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RECURRENT SELECTION IN SORGHUM[1]

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ABSTRACT

Genetic male sterility is an important tool that permits the recurrent selection methods developed and used so successfully for maize to be applied to other crops. A breeding system utilizing recurrent selection has been initiated at Serere for sorghum (*Sorghum bicolor* L. Moench.) using Coes male sterility (ms_3). A detailed description of this breeding system is given including the compositing of the two breeding populations, the recurrent selection method used, and the subsequent development of hybrid varieties using the cytoplasmic male-sterility and restorers.

JOWETT (1, 2) used cytoplasmic male-sterility to apply recurrent selection to sorghum (*Sorghum bicolor* (Linn.) Moench.) and Gilmore (4) suggested methods of utilising both cytoplasmic and genetic male-sterility for this purpose. Webster (Webster O. J., 1966 personal communication) did three cycles of recurrent selection in a bulk population using cytoplasmic male-sterility, and he also set up a further bulk population using the Coes genetic male-sterile, ms_3 (8).

Male-sterility is an important tool that permits the recurrent selection breeding methods, developed and used so successfully for maize, to be applied to sorghum breeding. Harvesting only male-sterile heads ensures that all seed from these heads is cross-pollinated so that laborious hand crossing is not required to obtain recombination.

Since hybrids are now the normal commercial product in sorghum, the application of the comprehensive breeding system outlined by Eberhart et al. (3) should increase the efficiency of sorghum breeding programs. The system also produces better varieties that can be used in countries where hybrids are not yet feasible because of seed production problems. The production of commercial sorghum hybrids utilizes the cytoplasmic sterility-restorer system. Two divergent sorghum populations should be formed, as with maize. Population I should be homozygous for the genetic restorer factors for cytoplasmic sterility. Population II should consist of nonrestorers, homozygous for the male-sterility gene ms_c, but in fertile cytoplasm. Both populations may be obtained either by initial choice of the material to be composited, or by testing and selection once they have been formed. Once the system has been established, elite lines selected from population II can be used as B lines and the cytoplasmic-sterile A line counterparts can be developed from them. Elite lines selected from population I are immediately usable as restorer lines in hybrid combination with cytoplasmic sterile lines because they are already homozygous restorers.

A simple recessive male-sterile genetic factor such as Coes (ms_3) has two characteristics which makes it a more desirable tool to obtain recombination in the recurrent selection cycles within populations I and II than the cytoplasmic sterility system. Firstly, the ratio of fertiles to male-steriles (Ms_3—:ms_3ms_3) is 3:1 with no modifying factors. A check at Serere on 1,145 F_2 plants from 16 crosses chosen at random showed 19.3% sterile plants, which is a low estimate because at the peak flowering period some of the male-steriles did not get tagged. Partial steriles are few, and such partial sterility is usually confined to the upper part of the panicue. By contrast, the proportion of completely male-sterile plants from cytoplasmic male-sterility in heterozygous populations formed from divergent material may be extremely low (at Serere as few as 5% of the plants are fully sterile in certain populations). Many partial steriles are also present (Miller and Pickett, 6). Secondly, the genetic male-sterility (ms_3) is unaffected by type of cytoplasm so that it can be used in both populations whereas the cytoplasmic sterility in population II would make the extraction of maintainer (B) lines very difficult. If Coes sterility is used in population I to obtain recombination, the entire population can be homozygous for the cytoplasmic restorer genes so that any lines extracted are immediately homozygous restorer lines. But if cytoplasmic sterility is used to obtain recombination, population I must be heterozygous for the restorer factors, and all lines extracted must be tested and selected for homozygosity before they can be used in hybrid production.

Two basic breeding populations have therefore been set up at Serere. Population I was made up from 121 restorer lines of good yielding ability, crossed and backcrossed to genetic male-sterile stocks (ms_3). Population II B was similarly produced from 101 good maintainer lines or sterile producers, i.e., those which contain genes of the ms_c type, but in fertile cytoplasm.

Several methods of recurrent selection may be used for population improvement once the populations are formed (7). Because there is no evidence that overdominance or over-dominant types of epistasis are important in sorghum, the extra work required to obtain the testcross seed for reciprocal recurrent selection is not justified.

Mass selection and Lonnquist's modified ear-to-row procedure (5) may be relatively efficient when only one crop can be grown per year, and these can be used advantageously when staff and funds are limited. If facilities permit a more intensive breeding program to be used, S_1 testing *per se* has many advantages. Variation among lines is increased to give higher heritabilities so that progress from selection should be greater (7). More plants can be handled so that selection for desirable agronomic traits prior to the yield tests each cycle can be more effective. Furthermore, in sorghum the amount of outcrossing is low enough for open pollinated fertile heads to be treated as selfed heads so that S_1 seed can easily be obtained for testing. By contrast, a large amount of skilled labour is re-

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quired to produce the testcross seed for reciprocal recurrent selection or for recurrent selection for general combining ability.

The number of seasons per year determines the years required per cycle. Rainfall at Serere is divided into two seasons: most of the sorghum is grown in the second rains because of good drying weather at the end of these rains and freedom from bird damage. The dry season following the second rains is long enough to permit a crop of sorghum to be grown under irrigation. Hence, a cycle per year can be obtained at Serere in which phenotypic selection for agronomic traits is combined with head-to-row selection and S_1 testing *per se* for yield in the following system.

First rains. A large head-to-row trial containing 800 or more entries is grown at one location with only one replication. These entries are male sterile heads (ms_3ms_3) from the parental population which have been pollinated by Ms_3— plants. To reduce environmental variation these entries are assigned to blocks of 20 to 40 entries. A head from the most agronomically desirable fertile plant (Ms_3ms_3) is selected within each of the higher yielding 30-50% of these head rows, which are segregating Ms_3ms_3 and ms_3ms_3. Because of the low amount of natural outcrossing these selected fertile heads will be treated as selfed heads.

Second rains. Replicated trials of 400 or more S_1 entries are grown at as many locations as possible. (Heritabilities will usually be larger if the number of replications is a minimum (2 or 3) and the number of locations is a maximum). Remnant seed of each S_1 head must be retained and can be increased in the nursery if necessary. From the results of the S_1 yield trials, the highest yielding 10-20% of the entries will be selected.

Dry season (with irrigation). The remnant seed of the selected S_1 lines (Ms_3ms_3) is mixed and grown as a bulk in isolation to form the improved version of the variety. Male sterile heads (about 25% of the population) are identified. Only the most agronomically desirable plants are tagged and undesirable male fertile plants can be removed before pollen is shed. Additional selection among tagged plants can be done at harvest if a large enough population is grown.

At Serere, population IIB will be crossed and backcrossed each cycle to a cytoplasmic male-sterile, thus developing the male-sterile counterpart of IIB, to be designated population IIA. This population IIA may be pollinated by population I to give a variety cross hybrid, which might be considered for immediate release to growers in areas where a non-uniform hybrid is acceptable. During seed increase, population IIA will be multiplied by crossing with the most recently developed population IIB so that the hybrid will be very similar to (population IIB × population I). It is also probable that the development of A and B lines from selections out of population IIB will be hastened by crossing with suitably chosen sterile plants from population IIA.

The selected S_1 lines from each cycle of recurrent selection will be selfed to homozygosity and evaluated. The genetic male sterile gene (ms_3) will be eliminated during the selfing phase. Superior lines can be released as improved pure line sorghum-varieties. Population I will be used as the tester to evaluate lines and sublines from population II using the genetically male-sterile heads (ms_3ms_3) in population I to simplify crossing. The lines from population I can easily be crossed to the male-sterile population IIA for the evaluation of testcrosses. Conventional hybrids will be formed from the selected sublines for the final evaluation. Hence, the recurrent selection program provides elite lines with early generation testing and reduces the work load of an inbreeding-hybridization program. The resulting hybrids from each cycle should be superior to previous material in such a systematic breeding program.

The flexibility of such a system should be evident. The method of recurrent selection can be varied depending on facilities and personnel available. The commercial product can be a single cross hybrid, a variety cross hybrid or a pure line variety. New material can be added at any time by mixing with the selected bulked S_1 seed prior to recombination.

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