Disease-resistant Tropical Supersweet Corn Populations

James L. Brewbaker

Department of Tropical Plant and Soil Science, University of Hawaii, Honolulu, HI 96822

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Temperate sweet corn hybrids cannot be grown year-round in Hawaii, or in most other tropical climates, because of disease susceptibility and low yields under conditions of low incident light and high levels of diseases and pests (Brewbaker, 1983; Brewbaker et al., 1966). A primary problem in Hawaii is maize mosaic virus (MMV), to which no temperate sweet corns are resistant (Brewbaker, 1981a). Additionally, no temperate sweet corns are sufficiently tolerant of common rust (Puccinia sorghi Schw.), seedling and kernel rot (Fusarium moniliforme Sheld.), Northern leaf blight (Exserohilum turcicum Pas.) Leonard & Suggs), and corn earworm (Helicoverpa zea (Bodde)) for year-round production (Kim et al., 1988). The populations described here were bred to make production cost-effective in Hawaii with minimal or no use of pesticides.

In 1961, breeding was initiated of tropically adapted open-pollinated populations and hybrids based on the sugary1 gene (Brewbaker, 1968). Emphasis shifted to high-sucrose genes, such as shrunken2, for enhanced postharvest quality (Banafuntzi, 1974). The high-sucrose mutant that has been exploited most extensively in Hawaii is brittle1, with the first varietal release in 1977 (Brewbaker, 1977). The 17 populations described represent >200 cycles of recurrent mass and backcross selection for quality and disease and pest resistance. They are marked by resistance to MMV and high tolerance of fusarium seedling and kernel rot, common rust, and earworms. They also segregate for general resistance to Southern rust (Puccinia polysora Underw.), bacterial leaf blight, maize dwarf mosaic virus, and Northern leaf blight. Four types of sweet corn are represented, based on genes sugary1, shrunken2, brittle1, and brittle2.

Origin

The 17 populations described here were bred largely at the Waimanalo Research Station of the Univ. of Hawaii on Oahu at sea level, lat. 20°N. They differ greatly from temperate sweet corns, as they are derived largely from tropical field corns (notably, the Caribbean Flints), which resemble in height and stature, prolificacy, sensitivity to photoperiod (Brewbaker, 1981b), husk number, and the rarity of tillers and flag leaves. Corn breeding is conducted year-round in Hawaii. No insecticide or fungicide treatments have been applied in almost every field to experimental fields at Waimanalo, Oahu, creating ideal conditions for natural epidemics of diseases and insect pests. Summer corn grain yields are twice winter yields at Waimanalo, even in the absence of disease, because of fluctuations in incident light (Jong et al., 1982). A shuttle breeding strategy was used, in which cycles of selection were continued year-round, from the warm, dry, long-day summers to cool, wet, low-light winters. Disease and insect epidemics were cyclical, usually short-lived, rarely severe, and abiotic stresses were transient. Bottle-neck-breeding (Mangelsdorf, 1952), a form of periodic intensive selection, was practiced whenever conditions were optimum, e.g., roguing during a brief increase in populations of corn leaf aphid (Rhopalosiphum maidis Fitch) before predators eliminated them (Chang and Brewbaker, 1976).

Genetic advance was achieved largely through recurrent mass selection (RMS) using the two following methods. 1) Populations of 2000 to 4000 plants at a density of 250,000/ha were hand-sibbed, rogued, and thinned prior to pollination, retaining from 150 to 250 ears. Ear quality selection was often achieved by bite-testing in the field at 20d after pollination (Ito and Brewbaker, 1981) and carefully drying selected ears for the next generation. 2) High-density plantings of 3000 to 10,000 plants were rogued prior to anthesis to 30% to 50% stand, open-pollinated under isolation, and roguing during the brief increase in populations of corn leaf aphid (Rhopalosiphum maidis Fitch) before predators eliminated them (Chang and Brewbaker, 1976).

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1Professor.
Table 1. Agronomic and disease tolerance traits of Hawaiian sweet and supersweet corn cultivars.

<table>
<thead>
<tr>
<th>Name</th>
<th>Gene</th>
<th>Color</th>
<th>Depth (mm)</th>
<th>Mass (mg)</th>
<th>Row no.</th>
<th>Ear length (cm)</th>
<th>Plant height (cm)</th>
<th>Ear height (cm)</th>
<th>Resistance&lt;sup&gt;a&lt;/sup&gt;</th>
<th>MMV</th>
<th>Rust</th>
<th>Fus</th>
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<td>11.1</td>
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Mean 9.4 154 13.6 12.2 195 76 47

Haw‘n Sugar sul Y 8.9 222 12.9 13.7 206 93 5 24
Jubilee sul Y 10.8 158 14.8 12.5 138 49 8 93

<sup>a</sup> MMV = Maize mosaic virus, R = Resistant, S = Susceptible; Rust = Common rust resistance on 1 (resistant)–9 (susceptible) score; Fus = percent reduction of germination by the fungus <i>Fusarium moniliforme</i>, winter nursery.

5L–42). The allele was obtained from Maize Genetics Coop stock 63-3023-8 x 3033-10 (a1 btl pr A C R). Despite the dominance of <i>shrunken2</i> in temperate sweetserennitisation, tropical field germination and organoleptic tests (Banafunzi, 1974; Zan, 1995; Zan and Brewbaker, in press) led us to abandon this genetic background in favor of <i>brittle1</i>. The only supersweet corns presently marketed with this gene (Hawaii, Australia, Thailand, Nigeria) trace back to Hawaiian germplasm. The gene has been sequenced and is believed to control membrane transport phenomena in the endosperm (Sullivan et al., 1991).

Five <i>btl</i> COMPs and two <i>btl</i> SYNs are being released. Hi byb SYN 2 was derived from cress of SYN 1 (a 5-inbred synthetic) to 10 other inbreds out of Hi byb COMP 3. Hi byb SYN 2 was advanced through four cycles of recurrent mass selection (RMS) followed by selfing four generations and recombining inbreds selected for tenderness and field performance. This synthetic is our best present genetic base for inbreeding, with a wide array of tolerances to diseases and pests.

Hi byb SYN 3 was bred from five outstanding <i>btl</i> inbreds derived from Hi byb COMP 3. Three of these (Hi36, Hi37, Hi38) serve as the basis of commercial hybrids ‘Waimanalo Super sweet’ (SX) and ‘Hawaiian Super sweet #10’ (3X). It was advanced through six cycles of high-intensity selection among 3000 plants in winter months, retaining ≈200 ears per cycle. The synthetic is low in variability, short in stature, and high in rust resistance (Table 1).

Hi byb COMP 3 (<i>‘Hawaiian Super sweet #9’</i>) was derived from two earlier COMPs (1 and 2) that were five-backcross conversions of <i>sugary1</i> composites introgressed with the <i>ht1</i> gene (effective in Hawaii until about 1975). It was named after eight cycles of RMS (Brewbaker, 1977). Several later cycles of RMS were based on bite test scores and percent carp thickness measurements (Ito and Brewbaker, 1981). Subsequent selection cycles included one SI, one S2 and 12 RMS (eight hand-sibbed), with emphasis on kernel quality, silk color, disease, and earworm resistance. Hi byb COMP 3 has been grown commercially throughout the tropics, and enters the pedigree of all other Hawaiian <i>btl</i> COMPs, SYNs, and inbreds. It is marked by high tenderness, high flavor scores, good uniformity and yields (Krakyta et al., 1989). It has superior tolerance to solborne fungi (Table 1), and yield losses to common rust, Northern leaf blight, and earworms are very small under no-pesticide regimes. A conversion to <i>yflk1</i> (white kernel) was marketed in 1998 as ‘#9 Silver’.

Hi byb COMP 4 derives from crosses of Hi byb COMP 3 with inbreds from a superior Thai composite, ‘Suwan 1’. It was advanced through seven cycles of RMS (hand-sibbed). This composite resembles Hi byb COMP 3 but has a palette of disease and pest resistances not available or rare in American supersweets, including some tolerance to borers and to the downy mildew (Sclerospora sp.), Stwrap’s bacterial wilt (<i>Erwinia Stewartii</i> (E.F. Smith) Dye), curvularia leaf spot (Curvularia sp.), Southern rust, and maydis leaf blight.

Hi byb COMP 6 is a six-backcross conversion of Hi byb COMP 3 to the genes <i>A1</i>, <i>B1</i>, and <i>P11</i> for purple stalk, husks and cob, and four cycles of RMS. This was released in 1996 as ‘Kalakaua Super sweet’ (‘Kalakau’ is the Hawaiian name for colorful, as in calico prints). Seed mass and ear length are reduced somewhat under low light conditions, but it performs well in the summer (Table 1). Silks are colorless and kernels are yellow or blush-colored at sweet corn stage. Both a <i>yflk1</i> (white seed) and an <i>Ogl1</i> (Old gold stripe) version of this composite have been bred, and a bicolor hybrid is marketed.

Hi byb COMP 7 was derived from <i>btl</i> seg-
Hi sh2 SYN 6 (Table 1) was created by combining sh2SYN2 (based on 23 inbreds from 'Hawaiian Sugar' x AAS8sh2) and sh2SYN4 (25% AAS8sh2 and 75% from inbreds 2256sh2, R819, R821, R825, R839, and R853). It was advanced through five cycles of RMS. With a broad tropical x temperate base and high table quality, it is a useful genetic resource for shrunken-2 inbreds. However, ears are short, kernels are small, and fusarium tolerance is low (Table 1).

Two composites were based on shrunken-2, of which Hi sh2 COMP 2 (Table 1) survived. It was bred from hybrids of the sh2 version of sugary Hawaiian inbred AAS8 with a wide range of tropical flints (Antigua 2d, Mexican and Philippine hybrids, Guatemalan and Caribbean composites, Indian flint inbreds). Six RMS cycles were grown under isolation in blocks of 1000 to 8000 plants, with 250 to 500 ears harvested from disease-resistant plants. Eight cycles of selection involving sib matings or chain crosses were added for more intense selection. This composite is largely daylength-sensitive with long ears and large kernels (Table 1), and should be a rich resource of pest, disease, and stress resistance genes.

4) Populations based on sugary. Two synthetics and four composites (Table 1) have been retained from 15 sugary populations bred in Hawaii. All trace back in part to 'Hawaiian Sugar', released by Mangelsdorf (Brewbaker, 1968) in 1945 from crosses of a Puerto Rican population, USDA34, with 'Golden Cross Bantam'. Hawaiian Sugar was chosen for its tolerance to low-light conditions, resistance to MMV, and tolerance of other diseases and earworms. It handily outyielded all U.S. hybrids tested in Hawaii and the Philippines in the 1960s (Brewbaker et al., 1966). Relatively few other tropical sweet corn varieties were available at this time, among them Pajimaca (Cuba), USDA34 (Puerto Rico), Chullpi and related races (Andes) and Maize Chirpo Dulce (= Maize Dulce, Mexico). Although grown regularly in Hawaiian trials, they had too many negative features to encourage their use in breeding.

The two sug synthetics were based on inbreds derived from 'Hawaiian Sugar' introgressed with genes Htl and Rpl-d. Hi sug SYN 3 represents 20 generations of RMS and closely mimics parent 'Hawaiian Sugar' in performance (Table 1), but excels in uniformity of maturity and quality. Hi sug SYN 4 was based on 15 outstanding singlecrosses in 1966 of Hawaiian and Mainland inbreds (190a, 442, 637, 650, C42, C53, P39, P51, and T33), selected through eight cycles in Thailand and Hawaii for low ear position and improved kernel quality and mass (Table 1). Highly variable in horticultural characters, it is a useful repository of tropical and temperate genes for table quality, yield, and resistance.

Four composites were retained on the sug background (Table 1). Stiff stalk and lodging tolerance were introduced into Hi sug COMP 6 from inbred N28, along with alleles Htl and Rpl-d, during seven cycles of RMS. Hi sug COMP 10 excels in fusarium tolerance (Table 1), with large kernels and tender pericarps. It has a complex 23-generation pedigree that includes 5/8 'Hawaiian Sugar', 1/8 Hi br COMP 1, and 1/8 inbred IL677A. The inbred 677A is sul sel (sugar-enhancer) and provides the only specific resistance gene effective against common rust in Hawaii, allele rp-677a (Kim and Brewbaker, 1987). The broad tropical base of this composite included many types of disease and pest resistance.

Hi sug COMP 12 is bulked through seven BC conversion of 'Hawaiian Sugar' to genes ACRPr from marker stock H27 (Brewbaker, 1995). This composite showed high table quality following five additional cycles of RMS, and had green plant and silk color, low ear position and good lodging tolerance. Composite Hi sug COMP 13 was based entirely on 'Hawaiian Sugar' and its inbreds, involving 25% AAS (Htl conversion), and was advanced through seven cycles of RMS (Table 1). Like other early sugary populations, it is late, small seeded, and poorly rooted, but high in fusarium tolerance, husk number, and general disease resistance.

Intended Use

Hawaii's composites of supersweet and sweet corns have been assembled on a broad genetic base of tropical field corns, which they mimic, as a genetic resource for breeders. They are comparable to CIMMYT's populations and pools of field corn. The synthetics were designed as a basis for inbred and hybrid development and for direct use as cultivars. Many have entered international vegetable corn breeding, and several are marketed commercially under other names.

Availability

All seeds are open-pedigree and available at cost from Hawaii Foundation Seed Facility, Dept. of Tropical Plant and Soil Science, College of Tropical Agriculture and Human Resources, Univ. of Hawaii, Honolulu, HI 96822. Earlier informal releases of some of these lines must be considered obsolete.

Literature Cited

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