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EVALUATION OF 'WAIMANALO,' A NEW PAPAYA STRAIN

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The Solo is the only papaya strain in Hawaii with small fruits that has persisted throughout the years. During this time it has been vastly improved in many tree and fruit characteristics. Major improvements were possible because the characters were still segregating in varying degrees, allowing selection of individual trees that possessed the more desirable traits. The Line 5 Solo, introduced in 1948, the Line 8 Solo, which replaced it in 1953, the 'Kapoho Solo,' and the recently introduced Line 10 Solo *(1)* resulted from selection and inbreeding.

With continual self-pollination, later progenies will attain uniformity except for some traits that are governed by many genes or by a number of modifying genes and are difficult to fix by inbreeding. Selecting from such a population or even crossing between two Solo strains will produce little change because most of the genes are common to both.

To achieve significant improvements in the major tree and fruit characters, crosses between distinctly different varieties must be used. This is a time-consuming process because, along with a few good traits, many undesirable traits will be introduced into the new hybrids. It may take years before commercially acceptable strains can be produced.

This bulletin reports the testing of a selection that resulted from a breeding program in which widely different strains were used as the original parents. This test strain, designated as Selection No. 77, is now called the 'Waimanalo' strain of papaya. It has been test-grown by growers in the Waimanalo and Kaneohe areas over several years and has become well accepted as a commercial strain, particularly for the Hawaiian market.

DERIVATION OF 'WAIMANALO'

The derivation of the 'Waimanalo' strain is illustrated in figure 1. It dates back to 1948 when the Line 5 Solo was crossed with 'Betty,' a dwarf, early-bearing, dioecious cultivar from Florida *(3)*.

A low-bearing F_2 selection was designated as $2F_2$. Because the F_2 selection had few of the desirable qualities of the Solo parent, an individual plant selection was backcrossed to the Solo (Line 5 Solo) and subsequently self-pollinated.

In the F_2 of the cross with Line 8 Solo, several individual selections were made, one of which, No. 11-8, was crossed to No. $10F_2$, a selection derived from selfing an original backcross (Line 5 Solo) selection. This was done to incorporate the latter's preferred fruit shape, size, and skin texture. The F_1 of this cross was backcrossed to No. $11\text{-}8F_3$. No. 77 was a selection from the F_2 population of the latter cross and was maintained by repeated inbreeding. 'Waimanalo' represents eight generations of inbreeding in 1968.

EXPERIMENTAL PROCEDURE

Tests were conducted at the Waimanalo Experimental Farm on Oahu and the Kauai Branch Station in Wailua, Kauai. At the latter station, the Kauai Branch Station Solo, a strain of 'Kapoho Solo,' was used in place of the Line 8 Solo.

Seeds of Line 8 Solo and 'Waimanalo' were germinated in community pots using vermiculite as the germinating medium. At the cotyledonary leaf stage (the first two oval-leaf stage) they were transplanted individually into 3-inch jiffy pots and grown for approximately six weeks before field transplanting. Each hole was planted with two plants to assure the largest number of hermaphrodites (selfed seeds from hermaphroditic trees will segregate into one-third females and two-thirds hermaphrodites, the latter being the preferred sex type for commercial planting). Planting distances were 8 feet between plants and 10 feet between rows. Each plant received approximately ½ pound of 10–10–10 fertilizer every two months until flowering time when the amount and the formulation of the fertilizer were changed to 1 pound per two months of 10–20–20 per tree.

There were five replications, each containing eight plants each of the two strains. Plant height and precocity data were taken from all plants but yield and fruit data were taken from four trees per strain in each replicate.

Percentage of soluble solids in the juice was determined by the use of a hand refractometer. Soluble solids have been shown to give good estimates of sugar content in the papaya *(2)*.

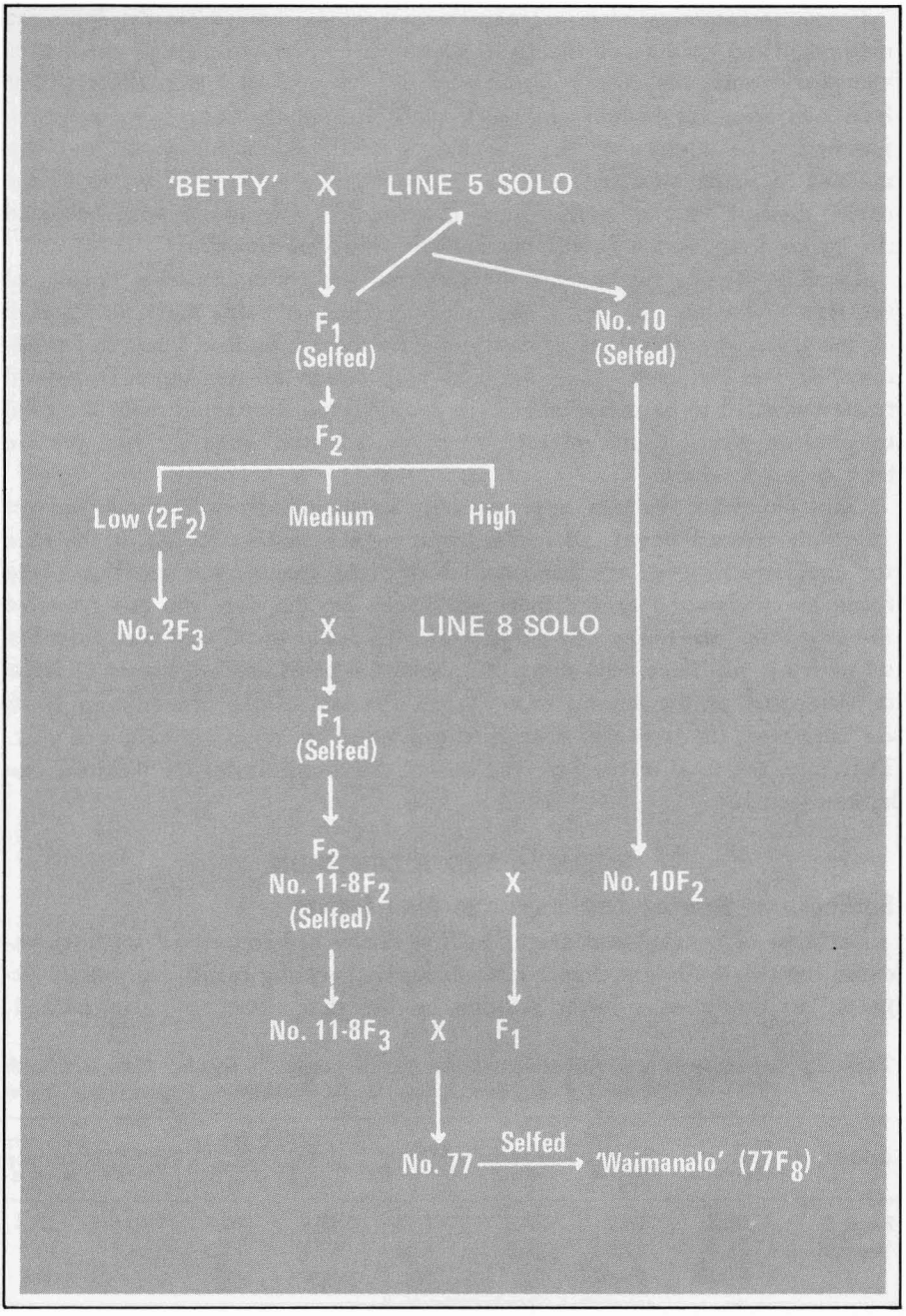


Figure 1. Derivation of the new papaya 'Waimanalo.'

Cavity percentages were calculated from ratios derived by the following method. Total volume of the fruits was measured by immersing them in a volumetric tank, and water displacements were recorded in milliliters. The fruit was then cut in half cross-sectionally and all the seeds were carefully removed. The cavities of the two halves were filled with water and this amount of water was measured in milliliters. The volume of water in the cavity divided by the total volume displaced by the whole fruit provided the ratios from which cavity percentages were calculated.

Total fruit yields were taken by counting the fruits from the bottom of the tree to the top, including the latest set fruit. A paint mark was placed on the trunk just above this fruit to indicate the last fruit in what was designated as the first crop. After the total fruit count, all misshapen fruits and fruits too small to be marketable were counted and subtracted from the total to give net yields. Fruits on each tree were counted when the first mature fruit began to ripen.

Since papaya fruits take approximately six months from flower to harvest (partially colored stage), all fruits, including the flowers setting at the time the first fruits ripen, are harvested during the ensuing six months. These fruits are designated as the first-crop fruits. By the time the last fruits of the first crop just below the paint mark are ready to be harvested, another set of fruits will have been produced above the paint mark. This set of fruits is designated as the second crop. When the last of the second-crop fruits are harvested, the trees will have been producing for approximately one year. Therefore, the total of the first and second crops constitutes the yield for one harvest year.

RESULTS AND DISCUSSION

Earliness of Bearing and Height to First Flower

Earliness of bearing and height to first flower are considered together because the two traits are closely related. Early-flowering plants are usually expected to flower at a lower position on the stem. Data given in table 1,

Table 1. Summary of tree and fruit data for the first crop (November 1966 to March 1967) of 'Waimanalo' and Line 8 Solo at the Waimanalo Experimental Farm

STRAIN	AVG. WKS. TO 1ST FLOWER	AVG. HGT. TO 1ST FLOWER (IN.)	AVG. WT. PER FRUIT (OZ.)	PERCENT CARPELLODY	AVG. NET YIELDS		PERCENT CAVITY	PERCENT SOLUBLE SOLIDS
					NO. OF FRUITS	POUNDS PER TREE		
Line 8	30.3	60.7	20.2	1.45	57.9	70.8	19.4	15.7
Waimanalo	26.4	32.0	21.9	1.37	52.1	73.3	14.7	15.2
	P=.05	P=.01	NS	NS	NS	NS	P=.01	NS

NS = not significant.

column 2, show that the 'Waimanalo' flowered, on the average, a month earlier than the Line 8 Solo. 'Waimanalo' flowered from 24 to 27 weeks after seeding. Line 8 Solo flowered from 26 to 33 weeks after seeding.

More significant than precocity is the height at which the first flower is borne. 'Waimanalo' flowered at approximately half the height of Line 8 Solo. If the space between nodes were the same for the two strains, 'Waimanalo' should have flowered much earlier than the average of 26.4 weeks shown in table 1. Since there was only a month difference in flowering, the lower bearing height of 'Waimanalo' must have been due primarily to closer spacing between nodes.

Precocity and flowering height data were not taken at the Kauai Station because field transplanting was delayed for several months due to poor weather conditions, which prevented field preparation. This delay stunted the plants, invalidating such measurement data.

Height from the ground to the lowest fruit on the tree for the second crop at the Waimanalo Farm was measured; the average heights are presented in table 3. Fruits of 'Waimanalo' were around 1.5 feet lower on the stem than those of Line 8 Solo. Although total tree height was not measured, trees of 'Waimanalo' were observed to be somewhat shorter. The lower bearing height and the lower position of the fruits as the trees grow would give considerable harvesting advantage to the new strain.

Weight of Fruits

The weight of the individual fruit is an important trait, particularly in the export trade, which demands fruits of approximately a pound. Mean fruit weight of the two strains tested did not show any difference (table 1) but both tended to be at the maximum limit for export. Fruit size of 'Waimanalo' showed a wider variability than desired, with weights ranging from 12 to 29 ounces. However, growers who have planted 'Waimanalo' for several years have not indicated any difficulty in marketing the larger fruits locally.

The Kauai trials showed that fruit size was much larger there than at the Waimanalo Farm (table 2). Both 'Waimanalo' and the Kauai Branch Station Solo (KBS Solo) tended to be large. The difference in weight between

Table 2. Summary of fruit data for the first crop (December 1966 to May 1967) of 'Waimanalo' and KBS Solo at the Kauai Branch Station

STRAIN	AVG. WT. OF FRUIT (OZ.)	PERCENT CARPELLODY	AVG. NET YIELDS/TREE		PERCENT CAVITY	PERCENT SOLUBLE SOLIDS
			NUMBER	POUNDS		
KBS Solo	14.4	17.9	26.5	23.9	17.5	11.8
Waimanalo	26.2	2.8	29.2	48.0	16.2	11.9
	P=.01	P=.05	NS	P=.05	NS	NS

NS = not significant.

the two strains was not significant. During the period of fruit development and maturation the Kauai Station had approximately 30 inches more rain than the Waimanalo Farm. In spite of occasional supplemental irrigation provided at Waimanalo, the larger fruit size at the Kauai Station was probably the result of higher moisture availability during the test period.

Compared to the first crop, the second crop (table 3) produced Line 8 Solo fruits that weighed less and 'Waimanalo' fruits that weighed slightly more. The average fruit weight of 17 ounces for Line 8 Solo in the second crop is more desirable for the export trade than the larger fruits of 'Waimanalo.'

Average Net Yields

There was no significant difference in average net yield at Waimanalo, whether the average was based on number or weight of fruits (table 1). 'Waimanalo' performed as well as the standard strain.

The hermaphroditic form of papaya is subject to seasonal changes in the sex of the flowers. Flowers initiated during winter and early spring tend to develop into misshapen fruits commonly referred to as "cat-faced" fruits. This phenomenon consists of the transformation of stamens into carpel-like structures which make up part of the fruit and cause malformation of the fruits. This is referred to as carpellody of stamens in more technical terminology. Flowers initiated during late summer and early fall tend to become female sterile, *i.e.*, male flowers, due to loss of ovary. The degree and length of time this phenomenon occurs depend upon the strain. It is apparent that net yields of a papaya tree are greatly influenced when cat-faced fruits or female sterile flowers are produced.

Data given in table 1, column 5, show very little production of cat-faced fruits in both strains. Minimum production of cat-faced fruits was expected during the time the flowers producing the first crop were differentiating. This was during summer and early fall, a period more conducive to the production of female sterile flowers.

Fruit yields in the Kauai trial (table 2) were low compared to those of Waimanalo. This is attributed to the initial stunting of the plants caused by delayed planting. The KBS Solo produced more fruits than 'Waimanalo' but because it also produced more cat-faced fruits (approximately 18 percent), its net yield reduced to approximately that of 'Waimanalo.'

In terms of pounds per tree the yield of 'Waimanalo' was roughly twice that of the KBS Solo, primarily because of the larger size of the 'Waimanalo' fruits.

In the Waimanalo test plot the average net yields of the second crop (table 3) of both strains were half those produced in the first crop. These reduced yields cannot be explained on the basis of sterility because the

flowers producing the second crop differentiated during late fall through winter and early spring, a period favoring the production of fertile flowers rather than female sterile flowers.

Data given in column 3 of table 3 show a slight increase in the percent carpellody of the Line 8 Solo while that of 'Waimanalo' remained virtually the same. This incidence of carpellody is considered to be very low. No other explanation can be given for the low yields obtained in the second crop. The heavier fruit weight of 'Waimanalo' is reflected in the higher yields in pounds per tree.

Table 3. Summary of tree and fruit data for the second crop (April to September 1967) of 'Waimanalo' and Line 8 Solo at Waimanalo

STRAIN	AVG. HGT. TO LOWEST FRUIT (FT.)	AVG. WT. OF FRUIT (OZ.)	PERCENT CARPELLODY	AVG. MARKETABLE YIELDS		PERCENT CAVITY	PERCENT SOLUBLE SOLIDS
				NUMBER	POUNDS/TREE		
Line 8	8.8	17.4	3.5	18.5	20.1	19.8	16.4
Waimanalo	7.3	23.3	1.0	26.0	37.9	16.3	15.1

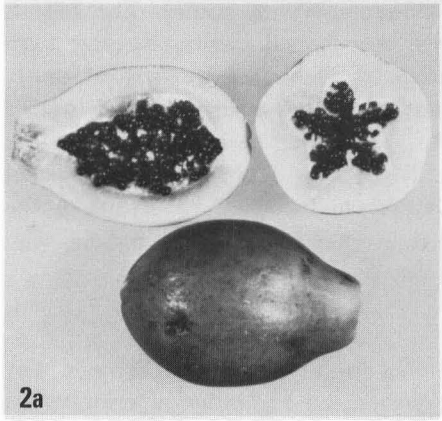
Note: Data are not analyzed statistically because of loss of trees caused by the papaya mosaic virus.

Cavity Size

Cavity size and shape depend upon factors that affect carpel development, but to a large extent they are characteristic of strains. The Line 8 Solo characteristically has a fairly large star-shaped cavity, ranging from 14 to 23 percent (fig. 2A). The 'Waimanalo' also has a star-shaped cavity but those grown at the Waimanalo test plot had a significantly smaller cavity than the standard strain (fig. 3A). There was no difference in cavity size between the 'Waimanalo' and the KBS Solo. The latter strain has a smaller cavity than the Line 8 Solo. As shown in figure 3A, fruits of the 'Waimanalo' strain have thicker flesh than that of the Line 8 Solo (fig. 2A). There was little change in cavity size in the second crop.

Soluble Solids Content

The Line 8 Solo has always been known for its high sugar content. For this reason a desirable new strain must possess, among other superior traits, sweetness that is equal to or better than the Solo. The average percentages of soluble solids for the two strains grown at Waimanalo are given in table 1. No difference was noted between them, and the range for both extended between 14 and 17 percent. This is rather high, considering the fact that soluble solids readings were taken between November and March, a period of high rainfall and cloudy skies.



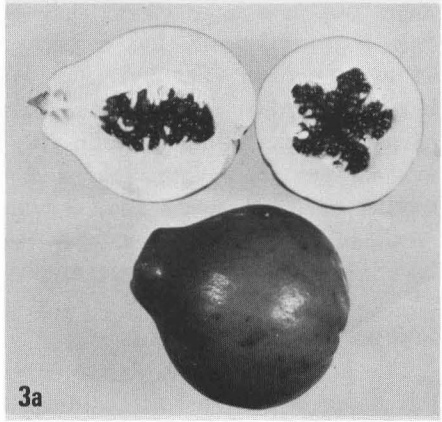


Figure 2. Line 8 Solo tree showing high-bearing tendency; 2A shows the whole and halved (longitudinal on the left and cross-sectional on the right) fruits of the Line 8 Solo.

Figure 3. 'Waimanalo' tree showing low-bearing tendency; 3A shows the whole and halved (longitudinal on the left and cross-sectional on the right) fruits of the 'Waimanalo.'

Soluble solids contents of both 'Waimanalo' and KBS Solo at the Kauai Station were very low. The lower sugar content is undoubtedly the effect of prolonged high precipitation and many cloudy days.

Soluble solids readings for the second crop showed little change from those of the first crop for both strains. Higher soluble solids readings were expected from the second crop since these fruits were maturing during the warmer and drier periods of the year (April to September), but this did not occur.

In spite of the low percent soluble solids obtained for 'Waimanalo' at the Kauai Station, the high readings obtained at Waimanalo indicate the genetic potential of the fruit to accumulate high sugars under favorable conditions.

Firmness

It is generally agreed by those familiar with fruits of both strains (growers, researchers, and Extension personnel) that at the ripe stage, fruits of 'Waimanalo' are definitely firmer than those of Line 8 Solo. The quality of firmness makes it possible to keep the fruits until a more uniform orange-yellow skin color is obtained. This is a decided advantage over Line 8 Solo which characteristically becomes soft with slight changes in skin color.

Flesh and Skin Color

Flesh color of 'Waimanalo' is also an improvement over that of the Line 8 Solo. Its bright orange-yellow color has been favorably accepted by those familiar with the fruit.

Green fruits of 'Waimanalo' have a shiny green luster while those of Line 8 Solo are dull green. These fruits are susceptible to the same types of skin blemishes as those found on the Solo fruit. Whole fruits of Line 8 Solo and 'Waimanalo' are shown in figures 2A and 3A.

Brief Description of 'Waimanalo'

Comparative analyses of several important traits have shown that the new 'Waimanalo' strain has a number of advantages over Line 8 Solo. Those traits that were not superior were at least equal to those of the Solo. Also, papaya growers on Oahu and Kauai have shown great interest in the new strain. The name 'Waimanalo' has been selected because it is the first new papaya produced from the breeding program conducted at the Waimanalo Experimental Farm and initially tested by the growers in this area.

Tree characteristics: The 'Waimanalo' is a vigorous grower with intermediate bearing height, producing its first flowers approximately six months from seeding. Internode length is somewhat short but overcrowding of fruits has never been observed. Total height of the tree is shorter than that of the Line 8 Solo. Production of cat-faced fruits at the Waimanalo Farm and

at the Kauai Branch Station has been low but occasional skips (female sterility) have been observed. Line 8 Solo and 'Waimanalo' trees are shown in figures 2 and 3, respectively.

Fruit characteristics: The characteristic fruit shape of the 'Waimanalo' is round with a short neck. Figures 2A and 3A show whole and cut fruits of both strains. Fruit size varies rather widely and, on the average, is slightly larger than the Line 8 Solo. Green fruits are shiny green. The fruit ripens uniformly with relatively clean skin, with minor blemishes. Flesh is firm upon ripening with a bright orange-yellow color. Texture is excellent. The fruit has a high sugar content under favorable conditions.

Recommendations

Because of its larger fruit size, the new strain is recommended for the drier areas of the State. Dry conditions with some supplementary irrigation would tend to reduce fruit size. For commercial enterprises it is recommended that growers plant the new strain initially for the local market. The smaller fruits meeting export requirements may be segregated for that purpose. The new strain is also excellent for the home grower.

Seeds of 'Waimanalo' are available in small quantities to local commercial growers first and later to the home grower through the Seed Distribution Service, Department of Horticulture, University of Hawaii. Requests for seeds should be made through the county offices of the Cooperative Extension Service.

SUMMARY AND CONCLUSIONS

Comparative field tests between a new papaya 'Waimanalo' and the standard Line 8 Solo were conducted in two localities. It was found that 'Waimanalo' was superior in precocity, fruiting height, and cavity size. It performed equally well in total marketable yields and in sweetness. Production of cat-faced fruits at the Waimanalo Farm was low for both strains but, at the Kauai Station, 'Waimanalo' produced significantly less misshapen fruits than the KBS Solo. Fruit size of 'Waimanalo' was found to be more variable than those of the standard strains.

Because of these and other superior attributes such as color and firmness of the fruit, it is now released to the commercial growers and the public.

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