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ABSTRACT

University of Hawaii corn performance trials since 1961 and cooperative large-scale trials in 1966 encourage the development of winter corn breeding and seed production nurseries on the island of Molokai, Hawaii. Pollination success, greatly exceeding that of Florida nurseries, is comparable to that achieved in summer Corn Belt plantings, and there are no apparent hazards or pests jeopardizing the success of future plantings in the area.

* * * *

Commercial winter corn breeding nurseries were instituted in 1966 on the island of Molokai, Hawaii, in an area chosen for its uniquely dry and moderate climate. Corn Belt and tropical maize varieties produced excellent seed yields in these nurseries, and future development of the area by the seed industry appears probable. Some characteristics of this area and of corn grown there will be discussed.

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Much data to be presented were collected in the cooperative 1966–67 breeding nurseries of Cornnuts, Inc., and the University of Hawaii; the authors acknowledge with thanks the assistance and use of data of Dr. D. L. Shaver (Cornnuts, Inc., Salinas, California) and the use of data from Mr. Clarion Henderson (Illinois Foundation Seeds, Inc., Champaign, Illinois).

The area chosen[2] for nursery development is in the vicinity of Kaunakakai (sea level), on the southern, leeward coast of Molokai, 25 miles by air from Honolulu (4 flights/day). The area is sunny, dry, and cooled by tradewinds that often blanket the island's mile-high hills with clouds. Although corn performs well throughout the year in Hawaii, the winter performance on Molokai has been superior due to the warm, dry, sunny conditions prevailing in this area. Comparable areas exist on the islands of Oahu, Kauai, Maui, and Hawaii, but were considered less suitable for commercial development due to present and prospective land usage, or absence of irrigation water.

TOPOGRAPHY OF MOLOKAI

Molokai (the "Friendly Isle") has a population of about 6,000 people. Kaunakakai is its major town (population 740), with a shallow harbor navigable only by barges, currently operating three times weekly to and from Honolulu. The major industries on Molokai are pineapple (16,300 acres), and ranching (principally on Molokai Ranch, 2,000 head, and Puuohoku Ranch). Very limited acreages are in potatoes, alfalfa, and citrus and other fruits. Unlike most of Hawaii's islands, Molokai has no commercial sugar cane acreages, which are normally competitive for lands most suitable to corn and sorghum.

The rectangular island of Molokai (8 x 35 miles) lies in an east-west direction southeast of Oahu, at 19° N. latitude (Figure 1). It is capped by two volcanic mountains (maximum elevation 4,970 feet) separated by a flat fertile area, the Hoolehua Plains. The southern side of the island slopes gradually to the sea, while steep cliffs form the northern coast.

The 167,085 acres of Molokai have been classified by the Land Study Bureau of the University of Hawaii (Nunns, 1959, and Baker, 1960) as to suitability for intensive agriculture. About 8,000 acres of the island were placed in Classes A and B; 6,700 acres of Class B would be classifiable as A when irrigation is available. This acreage has deep, well-drained soil, good temperature and moisture conditions, and is well suited to corn, pineapple, vegetables, etc. Lands of Class C totaled 31,790 acres; although marginal for intensive agriculture, these can be used profitably for grazing

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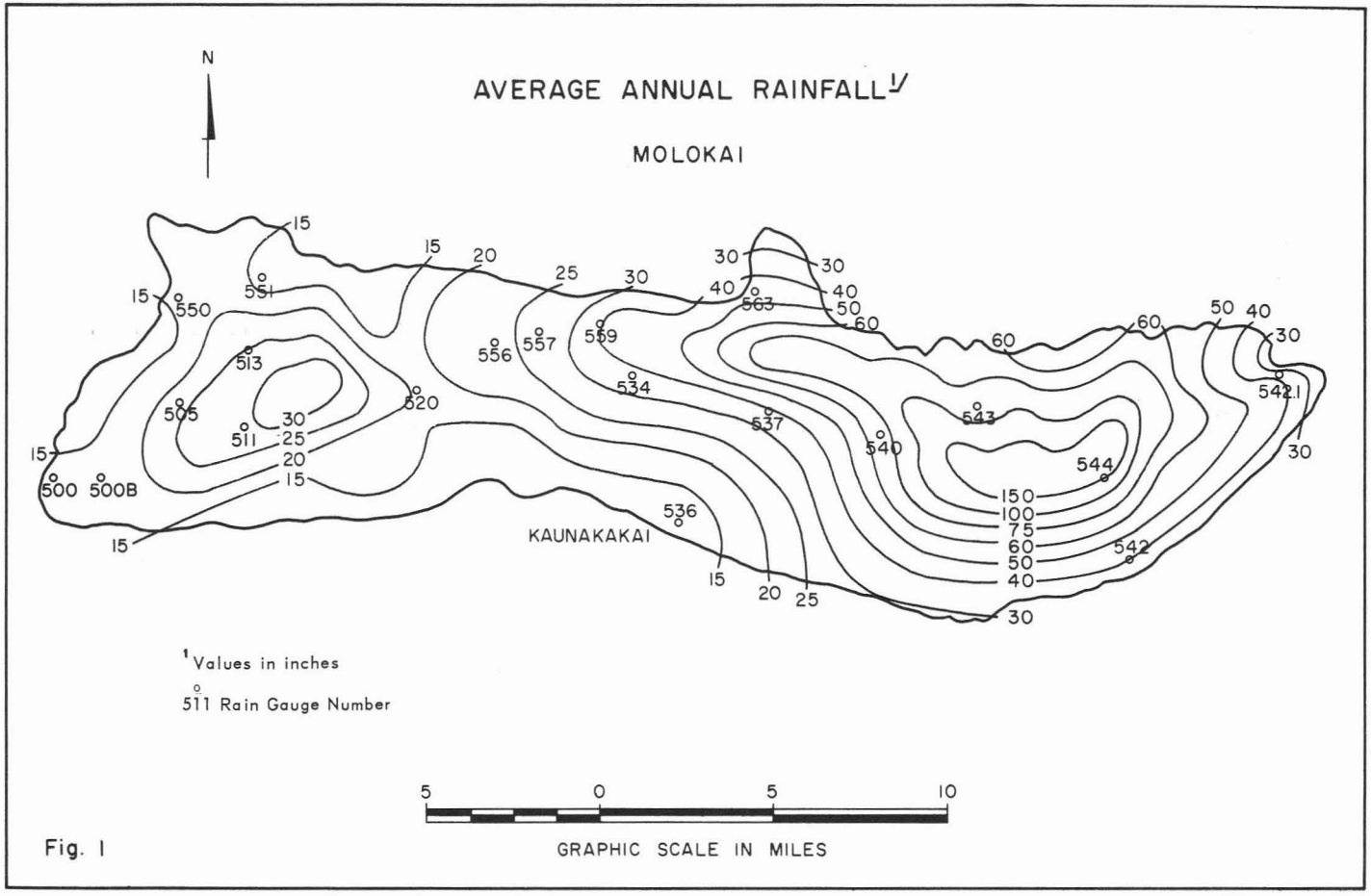
[2]In consultation with County Extension Agent, John R. Blalock, to whom we express our appreciation.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AVERAGE ANNUAL RAINFALL 1/
MOLOKAI
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GRAPHIC SCALE IN MILES

Fig. 1

and for low-water-requiring crops such as pineapple (there is no sugar cane on the island). Much of this land could also acquire Class A (11,300 acres) or Class B ratings (5,640 acres) if irrigation were provided. The remaining Class D lands (126,575 acres) were found to be unsuitable for agriculture; they are used to some extent for pig, dairy, and poultry farming, flower and timber production, and industrial and urban purposes.

The island itself may be divided roughly into four areas: Hoolehua Plains, West Molokai, East Molokai, and Kalaupapa. Of these, the west-central portion of Molokai known as the Hoolehua Plains (rain gauges 520, 536, and 556 on Figure 1) is the most attractive for corn seed production. Soils of the Plains and Kaunakakai lowlands are reddish oxisoils (of the Low Humic Latosol group), belonging to the Molokai family (Molokai or Lahaina series). They have a pH near 6, low phosphate availability, kaolinitic (1:1 clay) colloids, high iron oxide contents, and organic matter contents (uppermost horizons) exceeding 2.5%. Rainfalls vary from 15 to 30 inches per year. Irrigation water has become increasingly available for this area through the construction of a major pipeline conveying water from the island's north slopes. Prevailing tradewinds which cool the area are predominantly out of the northeast (thus making the Hoolehua Plains a leeward area), and average from 10 to 20 mph. Pineapple has been the major crop in this area, but with the availability of irrigation water, the land is attracting other crops; yields of peppers, tomatoes, onions, and other vegetables in University of Hawaii demonstrations were exceptionally high (Larson et al., 1966, and Rankine et al., 1966).

Nearly 70% (116,022 acres) of the total area of Molokai is privately owned; 44.3% by Molokai Ranch, Ltd. (West Molokai), 7.9% by Puuohoku Ranch (East Molokai), and 17.2% by other various smaller estates. The public lands are controlled by the Hawaiian Homes Commission (15%) and by the State Department of Agriculture and Conservation. Hawaiian Homes land is in the Hoolehua area and comprises some of the best agricultural land in the State, especially when it is supplied with water. However, this land is still available only to Hawaiians (at least 50% Hawaiian ancestry). The Department of Agriculture and Conservation lands comprise mainly forest reserves in the mountainous areas.

CLIMATE OF MOLOKAI

Daylengths range from 10:50 to 13:10 hours at 19° N. latitude, and Molokai's climate permits a 12-month growing season, due to its subtropic

temperatures. For example, maximum and minimum temperatures on the Hoolehua Plains at Molokai Airport (443 feet) were 88° F. and 59° F., respectively, in 1966 (Table 1*a*), while the monthly averages ranged from 70° to 77° and averaged 73.5° over a 20-year period (Table 1*b*). At Kaunakakai, temperatures are approximately 2 degrees higher than those at the airport.

The prevailing tradewinds are in a northeast direction 82% of the time. Winds measured at the Molokai Airport reach 4 to 12 mph approximately 36% of the time, and 13 to 24 mph 52% of the time. Velocities below 4 mph and above 25 mph are rare (4% and 6%, respectively). As one descends from the Hoolehua Plains to the coast, winds are less severe. Although wind may be severe enough to damage vegetable crops on the Hoolehua Plains, this effect can be alleviated by windbreaks installed at right angles to the direction of the prevailing northeasterly wind, since damaging winds from other directions are rare.

Rainfall varies greatly throughout Molokai (Table 2 and Figure 1). Data for the Mahana rain gauge No. 520 (near airport) and Kaunakakai (rain gauge No. 536) are most representative of the area being considered for corn production. These areas average 20 inches/year, and winter rains rarely exceed 3 inches/month. Daily showers which occur in the highlands of northeast Molokai provide the primary source of water for the island. A pipeline has been constructed which will supply water from the Waikolu Valley to much of the Hoolehua Plains. In this area, 5,700 acres is under irrigation, and immediate plans provide for water on an additional 2,000 acres in this region, with prospective irrigation of 7,600 acres. Included in this is construction of a 1.4-billion-gallon reservoir. The total capacity of the completed irrigation system is projected at 45 million gallons per day, thus opening up much more land area for intensive agriculture.

PERFORMANCE OF CORN IN HAWAII

A diverse group of about 600 temperate and tropical corn varieties, hybrids and inbreds, have been tested since 1961 at seven experiment stations of the University of Hawaii (sweet corn hybrid data are summarized by Brewbaker, et al., 1966). Seed production rarely presents difficult problems, and breeding at the University has been geared routinely to a 3+ crop/year operation. Among major problems encountered are the reduction of vigor in winter plantings due to short daylengths, sweet corn mosaic-stripe, *Helminthosporium turcicum* blight, and earworms. Borers and rusts have not been observed; cutworms and smuts are rare or absent.

TABLE 1*a*. Monthly maximum, minimum, and average temperatures at Molokai Airport, 1966

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Max.	80	81	81	82	84	87	87	88	87	85	85	85
Min.	61	59	60	60	64	69	68	68	68	68	66	65
Avg.	70.2	68.7	71.2	71.8	74.5	77.1	77.8	77.8	77.9	76.7	75.2	74.3

TABLE 1*b*. Mean monthly and annual temperatures (° F) on Molokai, 1948–1957 (from Baker, 1960)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
Airport (443 ft)	70.1	70.0	70.6	72.1	73.6	75.3	76.4	76.9	76.5	75.7	73.9	71.2	73.5
Kalaupapa (50 ft)	71.8	71.6	71.9	72.9	74.2	76.2	77.1	77.8	77.8	76.8	74.5	72.3	74.5
Maunaloa (1100 ft)	67.7	68.6	68.7	69.4	71.5	73.8	74.7	75.5	75.3	74.7	72.5	69.7	72.1

TABLE 2. Annual and seasonal rainfall on Molokai (25 years)

Rain Gauge Number	Location	Annual Rainfall (inches) Average	Low Year	High Year	% of Annual: Nov.–Mar.	May–Sept.
500	Kamakaipo (50 ft)	13.98	2.75	26.70	71.5	11.8
511	Maunaloa (1100 ft)	28.56	13.48	50.93	62.8	20.0
520	Airport (440 ft)	19.97	3.41	31.16	69.8	10.3
556	Hoolehua (850 ft)	22.26	5.54	40.48	66.4	13.2
536	Kaunakakai (20 ft)	13.49	2.77	29.22	78.4	8.4
563	Kalaupapa (50 ft)	45.57	17.45	84.00	57.6	22.5
543	Pelekunu (1000 ft)	74.64	66.00	142.20	–	–
542	Mapulehu (20 ft)	41.71	18.96	64.81	51.5	32.4

Winter daylength stunting is most pronounced in areas of high overcast, but is minimized in sunny leeward areas. Very early North American inbreds are most affected, while Corn Belt inbreds are less so. The sweet corn virus mosaic ("stripe" in Central America) is transmitted by a leafhopper, *Peregrinus maidis*, which builds up in areas where corn is continuously grown (Brewbaker and Aquilizan, 1965). While mosaic can severely stunt the growth of susceptible lines (most North American corns are susceptible), leafhopper control is easily achieved by two DDT sprays in seedling stage; late infections do not affect seed set. Blight has been most severe only in cooler moist areas (usually at high elevations, or in winter

months); it is rare in dry lowland areas and is not expected to be of consequence on Molokai. Earworms also build up in corn-growing areas, of course, but they have little effect on seed production and are readily controlled in Hawaii (Dr. W. C. Mitchell, unpublished data).

Sporadic pests of corn in Hawaii include birds, rodents, deer, and rose beetles; none have posed serious problems to seed production. Weed control has been a problem only where nutgrass (*Cyperus* spp.) is prevalent; otherwise, atrazine, Randox and other herbicides effect suitable control.

PERFORMANCE OF CORN ON MOLOKAI (1966–1967)

Two major corn nurseries were planted on the Molokai Ranch[3] near Kaunakakai in November and December 1966. University of Hawaii sweet corn research materials were incorporated in a 4-acre nursery of Cornnuts, Inc., Salinas, California, and all data which follow (of Table 3) are derived from this nursery. Other breeding nurseries and seed production fields were planted by the firm of Holden Seed Farm, Inc., Williamsburg, Iowa.

Molokai Ranch lands, formerly in grass or alfalfa leys, were plowed, sprayed with atrazine, and fertilized (circa 600 pounds 10:30:10, with later urea applications bringing N to 210). Seedlings were dusted at the 3-leaf stage with DDT, which was also applied for earworm control during silking. No blight sprays were made; blight was intentionally introduced for small epiphytotics and remained well confined in the comparatively dry warm climate.

Damage from chewing insects and earworms was minimal, aphids were sporadic (aerosol sprayed during pollination), and sweet corn mosaic stripe was observed on fewer than 40 plants in the 4-acre nursery. Symptoms of *H. turcicum* blight and other leaf diseases were observed in very few plants. Weed control was excellent except on areas of former leys of *Panicum* spp., where plowing had preceded planting less than 6 weeks. Data are presented in Table 3 for selected groups of dent and sweet corn inbreds and sweet corn hybrids, most of which were planted November 21, 1966, in the Cornnuts, Inc., nursery 3 miles west of Kaunakakai. Silking was concentrated between about 8 and 9 weeks after planting.

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[3]We acknowledge with thanks the assistance and interest of Molokai Ranch manager Henry Meyer and ranch owner Harrison Cooke, in the management of these plantings.

TABLE 3. Performance data of selected corn lines grown on Molokai, 1966–67 (planting date, November 21)

	Days to silk	Plant height (feet)	Ear height (feet)	Filled ear length (inches)
Corn Belt Inbreds				
38-11	64	5¾	2¼	7¼
A239	61	5	1	5
A619	59	5½	1½	6½
B14	63	6	1¾	5
B37	62	6	1¾	6
C103	62	6½	1½	6½
C121E	66	5¾	2	5½
Hy 2	58	5½	2¼	8
K44	66	5¾	1¾	6¾
K55	62	5½	1	4¼
K64	64	6	1½	4¼
M14	59	5	1¼	4½
Oh51a	61	4	½	5
Va 45	60	5¾	2	6½
W153R	53	5¼	1½	6½
Wf9	62	5¾	1¾	5
Sweet Inbreds				
190a	59	3½	1½	4
442	60	6½	2½	4
650	56	5	1½	5
661	57	4	1½	3½
2256	58	4	1½	3
2277	57	3	1	3
5480	57	3½	1	4
6053	61	4	1	4
C53	62	6	2	4
P39	58	3½	1	4½
P51	54	5	1½	4½
T24	60	4	1	3
T36	56	4	1½	4
T55	59	4	1	4
Sweet Hybrid or Variety				
Tokay Sugar	45	4½	½	3
Golden Security	54	6½	2	6
Country Gentleman	58	6	2	7½
Hawaii H68	58	8½	2½	7½

While pollination failures on mainland sweet corn inbreds averaged 6%, less than 2% loss occurred among 500 pollinations on inbreds of Hawaiian origin (Brewbaker, 1965). Most lines were harvestable in 15 weeks and harvest was completed 114 days after planting, on March 15. Ear molds

accounted for some seed loss at the butt of soft dent ears, but earworm loss was minimal.

In the judgment of mainland breeders visiting or conducting the Molokai trials, pollination results with Corn Belt lines were measurably superior to those achieved in Florida winter nurseries and were comparable to those of summer nurseries in the Corn Belt.

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