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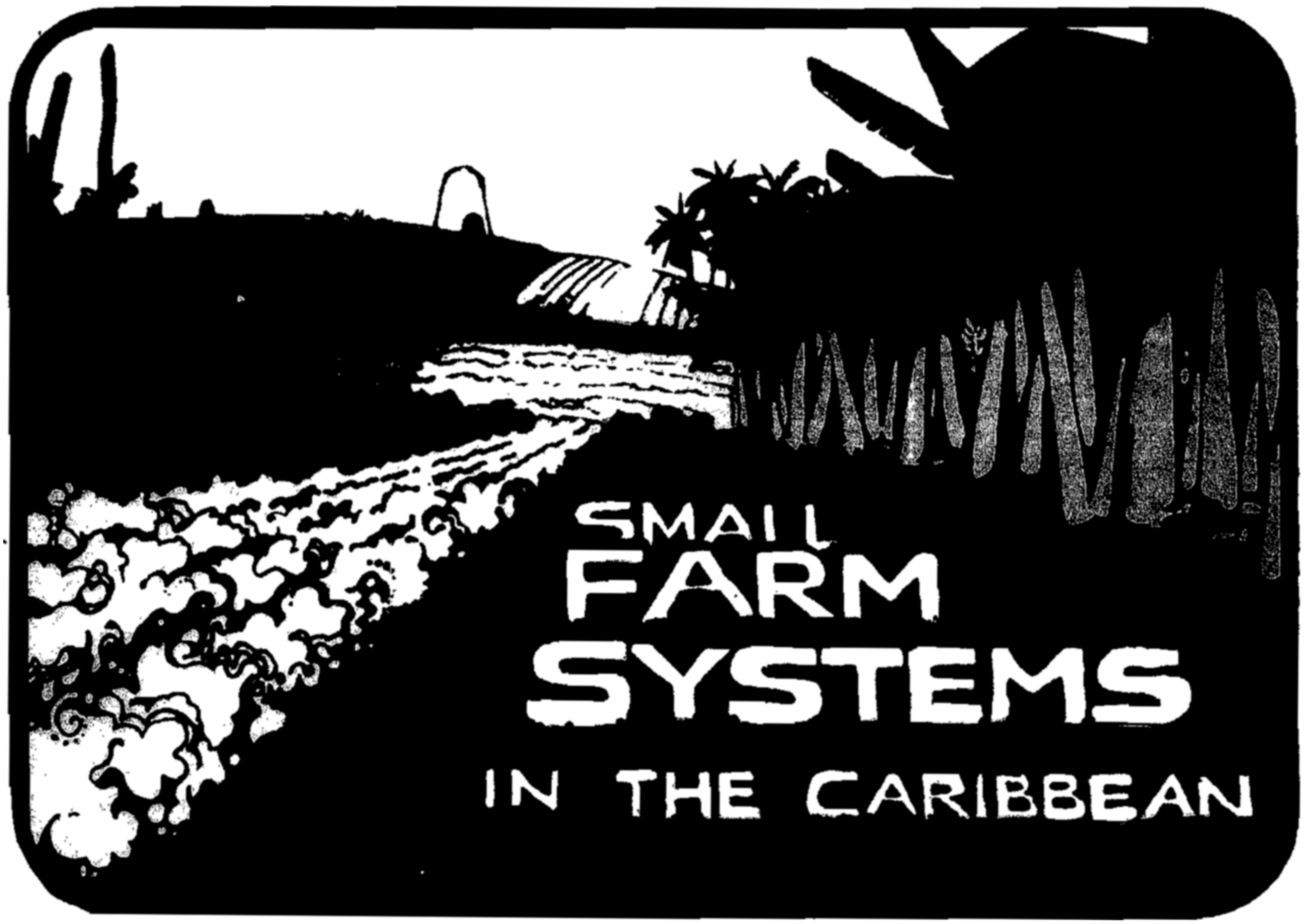

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Breeding and Agronomic Studies with Sorghum in Puerto Rico

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Sorghum (*Sorghum bicolor* [L.] Moench.) research activities at the Tropical Agriculture Research Station (TARS), Mayaguez, Puerto Rico, are described. In cooperation with the Texas Agricultural Experiment Station, 423 daylength insensitive lines from the Sorghum Conversion Program were developed. Numerous new collections were evaluated and classified. Other activities include the evaluation of new cytoplasms and their reactions when crossed to converted lines, the evaluation of grain and forage hybrids, the comparison of daylength sensitive versus daylength insensitive forage hybrids and the development of single and three-way hybrids. Newly developed single and three-way forage hybrids yield over 25 tons ha^{-1} of dry forage in 180 days. Sorghum populations developed, or in process of development, at TARS in cooperation with other scientists include:

1. populations with reduced hydrocyanic acid (HCN) potential;
2. populations of high yield potential; and
3. populations with increased resistance to common tropical diseases of sorghum.

Sorghum (*Sorghum bicolor* [L.] Moench) has the potential to play an important role in reducing hunger in the tropics either by its direct human consumption or indirectly by its use as feed to produce meat, eggs and milk. It is the fifth most important cereal grain in the world, exceeded only by wheat, maize, rice and barley (Martin, 1984). Sorghum possesses many desirable traits, such as high yield potential, excellent tolerance to periodic drought and ability to grow under diverse soil environments.

Grain sorghum is grown on a limited scale in Puerto Rico although more than 250,000 tons of maize are imported yearly for chicken, poultry and cow feed. Grain sorghum production is limited to a few hundred hectares in the northern and southern parts of the island. On the south coast of Puerto Rico there are over 100,000 ha, either under intensive winter vegetable production which remain idle during spring and summer, or which are unprofitable for sugarcane production. On the northern slopes of Puerto Rico, areas too steep for rice culture could be utilized for grain and forage sorghum production.

A great potential exists for the production of sorghum in Puerto Rico and in the surrounding areas of the Caribbean Basin. This potential can be realized only if proper cultivars are utilized and a complete package of practices can be developed for producing high economic yields under diverse agro-ecosystems.

The sorghum research program at the Tropical Agriculture Research Station (TARS) deals with many aspects which could be of value to sorghum workers in tropical and temperate areas.

The main sorghum activities conducted at TARS, Mayaguez, Puerto Rico are:

1. the Sorghum Conversion Program (SCP);
2. winter nurseries for U.S. scientists;
3. development and evaluation of collections; and
4. breeding and management studies, with emphasis on tropical environment adaptation.

These activities are conducted at Mayaguez, at the TARS Isabela experiment farm, at private farms, and at the Lajas Agricultural Research and Development Center, Agricultural Experiment Station, University of Puerto Rico. These sites represent diverse environments varying in soil types, moisture and temperature regimes.

The Sorghum Conversion Program

The SCP first described by Stephens et al. (1967) is a joint venture by the Texas Agricultural Experiment Station (TAES) and USDA. The SCP is an excellent channel through which selected tropical types are made available to breeding programs in temperate climates. The program involves a series of crosses and backcrosses in Puerto Rico, and careful selections for photoperiod insensitivity and shortness in Chilicothe, Texas (Fig. 1). In addition to releasing converted lines, two types of bulks for each exotic are released. One called "temperate bulk" is selected in Texas from the F_2's of the last backcross and contains an array of height and maturity genotypes not found in the short, early converted lines. The other called "tropical bulk" contains an array of height and maturity, genotypes selected under short-day conditions in Puerto Rico. At present there are 1,361 items in the SCP of which 423 have been fully converted.

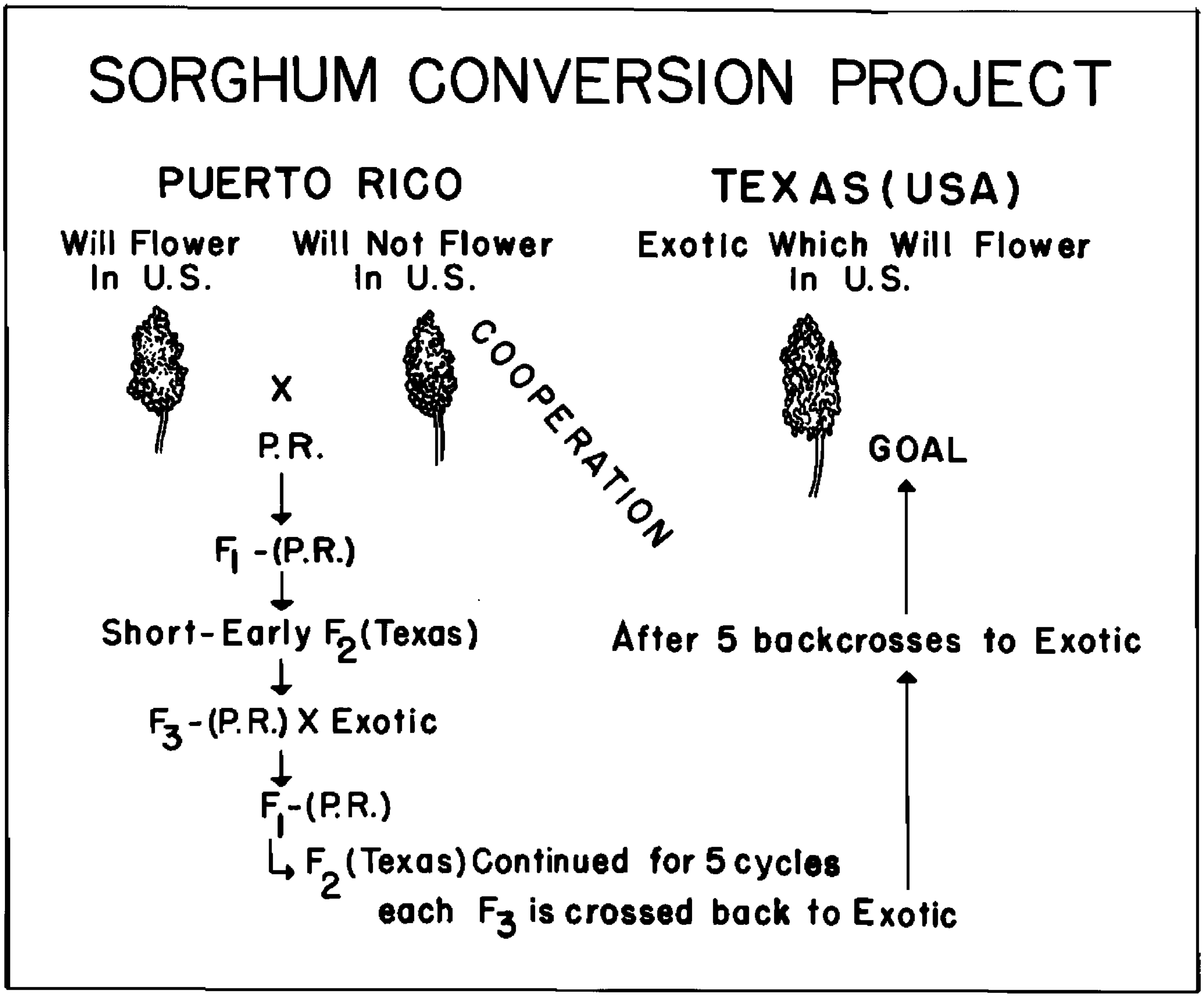
Sorghum Populations Developed

The following populations have been developed at TARS, primarily for use in the tropics:

PR1BR. Population PR1BR was developed by O. J. Webster and released in 1976 (Webster, 1976). The male components of PR1BR are 41 cultivars from 11 African countries and the population includes both photoperiod-sensitive and insensitive genotypes. Seed of this population is available in limited amounts from TARS.

PR2BR. In 1978, the Agricultural Research Service (ARS) of the USDA announced the release of sorghum population PR2BR as germplasm for breeding. This population is based on 34 selections out of 435 rows from the SCP, the "All Disease Nursery" of the University of Texas, and the temperate and tropical bulks grown at Isabela, Puerto Rico in January 1975. The 34 selections were transplanted to Mayaguez and used as females when crossed by a dayneutral source of Ms_7ms_7. These crosses represent 34 potential cytoplasms instead of one, as in most other populations

FIG. 1. Diagramatic description of the sorghum conversion program.



in which a genetic male sterile is used as the female. Three random mating cycles were completed in Puerto Rico, two under long days. Seed of PR2BR has been distributed to many places in the tropics.

PR3BR. Population PR3BR was released in 1977 by the ARS, USDA as germplasm for breeders, primarily in the tropics. The population was developed at TARS. In the summer of 1974, sorghum population PR1BR was planted in alternate rows with TP4R (Texas Population 4). The steriles in each row were bagged and, when in full bloom, pollinated by bulk pollen from adjacent rows. Equal quantities of seed from each of the head pollinated were bulked together and planted to begin PR3BR. Four random mating cycles were completed under long days in Puerro Rico in June 1977. Seed of this population is also available in limited amounts from TARS.

PR4BR. Population PR4BR was released in 1978 by the University of Puerto Rico (UPR), Agriculrural Experiment Station, and TARS. The components of two populations include 88 sorghum cultivars from difference sources such as the SCP, the "All Disease Nursery" of the University of Texas, breeding lines from the UPR-AID and TARS sorghum projects. The selection of the 88 cultivars was based on possible resistance to head and foliar insects and diseases. the initial screening and first crosses using TP4R as female were done at the UPR, Isabela Experiment Substation by Morales, Powell, and Cruz. The subsequent development of the population was done at TARS. Three random mating cycles were complered by May 1978. Seed of PR4BR has been distributed to many places in the tropics.

PR5BR. In 1983 PR5BR was released by the UPR Crop Protection Department and TARS. The components of PR5BR are KP-5 (Kansas population 5) and Millo Blanco (MB). The KP-5 population is a potentially good source of resistance to maize dwarf mosaic and anthracnose caused by *Colletotrichum graminicola* (Ces.) G.W. Wilson. Millo Blanco is a vigorous local forage and grain sorghum with photoperiod-sensitivity, and considerable drought tolerance. Local trials show its excellent yield compared to other forage species in Puerto Rico (Sotomayor-Ríos and Telek, 1977). In January 1976, more than 200 crosses of MB with photoperiod insensitive male sterile plants from KP-5 were complered. The F_1 seed was bulked and planted under long days at Isabela in May 1977. By 60 days after planting more than 300 plants had flowered: these were selfpollinated and bulked to begin development of PR5BR (photoperiod-insensitive). During 1978 and 1979, seeds from F_2 plants were bulked and grown under long days at Isabela where the population was subject to random mating. In 1980, 1981 and 1982 the population was grown under long days at Isabela. At the end of each random mating cycle, male sterile plants were selected for resistance to anthracnose, rust, fusarium root and stalk rot, zonate leaf spot, sugarcane borer and lodging. PR5BR is photoperiod insensitive, and should be a source of both B-lines (maintainers) and R-lines (restorers). Seed of this population is available in small quantities from TARS.

Other sorghum populations developed in cooperation with TARS are as follows: RP1R and RP2R (Ross et al., 1977); RSP3BR (Craig et al., 1979); Three Pairs (A and B) of Sorghum Lines with A_2 Cytoplasmic-Genic Sterility (Schertz et al., 1981); GPT2RB (Duncan et al., 1982); and NP22 (Gorz et al., 1984).

Agronomic Studies

During the last decade a series of studies on sorghum grain yield have been conducted in Puerto Rico. Wahab et al. (1976), Sotomayor-Ríos and Miller (1977), and Sotomayor-Ríos and Weibel (1978) reported yields averaging 4,000 kg ha^{-1}. Sotomayor-Ríos and Lugo-López (1978) reported grain yields which ranged from 4,504 to 6,884 kg ha^{-1} in studies of nitrogen application and timing. Split application of the maximum quantity of N (280 kg ha^{-1}) resulted in the highest crude protein content. Near maximum yields (almost 90%) were found with one application of 56 kg ha^{-1} N. In cooperation with Texas A&M University, Sotomayor-Ríos et al. (1984) evaluated 15 grain sorghum cultivars with potential for the tropics on an Oxisol and on a Vertisol. The hybrids ATx634 × 76CS490, ATx623 × RTAM428 and ATx378 × RTx430 were the highest yielding entries during the plant and ratoon crops. Cultivars such as these appear capable of yields of over 8-10 tons in a 240-day period under two consecutive harvests. Better resistance to the local diseases and insects should raise the yield potentials of sorghum even higher.

We have studied the development, selection and testing of sorghum × sudan and sorghum × sorghum forage hybrids in Puerto Rico (Sotomayor-Ríos and Telek, 1977; Sotomayor-Ríos and Santiago, 1981; Sotomayor-Ríos et al., 1981; Torres-Cardona et al, 1983; Sotomayor-Ríos and Torres-Cardona, 1982; Sotomayor-Ríos et al., 1983; Torres-Cardona et al., 1984; Sotomayor-Ríos and Torres-Cardona, 1984a; and Sotomayor-Ríos and Torres-Cardona, 1984b). Locally developed single and three-way forage sorghum hybrids (Torres-Cardona et al., 1983) are capable of producing over 25 tons of dry forage ha^{-1} with about 10% crude protein in only 180 days. The excellent dry forage yield potential, relatively low HCN-p values and high protein content of these hybrids, make them adaptable to intensive forage production schemes in the tropics. Forage sorghum height and leaf area have been highly correlated with forage yields in Puerto Rico (Sotomayor-Ríos and Torres-Cardona, 1984a; and Sotomayor-Ríos and Torres-Cardona, 1984b). Forage quality improvement depends on increasing digestibility and animal intake. Improved quality is shown by increasing *in vitro* dry matter disappearance (IVDMD), higher protein, and adequate levels of essential minerals. Decreasing non-digestible constituents, eliminating or lowering toxic components, and developing disease resistant genotypes will contribute to obtaining a forage of improved quality. Studies conducted at TARS are aimed at the development of lines or cultivars with higher IVDMD, possessing the brown midrib character (bmr). This gene has been associated with lower lignin content and increased digestibility compared to normal sorghum genotypes (Gourley and Lusk, 1978).

Bird, Insect, Disease and Nematode Problems

The most serious pests of sorghum in Puerto Rico are birds and insects. Birds cause damage from the milk stage to maturity, especially on small scale winter plantings. Generally, the grain sorghums most susceptible to bird damage are the white and yellow-seeded varieties, while the brown types (high tannin) are the most resistant. Brown seeded, high tannin sorghums have the disadvantage of reduced feed value for monogastric animals. To protect grain sorghums from bird damage under experimental conditions, breeders have used various methods. The application of bird repellents and the use of an alarm-method have not been effective in keeping the birds from attacking the sorghum grain.

The most important insects attacking sorghum in Puerto Rico (Barbosa, Pedro, *Personal communication*) are the sorghum midge, *Contarinia sorghicola*; and sorghum webworm, *Celama sorghiella*; and *Stenachroia elongella*, the old world webworm. Other economically damaging insects on local sorghum include: the corn earworm, *Heliothis zea*; the fall armyworm, *Spodoptera frugiperda*; the sugarcane borer, *Diatraea saccharalis*; the lesser cornstalk borer, *Elasmopalpus lingnosellus*; the corn aphid, *Rhopalosiphum maidis*, and the chinch bug, *Blissus leucopterus*.

Limited research on sorghum diseases has been reported in Puerto Rico (Alconero et al., 1977; Powell et al., 1977; and Hepperly et al., 1982). The main field diseases affecting sorghum in Puerto Rico are rust (*Puccinia purpurea* Cke), anthracnose (*Colletotrichum graminicola* [Cesati] G. W. Wilson), root and stalk rot (*Fusarium moniliforme* Sheid), gray leaf spot (*Cercospora sorghi* Ellis and Everhart), zonate leaf spot (*Gloeocercospora sorghi* Bain and Edgerton), leaf blight (*Helminthosporium turcicum* Pass), downy mildew (*Sclerospora sorghi* Weston and Uppal) and maize dwarf mosaic virus (MDM). Grain molds and storage decay are serious contraints to production of quality sorghum seed under the humid tropical island climate.

The world losses due to nematode damage requires more attention in sorghum production areas. Limited research on the effect of nematodes on sorghum has been conducted in Puerto Rico. Bee-Rodríguez and Ayala (1977) reported on the interaction of *Pratylenchus zeae* with four soil fungi. The authors concluded that, under greenhouse conditions, a population consisting of 1,500 *P. zeae* in 20-cm pots were pathogenic on sorghum and suppressed top and root growth. Hernández-Catalán (1977) evaluated 10 sorghum lines (selected from PR2BR population) for nematode resistance. He found that the average yield of the 10 sorghum lines when planted in soil treated with Dasanit (Fensulfothion) at the rate of 33.7 kg ha^{-1} (active ingredient) yielded about 3,095 kg ha^{-1} of grain. The same ten lines, however, yielded an average of 2,650 kg ha^{-1} of grain when planted on the soil not treated with Dasanit. Ayala and Bee-Rodríguez (1978) described the field symptoms of nematode susceptibility in sorghum of plants growing at the TARS Isabela experiment farm. These authors reported that two to three weeks after germination most plants turned purplish, wilted and died in a few days, a symptom typical of dieback. The roots turned deep red and the cortex was loosened. Nematodes of the species *P. zeae* were invariably associated with the symptoms.

Black Layer Studies

Quinby (1972) and Eastin et al. (1973) studied the use of black layer (BL) formation in grain sorghum as an indicator of physiological maturity. Weibel et al. (1982) reported on the relationship of BL to sorghum kernel moisture content and maximum kernel weight in nine hybrids in Puerto Rico. In most cases BL formation and maximum dry weight occurred at the same time or within one maturity stage. They concluded that BL formation can be used as a good indicator of physiological maturity and maximum dry weight under tropical conditions.

Studies of B and R Reactions

The necessity of hybrid production using other resources than A_1 in order to improve yield and resistance to diseases and insects is evident. In January 1983, 182 converted lines from SCP were crossed with three genic-cytoplasmic male sterility sources (A_1, A_2 and A_3) at TARS to determine the fertility-sterility reaction of the produced F_1's. Preliminary results show that most of the converted lines were fertility restorers (R) when crossed to A_1 and maintainers (B) when crossed to A_3. Approximately 50% of the converted lines were fertility restorers (R) when crossed to A_2.

SUMMARY

Sorghum researchers at TARS, USDA-ARS, Mayaguez covers two main areas:

1. nursery programs and the sorghum conversion program, and
2. local focus on sorghum breeding and genetic research for the tropics.

Agronomic studies have demonstrated the potential of sorghum for the tropics and will lead to the development of complete packages of practices for the high economic yields both on grain and forage sorghum on the farmer level. Private industry utilizing converted lines benefit from our work. Information obtained on sorghum breeding, genetics and agronomy has been useful not only to breeders and agronomists but also to farmers in Puerto Rico engaged in sorghum production.

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