied by use of a rubber band around an individual panicle and hot water added rendering the pollen inviable (MP-14). A plastic bag technique (MP-15) may be used to keep the humidity around the anthers high, allowing for the anthers to be shaken off prior to their shedding of pollen. This permits receptive stigmas to develop which can be pollinated by bringing pollen from a male plant at a later date.

7. Breeding terminology as presently suggested is listed in MP-22.

HARVESTING AND DRYING

1. Timely harvest is important to reduce bird damage, insect damage, lodging, and weathering damage. Grain normally reaches physiological maturity at about 30 percent moisture. At this stage in the field, many varieties show a black layer at the tip of the grain. Harvest can usually start when the grain contains 25-30 percent moisture providing mechanical damage to grain is avoided. All grain harvested at 20-25 percent moisture will require drying to below 12 percent moisture to permit safe storage. If artificial heat is used the temperature should not exceed 45°C to prevent loss of germination or 60°C to prevent quality deterioration, when good germination of seed is not required.

2. Determination of moisture percent at time of harvest (MP-16) is an estimation of maturity at harvest. When wet weights of harvested

grain are used in calculation of yield all weights require adjustment to a yield at a constant moisture percentage (MP-17).

3. Careful handling procedures and instructions to harvest laborers will help prevent contamination and errors by mis-identification. Avoid hand copying of identification by use of transferable tags and machine numbering. Pre-numbering of threshed seed containers (envelopes, bags, etc.) to be used to identify panicles or harvested plant parts until dry, threshed, and used for storage avoids copying errors and facilitates rapid and orderly harvesting.

THRESHING

1. Most varieties thresh with least damage to grain and loss at 12-15 percent moisture. Collecting small panicle branches at time of threshing and using these to verify and identify seed harvested efficiently provides an accurate checking method (MP-19).

2. Use of small head threshers reduces time of threshing when large numbers of single heads are threshed independently. It is essential that a thresher be rapidly self-cleaning and easily checked for completeness of cleaning out to make sure the next lot of seed is not contaminated by the previously threshed sample.

3. Use of sieves to remove trash and foreign material is essential for good storage of seed and can best be done soon after or at the time of threshing.

STORAGE

1. All samples should be dried to below 12 percent moisture before

storing. Plastic containers (air-tight envelopes, bottles, or boxes) allow for direct visual observation of stored sample, and due to air-tightness assure longer germination than paper envelope storage.

2. Maintenance of field identification by year, experiment number, and row location facilitates future selection and usage of seed. Store in a dry, cool facility (30 percent relative humidity at 70°F or some combination of these two factors summing 100), to insure maintenance of high seed germination and increase freedom from insect damage.

3. Protection of germplasm from rodents and other pests is essential and every precaution (wire netting, metal containers, concrete structures, door guards, etc.) must be utilized. Some germplasm, if lost to pests, can never be replaced.

ESTIMATES OF QUALITY

1. Numerous characteristics of the grain are used to predict grain quality relative to a sample's anticipated biological performance.

a) The moisture content at harvest is an indicator of maturity. Most varieties reach maturity at 28-30 percent moisture (MP-16).

b) Seed weight and seed density (MP-21) reflect maturity and relationships of seed surface area relative to quantity of endosperm and embryo and thus, grain quality.

c) The degree of weathering and incidence of pericarp infestations by molds, etc., reduce grain quality as the degree of attack increases.

d) Residual sprays and seed treatments must be considered as potentially harmful to grain quality and the amount of contaminate determined

before the grain is used for feed or food.

e) Estimates of percent protein, amino acid concentrations, percent oil, and various individual elements have been available or are being developed (MP-12). Identification of protein content and amino acid balance allows for a more accurate estimate of chemical quality prediction when tannins are considered (MP-19).

f) Tannin estimates: The presence of tannins lowers the biological value of grain sorghum. Catechin equivalent (CE) estimations of tannins (MP-19) will permit the identification of grain sorghum selections which have low tannin values that will give the anticipated biological performance based on protein and amino acid estimates. Samples containing tannins (high CE values) will result in lower than expected biological performances from protein and amino acid analyses. Pericarp and testa which contain the tannin can be partially removed, thus reducing the tannins to a low level by use of the NaOh dehulling procedure (MP-20). This process slightly reduces the fiber content of a sample and slightly increases the protein concentration and for high tannin samples greatly increases the growth rates in biological tests.

UTILIZATION OF FINDINGS

Research findings have little value unless they are disseminated to those who can profit from them. This involves more than cataloging and publishing results and in most cases the persons who identify a valuable characteristic or trait can best help explain its value, limitations, and possible acceptability. Practical application of new breeding stocks,

management procedures, production potentials and extension procedures should be developed as a part of research procedures to facilitate the use of research results by producers and consumers.

MANAGEMENT PROCEDURE-1

Uniform Variety Trial

This trial is to identify uniform plots for arrangement of yield, disease, and quality trials. This is considered a preliminary trial to determine variability in soil and other factors to see if the field is suitable for growing experimental materials. One variety would be planted and treated the same over the entire area, (statistically there would be no treatments per se). Crop growth and yield data would be used to map the area relative to differences in soil type, water drainage, water-holding capacity, fertility levels, and other variations due to previous cropping systems and management practices.

The area studied should be marked in uniform regular plots to record data relative to germination, flowering, height, yield, quality, and other observable factors of interest. The smaller the plot size the more detailed the information obtainable and the more accurate the possibility of mapping differences. At the same time, the time and labor requirements are increased as size of plots is decreased, but plot size should not be larger than anticipated experimental plot area to be utilized in subsequent trials. Division of the area into one, two, or three-row plots, two to four meters long, would allow a reasonable mapping of differences, if subsequent plot size would be of similar size. This would allow subsequent trials to be arranged to make maximum use of uniform and known diverse areas. It is suggested that experimental plots should be narrow and relatively long and placed across soil and fertility gradients, while each block should be as nearly uniform as possible for all factors.

MANAGEMENT PROCEDURE-2

Sampling for Soil Testing

It is very important to adequately and correctly sample the soils of a given area as the data obtained from a sample cannot be better than the sample taken.

Suggested procedure:

1. Obtain: sampling tube, auger or spade, and clean container.
2. Draw a sketch of the field.
3. Identify cropping, fertilizer, and other past treatment information.
4. Divide the field into uniform areas having the same soil color, soil texture, and same cropping, fertilizer and liming treatment.
5. Sample at 10 or more places in each area separately (do not mix light and dark colored soils together). Sample by collecting equal amounts to plow or cultivation depth.
6. Place sample from auger or spade (thin slice to maximum depth of sample) in a clean container and mix thoroughly.
7. Allow mixed sample to air dry on clean paper in a clean area.
8. Send from each different area about one-half liter to a soil testing laboratory. Discard the remainder. Label and number the sample container according to the map.

MANAGEMENT PROCEDURE-3

Determination of Fertilizer Needs

Estimated nutrients required to produce various yields of grain must be furnished by the soil plus applied forms of fertilizer to obtain the selected yield.

Grain yield kg/ha	Nutrient Requirement (kg/ha)							
	N	P_2O_5 (43.7%P)	K_2O (88.7%K)	Mg	Ca	Zn	Mn	Cu
4000	98	42	136	11	11	.13	.13	.044
6000	146	64	205	17	17	.19	.26	.066
8000	195	85	273	22	22	.26	.34	.088
10000	244	106	341	28	28	.32	.43	.110

It will be noted that nutrients are taken up and dry matter accumulated at the following estimated rate: (See MP-12 for more detail of growth stages.)

Growth stage:	Seedling	Rapid Growth	Early Bloom	Grain Form	Maturity	Total
Approx. days:	0-20	24-40	41-60	61-85	86-95	
Nutrient: N	5	33	32	15	15	100
P_2O_5	3	23	34	26	15	100
K_2O	7	40	33	15	5	100
Dry matter	2	15	32	32	19	100

The above data would indicate a split application of N should be made at 35-40 days of development particularly for light sandy soils and tropical sites.

REFERENCES:

Vanderlip, R. L. 1972. *How a sorghum plant develops.* Cooperative Extension Service, Kansas State University, Manhattan, Kansas. C-447, No. 1203.

Wall, J.S. and W. M. Ross. 1970. *Sorghum production and utilization.* The AVI Publishing Co. Inc., Westport, Connecticut.

Better Crops from Plant Food. February 4, 1973 edition. North American Potash Institute, 1649 Tullie Circle, N.E. Atlanta, Georgia.

MANAGEMENT PROCEDURE-4

Potential Diseases, Insects, Parasites, Pests, and Weeds

The magnitude of potential maladies makes it inadvisable to describe all the known organisms that attack or reduce sorghum performances. You are referred to MP-25 for sources of more information. An outline of types of adverse organisms is included here:

Diseases (See MP-12)

Downy Mildew
Virus - Maize Dwarf Mosaic (MDM)
Sugar Cane Mosaic
Ergot
Smuts
Bacteria Leaf diseases
Foliage diseases (fungi)
Rusts
Small Seed
Stalk Rots
Milo disease

Parasitic Plants

Striaga sp. (Witchweed)

Insects (See MP-12)

Soil
Seedling
Foliage
Panicle

Pests

Birds (See MP-24, 25)
Stray farm animals
Wild animals
Rodents
Humans

Weeds

Clean culture is essential for maximum production as any other plant will compete with sorghum for water, light, and nutrients, and often weed plants survive due to their ability to extract nutrients more efficiently than the desired crop plant. Sorghum is most damaged by weeds in its early stages of growth. Recommended chemicals are Propazine and Atrazine, as well as an Atrazine/Ramrod combination. Timely cultivation is essential and under most conditions economical in combination with chemical treatment.

MANAGEMENT PROCEDURE-5

Determination of Seeding Rates for a Given Desired Plant Population

Seeding rates are dependent on viability of seed, space between rows and number of plants required per hectare relative to availability of water, fertility of soil, and desired level of production. If seed is planted by weight then size of seed must also be considered. In very dry areas planting rates would vary from 35,000 to 125,000 plants per hectare, while well fertilized and irrigated plots would require 245,000 to 300,000 plants per hectare to produce maximum yields. Under most conditions a field emergence rate of 75% of the seed planted can be expected, but a higher or lower figure may be valid from experience or from seed germination tests.

To test for germination, 100 or more seeds of each variety should be placed in a soil with temperature and moisture conditions similar to field conditions at planting time (moisture at field capacity and temperature above 20°C). Plants which emerge can be counted to determine percent germination. One hundred or more seeds of each lot can be placed on paper or cloth so that seeds do not touch each other, carefully rolled, moistened, and placed on and in a jar containing a small amount of water at a temperature of 20-40°C. Germinating seed can be counted after five days and divided by the number of seeds tested to determine percent germination.

It is recommended that seeding rates be increased (125% overplant) in nursery plots where yield estimates are to be obtained so that the stand can be thinned to the desired uniform plant population <u>before</u> the seedling exceeds 10 cm in height.

MANAGEMENT PROCEDURE-5 (continued)

No. of plants per hectare	No. of seeds (75% emergence) to plant per row of 4 m length*			
	.50 m	.60 m	.75 m	1 m
40,000	14	17	20	27
100,000	17	40	50	68
125,000	22	50	64	84
250,000	42	100	125	168
300,000	50	120	150	200

No. of plants per hectare	Distance (cm) between plants in the row width of:			
	.50 m	.60 m	.75 m	1 m
40,000	50	40	33	25
100,000	20	16	13	10
125,000	16	13	10	8
250,000	8	6	5	4
300,000	6	5	4	3

To insure the correct planting rate by weight, if weight is normally used for packeting or planting, the weight per seed should be estimated by counting and weighing 100 or 1000 seeds which are to be planted from which the weight of the seed to be planted for a desired plant population can be calculated.

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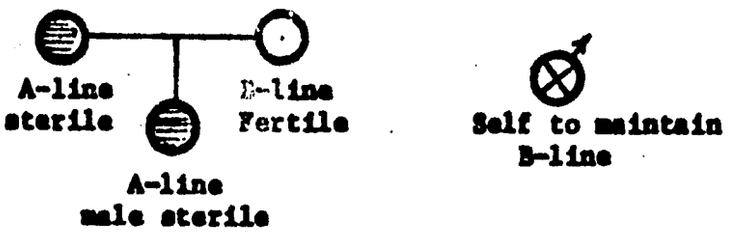
* 125% overplant included.

MANAGEMENT PROCEDURE-6

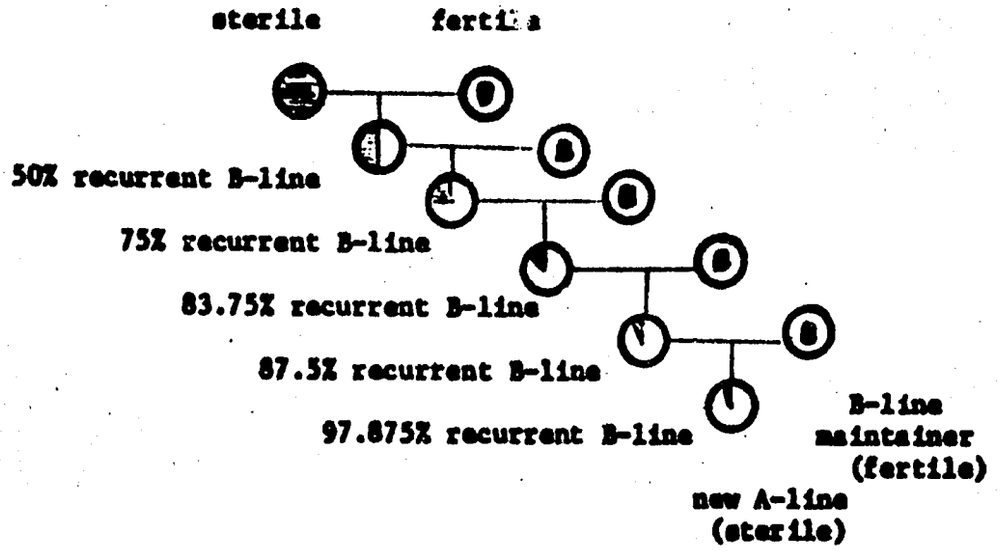
Maintenance of Cytoplasmic Lines

If cytoplasmic male sterile seed and the maintainer line are to be increased the sterile A-line can be planted adjacent to the B-line (maintainer) and when selfed A-line plants have viable stigmas the pollen from the adjacent B-line can be dusted upon them by bringing the panicles together across the rows. The following is an illustration of the steps for maintenance and establishment of a cytoplasmic line and its maintainer line:

a) Maintenance of Cytoplasmic Male Sterile A-line.



b) Establishment of a Cytoplasmic A-line.



MANAGEMENT PROCEDURE-7

Use of Genetic Male Sterility for Random Mating Population Development

Random mating populations provide a procedure to randomly combine diverse sources of genes which can be identified in desirable combinations as individual plants are selected. The following is an illustration of an anticipated number of sterile plants in each random mating cycle. It is suggested than an isolation area of at least 1/10 hectare be allowed with 300 meters or greater distance from other sorghums, or 20-30 days difference in planting be allowed between random mating blocks, if intercrossing is undesirable. If a wide range of maturity is desired, the use of two or more planting dates in an isolation block will allow for early and late maturing plants to random mate. Sterile plants (no pollen shed) are best identified when pollen is being shed by fertile plants. A system of tagging (plastic, string, cloth, or tags) the steriles for harvest of only cross-pollinated plants is required during random mating to allow for the harvest of 500-1000 cross-pollinated panicles for combining (equal seed from each plant) at harvest time.

MANAGEMENT PROCEDURE-1 (continued)

Step A: Cross with male line selections.

$ms_3\ ms_3$ x $Ms_3\ Ms_3$

sterile
(female source)

Step B: Plant F_1 and self.

$Ms_3\ ms_3$ (combine seed - equal amounts from each selected plant.)

fertile

Step C: Plant F_2 in isolation. Identify male sterile females at pollination.

$ms_3\ ms_3$ x $Ms_3\ ms_3$ or $Ms_3\ Ms_3$

sterile fertile fertile

Ratio: 1 : 2 : 1

Harvest only identified panicles. (combine seed - equal amounts from each selected plant).

Step D: Plant in isolation. Identify male sterile females at pollination.

$ms_3\ ms_3$ x $Ms_3\ ms_3$

sterile fertile

Ratio: 1 : 2

Harvest only identified panicles. (combine seed - equal amounts from each selected plant).

Step E: Plant in isolation. Identify male sterile females at pollination.

$ms_3\ ms_3$ x $Ms_3\ ms_3$

sterile fertile

Ratio: 1 : 1

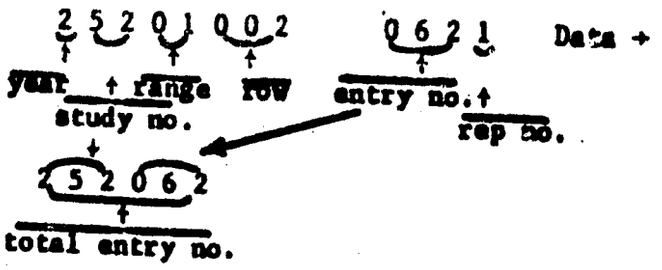
Harvest only identified panicles. (See General References for details to select plants for hybrid or line development, i.e., *Sorghum in the 70's*.)

MANAGEMENT PROCEDURE-

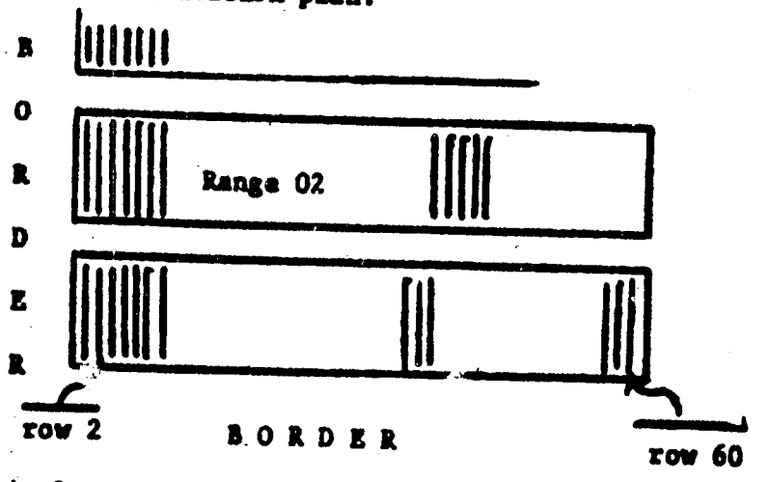
Suggested Mapping and Identification System

Illustrated below are systems adaptable to handling with a computer*.

a) A computerized numbering system:



b) An identification plan:



c) A planting map for 252:

Study 252 map

Row No.	Range No. 1	2	3	4
1	016	025	034	161
2	062	142	002	153
3	621	431		

entry no. 252062

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* Computer programs for printing maps and field books are available from Purdue University.

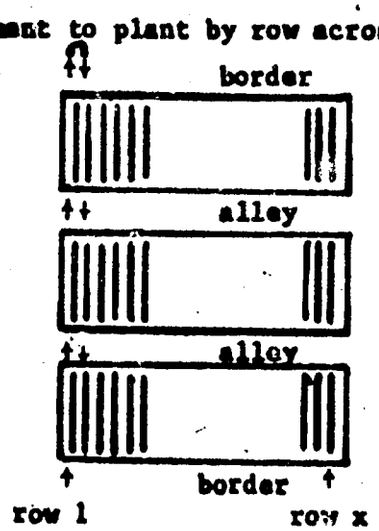
MANAGEMENT PROCEDURE-9

Arrangement of Packets for Planting

Seed packets containing the seed to be planted in a given row should be arranged in flats or seed boxes in the order as indicated by the planting map prior to time of planting. This allows for checking and re-checking of packet arrangement prior to planting to prevent all possible errors in arrangement of packets.

a) Arrangement by ranges: When planting is to be done by individual rows in each range, then packets for one entire range should be temporarily fastened together to be laid out in the field on each row.

b) Arrangement to plant by row across ranges:



When a planter is used to follow row one across more than one range, turn around and return on row two. The packets should be laid out by map order, checked and then row one picked up across all ranges. Then in reverse range order, row two would follow with row two range.

MANAGEMENT PROCEDURE-10

Water Requirements and Irrigation Procedures

Water requirements are influenced by duration of growth, temperature, relative humidity and soil water-holding capacity. The total use of water for the growing season is estimated to range from 55 to 60 cm for a 6000 kg/ha grain yield. Peak demands for water occur during the late boot through early heading stages where up to 0.8 to 1 cm of water would be used per day. An average usage of approximately 0.6 cm per day should be expected from boot stage through late dough stage.

Effective rainfall will lengthen the period between irrigations. Whenever water is applied the soil profile should be filled to field capacity to make best use of the water and facilitate maximum root growth. In the absence of rainfall, lighter soils will require irrigation every four to five days while on heavier soils it may be required every 10-15 days with the last irrigation on heavier soils at about the time of flowering, if the soil in the upper 60 cm is up to field capacity.

Selection of non-tillering varieties and adjustments in plant population can be made to conserve limited sources of water.

(Please refer to table which follows)

MANAGEMENT PROCEDURE-10 (continued)

Estimated Water Usage for Approximately 6000 kg/ha Grain Yield*.

Growth Stage†	Number of Days After Emergence	Plant Height§ (cm)	Characteristics	Cumulative Water Use (cm)
0	0		Emergence	
1	10	10	Color of 3rd leaf visible	
2	20	30	Color of 5th leaf visible	10-13
3	30		Growing point differentiation (8th leaf)	
4	40	60	Final leaf visible in whorl	
5	50		Boot. Head extended into flag leaf sheath	20-25
6	60		Half bloom	
7	70		Soft dough	
8	85		Hard dough	
9	95		Physiological maturity	55-60

* Vanderlip, R. L. 1972. *How a sorghum plant develops.* Cooperative Extension Service. Kansas State University, Manhattan, Kansas. C-447, No. 1203.

† See MP-12.

§ Three-dwarf type plants.

MANAGEMENT PROCEDURE-11

Thinning

Thinning should be done as soon as possible after all seeds have germinated and before plants reach a height of 10 cm. There should be a minimum disturbance of plants selected to remain in each plot.

Number of plants to be left at thinning:

Plants/ha	Row Width .50 m	.60 m	.75 m	1 m
	(Number of plants per 1 m of row)			
40,000	2	2.5	3	4
100,000	5	6	7.5	10
125,000	6.25	7.5	9.4	12.5
250,000	12.5	15	18.8	25
300,000	15	18	22.5	30

If a two-meter stick is used the above selected numbers should be doubled and plants thinned and as equally spaced as possible, but leave the actual required number in each meter of row space.

MANAGEMENT PROCEDURE-12

Field Note-Taking Codes

Suggested number-rating scales utilizing whole numbers to facilitate the use of a computer follow:

Flowering date: Recorded as the number of days from date of planting to date when 50% of plants are 50% in bloom.

Stand:
- 1 = very thick
- 2 = good
- 5 = poor
- 7 = less than 5
- 9 = no plants

Restorer genes:
- 1 = pollen shed
- 9 = sterile

Tillers of stand:
- 1 = less than 10% of heads on tillers
- 9 = 90% or more of heads on tillers

Canopy Cover: (1-9)
- 3 = complete
- 5 = moderate
- 7 = open

Leaf angle: (1-9)
- 3 = very upright leaves
- 5 = horizontal leaves
- 7 = drooping leaves

Midrib color:
- 1 = white
- 2 = semi-white
- 3 = dull
- 4 = yellow
- 5 = orange
- 6 = brown

Head compactness:
- 3 = compact
- 5 = semi-compact
- 7 = loose

Central rachis:
- 3 = contracted
- 5 = semi-curved
- 7 = completely extended

Peduncle shape:
- 3 = straight
- 5 = semi-curved
- 7 = curved

Awns:
- 1 = no awns
- 5 = short awns
- 9 = long awns

Head Exertion:
- 3 = well extended
- 5 = above flag
- 7 = below flag

Glumes:
- 1 = no glumes
- 3 = 1/4 covering
- 5 = 1/2 covering
- 7 = 3/4 covering
- 9 = complete cover

Glume Color:
- 1 = white
- 2 = straw
- 3 = yellow
- 4 = orange
- 5 = light brown
- 6 = brown
- 7 = red brown
- 8 = gray
- 9 = purple

MANAGEMENT PROCEDURE-12 (continued)

Seed Color:
1 = white
2 = straw
3 = yellow
4 = orange
5 = light brown
6 = brown
7 = red brown
8 = gray
9 = purple

Weathering: (1-9)
1 = resistant
9 = very susceptible

Yield
3 = above average
5 = average
7 = below average

Lodging: (1-9)
1 = resistant
5 = intermediate
9 = susceptible

Environment:
3 = accelerated growth
5 = normal growth
7 = retarded growth

Bird damage:
3 = resistant (partial)
5 = moderate damage
7 = susceptible

Endosperm:
3 = floury
5 = both floury and vitreous
7 = vitreous

Other measurements that might be taken:

plant height (top of head) (cm)
stem diamter (cm)
head exertion (cm)
head length (cm)
head width (cm)
falg leaf length (cm)
flag leaf width (cm)
3rd leaf from flag leaf length (cm)
3rd leaf from flag leaf width (cm)
number of nodes
stand - main plants
stand - tillers
total number of heads harvested
length of row harvested
weight harvested
number of heads sampled
sample weight (wet)
sample weight (dry)
moisture percent

MANAGEMENT PROCEDURE-12 (continued)

A Classification of Races

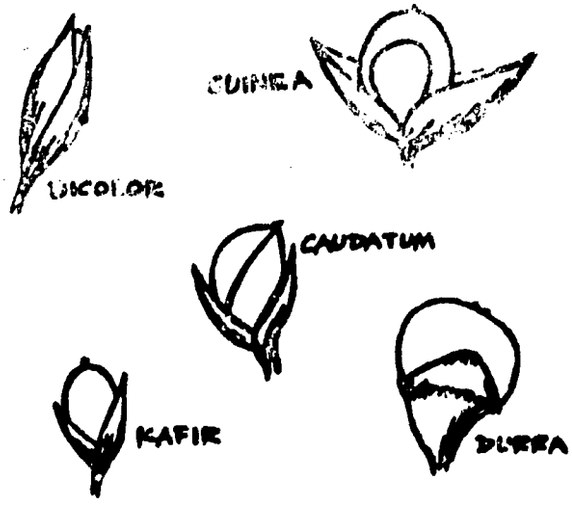


Fig. 1. Five basic spikelet types of cultivated sorghum; wild-type and shattercane not shown.

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

Basic races:

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

Intermediate races: (all combinations of basic races,

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

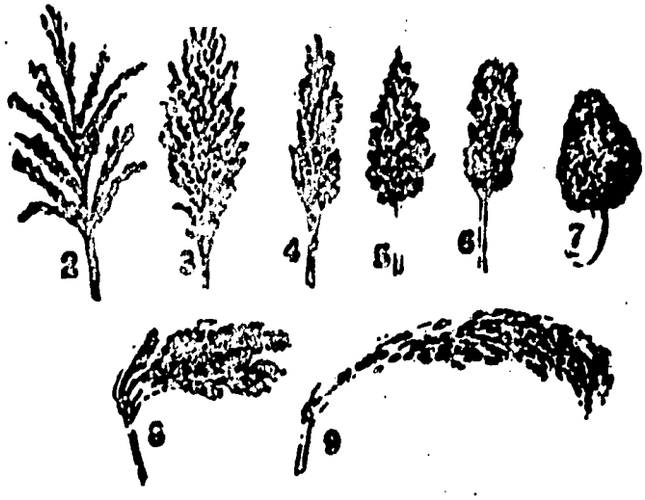


Fig. 2. Head types of cultivated sorghum. Type 1 is reserved for wild races and is considerably more diffuse than type 2.

REFERENCE:

Harlan, J. R. and J. M. J. deWet. 1972. A *simplified classification of cultivated sorghum*. Crop Sci.12:172-176.

MANAGEMENT PROCEDURE-12 (continued)

Stages of Plant Growth in Sorghum

A suggested rating for stages of plant growth follows.

Stage	Days after emergence (approximately)	Description
0	0	Emergence, first leaf visible at soil surface
1	10	Three leaves with fully developed sheath, i.e., third leaf sheat elongated and collar between blade and sheath visible.
2	20	Five fully developed leaf sheaths, i.e., fifth leaf sheath elongated and collar between blade and sheath visible.
3	30	Growing point differentiation--on RS 610 eight leaf sheath elongated and collar visible, but this characteristic differs in various hybrids. Culm has not started to elongate. (Plant may have to be disected to distinguish this and separate from following stage.) One or more leaves may have been lost.
4	40	Final leaf visible in whorl. Culm undergoing rapid elongation. Lower 1-3 leaves may have been lost.
5	50	Boot stage. All leaves fully expanded. Head nearly full length and enclosed in flag sheath. Peduncle elongation occurring. Total leaf area has been attained.
6	60	Half-bloom. One-half of the main heads are in some stage of flowering.
7	70	Soft dough.
8	85	Hard dough.
9	95	Physiological maturity.

REFERENCE:

Vanderlip, R. L. 1972. *How a sorghum plant develops*. Cooperative Extension Service. Kansas State University, Manhattan, Kansas. C-447, No. 1203.

MANAGEMENT PROCEDURE-12 (continued)

Disease and Insect Evaluation

1. Downy mildew. If sorghum downy mildew is present, data should be collected on the incidence of systemically infected plants, as well as the severity of foliar infection (local lesion phase). Systemically diseased seedlings and plants will develop striped or streaked leaves with alternate green and yellow or chlorotic stripes. Down (asexual sporulation) is common to abundant on the lower leaves of these plants during humid weather with moderate to cool temperatures. The local lesion phase will develop extensively in Sweet Sudangrass under favorable conditions and could develop to a lesser extent on many of the entries in the test. Disease evaluations can be made for this phase as for other foliar diseases.

2. Head smut. Determine the incidence of disease in each plot on or about the souft dough stage of growth.

3. Maize dwarf mosaic virus or sugarcane mosaic. Data may be obtained at the boot stage of growth or after flowering, based on the rating system of Toler et al.(Texas A&M, Department of Plant Sciences). From flowering on, the mottling and chlorosis usually disappear, thus, one cannot determine 2 or 3 in late growth stages. Cool temperatures of 60°F or lower make symptoms much more severe, especially on susceptible lines. The red leaf symptom often does not develop in the absence of such cool temperatures. Note: Certain genotypes will show chlorotic and stunted

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REFERENCE:

Frederiksen, R. A. (Unpublished information) *Sorghum Disease and Insect Evaluation - Note-taking Instructions*. Department of Plant Sciences, Texas A & M University, College Station, Texas 77843.

MANAGEMENT PROCEDURE-12 (continued)

plants without significant necrosis. These should be rated a 5. Incidence may be important and may be reported as a percentage. This is especially important when incidence is near 100% in some entries.

0 = disease not present.
1 = no apparent symptoms.
2 = leaves with mottling only.
3 = mottling and significant chlorosis.
4 = mottling with significant leaf necrosis (red leaf on most genotypes)
5 = the above accompanied by severe stunting or death.

4. Foliar diseases. A rapid evaluation of foliar disease incidence and severity can be made for the following diseases: Grey leaf spot, sooty stripe, zonate leaf spot, rough spot, bacterial stripe, physiological or genetic spotting, insecticide damage, Helminthosporium blight, rust and downy mildew. A rating system, as devised by Zummo (Research Plant Pathologist, Meridian, Mississippi) is as follows:

0 = disease absent
1 = resistant
2 = disease inconspicuous or present on an occasional plant.
3 = disease abundant (over 50% prevalence with low severity, apparently causing little economic damage).
4 = disease severe (100% prevalent, estimated leaf area destroyed up to 25%, disease appears to be of economic importance.
5 = as in 3, but over 25% of leaf area destroyed.

5. Stalk rot. Data should be collected at about physiological maturity, or when the grain has completely matured. (Note: At times following artificial inoculation, little disease develops. Nevertheless, good comparative data can usually be obtained by recording differences among entries within inoculated internode.) The following rating system can be used in evaluating the severity of anthracnose, Fusarium, and charcoal rot following artifical inoculation:

MANAGEMENT PROCEDURE-12 (continued)

0 = none present.
1 = up to, but less than 1 basal internode affected.
2 = more than 1 but not more than 2 internodes affected, infection must have spread through at least 1 internode.
3 = infection has passed through 2 or more internodes.
4 = extensive invasion of plant but not killed.
5 = death of plant due to stalk rot.

6. Lodging. The ratings below based on percentage of lodged plants should be recorded. This lodging can be any one or a combination of: weak neck (breaking at base of peduncle), stalk breakage (due to stalk rots or weakened stalks due to stress, or very high wind), or root lodging (entire plant leans or falls due to wet soil and wind). The predominant type of lodging should be recorded. Use rating or actual percent.

0 = not present.
1 = 2% or less.
2 = 3-10%.
3 = 11-30%.
4 = 31-70%.
5 = 71-100%.

7. Fusarium Head blight. Infection and death of rachis branches, rachis, and often peduncle (maybe even progressing downward to the base of the stalk) should be rated as below. The panicle branches of infected heads often droop severely after maturity. Infected rachis branches and peduncles have both external and internal discoloration as contrasted to MDM induced discoloration which is limited to external discoloration only. The disease usually develops or becomes obvious at about physiologic maturity of the grain or later.

0 = none present.
1 = resistant - no infection in rachis branches or head.
2 = infection limited to head, particularly rachis branches.
3 = whole head infected.
4 = both heads and peduncles affected.
5 = head blight resulting in death or lodging of plants.

MANAGEMENT PROCEDURE-12 (continued)

8. Anthracnose (Harris, H. B. et al. 1964. Crops and Soils 4:460-462)

a) Natural infection - each of the following are rated from 1 to 5 based on 1 = resistant to 5 = death of the tissue or plant: leaves (foliage), stalk (peduncle), and head.

b) Artificial inoculation - toothpick method, same as for stalk rot evaluation or conidial injection, same as for natural infection.

9. Pythium root rot. Ratings of root rot should normally be made at maturity, but before plant has died. Ratings are based on the following scale:

0 = disease not present.
1.0 = roots free from disease.
2.0 = no root rot near crown or on major brace roots.
2.5 = at least one dead major brace root.
3.0 = more than one to one-half, but not all brace roots dead.
3.5 = more than one-half, but not all brace roots dead.
4.0 = all roots dead, but base of stalk still alive.
5.0 = all roots and base of stalk dead.

10. Seed weathering. A major environmentally and maturity related problem affecting both quality and quantity of seed is weathering. Should the opportunity present itself, data on incidence of seed mold associated with weathering should be recorded on a 1 to 4 scale as noted:

0 = disease absent.
1 = seed bright, generally free from mold damage.
2 = seed moderately resistant to weathering, or weathering is delayed following seed maturity.
3 = generally susceptible to weathering.
4 = very susceptible to weathering damage occuring shortly after maturity with few periods favorable for damage.

11. Greenbugs. Data may be obtained at any plant growth stage when greenbugs are present. It is suggested that estimates of greenbug members be taken, if possible. Also, record plant growth stage as outlined in MP-12, (Stages of Plant Growth in Sorghum section).

MANAGEMENT PROCEDURE-12 (continued)

0 = no evaluation possible.
1 = no red spotting on leaves.
2 = red spotting on leaves.
3 = portion of a leaf killed by greenbugs.
4 = one entire leaf killed by greenbugs.
5 = two entire leaves killed by greenbugs.
6 = four entire leaves killed by greenbugs.
7 = six entire leaves killed by greenbugs.
8 = eight entire leaves killed by greenbugs.
9 = dead plant.

12. Midge. Damage based on percent "blanted" seeds. Rate no sooner than 20 days after bloom. Take care to differentiate midge damage from bird damage and sterile florets. The presences of a cocoon at the tip of the seed is proof that a seed was damaged by midge.

0 = no evaluation possible.
1 = no damaged seed.
2 = 1-10% damaged seed.
3 = 11-20% damaged seed.
4 = 21-30% damaged seed.
5 = 31-40% damaged seed.
6 = 41-60% damaged seed.
7 = 61-80% damaged seed.
8 = 81-90% damaged seed
9 = 91-100% damaged seed.

MANAGEMENT PROCEDURE-13

Hand Emasculation

The three anthers of individual spikelets can be gently removed by use of tweezers or a blunt pencil point just prior to anther extrusion. Selection of spikelets near the center of the panicle which are nearly ready to flower, and trimming away of smaller, excess florets, permits the isolation and identification of 20-50 florets to be emasculated. The emasculated spikelets should be covered with a small glassine or paper bag until the stigma protrude (two to four days later) and then pollinated with a selected source of pollen. Pollination can be repeated one or two days later to increase seed set. Examination of emasculated spikelets prior to pollination insures that all anthers were actually removed and stigma not damaged.

MANAGEMENT PROCEDURE-14

Hot Water Emasculation

A panicle estimated as being within one to three days from beginning anthesis is selected. An open-ended supported (crochet ring or hoop, at the upper end of the tube supported from a tripod) plastic tube is placed around the panicle and secured at the base of the inflorescence with an elastic band. (Tall plants can be bent over into a bucket of water) Hot water is then poured into the tube and left for a given length of time. An initial temperature of 48°C left for a period of ten minutes with a drop of two or three degrees is usually the most effective for diverse materials. The length of time is not as critical as the temperature of the water at the start of the procedure. Each line should be evaluated for the most efficient temperature. The greatest amount of selfed seed occurs on the lower panicle branches and the greatest amount of female sterility occurs on the upper panicle branches. When a more immature panicle is selected a greater amount of selfed seed will be obtained. The amount of selfed seed can be estimated by placing a small glassine bag over the lower most panicle branch right after emasculation. Pollinations can be made three or four days after the emasculation and repeated again one or two days later to insure maximum seed set.

REFERENCE:

Stephens, J. C. and J. R. Quinby. 1933. *Bulk emasculation of sorghum flowers.* J. Am. Soc. Agron. 25:233-234.

MANAGEMENT PROCEDURE-15

Plastic Bag Emasculation

Panicles about to start shedding pollen at the tip are covered with plastic bags to prevent the anthers from dehiscing (shedding pollen). It has been found that two plastic bags improve the procedure at Purdue University. The (thin guage) double plastic bags cause the humidity to remain higher and the anthers can be shaken off the panicle inside the plastic bag when the stigma are viable in the central section of the panicle. The lower portions of the panicle can then be cut off to prevent further development of anthers, the panicle allowed to dry (protected by paper bag) and then dusted with viable desired pollen. This method is more rapid, but due to variable degrees of selfing that occurs, it is only useful when it is easy to distinguish crosses from selfs in the succeeding generation. This, however, is usually easy to do at that time with any of a number of markers, such as height, panicle type, leaf angle, grain color, glume color, etc.

REFERENCE:

Sharts, K. F. and L. E. Clark. 1967. *Controlling dehiscence with plastic bags for hand crosses in sorghum.* Crop Sci. 7:540-542.

MANAGEMENT PROCEDURE-16

Measuring Moisture in a Sample of Grain

a) Weigh 5 - 20 g of a representative fresh sample. Place weighed sample in oven (105°C) for 5 - 12 hours (constant weight). Determine dry sample weight and calculate percent moisture.

Example: Fresh weight = 6.789 g
Oven dry weight = 5.463 g
6.789 - 5.463 = 1.326 g (water lost from sample)
1.326 ÷ 6.789 x 100 = 19.53% moisture in fresh sample

b) Another method is by use of boiling oil.

- Boil oil to remove any possible moisture.
- Place weighed fresh grain sample in cool (20-25°C) boiled oil (note oil temperature).
- Weigh sample plus container.
- Heat oil containing sample to 105°C for five minutes.
- Cool oil to original temperature.
- Weigh cooled oil and sample and calculate loss in weight.
- Divide loss of weight by wet sample weight and multiply by 100 to determine percent moisture in original sample.

Example: Weight of wet sample = 21.34 g
Weight of cool oil + container + wet sample = 256.34 g
Weight of cool oil + container + boiled sample = 251.21 g
Loss of weight (256.34 - 255.21) = 5.13 g
Percent moisture in wet sample (5.13 ÷ 21.34 x 100) = 24.03%.

c) Electronic moisture meters are commercially available.

MANAGEMENT PROCEDURE-17

Factors for Conversion from Known Moisture Percentage to a Constant Percent Moisture.

Measured Moisture Percentage	Desired Adjusted Basis			
	15%	12%	10%	0%
8.0	1.082	1.045	1.022	.920
9.0	1.071	1.034	1.011	.910
10.0	1.059	1.023	1.000	.900
11.0	1.047	1.011	.989	.890
12.0	1.035	1.000	.978	.880
13.0	1.024	.989	.967	.870
14.0	1.012	.977	.956	.860
15.0	1.000	.966	.944	.850
16.0	.988	.955	.933	.840
17.0	.976	.943	.922	.830
18.0	.965	.932	.911	.820
19.0	.953	.920	.900	.810
20.0	.941	.909	.889	.800
21.0	.929	.898	.878	.790
22.0	.918	.886	.867	.780
23.0	.906	.875	.856	.770
24.0	.894	.864	.844	.760
25.0	.882	.852	.833	.750
26.0	.871	.841	.822	.740
27.0	.859	.830	.811	.730
28.0	.847	.818	.800	.720
29.0	.835	.807	.789	.710
30.0	.823	.796	.798	.700

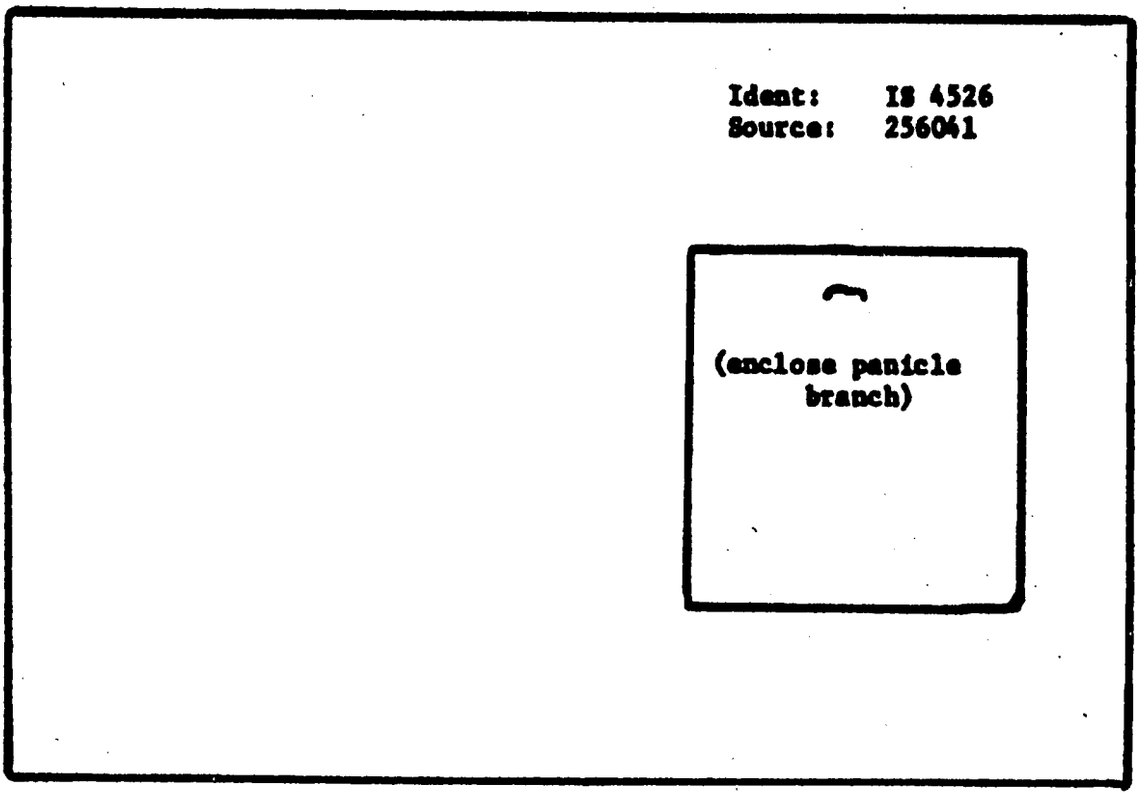
Procedure: Determine moisture percent of harvested grain sample (MP-16) multiply wet measurement of grain by the correct conversion factor to obtain adjusted weight at a desired moisture percentage:

Example: Harvested grain moisture = 18%
Desired percent of moisture = 10%
Conversion factor from table = .911
Wet grain sample weight = 1124 g
Sample weight adjusted to 10% moisture = 1024 g
(.911 x 1124 = 1023.96)

MANAGEMENT PROCEDURE-18

Panicle Branch Usage for Identification Purposes

The enclosing of a panicle branch in a small plastic envelope is a convenient way to positively identify varieties. Attachment of the enclosed branches to a 5" x 8" card as indicated below, permits storage and use of the sample for easy verification of seed for planting, seed harvested, and in field identification to avoid and identify errors in planting and handling. Selections can also be identified as to race from these panicle branches.



MANAGEMENT PROCEDURE-19

Estimation of Level of Tannins by Determination of Catechin Equivalents

The VANILLIN-HYDROCHLORIC ACID TEST method has shown high correlation with biological estimates of quality (rat growth).

Reagents: Vanillin-HCl. Prepare daily. Eight percent concentrated HCl in methanol. Four percent vanillin in methanol. Mix equal volumes of these solutions just before use. Do not use after trace of red appears.

Standard Curve: (optional) Add 40 mg catechin to 100 ml methanol. Use from full strength to 1:9 dilution to construct a standard curve. Pipet 1 ml of each dilution into separate tubes. Use two tubes per dilution. When approximately 20 tubes have been prepared, quickly add 5 ml of vanillin-HCl reagent to each. Read on colorimeter at 500 mu after a uniform length of time (20 minutes is satisfactory). Plot transmittance against catechin concentration.

Determination: Place 1 g of ground grain (20 mesh or finer) in 125 ml flask. Ad 50 ml methanol, stopper, swirl, place at a constant temperature (between 24° and 32°C) for 24 hours. Samples can set 20-28 hours (use same length of time for all samples). Swirl sample and let settle. Pipet 1 ml of supernatant into each of two tubes and proceed as with the standard.

REFERENCE:

Burns, R. E. 1971. *Methods of estimation of tannin in grain sorghum.* Agron. J. 63:511-512.

MANAGEMENT PROCEDURE-19 (continued)

The MODIFIED VANILLIN-HYDROCHLORIC ACID TEST method follows the vanillin-hydrochloric acid test procedure except as follows:

Add 50 ml of acidified methanol (5% HCl) to 1 g grain sample, shake for one hour and then let stand for approximately 24 hours. This procedure gives higher CE values for samples containing a pigmented partial testa and a complete testa. The use of the VHCl and MVHCl test will identify grain sorghum varieties with a testa and relatively good biological performance value as cultivars giving a low VHCl reading (below 1.0 CE) and a high (above 2.0 CE) MVHCl estimate of tannins possess a testa and do not greatly reduce biological estimates of protein quality when fed to weanling rats. (D. L. Oswalt, *Testa and tannin characteristics associated with nutritional quality in Sorghum bicolor (L.) Moench grain.* 1974 Agronomy Abstracts, p 107.)

REFERENCE:

Maxson, E. D. and L. W. Rooney. 1971. *Evaluation of methods for tannin analysis in sorghum grain.* Cereal Sci. Today 16:308.

MANAGEMENT PROCEDURE-20

Dehulling Procedure by Use of Sodium Hydroxide.

The following procedure can be used to dehull grain sorghum: Stir constantly through all procedures.

a) Temper samples in 140°F water for five minutes, drain.

b) Heat in 20% NaOH at 160°F for five minutes.

c) Drain, wash six times with 140°F water.

d) Neutralize with 5% glacial acetic acid at 140°F during a five minute period.

e) Wash five times with 140°F water.

f) Drain and dry at 113°F to approximately 12% moisture.

At Purdue University the above procedure reduces catechin equivalent values (tannins) from above 4.0 percent to less than 1.0 percent with no significant change in protein percent of sample when fully mature seed is treated.

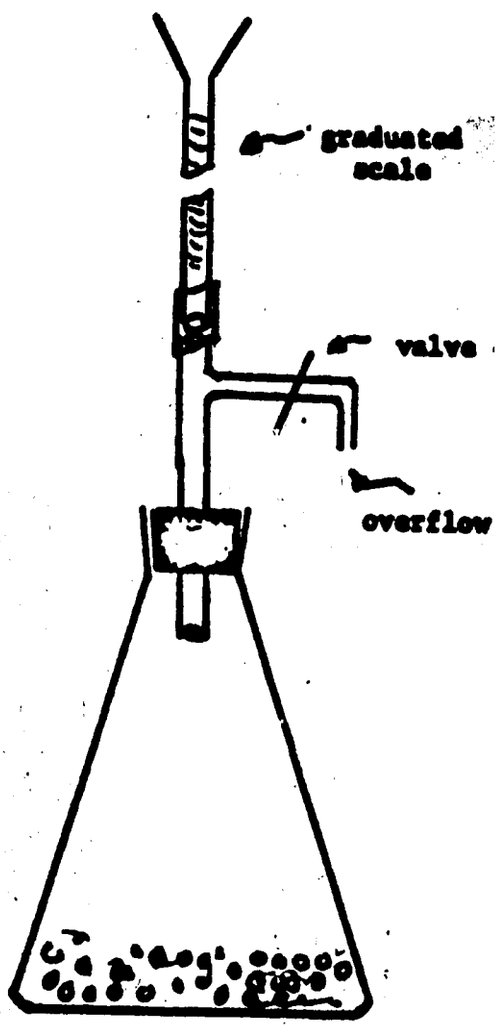
REFERENCE:

Blessin, C. W. 1971. *Processing sorghum grain to improve nutritional quality and industrial use.* Seventh Biennial Grain Sorghum Research and Utilization Conference PROCEEDINGS. p. 70.

MANAGEMENT PROCEDURE-21

Determination of Seed Density.

The weight per seed can be determined by randomly selecting 100 to 1000 seeds and dividing by the number weighed. The volume per seed can be determined by completely emersing 100 or 1000 seeds in alcohol, where the volume of the alcohol can be measured before and after the seed is added (graduated cylinder, as diagrammed, is useful when working with large numbers of samples).



Example:

Weight of 100 seeds (dry) = 2.85 g

Volume (100 seeds)
alcohol + seed = 22.55
- alcohol 20.00

= 2.55 cc/100 seeds

Density = weight of 100 seeds
÷ volume of 100 seeds or
2.85 ÷ 2.55 = 1.118

MANAGEMENT PROCEDURE-22

Suggested Terminology.

a) **Regular Breeding Program:**

F_1 = crosses with hand-emasculated plants or with male steriles

F_2 = the selfed F_1 plants

F_3 = the selfed segregating F_2 plants

male steriles = plants which do not produce anthers which shed pollen

⊗ = self pollinating a plant

backcross = selection of an F_1 plant which is crossed to one of the original parents

genetic male sterility (ms$_1$ to ms$_7$ and al, etc.) = usually a single recessive genic control of male sterility presently used mostly in random mating populations.

isolation = protecting a random mating or hybrid seed production field from wild and other sources of pollen by use of distance or time of planting.

b) **Random Mating Populations:**

All plants are, in effect, F_1's as male sterile plants are identified and advanced to the next cycle and such plants produce F_1 seed.

S_1 = fertile selfed plants in populations which result in S_1 progenies or advanced families, i.e., S_2's, S_3's.

Full sib = a hand-made cross between a single male sterile plant and a single fertile plant. (Same brother-sister relationship as in a litter of swine or in a human family).

MANAGEMENT PROCEDURE-22 (*continued*)

Half-sib = randomly mated male sterile plants. (Each plant in a family row has a half-brother or half-sister relationship as they have a common female from different male parents).

B-Random Mating Population = a selection of B-lines randomly mated using the genetic sterility systems.

R-Random Mating Population = a selection of R-lines randomly mated using the genetic sterility systems.

BR-Random Mating Population = a selection of B and R lines randomly mated using the genetic sterility systems.

c) Cytoplasmic-Genic Male Sterility (msc_1):

Originally identified as male sterility caused by an interaction of cytoplasm from milo with genes from kafir.

A-line = cytoplasmic male sterile.

B-line = maintainer of male sterile.

R-line = restorer line or male parent of a hybrid where an A-line is used as the sterile female.

REFERENCE:

Ross, W. M. 1973. *Use of population breeding in sorghum-problems and progress.* PROCEEDINGS of Twenty-Eighth Annual Corn and Sorghum Research Conference, Chicago, Illinois (American Seed Trade Assoc.)

MANAGEMENT PROCEDURE-23

Procedure for Protein and Amino Acid Estimations.

The consistency and accuracy of the laboratory analysis depends initially on the securing of mature representative samples of grain. The adverse influences of variable plant density, border influences (plant heights, open space, and variety interactions) must be recognized and reduced to a minimum by careful harvesting techniques. (See plot design on page 3.) All samples should be dried to a uniform moisture content, ground uniformly, and after grinding thoroughly mixed to remove any particle size separation which may have occurred during grinding. Samples must be carefully stored prior to analysis to prevent contamination, undesired alterations in moisture content, and insect infestation. Note: The Cyclone Sample Mill type grinder (See MP-24) is capable of efficiently grinding small samples to a very uniform size and without major separation of particles variable in hardness or size.

Protein Quality Estimates.

An amino acid analyzer utilizing ion-exchange resin chromatography can be used to obtain the complete amino acid analyses or only the short column can be run to obtain the estimate of basic amino acids (including lysine).

The dye binding procedure (See MP-24 (Udy)) is based on the reaction of proteins with the monosulfonic azo dye, Acid Orange 12, to form an insoluble complex. The estimate of protein is based on colorimetric measurements of unbound dye through its relationship to total nitrogen.

MANAGEMENT PROCEDURE-23 (*continued*)

Non-protein nitrogen is not bound. Because the dye-binding properties of a protein are largely determined by its content of basic amino acids, the amount of dye bound per unit weight of protein provides a measure of the three basic amino acids. Thus, if arginine and histidine content of samples are assumed to remain constant the variation in amount of lysine in a unit of protein can be estimated by use of the dye binding procedure when the dye binding value is used in conjunction with an estimate of protein.

MANAGEMENT PROCEDURE-24

Equipment and Supplies List.

A few suggestions of the type of equipment and supplies which may be needed are listed below. The estimated cost and possible source for selected items are given to facilitate planning of a nursery. Note: Many of these items should be available from other supplies, this is in no way a preferred or exclusive list.

Item	Source	Approx. US $ Cost
Thresher (small plant and head)	Allen Machine Co. 224 Duff Ames, Iowa 50010	500
Thresher (heavy duty plot)	Seedburo Equipment Co. 616-626 W. Jackson Blvd. Chicago, Illinois 60606	1000
Seed Cleaner (Laboratory-type air blast Model ABSC-1)	Allen Machine Co. 224 Duff Ames, Iowa 50010	300
Cone Seeder (sample plot)	Swanson Machine Co. 20-26 E. Columbia Ave. Champaign, Illinois	300
Automatic Scarecrow (for bird control)	B.M. Lawrence Co. (Zon Guns) 24 California St. San Francisco, California 94111	150
Sample Grinder (Cyclone Sample Mill Model MS)	Udy Analyzer Co. P.O. Box 148 Boulder, Colorado 80302	325
Dye and dye-binding supplies and equipment	(same as above)	
Grain Quality Analyzer	NEOTEC 2431 Linden Lane Silver Spring, Maryland 20910	
Scientific Instruments	Technicon Industrial Systems Tarrytown, N.Y. 10591	

MANAGEMENT PROCEDURE-24 (Continued)

Item	Source	Approx. US $ Cost
Pollinating Bags #400 4-3/4 x 4-1/4 x 2-1/2 x 15-1/2	Lawson Labels, Inc. (plain) 520 N. E. Monroe St. (striped) Peoria, Illinois 61601	11.50/100M 15.00/M
Paper Coin Envelopes (3½" x 6" with metal tab) (2½" x 4¼ (3¼" x 6")	Consumer Business Supply, Inc. P.O. Box 19261 Indianapolis, Indiana	15/M 4/M 6/M
Plastic Envelopes (3" x 7" with metal tab) other sizes available	Albert Mojonnier, Inc. 9151 Fullerton Franklin Park, Illinois	24/M

Other items to consider from local sources or perhaps from other companies, such as NASCO of Fort Atkinson, Wisconsin 53538 and A.M. Leonard and Co. of Piqua, Ohio 45356 are listed below:

bird control chemicals	fertilizers
fumigants	grain driers
herbicides	hoes
knives	labels
numbering machines	measures for packeting equal amounts of seed
plastic bags	plot stakes and labels
rubber stamps	scales
seed screens (recommended sizes are:	
seed storage metal boxes	
fungicide and insecticide for seed treatment	
sprayers (hand or power)	staplers and staple removers
steel tape	tripod to hold scales

MANAGEMENT PROCEDURE-25

List of General References:

Sorghum. H. Doggett. 1970. Longmans, Green and Co. Ltd. London, England.

Sorghum Production and Utilization. J. S. Wall and W. M. Ross. 1970. AVI Publising Co. Westport, Connecticut.

Sorghum Diseases. Texas Agricultural Extension Service, Texas A & M University, College Station, Texas. Bulletin No. B-1085.

How a Sorghum Plant Develops. R. L. Vanderlip, Agronomy Department, Kansas Agricultural Experiment Station, Manhattan, Kansas 66502. Contribution No. 1203.

Sorghum Downy Mildew...A Disease of Maize and Sorghum. Texas Agricultural Experiment Station, Texas A & M University, College Station, Texas. Research Monograph 2 - December 1973.

Sorghum in the Seventies. N. G. P. Rao and L. R. House. 1972. Oxford and IBH Publishing Co. New Delhi, India.

World Collection of Sorghums..List of Pedigrees and Origins. Purdue-AID Sorghum Project, Department of Agronomy, Life Science Building, Purdue University, W. Lafayette, Indiana 47907. Computer Printout.

Grain Sorghum Research in Texas 1970. Texas Agricultural Experiment Station, Texas A & M University, College Station, Texas. Consolidated PR2938-2949, April 1971.

Compilation of Gene Symbols, Recommended Revision and Summary of Linkages for Inherited Characters of Sorghum vulgare (Pers.). K. F. Schertz and J. C. Stephens. 1966. Soil and Crop Science Department, Texas A & M University, College Station, Texas. Technical Monograph 3.

Annual Research Reports. 1966 to present. Purdue-AID Sorghum Project, Department of Agronomy, Life Science Building, Purdue University, W. Lafayette, Indiana 47907.

MANAGEMENT PROCEDURE-25 (continued)

Research Centers

ICRISAT (International Crops Research Institute for Semi-Arid Tropics) Ralph Cummings, Director, 1-11-256 Begumpet, Hyderabad-500016, A.P. India.

ALAD (The Arid Lands Agricultural Development Program) Director, The Ford Foundation, P.O. Box 2379, Beirut, Lebanon.

CIMMYT (International Maize and Wheat Improvement Center) Waldore Hanson, Director General, Apartado Postal 6-641, Londres 40, Mexico 6, D.F.

IRRI (International Rice Research Institute) P.O. Box 933, Manila, Phillippines.

IITA (International Institute of Tropical Agriculture) P.M.B. 5320, Ibadan, Nigeria

CIAT (International Center of Tropical Agriculture) Apartado Aereo 67-13, Cali, Colombia

The Physiology of Yield and Management of Sorghum in Relation to Genetic Improvement. Jerry Eastin, Project Director, Department of Agronomy, University of Nebraska, Lincoln, Nebraska 68503.

Control of Weeds in LDC's. International Plant Protection Center. Oregon State University, Corvallis, Oregon 97331.