DRY MATTER ACCUMULATION AND GRAIN FILLING PERIOD IN TROPICAL MAIZE

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ABSTRACT

Tropical adapted maize inbreds were studied over two locations/seasons with the Dry Matter Accumulation (DMA) rates and Grain Filling Period (GFP) durations calculated and analyzed for future breeding qualities. Assessment of the inbreds response to variations in solar radiation and temperature was also evaluated. Over 100 varieties were selected from a wide resource base of the Maize Inbred Resistance program at the U. of Hawaii.

Inbreds were harvested at 4 different dates after pollination (14, 21, 28, and 35 DAP) in addition to a final maturity harvest in order to map the accumulation of dry matter. Linear regression analysis was performed for each variety to determine the DMA rate and GFP duration. The DMA rates significantly decreased from summer to winter, and the GFP durations were significantly extended for the majority of inbreds.

Six inbreds were then selected on the basis of fast, slow, and average rates and durations then crossed in diallel form to produce fifteen hybrids. The parents and hybrids were grown and harvested in the previous fashion with the DMA rates and GFP durations assessed. General and specific combining abilities were assessed using Griffing's Method II of diallel analysis on a Lotus123 spreadsheet.

Broad sense heritability was determined to be 83.5% for kernel dry weight at final maturity, 96.8% for rate of dry matter accumulation, and 67.7% for grain filling period duration.

Analysis of variance conducted on the parent and hybrid materials indicated that increasing the rate of DMA may have a more significant effect on grain yields than trying to extend the grain filling period. Data implied that effects from breeding for the DMA rate may be easier to determine than selecting for extensions in the filling period. Further studies should be conducted to verify and expand on knowledge gained through these trials and analyses.

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CHAPTER 1

INTRODUCTION AND OBJECTIVES

Maize (Zea mays L.) is a diploid (2n=20) grass of the tribe Maydeae, family Gramineae, native to the New World tropics (Timothy et al., 1988). Primitive maize varieties range widely in genotype and have been exploited commercially in almost all of the important agroecosystems of the world. Among these varieties are those with very large kernels (fewer than 1000 kernels/kg) and very tiny popcorns (more than 10,000 kernels/kg), as well as varieties that range in maturity from 80 to 120 days (in Hawaii). These genetic variations appear to represent differences in the rate of dry matter accumulation (DMA) of the kernel and in the length of grain filling period (GFP)--issues that are the subject of this thesis study.

Maize is the second most important cereal crop in the world, ranking closely behind wheat and followed by rice. It is a crop grown in almost every country in the world, ranging from hot tropical to extremely cold temperate regions, reflecting a wide genetic variation (Timothy et al., 1988). Maize in temperate regions--adapted to long days--now accounts for over half of the world production, although the species evolved in the tropics with high sensitivity to long days. Average tropical yields fall far below those of the temperate regions, however, averaging about 1/5 of that (6 t/ha) in developed temperate countries. At the same time, temperate varieties perform poorly in the tropics where short days and low solar insolation result in small kernels and low grain yields (Brewbaker, 1985).

It is suspected that one method of increasing tropical maize yields involves increasing the rate of daily dry matter accumulation (DMA) and extending the number of days for the grain filling period (GFP). The following study thus sought to identify variations in DMA and GFP among inbred lines bred from tropical germplasm with their sensitivity to long daylengths. It sought further to relate these variations to environmental changes in temperature and in solar insolation. Finally, it sought to assess the combining abilities of genes controlling variations in DMA and GFP through diallel analytic quantitative genetic methods.

Specific objectives include:

1.) To determine the dry matter accumulation (DMA) rates and grain filling periods (GFP) of 100 tropically derived maize inbreds, and to assess their response to solar radiation and temperature.

2.) To evaluate a diallel set of 15 F_1 hybrids and their 6 parents for genetic control of DMA and GFP, and assess correlations between these traits and other components of grain yield.

CHAPTER 2

LITERATURE REVIEW

2.1 DRY MATTER ACCUMULATION (DMA) IN KERNELS OF MAIZE

The grain yield of maize is the integral of kernel dry matter accumulation (DMA) over time. The rate and duration of kernel fill have been suggested as factors that might be improved through selection to result in yield improvement (Frey, 1981).

The relationship between kernel dry matter accumulation and the different growth stages of corn has been well defined and is easily recognizable. At 75% plant silk emergence (pollination), vegetative growth ceases and all future growth occurs in the ear. This stage is easily identifiable by the emergence of silks and the shedding of pollen. The tassel, stem, and leaves are all fully grown. The plants have attained full height, and the cob and ear shank begin growing rapidly. There is also little root growth after this stage (Frey, 1981).

About 12 days after 75% silking, the cob and ear shank approach full size, and the kernels are in the "blister" stage containing very little dry matter. Starch has just begun to accumulate in the endosperm resulting in rapid DMA in the kernels (Sass, 1955). At this stage of kernel development, growth changes from the curvilinear lag phase to linear as the kernel DMA begins a rapid, constant, daily rate. Loss of N and P from other plant parts to the developing grain begins and continues to physiological maturity.

Three weeks after pollination, the growth of the entire kernel is rapid and linear with embryo growth slow in comparison to the endosperm. Cell division in the epidermal layer of the endosperm ends at this stage, and a rapid increase in size of the embryonic plant begins (Randolph, 1936).

Depending upon variety and location, the rate of kernel DMA begins to decline between 35 and 45 days after pollination (DAP). The embryo is morphologically mature, but a further slight increase in size may still occur (Sass, 1955). At this time, the growth curve tapers off to the maximum level of dry matter.

The final growth stage of corn related to grain DMA is defined as physiological maturity. Aldrich (1943) defined maturity as the time at which maximum dry weight of the grain is first attained. This definition was later termed "physiological maturity" by Shaw and Loomis (1950). At this stage, kernel DMA has ceased, and the husks with some leaves are senescent (Frey, 1981).

Physiological maturity for corn can be difficult to determine. Corn varieties are considered physiologically mature when the grain moisture content reaches 30 to 35%.

Daynard and Duncan (1969), Dessureaux et al. (1948), and Hallauer and Russell (1962) have shown that physiological maturity can occur in corn hybrids at moisture contents ranging from 28 to 42%.

Johann (1935) and Kiesselbach and Walker (1952) suggested that the formation of a black aleurone layer at the base of kernels might serve as a reliable indicator of physiological maturity in corn. Daynard and Duncan (1969) later demonstrated that this black layer in the placental region of corn developed in 3 days or less, and its appearance coincided with maximum kernel dry weight. The "black layer maturity" technique has been used widely and was used in this study to define physiological maturity.

In 1975-6 field experiments conducted by Pioneer Hi-Bred International Inc., kernel development was observed at three positions on the ear to determine whether there were different rates of DMA (Frey, 1981). Kernels at the base and middle of the ear began linear kernel fill at the same time and maintained nearly identical rates of DMA through physiological maturity. Tip kernel development paralleled that of the middle and basal regions yet had noticeably lower mature kernel weights and a slower DMA rate. Therefore, kernel samples taken for the purpose of this study were collected from the middle region of each ear.

2.2 GRAIN FILLING PERIOD (GFP)

The contribution to yield potential of many plant and seed morphological and developmental traits have been studied, but few have led to significant increases through plant breeding. The rate and duration of the grain filling period of maize have been positively correlated with grain yield (Daynard et al., 1971, 1976; Hanway et al., 1969; Peaslee et al., 1971). Corn grain yield is a function of the rate and duration of the grain filling period (GFP). The yield can be defined as the product of average rate of grain production (dry weight increment per unit time) and duration of grain formation (Daynard et al., 1971).

Johnson and Tanner (1972) developed a technique for calculating the rate and duration of the GFP for corn based upon a regression analysis of yield over time. They found that at least 90% of the grain accumulated linearly beginning 2.5 weeks after silking (pollination). Therefore, the GFP rate and duration were calculated simply by harvesting ears of uniform pollination dates at three sampling dates between 3 and 6 weeks after silking. A regression line was calculated with the independent variable as the number of days after pollination (DAP), and the dependent variable as the kernel dry weight in kg/ha. The rate of GFP was the slope of the regression line as a daily measurement of kernel dry weight gain (kg/ha/day). The duration of GFP was calculated by dividing the final kernel weight (kg/ha) by the rate of GFP (kg/ha/day). Later studies conducted by Cross (1975) and Poneleit et al. (1980) have satisfactorily used this same technique for calculating the rate and duration of the GFP for kernels of maize.

Historically, there has been some debate as to the importance of increasing the DMA rate compared to extending the GFP duration for their relative effects on yield. Results from Daynard, Tanner, and Duncan (1971), Cross (1975), and Crosbie and Mock (1981) suggest that an extended grain filling period and later plant senescence rather than an increased rate of filling was associated with grain yield increases. However, Poneleit et al. (1980) felt that both a faster rate and a longer filling period were positively correlated with kernel size and thus yield. Both the DMA and GFP were measured in the present study to assess their importance in grain yield increases and to determine the heritability of each trait.

2.3 SOLAR RADIATION AND TEMPERATURE EFFECTS

Delays in tassel initiation or flowering of maize grown under long photoperiods have been shown repeatedly (Coligado et al., 1975; Francis, 1970, 1972; Kiesselbach, 1950; Lee, 1980; Thomas, 1948). Most maize genotypes are considered to be quantitative short-day plants since maize can flower under a 24-hour photoperiod (Francis, 1972; Thomas, 1948).

Day-neutral genotypes have also been identified, indicating genotypic variation for photoperiod response (Francis et al., 1970; Thomas, 1948).

Tropical-adapted varieties show higher photoperiod sensitivity than temperate (Darrah and Penny, 1974; Eberhart et al., 1973; Francis, 1972; Lee, 1980; Jong et al., 1982). Total accumulated light during tropical maize growing seasons is greatly reduced by shorter days, greater cloud coverage, and a shortened season due to high temperatures. Therefore, the yields of maize in the lowland tropics are generally very low compared with those of temperate regions, even with comparably high inputs.

Jong et al. (1982) found that cyclical changes of grain yield and its components closely followed those of solar radiation with a coefficient of determination of 78.5%. "Solar radiation was found to be the single most influential climatic factor affecting yield components. Average daily irradiance in the third month of growth (grain-fill period) explained more than 50% of the variation in grain yield" (Jong et al., 1982).

Temperature has been found to be a major influence on the maturation rate of corn. Variations in temperature parallel amounts of incident radiation throughout the year in Hawaii. Jong et al. (1982) found that a major effect of cool temperature on yield was an extension of the GFP and an increase in total light interception. Yields were thus significantly enhanced when light values were low. "The correlation of high yield with high elevation (low temperature) in the tropics is proposed to result largely from extended grain-filling periods under the cooler highland temperatures" (Jong et al., 1982). Hanway and Russell (1969) found similar results in 1964-5 trials conducted in Ames, Iowa. Lower temperatures in 1965 accounted for a slower rate of DMA and an extended GFP. Other morphological and physiological traits of corn affected by lower temperatures and solar radiation include reduced leaf area expansion and total plant DMA (Castleberry et al., 1978), decreased photosynthesis due to lower leaf temperature and slower phenological development, and shorter plant height due to smaller internode lengths and numbers (Duncan et al., 1973).

2.4 GRAIN YIELD COMPONENTS

The grain yield of maize plants can be considered as the result of two major components: 1.) caryopses number and development potential, and 2.) the photosynthate quantity translocated to the ear following fertilization. Kernel development goes through three physiological phases as follows: 1.) the lag period from silking to the onset of dry matter accumulation (DMA), 2.) the linear (DMA) period, and 3.) a phase with a slowing DMA rate ending with physiological maturity as defined by the formation of a black aleurone layer (Johnson and Tanner, 1972).

The parameters characterizing such kernel development components, their genetic and environmental variability, and their relationships to other physiological and morphological traits are needed to plan future production breeding (Mock and Pierce, 1975). Although it has been clearly established that the length of the reproductive period is an important yield component, various studies concerning the variability in this trait have shown contrasting results (Cross, 1975; Daynard and Kannenberg, 1976; Gunn and Christensen, 1965; Hanway and Russell, 1969).

Genetic differences with regard to the grain filling period (GFP) duration and the dry matter accumulation (DMA) rate have been studied with varying results (Carter and Poneleit, 1973; Hallauer and Russell, 1962; Hillson and Penny, 1965; Johnson and Tanner, 1972; Ottaviano et al., 1976; and Poneleit and Egli, 1979). There is some debate as to whether increasing the DMA rate or extending the GFP has a more significant effect on yield. Moreover, correlations between these two physiological parameters with yield and other morphological and physiological traits have generally been based on phenotypic values, whereas for breeding purposes correlations based on genetic effects are necessary.

In 1981, Ottaviano and Camussi of the Genetics Institute in Milan reported studies of certain kernel development components and their genetic relationships with yield. Physiological components of kernel development - lag period, GFP duration, DMA rate - in addition to ear moisture release, ear size (number of rows and kernels/row), days from emergence to silking, and number of leaves were examined on 45 F_1 hybrids (10 x 10 diallel cross) and their parents to determine genetic yield relationships (Ottaviano and Camussi, 1981).

They found that general combining ability (g.c.a.) effects described the genetic features of the parental lines with regard to the yield components studied. All the ear components significantly affected plant yields. Rate of DMA had the most significant effects, with the GFP duration following closely behind. No significant contribution of the lag period was detected. Negative effects on kernel weight arising mainly through DMA rate were found to be the result of ear size. Important specific combining ability (s.c.a.) effects were found for ear size on plant yield. Days from emergence to silking was negatively correlated with yield and positively correlated with leaf number, although it accounted for a small portion of yield variation. Ear moisture release, was found to be negatively correlated with number of lag period days, DMA rate, and GFP duration.

In conclusion, the three components taken to represent kernel weight (lag period days, DMA rate, and GFP duration) showed genetic variation arising mainly from g.c.a. effects. This indicates that such traits can be genetically improved and that selection programs can be based on simple methods taking advantage of additive genetic variance. In connection with breeding programs, it was noted that the lag period and GFP showed large amounts of genotype-environment interaction, while DMA rate was more stable. Similar results were obtained by Poneleit and Egli (1979) who found that GFP, but not DMA rate, is influenced by plant density.

2.5 DIALLEL ANALYSIS PROCEDURES

The diallel cross in plant breeding is defined as "all possible combinations of single crosses among 'n' parents", therefore, equaling n^2. Designs have been developed which utilize only part of the possible diallel matings. One such method is the half-diallel which considers crosses made in only one direction while assuming the reciprocal crosses yield the same results.

There are four underlying assumptions in diallel cross analysis (Griffing, 1956): 1.) parents are a random sample set from a population, chosen, or fixed set; 2.) parents are inbred lines derived from a parent population free from forces affecting gene frequency; 3.) segregation is normal and diploid; and 4.) linkage is absent. Based on these assumptions, Griffing (1956) also designed four different forms of analysis: 1.) parents with one set of F_1's and reciprocal F_1's; 2.) parents with one set of F_1's excluding reciprocal F_1's; 3.) F_1's and reciprocal F_1's but excluding parents; and 4.) one set of F_1's excluding reciprocal F_1's and parents.

Gardner and Eberhart (1966) presented a model for the estimation of genetic effects from the diallel cross of a fixed set of varieties. Their model was designed for parents and one set of F_1's while assuming arbitrary gene frequencies at all loci, diploid inheritance, two alleles per locus, and no epistasis. The analysis was partitioned into Varieties vs. Crosses which reflected average heterosis, and general and specific combining ability.

Both the Griffing (1956) and Gardner and Eberhart (1966) models focus on the estimation of genetic effects seen in a diallel cross. These effects are partitioned into general and specific combining ability. "General combining ability" (g.c.a.) has been defined as the average performance of a line in hybrid combination (Sprague and Tatum, 1942). In cases where a hybrid performs better or worse than expected, based on the parental line average, specific combining ability (s.c.a.) is said to occur.

Most critics of diallel analyses note that the assumption of independent gene distribution is rarely met, and that linkage of genes would violate such a premise (Baker 1978). Hayman (1954) calculated that the degree of dominance will be overestimated due to lack of parental gene independence. It is also necessary to assume no epistasis is present when using the Griffing or Gardner and Eberhart models. Interpretation should thus be limited to estimating general and specific combining ability mean squares and effects. Extrapolation of statistical results to include allele distribution, dominance, number of genes, or additive and dominant genetic variance can build on false assumptions (Baker 1978).

CHAPTER 3

MATERIALS AND METHODS

3.1 GRAIN FILLING PERIOD AND DRY MATTER ACCUMULATION RATES OF TROPICAL INBREDS

3.1.1 SITE DESCRIPTION AND PREPARATION

Trials were conducted at two locations during two seasons. The first trial was planted May 3, 1989 at the University of Hawaii Agriculture Experiment Station in Waimanalo, Oahu. The station is located on the northeast corner of the island at longitude 157^{o}, 43'W and latitude 20^{o}, 20' 30" N and an elevation averaging 21 m. Soils are well drained Vertic Haplustolls belonging to the Waialua series. They are derived from basic igneous rock with a pH of 6 - 6.5 in the surface horizon.

September 27, 1989 was the planting date of the second trial which was conducted at the UH Experiment Station in Kapaa, Kauai. This station is at an elevation of approximately 137 m and is on the central east side of the island. The location is at longitude 159^{o}, 28'W and latitude 22^{o}, 3'N. Soil type is of the Halii series consisting of well-drained silty clay soils developed in material weathered from basic igneous rock mixed with volcanic ash and ejecta

(Ikawa et al., 1985).

The field sites at both stations were tractor plowed and treated with Eradicane and Atrazine (pre and post-emergent herbicides). Then 150:90:90 N:P:K was added as side-dressing. Rows were planted 75 cm apart and seeds planted 20 cm apart with 2-3 seeds/hill which were later thinned to 1 plant/hill. Three rows of the earlier maturing Hawaiian Supersweet #9 were planted as borders.

3.1.2 VARIETY SELECTION AND DESCRIPTION

One hundred tropical adapted maize inbreds were selected from a wide resource base of the Maize Inbred Resistance program conducted by Dr. James Brewbaker of the University of Hawaii. Seed was obtained through the Hawaii Foundation Seed Facility (HFSF) located in Waimanalo, Oahu. Inbreds were chosen on the basis of outstanding performance in international yield and pest-resistance trials since 1980.

Inbred names, place and date of origins, available breeding pedigrees, seed colors and types are recorded in Table 1 (Brewbaker et al., 1989). Inbreds represented extremely diverse origins from the North and South Americas to Africa, across India to Thailand and the Philippines. The majority (>90%) of this tropical adapted germplasm is highly sensitive to long daylengths (Brewbaker, 1981).

3.1.3 EXPERIMENTAL DESIGN

A randomized complete block design with 2 replicates was used with 100 inbreds with 25 plants/inbred in one-row plots. Trials were planted at two separate locations under two different seasons as: Waimanalo/summer planting = May 3, 1989; and Kapaa/winter planting = Sept. 27, 1989. Five separate harvests were obtained from each plot with two samples/harvest collected as the first ears on separate random plants. Ears were chosen, husked in the field, and then placed in a dryer at 25°C for at least a week before shelling and kernel sample collection. Figure 3.1 is a field layout of the randomized complete blocks with 100 varieties and two replicates.

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////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////
///..2.1..4.2.3..5.43.1..5..   ...4.2..13.5..1.2..5.4..3///
///.3..5.1.24..5.1..2..3.4..   ..1.2..3.5.4.2..5.3..1.4.///
///                                                     ///
///      < 100 of these rows for replicate 1 >         ///
///                                                     ///
///                                                     ///
///                                                     ///
///      < 100 more rows for replicate 2 >             ///
///                                                     ///
///                                                     ///
////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////

/// = Hawaiian supersweet #9 border plants
....... = 25 plants/inbred/row
..1..1. = two ears selected from separate random plants for
          the first harvest date
.2...2. = two ears selected randomly for the second harvest
..3.3.. = two ears for the third harvest date
.4..4.. = fourth harvest
...5.5. = final harvest
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Figure 3.1. Field layout for 1989 Waimanalo/summer and Kapaa/winter trials with 100 maize inbred varieties in two replicates. Border rows and sampling procedure per row are demonstrated.

3.1.4 DATA COLLECTION AND ANALYSIS

One week after planting, germination percentages were estimated for each plot by counting the number of seedlings and dividing by fifty (based on 1 row plots X 25 plants/row X 2 seed/hill = 50 seedlings). Two weeks later, plants were thinned to one per hill prior to urea sidedressing. Silking (i.e., pollination) began to occur at the Waimanalo summer trial on June 18, 1989 which is about six weeks after planting. A pollination date was recorded for each plot when 50% of the ears had silk emergence. Ears which were the most uniform in size and silking date were spray-painted red for easy identification when sampling began. The same procedure was followed for the Kapaa winter trial. Due to low germination percentages obtained from the Waimanalo trial, stock seed was increased and mixed, then used for the Kapaa planting. Silking at Kapaa began on November 24, 1989 almost eight weeks after planting. Plant development was retarded by about two weeks for the winter trial due to the decrease in temperature and solar insolation.

Fourteen days after pollination (i.e., 14 DAP) for each plot, two red-painted ears were randomly harvested, husked, and placed together in the dryer. When the ears were sufficiently dry (in about 4 days), 20 kernels/ear were shelled from the middle portion of the cob, placed in envelopes, and dried at 30^{o}C for one week. At 21, 28, and 35 DAP, samples were collected and processed in the same manner. Since most corn plants reach final physiological maturity at 45+ DAP, one final harvest for all plots was collected at one time. The Waimanalo summer trial was therefore harvested on August 1, 1989, and the Kapaa winter trial on January 8, 1990.

Samples were weighed on a Sartorius analytical balance (Sartorius Corp., Bohemia, NY) and recorded as kernel weight (KW) in grams at 14, 21, 28, 35 DAP, and final harvest. Linear regression analysis was performed on the KWs at four dates (14 to 35 DAP) for 100 inbreds at each location with PC-SAS (SAS Institute, Cary, NC). The Johnson and Tanner (1972) method of calculating the DMA rate and GFP duration was employed. DMA rate was defined as daily kernel dry weight gain in g/day and equals the slope of the linear equation produced by PC-SAS. R-square values were retained to compare goodness of fit between the regression lines for each inbred.

The duration of the grain filling period (GFP) for each inbred was estimated in number of days, calculated by dividing final Kernel Weight (KW) (grams) by the DMA rate (grams/day). The GFP can be determined by the time of black layer formation, but this is very tedious for such a large number of inbreds. The method employed for GFP clearly can lead to errors, however, when yields are abnormally low due to disease or pest damage. While these problems were minimal in the summer trial, they were occasionally serious in the winter. Table 2 in the appendix is a list of germination percentages and specific inbred problems with *Fusarium* rots and bird damage.

Data was recorded on Lotus 123 spreadsheets (Lotus Development Corp., Cambridge, Mass.), and linear regression analysis, general linear model, univariate, and t-test procedures performed with PC-SAS. Macintosh Cricket graphics (Apple Computer, Inc., Cupertino, CA) was used to produce figures and slides.

Other agronomic traits were also measured to assess solar radiation and temperature effects. In addition to the germination percentages and the pollination dates, plant and ear heights were recorded for each plot. Simple visual estimation was used to select a plant of uniform size for each plot. Plant height was then measured from the ground to the top of the tassel with a meter stick to the nearest decimeter. Ear heights were measured in similar fashion from the ground to the basal node of the first or uppermost ear.

3.2 DMA/GFP QUANTITATIVE GENETICS

3.2.1 PARENTAL SELECTION

From the trial results of the previous study, fifteen inbreds were chosen as possible parents for a diallel. Inbreds were chosen from the means of the 1989 Waimanalo summer and Kapaa winter trials for the traits of DMA rate, GFP duration, and a calculated R^2 value > .80. Selection criteria for these traits was as follows: combinations of slow, medium, and fast DMA rates based on a mean of 6.24 +/- 0.5 g/day with short, average, and long GFP periods from a mean of 41.3 +/- 2.0 days. The fifteen inbreds with mean DMA rates, GFP periods, and combination descriptions are:

	INBRED	DMA RATE (g/day)	GFP (days)	COMBINATION (DMA, GFP)
1.	B37	5.70	40.7	slow, avg.
2.	CIM.A6	4.65	63.6	slow, long
3.	Fla2AT116	4.73	50.6	slow, long
4.	Hi26	7.90	40.2	fast, avg.
5.	Hi27	7.04	36.9	fast, short
6.	Hi28	5.94	45.2	med., long
7.	Hi33	6.66	37.8	med., short
8.	Hi41	4.99	47.6	slow, long
9.	KU1409	8.35*	41.5*	fast, avg.
10.	KU1414	7.00	45.3	fast, long
11.	MIT 2-S6	5.61	46.2	slow, long
12.	Tx601	5.99	38.9	med., short
13.	Tx602	8.90	32.1	fast, short
14.	Tzi3	7.40	40.1	fast, avg.
15.	Tzi4	4.70	53.9	slow, long

(* signifies that data is from Waimanalo trial only, prolems at Kapaa with this inbred deemed data unuseable)

These inbreds were planted on March 23, 1990 at the Waimanalo Station for observation and final selection of seven parents for crossing. Inbreds were planted as a RCB with 3 replicates, 2 rows/plot, and 25 plants/row. Final parent selection was based on good stand, disease resistance, and uniformity both within the plots and between inbreds for DTS for easy cross pollination. Seven inbreds were chosen for crossing to ensure success with at least six parents for diallel analysis. The seven inbreds chosen were the following: B37, CIM.A6, Fla2AT116, Hi27, KU1414, Tx601, and Tzi3.

3.2.2 DIALLEL CROSS DESCRIPTION

Seven parental inbreds were crossed in the following manner to attempt to produce 21 F_1 hybrids:

	B37	CIM.A6	Fla2AT116	Hi27	KU1414	Tx601	Tzi3
B37		X	X	X	X	X	X
CIM.A6			X	X	X	X	X
Fla2AT116				X	X	X	X
Hi27					X	X	X
KU1414						X	X
Tx601							X

Almost half of the crosses made with CIM.A6 as a parent were unsuccessful. Therefore, the remaining six parents were used with their 15 hybrids to perform further studies on quantitative genetics.

3.2.3 EXPERIMENTAL DESIGN

Six inbred parents with their fifteen hybrids were planted on July 26, 1990 at the Waimanalo Experiment Station and on July 28, 1990 at the Kapaa Experiment Station. A randomized complete block design was used with three replicates, 2 rows/plot, 15 plants/row, and 2-3 seed/hill. The field sites at both stations were prepared as in Study 1 including border rows of Hawaiian Supersweet #9.

Five separate harvests were obtained from each plot with three samples/harvest. Harvest times were at 14, 21, 28, 35 DAP, and final maturity. Samples were taken from separate random plants as the first or uppermost ear. The ears were husked in the field and placed in a dryer at 25^{o}C for one week prior to kernel shelling of fifty kernels per ear.

3.2.4 DATA COLLECTION AND ANALYSIS

Germination percentages were taken at both locations one to two weeks after planting. Percentages were estimated by counting the number of seedlings per plot and dividing by sixty (based on 2 rows/plot X 15 plants/row X 2 seed/hill = 60 seedlings). About two weeks later, plants were thinned to one per hill, and then sidedressed with urea. Ears at both locations were covered on each plant to achieve uniform pollination. When 75% of the covered ears in a plot began silk emergence, those ears were uncovered and marked with spray paint, and the pollination date recorded. Ear silk emergence (therefore, pollination) began about seven weeks after planting on Sept. 11, 1990 at Waimanalo and Sept. 17, 1990 at Kapaa.

Two weeks after pollination for a plot (i.e., 14 DAP), three painted ears were randomly harvested, husked, and placed together in the dryer at 25^{o} for one week. Kernel samples were taken from the middle portion of each ear and placed in separate envelopes with 50 kernels/ear/envelope. The envelopes were then placed in a freezer at -5^{o} for a minimum of two days to kill any corn weevils. The frozen kernel samples were transferred to a dryer at $30^{o}C$ for one week to remove all kernel moisture. At 21, 28, and 35 DAP, ear samples were harvested, husked, shelled, and processed in the same manner. One final harvest was collected at one time since all the corn plants reached physiological maturity and ceased kernel DMA at 45+ DAP. Samples were collected and processed as described for future calculations of GFP. The Waimanalo final harvest was taken on November 6, 1990 and the Kapaa harvest was two days later.

Kernel weights at each of the five harvests were recorded and linear regression analysis performed on the 14-35 DAP samples as in Study 1 (Section 3.1.4, data collection and analysis). The regression analysis was performed on each of the six parents and fifteen hybrids at each of the 2 locations using PC-SAS. The DMA rates and GFPs were calculated for each of the 21 entries at each location as in Study 1 using the Johnson and Tanner (1972) method (Section 3.1.4, data collection and analysis). Tables 5.1 and 5.2 (Chapter 5) are summaries of the 21 entries in alphabetical order with the observed final KWs, estimated DMA rates, calculated GFPs, and R^2 values produced for each location.

CHAPTER 4

GRAIN FILLING PERIOD AND DRY MATTER ACCUMULATION RATES OF TROPICAL MAIZE INBREDS

One hundred tropical maize inbreds were grown in two trials. The Waimanalo trial was conducted in the summer months under optimal growth conditions. In contrast, the Kapaa trial was in the winter under cool tem-peratures, reduced incident light and elevated levels of disease (Appendix Table 2). Data were taken on dry matter accumulation at weekly intervals between 14 and 35 days after pollination, together with mature dry kernel weights. These were used to calculate regression values for dry matter accumulation rates (DMA) for each inbred. Grain filling periods (GFP) were calculated by the Johnson and Tanner method (1972) of dividing the final KW by DMA rate for each inbred. Final kernel weights (KW) may be seen as the result of the product of DMA and GFP.

Final kernel weights, DMA rates, and the calculated GFP durations (cf. Johnson and Tanner, 1972) are summarized in Appendix Table 3. The final KW and DMA values were significantly lower for the winter trial at Kapaa, with means of 200.6 g/MVK (thousand viable kernels) and 4.68 g/day DMA. In contrast, the Waimanalo summer trial averages were significantly higher, 295.4 g/MVK and 7.79 g/day. The GFP was significantly longer in the Kapaa winter trial, under cooler temperatures, averaging 43.5 days vs. 39.1 days at Waimanalo in the summer. These variations, to be discussed, appear to relate directly to temperature values, as noted also in Hawaii by Jong et al. (1982).

Kernel weights, DMA and GFP values are summarized in Table 4.1 for five inbreds with the largest and smallest kernels among the hundred tested at each of the two locations. The extremely low values may be discounted due to disease. A wide range of values was observed at both locations for KW, DMA and GFP. R^2 values were estimated by PC-SAS for linear regression of 14-35 DAP kernel weight samples over time (DAP).

Table 4.1 Kernel weights (KW), dry matter accumulation rates (DMA), and grain filling periods (GFP) for the highest and lowest yielding inbreds from 1989 Waimanalo/summer and Kapaa/winter trials.

1. WAIMANALO - SUMMER 1989 MAY 3 - AUG. 3

Inbred	Final KW (g/MVS)	DMA rate (g/day)	GFP (days)	R^2
T232	440.2	11.37	38.7	.99
KU1403	387.6	7.37	52.6	.98
ICA L27	385.2	8.98	42.9	.98
H632F	384.6	12.95	29.7	.92
ICA L224	367.4	9.86	37.2	.92
B73	226.8	7.01	32.3	.99
Mp496	224.5	6.30	35.6	.97
H84	218.7	6.79	32.2	.94
Hi32	211.0	8.72	24.2	.82
HIX4231	142.0	7.01	20.2	.98

2. KAPAA - WINTER 1989 SEPT. 27 - JAN. 8

Inbred	Final KW (g/MVS)	DMA rate (g/day)	GFP (days)	R^2
H632F	303.9	5.08	59.8	.90
A619	287.4	4.73	60.8	.93
Va35	269.9	5.76	46.9	.87
KU1418	259.8	4.95	52.5	.85
Phil DMR6-S5	257.7	8.06	32.0	.91
HIX4267	143.5	3.94	36.4	.91
Mo20W	136.9	3.37	40.6	.84
HIX4263	134.5	5.07	26.5	.83
CIM.T11-ES	129.6	4.06	31.9	.94
SC43	94.5	2.55	37.0	.90

4.1 FREQUENCY DISTRIBUTIONS, NORMALITY, AND t-TESTS

The PC-SAS UNIVARIATE procedure was run to test the normality of each data set. The Final KWs (g/MVK) for both the Waimanalo summer and Kapaa winter trials were found to be normally distributed with Shapiro-Wilk statistics (W) = 0.99. Due to poor germination and some Fusarium interference, only 96 of the original 100 inbreds planted at Waimanalo, and 89 of 100 at Kapaa survived for complete data analysis. Germination percentages and experimental complications for each inbred at each 1989 trial are listed in Table 2 of the Appendix.

The mean final KW at Waimanalo was calculated as 295.4 g/MVK with standard deviation (STD) = 44.5 g/MVK. The coefficient of variation (C.V.) was determined to be 15% and skewness (SKW) was equal to 0.04. The Kapaa final KW mean = 200.6 g/MVK with STD = 36.4 g/MVK, C.V. = 18%, and SKW = 0.13. The t-TEST procedure showed that the final KWs were significantly different between the two trials by calculating a t value of -15.91. Figure 4.1 is a graphical representation of the frequency distributions for observed final KWs from the 1989 Waimanalo and Kapaa trials. Table 4 in the appendix is a complete listing of the final kernel weights (KW) per inbred sorted in descending order for each trial..pa

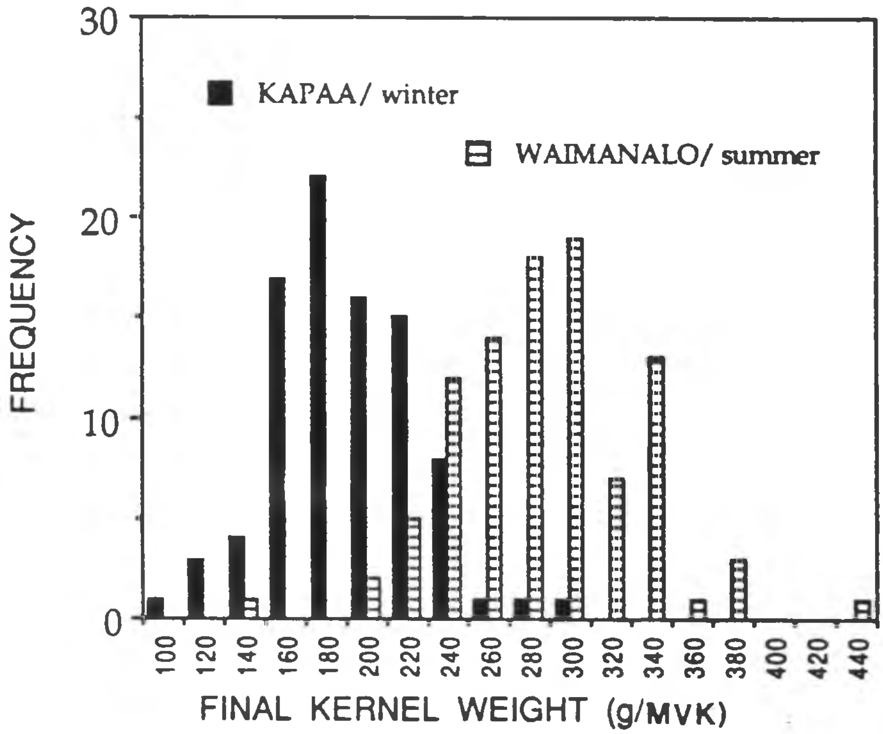

Figure 4.1 Frequency distribution for the observed final kernel dry weights (KW) in grams per 1000 viable kernels (MVK) for the 1989 Waimanalo summer and Kapaa winter trials.

The UNIVARIATE procedure also showed normal distribution of the estimated DMA rates for both the Waimanalo summer and Kapaa winter trials with W = 0.97 (Shapiro-Wilk statistic, SAS, ver. 6). The mean DMA rate for Waimanalo was 7.79 g/day with STD = 1.60 g/day. The C.V. was estimated to be 20% and SKW = 0.65. The Kapaa trial showed the estimated DMA rate mean to be 4.83 g/day with a STD of 1.5 g/day. The C.V. determined for this trial was 31% and SKW = 0.64. The t-TEST procedure calculated t = -13.12 which infers highly significant differences between the two sets of DMA rates. The frequency distributions are represented in Figure 4.2 for the estimated DMA rates (g/day) for the two trials. A list of all DMA rates for these trials is sorted in descending order in Table 5 of the appendix. Comparing the frequency distributions (Fig. 4.2) and the sorted list (Table 5, Appendix) to the specific inbred complications (Table 2, Appendix), the outlying DMA rates are usually due to missing data or samples damaged by Fusarium or weevils. More realistically, DMA rates appear to range from 5 - 10.5 g/day for the Waimanalo trial and from about 3 - 8 g/day at Kapaa.

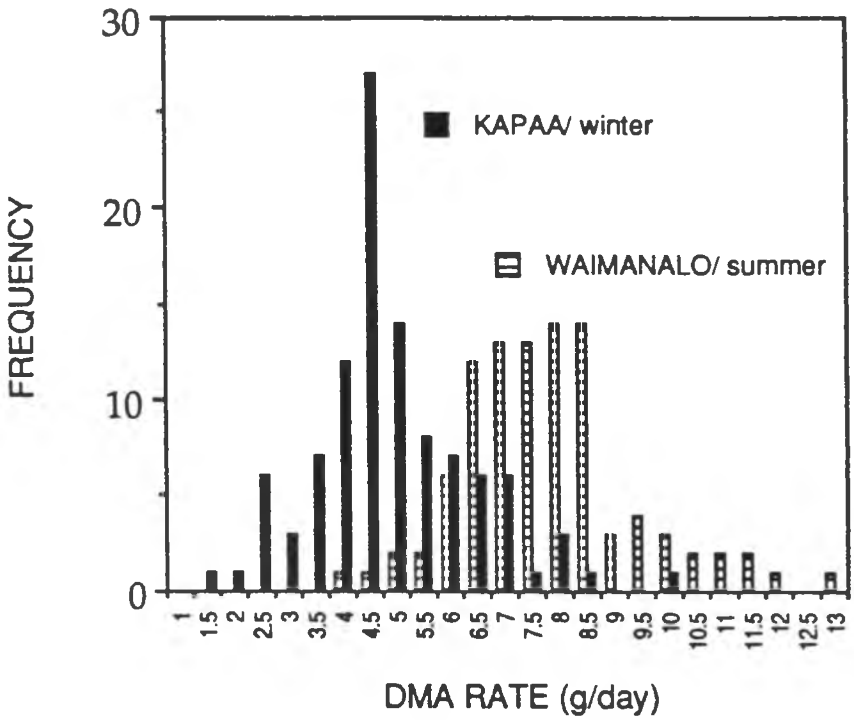

Figure 4.2 Frequency distribution for the estimated dry matter accumulation (DMA) rates in grams per day for the 1989 Waimanalo summer and Kapaa winter trials.

The GFP durations calculated for the Kapaa trial deviated slightly from the normal distribution with W = 0.85. The calculated GFPs for Waimanalo showed normality with W = 0.95. The mean GFPs for the two trials were very similar as compared to the final KW and DMA rate frequency distributions. The Waimanalo GFP duration mean = 39.1 days, STD = 8.5 days, C.V. = 22%, and SKW = 1.05. The Kapaa GFP mean = 45.5 days but had a high STD = 17.4 days, and the C.V. was also very high at 38% with skewness = 1.96. A t value of 3.14 was produced by the SAS t-TEST procedure showing significant differences between the two trials. This significance was not as high as the final KW and DMA rate t statistics of -15.91 and -13.12 respectively. Figure 4.3 shows the frequency distributions for GFP duration (days) for the 1989 Waimanalo summer and Kapaa winter trials. A complete listing is given in appendix Table 5 for the lengths of GFPs, sorted in descending order for all inbreds at each location. Comparing the data of GFP frequencies (graphed in Figure 4.3) to the inbred complications listed in appendix Table 2 clarifies the majority of extreme outlying values. In reality, GFP duration lasts a minimum of 33 days with some inbreds showing black layer at the 35 DAP harvest, and no longer than 55 days at Waimanalo in the summertime. At Kapaa during the winter, GFP usually lasts a minimum of 35 days but could be extended up to 65 days. The outlying values for GFP are magnified due to calculations based upon an estimated DMA rate, which may itself be quite erroneous due to trial complications. Examples of such are shown where the inbreds H632F, NC248, and Hi26 all have extremely high DMA rates at Waimanalo (Appendix Table 5) and unrealistically low GFP durations (Appendix Table 6) for the same trial.

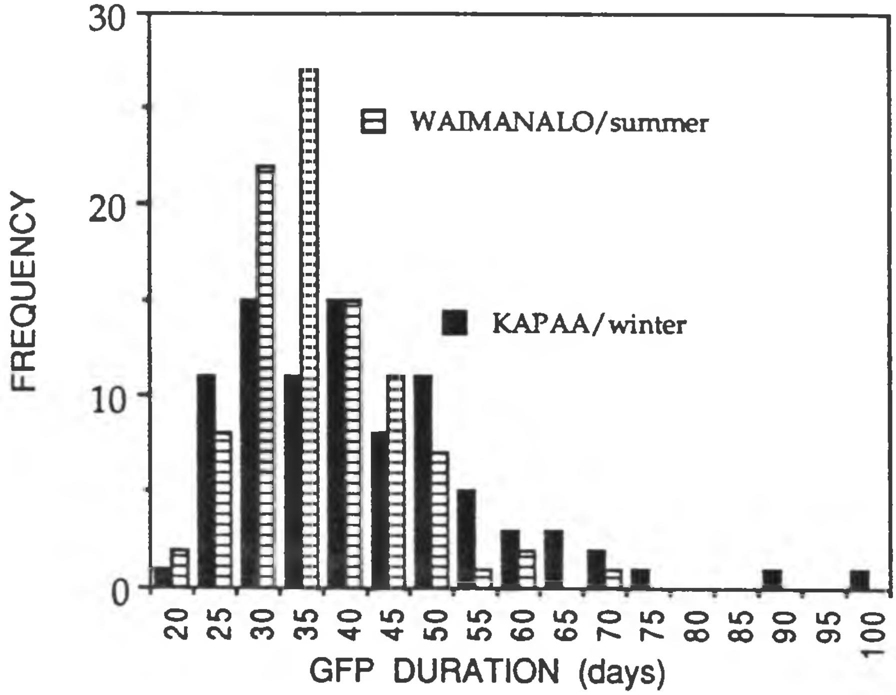

Figure 4.3 Frequency distribution for the calculated grain filling period (GFP) durations for the 1989 Waimanalo summer and Kapaa winter trials.

4.2 ANOVAS FOR HARVEST DATES

Separate analysis of variance procedures were performed on PC-SAS for the 14, 21, 28, and 35 days after pollination (DAP) harvests. The General Linear Models procedure was used with samples included in the model statement. Data was first sorted by harvest date, then a PROC GLM was run with replicates, inbreds, and samples defined as classes. The model statement included deviations between samples and a separate statement to calculate experimental error. Degrees of freedom were corrected for missing data points.

Table 4.2 shows the ANOVA table for the 1989 Waimanalo trial. Highly significant differences were found among inbreds for all harvest dates. Such high significant differences were expected since the 100 inbreds originated from very diverse backgrounds (Appendix Table 1). No significant differences were found between replicates or for experimental error for all harvest dates. The highest coefficient of variation (30.4%) was found for the 14 DAP harvest with the other dates showing variations < 11.8%. A higher coefficient of variation (C.V.) was expected for the 14 DAP harvest, since the inbreds were just beginning to change from the lag period into the linear DMA growth pattern. The C.V. was lowest for the 35 DAP harvest as expected since inbreds are approaching final yield peaks and physiological maturity. This trial at Waimanalo had few disease, insect, or bird problems and virtually no weed competition.

Table 4.2. Analysis of variance of 4 different days after pollination (DAP) harvests during the 1989 Waimanalo summer trial.

	14 DAP Harvest		21 DAP Harvest		28 DAP Harvest		35 DAP Harvest	
Source	df	MS	df	MS	df	MS	df	MS
Rep	1	0.020	1	0.008	1	0.006	1	0.003
Inbred	95	0.069**	95	0.100**	95	0.271**	95	0.454**
Exp Err	95	0.011	95	0.008	95	0.022	95	0.047
Samp Err	183	0.012	187	0.008	183	0.034	186	0.038
Total	374		378		374		377	
C.V. (%)	30.4		11.4		11.7		8.0	

* Significance at 0.05 level of probability
** Significance at 0.01 level of probability

The Kapaa trial showed quite different results. Since this experiment was conducted during the rainy fall and winter months, there was overall poorer performance and many problems with several diseases. The Kapaa Experiment Station has had additional problems with bird damage for many corn trials. Such experimental difficulties are listed in Appendix Table 2 with the germination percentages. These problems are reflected in reduced yields (Appendix Table 3) and in the ANOVA (Table 4.3). Sample numbers were significantly reduced, as reflected in the corrected degrees of freedom for missing values. Highly significant differences were found between inbreds for all harvests, as expected and observed in the Waimanalo trial. Significant differences were found among replicates for the 14 DAP harvest which may be explained by variations due to growth rate pattern changes. The 14 and 28 DAP harvests showed highly significant differences for experimental error which are most likely due to the high disease and other field problems (Appendix Table 2). The coefficients of variation were quite different with 21.8% at 14 DAP, 24.3% at 21 DAP, and 14.2% at 28 DAP. The lowest C.V. occurred at 28 DAP as the DMA growth curve for kernels began to stabilize and approach maximum yield as in the Waimanalo trial. Since there was such poor plant survival during the winter trial, a 35 DAP harvest was not taken in order to ensure enough samples would be available for the final harvest.

Table 4.3. Analysis of variance of 3 different days after pollination (DAP) harvests during the 1989 Kapaa winter trial.

Source	14 DAP Harvest df	14 DAP Harvest MS	21 DAP Harvest df	21 DAP Harvest MS	28 DAP Harvest df	28 DAP Harvest MS
Rep	1	0.021*	1	0.000	1	0.001
Inbred	91	0.008**	92	0.079**	95	0.189**
Exp Err	80	0.003**	88	0.014	90	0.029**
Samp Err	168	0.002	179	0.028	181	0.015
Total	340		360		367	
C.V. (%)	21.8		24.3		14.2	

* Significance at 0.05 level of probability
** Significance at 0.01 level of probability

4.3 TEMPERATURE EFFECTS ON AGRONOMIC TRAITS

Figure 4.4 is a graphical representation of monthly mean temperatures beginning January 1989 and continuing through November 1990 for the Waimanalo, Oahu and Kapaa, Kauai Experiment Stations. The months over which the Waimanalo summer and Kapaa winter trials were run are shown as labeled horizontal lines. The diallel trials (Study 2, Chapter 5) were run simultaneously at Waimanalo and Kapaa during the summer of 1990. The net effects of reduced temperatures from summer to winter were shorter plant and thus ear heights, and an increase in the number of days to silking (i.e., from germination to pollination).

Plant heights were found to be normally distributed at both locations with a mean of 2.25 meters at Waimanalo and 1.90 meters at Kapaa. Decreased solar radiation from summer to winter is also assumed to have affected the plant heights. Figures 4.5 - 4.8 show the plant height differences between the two locations/seasons. The inbreds are labeled as numbers 1 - 96 and the specific names may be located in Appendix Table 3.

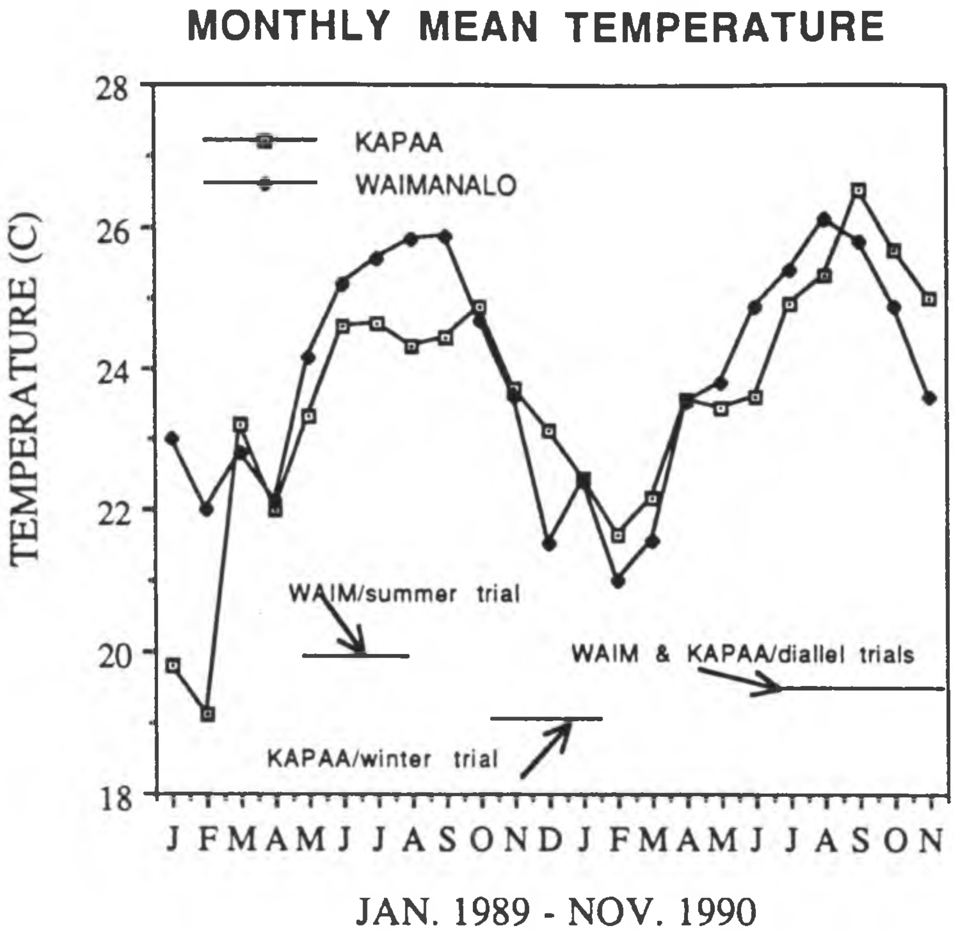

Figure 4.4 Monthly mean tempurature for 1989 and 1990 at the Waimanalo, Oahu and Kapaa, Kauai Agriculture Experiment Stations.

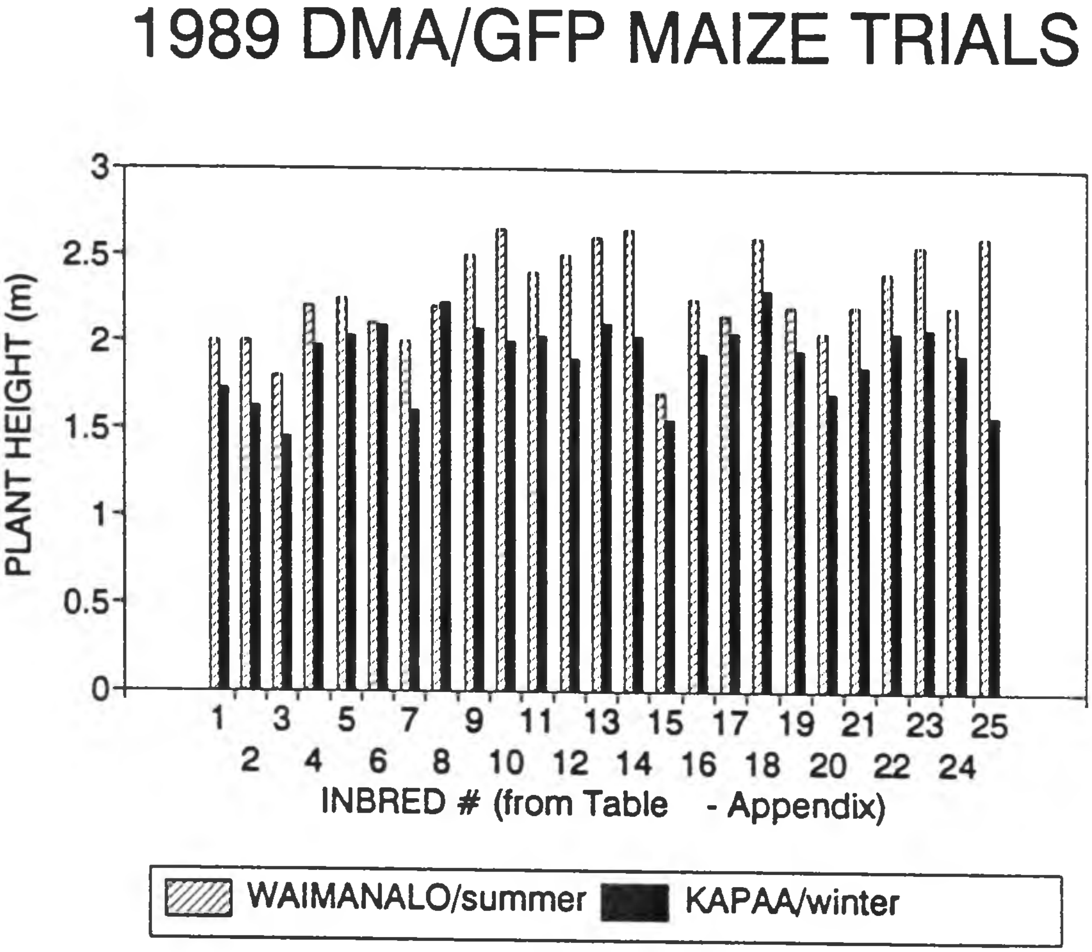

Figure 4.5 Estimated mean plant height in meters for Inbreds A619 through Fla2BT106 as numbered in Appendix Table 3.

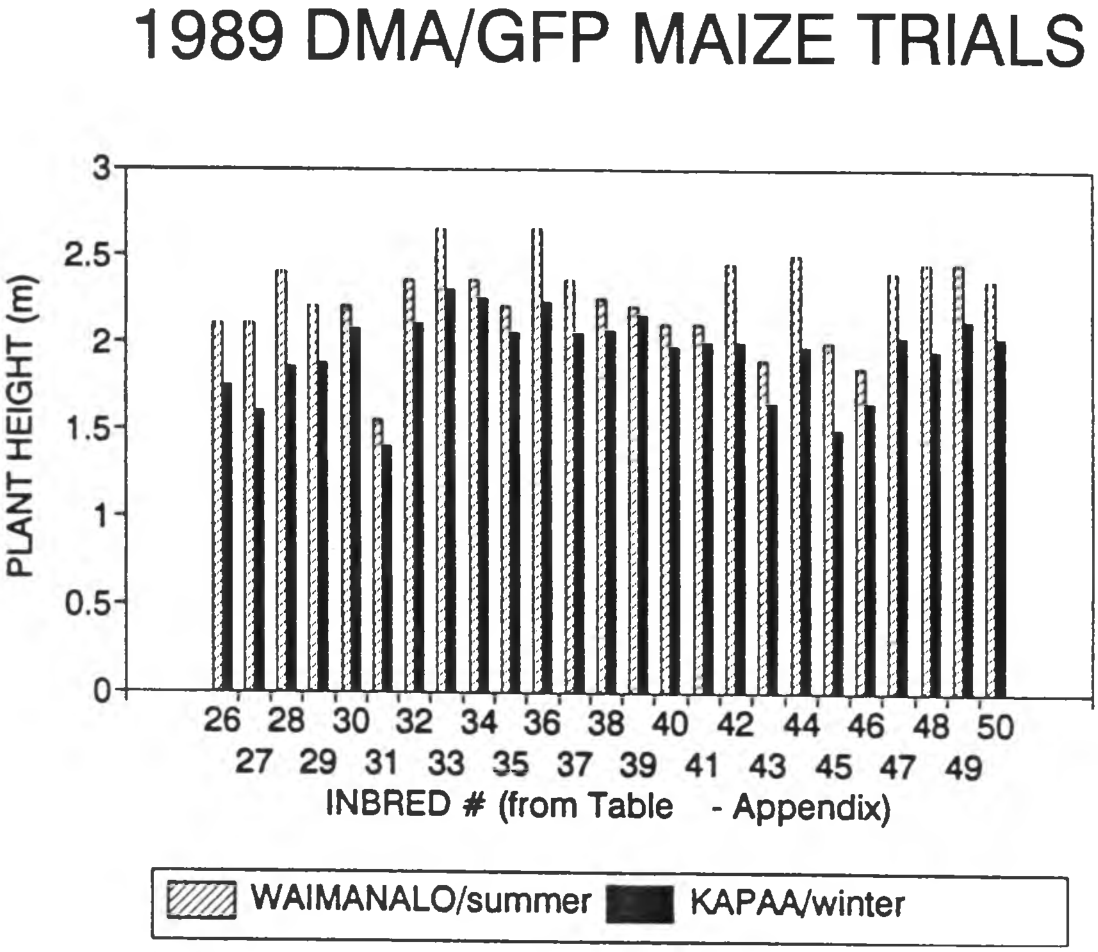

Figure 4.6 Estimated mean plant height in meters for Inbreds Ga209 through ICA L210 as numbered in Appendix Table 3.

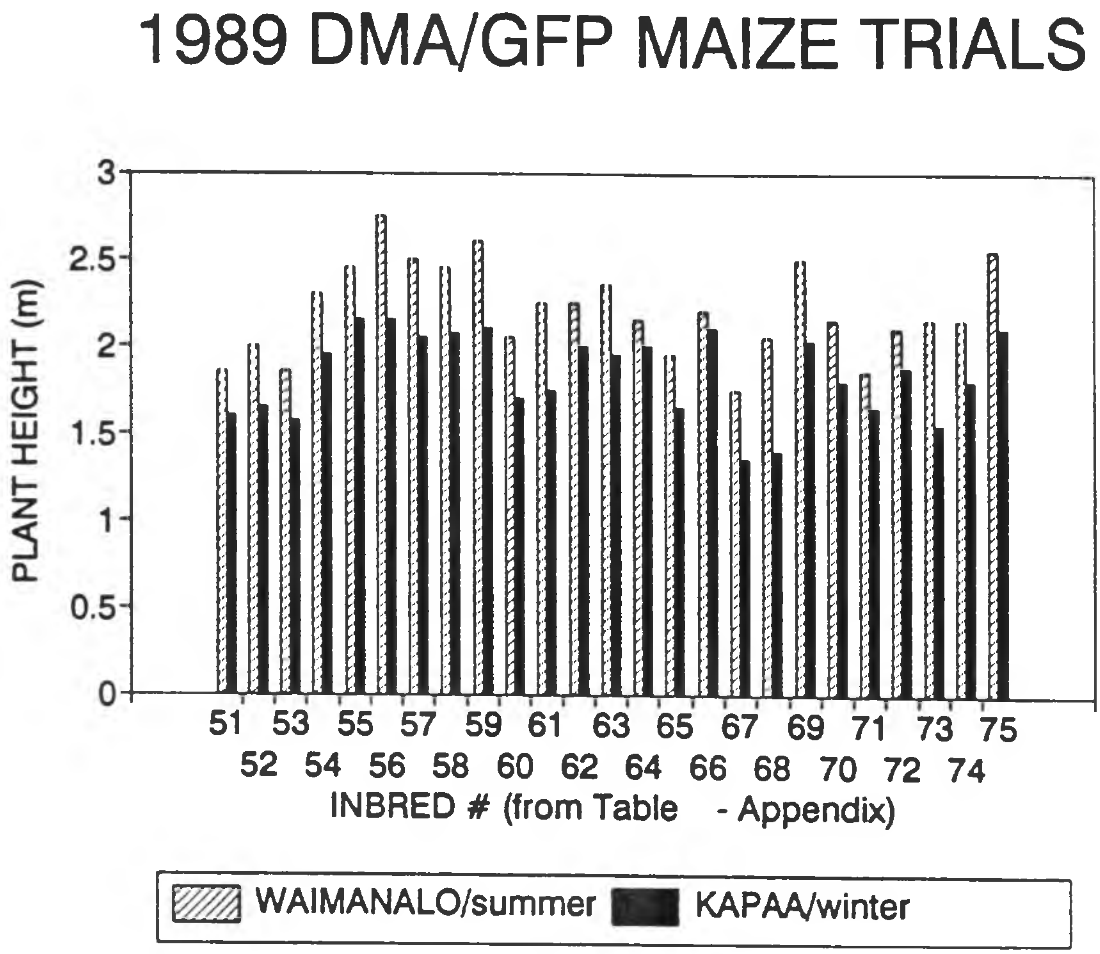

Figure 4.7 Estimated mean plant height in meters for Inbreds ICA L219 through NC248 as numbered in Appendix Table 3.

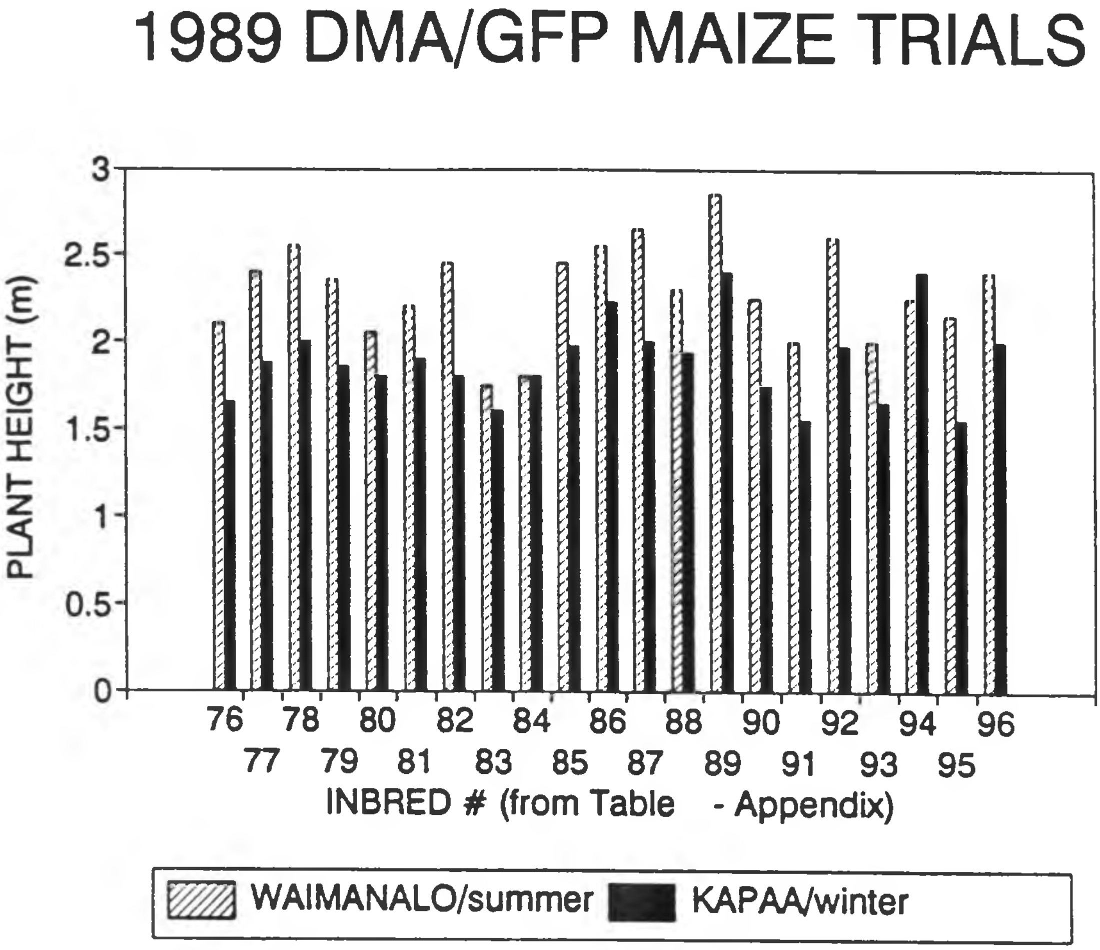

Figure 4.8 Estimated mean plant height in meters for Inbreds Oh43 through W64A as numbered in Appendix Table 3.

Ear heights are normally proportional to plant heights with about a 1.25 meter difference between the top of the stalk and the basal node of the uppermost ear. The mean ear height for the Waimanalo summer trial was 0.98 m which is 1.27 m less than the mean plant height. As mean plant heights decreased for each inbred during the winter Kapaa trial, the mean ear height decreased proportionately to 0.59 m. However, the difference between the plant height and ear height means was 1.3 m which was close to that of Waimanalo. Appendix Table 7 lists mean plant and ear heights and the difference between the two for each inbred in the 1989 trials. Standard deviations of all measurements were about 0.2 m and are listed in Appendix Table 7.

The number of days between germination and ear silk emer gence (i.e., days to silking, DTS) is known to be delayed by reduced temperatures and solar radiation. Such was evident in the mean DTS of 53 days at Waimanalo and 67 days at Kapaa. The standard deviation from the mean was 4 days at Waimanalo and 3.9 days at Kapaa. Mean temperatures for each trial during the DTS period were 24.8^{o}C for Waimanalo and 23.1^{o}C for the winter Kapaa trial. The number of DTS for each inbred per each trial are summarized in Appendix Table 8. Every inbred had a delay in the number of days to silking from the Waimanalo trial to the Kapaa trial. The average number of days that silking was delayed was about two weeks. Heavy cloud coverage at the Kapaa Experiment Station during the winter season greatly inhibits amounts of solar radiation thus aiding in the delay of DTS.

In general, germination percentages for tropical maize are usually reduced during the winter season. The opposite was true for the 1989 Waimanalo summer and Kapaa winter trials as summarized in Appendix Table 2. Such is probably due to the fact that the HFSF stock seed was increased during the summer of 1989, and the replenished seed was used for planting the Kapaa trial in late September (Chapter 3, Materials & Methods, Section 3.1.4). The majority of inbreds showing a low germination percentage at Waimanalo had improved viability at Kapaa as a result of the stock seed increase.

CHAPTER 5

DMA/GFP QUANTITATIVE GENETICS

Six parental inbreds were selected on the basis of earlier results and crossed as a half-diallel, planted with their hybrids, and data collected for calculating DMA and GFP. Parent crossing was performed at the Waimanalo Experiment Station during the spring of 1990. Two trials were planted simultaneously at Waimanalo and Kapaa, Kauai late in July 1990. Data were taken on dry matter accumulation at weekly intervals between 14 and 35 days after pollination, together with mature dry kernel weights of the six inbreds and their fifteen hybrids grown in 4 replicates. Linear regression analysis on the 14-35 DAP samples was used to estimate the dry matter accumulation (DMA) rate and grain filling period (GFP) for each parent and hybrid at each location.

Griffing's method II of diallel analysis was performed on the DMA rates, GFP periods, and final kernel weights to test for the effects of general and specific combining ability. General combining ability (g.c.a.) effects reflect the genetic ability of a parent to influence all of its progeny in the trait measured. Therefore, assessing which parents may successfully increase the DMA rate and extend the GFP period for a hybrid will enable breeders to produce higher yielding hybrids. The g.c.a. is an expression of additive genetic effects, those most easily influenced by selection. Specific combining ability (s.c.a.) effects represent departure from performance predicted on a simple additive model. In other words, s.c.a effects are high if two parents who usually produce high-performance hybrids end up making a poor hybrid when crossed. The s.c.a. effects reflect non-additive gene effects which possibly result from intra- or inter-genic interactions or multiplicative gene action.

5.1 RESULTS OF DIALLEL TRIALS

Results of the diallel study of the 6 inbred parents with their 15 hybrids grown at the Waimanalo Station are summarized in Table 5.1. The mean for the observed final KW was 292.1 g/MVK, ranging from a low of 242 (inbred Tx601) to a high of 322, with a standard deviation of 25.4 g/MVK. The coefficient of variation (C.V.) for final KW was fairly low at 8.7%. The mean for the estimated rates of DMA at Waimanalo was 6.53 g/day, and STD = 1.44 g/day, and C.V. = 22.0%. The calculated GFP duration mean = 47.1 days with a high STD = 12 days, and a high C.V. = 25.5%. R^2 values for goodness of fit for KWs from the 4 harvests to a linear regression had a mean of 0.84 and STD = 0.10.

The DMA rates estimated for the two parents, Tx601 and Tzi3, were very poor with R^2 values of 0.53 and 0.65 respectively. The DMA rate listed in Table 5.1 for Tx601 = 2.98 g/day and for Tzi3 = 4.14 g/day. These rates are extremely low as compared to other parents and to results from the earlier study (Appendix Table 3), where Tx601 had values of KW = 287 g/MVK with DMA = 7.17 g/day and Tzi3 had values of KW = 343 g/MVK with DMA = 9.54 g/day (Waimanalo data). The error of such low DMA rates was magnified in the calculations for the GFP durations with Tx601 = 81.2 days and Tzi3 = 77.7 days. In reality, grain filling lasts no longer than 50 days for any of the inbreds when grown at Waimanalo under sunny, warm, summer conditions.

Table 5.1. Summary results of 6 parents with 15 hybrids from half-diallel study at Waimanalo 1990.

Code	Inbred/Hybrid	Final KW* (g/MVK)	DMA RATE* (g/day)	GFP* (days)	Rsqr*
1	B37	247.0	5.50	44.9	0.78
2	Fla2AT116	281.6	4.74	59.4	0.77
3	Hi27	265.2	5.72	46.4	0.77
4	KU1414	315.1	6.08	51.8	0.75
5	Tx601	242.1	2.98	81.2	0.53
6	Tzi3	321.6	4.14	77.7	0.65
1x2	B37 X Fla2AT116	276.0	5.34	51.7	0.82
1x3	B37 X Hi27	288.8	6.70	43.1	0.88
1x4	B37 X KU1414	321.9	7.52	42.8	0.92
1x5	B37 X Tx601	273.0	5.76	47.4	0.83
1x6	B37 X Tzi3	276.0	7.66	36.0	0.87
2x3	Fla2AT116 X Hi27	281.7	6.88	40.9	0.89
2x4	Fla2AT116 X KU1414	348.2	7.92	44.0	0.92
2x5	Fla2AT116 X Tx601	304.1	7.22	42.1	0.91
2x6	Fla2AT116 X Tzi3	318.4	7.46	42.7	0.90
3x4	Hi27 X KU1414	288.4	7.66	37.7	0.91
3x5	Hi27 X Tx601	275.2	6.26	44.0	0.87
3x6	Hi27 X Tzi3	306.4	6.92	44.3	0.88
4x5	Ku1414 X Tx601	296.3	8.52	34.8	0.92
4x6	KU1414 X Tzi3	296.9	9.08	32.7	0.97
5x6	Tx601 X Tzi3	311.2	7.04	44.2	0.88
	MEAN =	292.1	6.53	47.1	0.84
	STD =	25.4	1.44	12.0	0.10
	C.V.(%) =	8.7	22.01	25.5	12.00

* Final KW = Observed final kernel weights measured in grams per 1000 kernels based on 3 reps, 3 samples/rep.
MVK = 1000 viable kernels
DMA RATE = Dry matter accumulation rate in grams per day as estimated by linear regression analysis of kernel weights for 4 harvest dates based on 3 reps, 3 samples/rep.
GFP = Grain filling period duration as calculated by the Johnson and Tanner method = (Final KW)/(DMA rate).
Rsqr = Coefficient of determination for linear regression analysis of kernel weights for 4 harvest dates based on 3 reps, 3 samples/rep.

Results from the duplicate trial conducted at Kapaa, Kauai were very similar to those from Waimanalo (Table 5.2). Mean final KW was found to be 216.3 g/MVK with STD of 37.3 g/MVS, and C.V. = 17.2%. The mean for the estimated DMA rates equaled 6.8 g/day having a STD of 1.41 g/day and C.V. = 20.67%. The calculated GFP durations had a low mean of 32.6 days and a STD of 6 days with C.V. = 18.4%. The coefficients of determination (i.e., Rsqr.) had a mean of 0.85 with STD of 0.09 which was within 0.01 of the mean and STD of the Waimanalo trial. The coefficients of variation were more erratic for the Kapaa trial than for Waimanalo. A high C.V. of 17.2% was determined for the observed final KWs. The C.V. increased to 20.67% for the estimated DMA rates, yet was lower at 18.4% for the GFP durations which calculations were based on the rates of DMA.

Table 5.2. Summary results of 6 parents with 15 hybrids from half-diallel study at Kapaa, Kauai 1990.

Code	Inbred/Hybrid	Final KW* (g/MVK)	DMA RATE* (g/day)	GFP* (days)	Rsqr*
1	B37	150.1	5.20	28.9	0.83
2	Fla2AT116	171.9	5.58	30.8	0.85
3	Hi27	169.4	6.52	26.0	0.70
4	KU1414	215.5	5.88	36.6	0.73
5	Tx601	134.2	3.74	35.9	0.74
6	Tzi3	198.5	3.66	54.2	0.57
1x2	B37 X Fla2AT116	193.5	6.82	28.4	0.88
1x3	B37 X Hi27	227.2	6.28	36.2	0.90
1x4	B37 X KU1414	241.2	7.48	32.2	0.90
1x5	B37 X Tx601	210.4	6.42	32.8	0.88
1x6	B37 X Tzi3	245.8	8.04	30.6	0.88
2x3	Fla2AT116 X Hi27	197.4	6.86	28.8	0.87
2x4	Fla2AT116 X KU1414	273.7	8.26	33.1	0.93
2x5	Fla2AT116 X Tx601	231.7	7.54	30.7	0.91
2x6	Fla2AT116 X Tzi3	256.1	8.00	32.0	0.91
3x4	Hi27 X KU1414	211.4	8.22	25.7	0.93
3x5	Hi27 X Tx601	210.7	6.74	31.3	0.87
3x6	Hi27 X Tzi3	241.2	6.84	35.3	0.85
4x5	KU1414 X Tx601	228.8	9.12	25.1	0.91
4x6	KU1414 X Tzi3	268.7	8.62	31.2	0.97
5x6	Tx601 X Tzi3	265.2	6.94	38.2	0.85
	MEAN =	216.3	6.80	32.6	0.85
	STD =	37.3	1.41	6.0	0.09
	C.V.(%) =	17.2	20.67	18.4	10.71

* Final KW = Observed final kernel weights measured in grams per 1000 kernels based on 3 reps, 3 samples/rep.
MVK = 1000 viable kernels
DMA RATE = Dry matter accumulation rate in grams per day as estimated by linear regression analysis of kernel weights for 4 harvest dates based on 3 reps, 3 samples/rep.
GFP = Grain filling period duration as calculated by the Johnson and Tanner method = (Final KW)/(DMA rate).
Rsqr = Coefficient of determination for linear regression analysis of kernel weights for 4 harvest dates based on 3 reps, 3 samples/rep.

Kernel weights were lower at Kapaa with a mean of 216.3 g/MVK versus 292.1 g/MVK at Waimanalo. These reduced weights were most likely due to increased cloud coverage at Kapaa, decreasing the amount of solar insolation received for dry matter accumulation. The average rate of DMA, however, was lower at Waimanalo (6.53) g/day versus 6.8 g/day for Kapaa. The calculated GFP was thus longer for Waimanalo at 47.1 days than for Kapaa at 32.6 days.

Comparing the results of Waimanalo (Table 5.1) to Kapaa (Table 5.2), temperatures were about 0.7°C cooler at Waimanalo (Figure 4.4) during the grain filling months of these 1990 trials. These lower temperatures appear to have slightly reduced the DMA rates (6.8 vs. 6.53 g/day) yet extended the GFPs enough to have the net effect of increased yield. The mean DMA rate at Waimanalo fell only 4% below the mean at Kapaa, but the GFP mean was extended by 44% (14.5 days) with STD of 6.0 days largely as a result of the high KW values at Waimanalo. In short, the Kapaa data do not appear completely plausible, for unknown reasons.

5.2 GRIFFING'S METHOD II OF DIALLEL ANALYSIS

Griffing's approach to diallel cross analysis includes four underlying assumptions: 1.) parents are a random sample set from a population, chosen, or fixed set; 2.) parents are inbred lines derived from a parent population free from forces affecting gene frequency; 3.) segregation is normal and diploid; and 4.) linkage is absent (Griffing, 1956). Based on these assumptions, Griffing also designed four different forms of analysis : 1.) parents with one set of F_1's and reciprocal F_1's; 2.) parents with one set of F_1's excluding reciprocal F_1's; 3.) F_1's and reciprocal F_1's but excluding parents; and 4.) one set of F_1's excluding reciprocal F_1's and parents.

5.2.1 DIALLEL ANALYSIS OF KERNEL DRY WEIGHT

Samples of 50 kernels at final maturity were dried exhaustively, weighed and recorded for each inbred and hybrid for the 1990 Waimanalo and Kapaa trials (Table 5.11). The observed weights were multiplied by 20 to give a final kernel weight in grams per thousand kernels (g/MVK). Along with the observed final kernel weights at each location, the mean and difference for the two locations are given for each entry. The data were analyzed using Griffing's (1956) Method II of Diallel Analysis on spreadsheet (Lotus123).

The mean final kernel weight observed for Waimanalo was 292.15 g/MVK with a standard deviation (STD) of 25.4 g/MVK (Table 5.11). Kapaa yielded a much lower mean of 213.87 g/MVK with a higher STD of 37.30 g/MVK. The average kernel dry weight at final maturity was 253.01 g/MVK with STD of 29.57 g/MVK for the combined locations. A wide range in differences of observed final kernel weights between the locations was from 28.2 to 123.1 g/MVK. The mean of the differences was 78.28 g/MVK with STD of 23.99 g/MVK.

Table 5.3. Kernel dry weights at maturity for 6 inbreds and 15 hybrids from the Waimanalo and Kapaa trials.

1990 - KERNEL DRY WEIGHTS AT FINAL MATURITY (g/MVK)

ENTRY	Waimanalo	Kapaa	MEAN	DIFF
B37	247.0	150.1	198.55	96.9
Fla2AT116	281.6	171.9	226.75	109.7
Hi27	265.2	169.4	217.30	95.8
KU1414	315.1	215.5	265.39	99.6
Tx601	242.1	134.2	188.15	107.9
Tzi3	321.6	198.5	260.05	123.1
B37 x Fla2AT116	276.0	193.5	234.75	82.5
B37 x Hi27	288.8	227.2	258.00	61.6
B37 x KU1414	321.9	241.2	281.55	80.7
B37 x Tx601	273.0	210.4	241.70	62.6
B37 x Tzi3	276.0	245.8	260.90	30.2
Fla2AT116 x Hi27	281.7	197.4	239.55	84.3
Fla2AT116 x KU1414	348.2	273.7	310.95	74.5
Fla2AT116 x Tx601	304.1	231.7	267.90	72.4
Fla2AT116 x Tzi3	318.4	256.1	287.25	62.3
Hi27 x KU1414	288.4	211.4	249.90	77.0
Hi27 x Tx601	275.2	210.7	242.95	64.5
Hi27 x Tzi3	306.4	241.2	273.80	65.2
KU1414 x Tx601	296.3	228.8	262.55	67.5
KU1414 x Tzi3	296.9	268.7	282.80	28.2
Tx601 x Tzi3	311.2	265.2	288.20	46.0
MEAN =	292.2	213.9	253.01	78.3
STD =	25.4	37.3	29.57	24.0

The analysis of variance for the kernel dry weights observed at final maturity for the inbreds and hybrids is shown in Table 5.12. The location x entry interaction was used as the error term. Highly significant differences were found between locations and entries. When the source "Entries" was subdivided into Parents, Parents vs. Hybrids, and Hybrids, each was found to have highly significant differences. A much higher F value of 44.27 was calculated for the source Parents vs. Hybrids than for Parents at 6.58 and Hybrids at 3.17. Such implies that there are greater differences found between the group of inbred parents and their hybrids than among the parents as a group and the hybrids as a group. The ANOV in Table 5.12 had an unusually low coefficient of variation (C.V.) of 0.71%.

Table 5.4. Analysis of variance for the kernel dry weights for 6 parental inbreds and their 15 hybrids from the 1990 Waimanalo and Kapaa trials.

Source	df	SS	MS	F
TOTAL	41	103148.65		
LOCATIONS	1	60382.29	60382.29	199.87**
ENTRIES	20	36724.06	1836.20	6.08**
Parents	5	9932.54	1986.51	6.58**
Parents vs. Hybr	1	13373.57	13373.57	44.27**
Hybrids	14	13417.95	958.42	3.17**
ERROR	20	6042.30	302.12	

C.V. = 0.71%

* Significance at 0.05 level of probability
** Significance at 0.01 level of probability

The diallel matrix of kernel dry weights is shown in Table 5.13. All hybrids had higher final kernel dry weights than the parental inbreds with the exception of the two heaviest parents KU1414 and Tzi3 at 265.3 and 260.1 g/MVK respectively. These two heaviest parents produced hybrids with the largest dry kernel weights all greater than 260.0 g/MVK with the exception of KU1414 x Hi27 at 249.9 g/MVK. The remaining four parental inbreds produced hybrids having similar ranges in final kernel dry weights. Hybrid average KWs for the 6 parents ranged only from 253 to 279 g/MVK, with a mean of 265.5 g/MVK. These values were well correlated with parental values (r^2=73.6%), although values for Hi27 and Tx601 exchanged positions in ranking.

Table 5.5. Diallel matrix of parental combinations and resultant kernel dry weights observed at final maturity for the 1990 Waimanalo and Kapaa trials.

	KERNEL DRY WEIGHT AT FINAL MATURITY (g/MVK)						
Parent	B37	Fla2AT116	Hi27	KU1414	Tx601	Tzi3	F_1 AVG
B37	198.6	234.8	258.0	281.6	241.7	260.9	255.4
Fla2AT116		226.8	239.6	311.0	267.9	287.3	268.1
Hi27			217.3	249.9	243.0	273.8	252.9
KU1414				265.3	262.6	282.8	277.6
Tx601					188.2	288.2	260.7
Tzi3						260.1	278.6

An analysis of general and specific combining abilities using Griffing's (1956) Method II for the Random Model is shown in Table 5.14. The entry "Hybrids" from Table 5.12 is subdivided for degrees of freedom (df) and Sum of Squares (SS) to permit comparisons of general combining ability (g.c.a.) and specific combining ability (s.c.a.). The degrees of freedom are divided in the following way: GCA has (n-1) df, and SCA has (n(n-3)/2) df where n = the number of parents which produced the hybrids. The variance ratio of GCA to SCA was 2.38:1. Estimations of the components of additive, dominant, and error variances are calculated at the bottom of Table 5.14. These components were used to estimate broad and narrow sense heritability values of 83.5% and 25.6% for the kernel dry weight. The fact that non-additive ("dominant") genetic variance component (531) far exceeded additive variance component (118) accounts for the great discrepancy in heritability values. Published data on KW suggest that this set of inbreds showed unusually high non-additive variance for KW.

Table 5.6. Analysis of variance of kernel dry weights observed at final maturity for inbreds and hybrids from the 1990 Waimanalo and Kapaa trials for combining ability analysis, Griffing Meth. II

Source	df	SS	MS	Random Model
GCA	5	8118.12	1623.62	Ve + rVsca + r(p+2)Vgca
SCA	9	10243.91	1138.21	Ve + rVsca
ERROR	20	3021.15	151.06	Ve

where Vgca = 1/(p+2) (MSgca - MSsca) = 117.6
Vsca = MSsca - MSE = 531.5
And, Vgca = 1/2 Va (Additive variance)
Vsca = Vd (Dominance variance); therefore
Va = 2 Vgca = 253.21
Vd = Vsca = 531.51
Ve = MSerror = 151.06, and,
Heritability in the narrow sense can be estimated by nH = Va/(Va + Vd + Ve) = 25.6%.
Heritability in the broad sense is estimated by bH = (Va + Vd)/(Va + Vd + Ve) = 83.5%.

5.2.2 DIALLEL ANALYSIS OF DRY MATTER ACCUMULATION

Using Griffing's method II, DMA rate data from the 1990 Waimanalo and Kapaa trials were analyzed including the inbred parents and one set of hybrid F_1's. The mean DMA rate for each parent and hybrid from each location is listed in Table 5.3 along with the average and difference of the locations for each entry. The mean DMA rate at Waimanalo was 6.5 g/day with a standard deviation (STD) of 1.4 g/day. The Kapaa DMA rate mean = 6.8 g/day with STD also = 1.4 g/day. The differences in DMA rates estimated between the two locations were very small, ranging from 0.0 - 0.8 g/day with the mean and STD both equal to 0.3 g/day.

Table 5.7. Dry matter accumulation (DMA) rates as estimated by PC-SAS linear regression for the 1990 Waimanalo and Kapaa trials. The mean and difference for the two locations are given for each entry.

ENTRY	DMA RATES (g/day) Waimanalo Rep I	Kapaa Rep II	MEAN	DIFF
B37	5.5	5.2	5.35	0.3
Fla2AT116	4.7	5.6	5.16	0.8
Hi27	5.7	6.5	6.12	0.8
KU1414	6.1	5.9	5.98	0.2
Tx601	3.0	3.7	3.36	0.8
Tzi3	4.1	3.7	3.90	0.5
B37 x Fla2AT116	5.3	6.8	6.08	0.5
B37 x Hi27	6.7	6.3	6.49	0.4
B37 x KU1414	7.5	7.5	7.50	0.0
B37 x Tx601	5.8	6.4	6.09	0.7
B37 x Tzi3	7.7	8.0	7.85	0.4
Fla2AT116 x Hi27	6.9	6.9	6.90	0.0
Fla2AT116 x KU1414	7.9	8.3	8.09	0.3
Fla2AT116 x Tx601	7.2	7.5	7.38	0.3
Fla2AT116 x Tzi3	7.5	8.0	7.73	0.5
Hi27 x KU1414	7.7	8.2	7.94	0.6
Hi27 x Tx601	6.3	6.7	6.50	0.5
Hi27 x Tzi3	6.9	6.8	6.85	0.1
KU1414 x Tx601	8.5	9.1	8.82	0.6
KU1414 x Tzi3	9.1	8.6	8.85	0.5
Tx601 x Tzi3	7.0	6.9	6.99	0.1
MEAN =	6.5	6.8	6.66	0.3
STD =	1.4	1.4	1.40	0.3

An Analysis of Variance (ANOV) for the DMA rates listed in Table 5.3 using Griffing's (1956) Diallel Analysis Method II was performed with Lotus 123. DMA rates showed that all main effects were significant (Table 5.4). This analysis was performed using results from Waimanalo as Replicate 1 and Kapaa as Replicate 2, and the coefficient of variation (C.V.) = 17.7% for the analysis (Table 5.4).

Differences between the two locations for DMA rates were not impressive (Table 5.4), but highly significant differences were found among Entries. The degrees of freedom (df) and Sum of Squares (SS) for Entries were subdivided into Parents, Hybrids, and Parents vs. Hybrids with each component showing highly significant differences. The comparison of Parents vs. Hybrids had the highest significant differences with an F value of 367.37.

Table 5.8. Analysis of variance for dry matter accumulation (DMA) rates from the 1990 Waimanalo and Kapaa trials.

Source	df	SS	MS	F
TOTAL	41	85.23		
LOCATIONS	1	0.72	0.72	5.58*
ENTRIES	20	81.931	4.10	31.76**
Parents	5	12.566	2.51	19.48**
Parents vs. Hybr	1	47.389	47.39	367.37**
Hybrids	14	21.976	1.57	12.17**
ERROR	20	2.58	0.13	

C.V. = 17.70%

* Significance at 0.05 level of probability
** Significance at 0.01 level of probability

The diallel matrix of DMA rates is given in Table 5.5. All hybrids demonstrated DMA rates that were greater than or equal to the fastest parental rate of 6.1 g/day (Hi27). The parent KU1414 produced hybrids with the fastest rates of dry matter accumulation which ranged from 7.5 to 8.9 g/day. Therefore, this inbred may become very important in future breeding strategies to increase the rate of dry matter accumulation in tropical maize hybrids. The parents which produced hybrids with the second and third highest DMA rates were Tzi3 (avg. 7.68 g/day) and Fla2AT116 (avg. 7.24 g/day). Tzi3 and Tx601 were parents with the slowest DMA rates of 3.9 and 3.4 g/day respectively (averaging 7.4 and 6.0 g/day, respectively, in the previous study - Appendix Table 3). A review of the Rsqr values listed in Tables 5.1 and 5.2 for these two inbreds shows unusually low values as compared to the other data in those tables, and for the inbreds' performance in Appendix Table 3. The DMA rates are estimates of the slope of the linear regression produced by PC-SAS, and therefore, Rsqr values measure the goodness of fit of the kernel weights from 14 - 35 DAP to a linear regression. Thus, kernel weight data that have poor linear fit will have some degree of error in the estimated DMA rates. In conclusion, DMA data on the two inbreds Tzi3 and Tx601 in this diallel are in some question. It is clear that they produce hybrids with some of the fastest DMA rates and should be studied further for their genetic effects on this desirable trait.

The three inbred parents, Hi27, Fla2AT116, and B37 produced hybrids with relatively equal ranges of DMA rates. Hybrids produced with Hi27 as a parent ranged from 6.5 to 7.9 g/day. Fla2AT116 produced hybrids which ranged from 6.1 to 8.1 g/day. The inbred parent which produced the slowest rates of dry matter accumulation was B37 with 6.1 to 7.9 g/day.

Table 5.9. Diallel matrix of parental combinations and resultant DMA rates for the 1990 Waimanalo and Kapaa trials.

	DMA RATES (g/day)						
Parent	B37	Fla2AT116	Hi27	KU1414	Tx601	Tzi3	F_1AVG
B37	5.4	6.1	6.5	7.5	6.1	7.9	6.82
Fla2AT116		5.2	6.9	8.1	7.4	7.7	7.24
Hi27			6.1	7.9	6.5	6.9	6.94
KU1414				6.0	8.8	8.9	8.24
Tx601					3.4	7.0	7.16
Tzi3						3.9	7.68

An analysis of general and specific combining abilities using Griffing's (1956) Method II for the Random Model is shown in Table 5.6. The entry "Hybrids" from Table 5.4 is subdivided for degrees of freedom (df) and Sum of Squares (SS) to permit comparisons of general combining ability (GCA) and specific combining ability (SCA). The GCA:SCA mean square ratio was 0.71, with very high relative value of SCA. Estimations of the components of additive, dominant, and error variances are calculated at the bottom of Table 5.6. These components were used to estimate the broad-sense heritability of 97%, whereas narrow-sense heritability was zero for the rate of dry matter accumulation in the hybrids studied. The predominance of non-additive effects here appear largely to be due to discrepancies in observed values for the inbred parents, perhaps due to inadequate sampling.

KU1414 and Tzi3 were the two parental inbreds which produced hybrids with the fastest rates of DMA as noted with observations of Table 5.5. KU1414 was one of the parents selected for its fast DMA rate, but Tzi3 was recorded as one of the slowest parents for rate of DMA. When reviewing the results of the GFP analysis, KU1414 was originally an average performing parent and Tzi3 had one of the longest GFPs of the parental inbreds. However, when KU1414 was crossed with the two longest GFP parents, Tx601 and Tzi3, the hybrids produced had the shortest GFPs of all the hybrids at 30.0 and 32.0 days respectively. Such observations lead to the already known conclusion that inbreds having the highest yields (greatest kernel weights) produce hybrids with the highest yields. An addition to this statement drawn from this study is that DMA rate and length of GFP interact and compensate for each other in a complex process which is very difficult to analyze. From the ANOV Tables 5.4 and 5.8, it appears that DMA rate may have more of an effect on final kernel weight (yield) than length of the GFP. It also appears to be easier to manipulate and understand the effects of breeding for increased DMA rate. Further conclusions and discussion are listed in Chapter 6 for these observations. Table 5.14 shows further quantitative analysis for the combining ability of kernel dry weight at final maturity.

Table 5.10. Analysis of variance of DMA rates from the 1990 Waimanalo and Kapaa trials for combining ability analysis in Griffing's Method II.

Source	df	SS	MS	Random Model
GCA	5	8.14	1.63	Ve + rVsca + r(p+2)Vgca
SCA	9	32.83	3.65	Ve + rVsca
ERROR	20	1.29	0.06	Ve

where Vgca = 1/(p+2) (MSgca - MSsca) = -0.0784

Vsca = MSsca - MSE = 2.127

And, Vgca = 1/2 Va (Additive variance)

Vsca = Vd (Dominance variance); therefore

Va = 2 Vgca = -0.157 (assumed to be zero)

Vd = Vsca = 2.127

Ve = MSerror = 0.064, and,

Heritability in the narrow sense can be estimated by nH = Va/(Va + Vd + Ve) = 0.

Broad sense heritability was:

bH = (Va + Vd)/(Va + Vd + Ve) = 96.8%.

5.2.3 DIALLEL ANALYSIS OF GRAIN FILLING PERIOD

The grain filling periods calculated from the 1990 Waimanalo and Kapaa trials were analyzed using Griffing's (1956) method II of diallel analysis. This method evaluates the inbred parents and one set of hybrid F_1's. The mean GFP for each parent and hybrid from each location is listed in Table 5.7 along with the average and difference of the locations for each entry.

The mean GFP calculated for Waimanalo was 47.1 days with a standard deviation (STD) of 12.0 days. The Kapaa GFP mean = 31.5 days with STD = 6.0 days. The difference in GFP days between the two locations ranged from 1.5 to 23.5 days with outliers of 28.6 and 45.3 days for Fla2AT116 and Tx601. Two extreme outlying values for GFP at Waimanalo of 81.2 and 77.7 days for Tx601 and Tzi3 are unrealistically high. Such are a result of calculations based on data having very low Rsqr values of 0.53 and 0.65 for linear fit (Table 5.1). In actuality, grain filling in tropical maize lasts no longer than 60 days which is an extremely long, slow filling period.

When Table 5.7 is separated into parental inbreds vs. hybrids, the range in differences between locations is much more variable for the inbreds from 15.2 to 45.3 days. The range of differences for the hybrids is only 1.5 to 14.6 days with an outlier of 23.3. Such demonstrates the occurrence of more uniform performance with hybridization.

Table 5.11. Grain filling periods (GFP) as calculated by the Johnson and Tanner method for the 1990 Waimanalo and Kapaa trials. The mean and difference for the two locations are given for each entry.

	1990 - GFP (days)			
ENTRY	Waimanalo Rep I	Kapaa Rep II	MEAN	DIFF
B37	44.9	28.9	36.89	16.0
Fla2AT116	59.4	30.8	45.11	28.6
Hi27	46.4	26.0	36.17	20.4
KU1414	51.8	36.6	44.24	15.2
Tx601	81.2	35.9	58.56	45.3
Tzi3	77.7	54.2	65.96	23.5
B37 x Fla2AT116	51.7	28.4	40.03	23.3
B37 x Hi27	43.1	36.2	39.64	6.9
B37 x KU1414	42.8	32.2	37.53	10.6
B37 x Tx601	47.4	32.8	40.08	14.6
B37 x Tzi3	36.0	30.6	33.30	5.4
Fla2AT116 x Hi27	40.9	28.8	34.86	12.1
Fla2AT116 x KU1414	44.0	33.1	38.55	10.9
Fla2AT116 x Tx601	42.1	30.7	36.42	11.4
Fla2AT116 x Tzi3	42.7	32.0	37.35	10.7
Hi27 x KU1414	37.7	25.7	31.68	12.0
Hi27 x Tx601	44.0	31.3	37.61	12.9
Hi27 x Tzi3	44.3	35.3	39.77	9.0
KU1414 x Tx601	34.8	25.1	29.93	9.7
KU1414 x Tzi3	32.7	31.2	31.93	1.5
Tx601 x Tzi3	44.2	38.2	41.21	6.0
MEAN =	47.13	31.5	39.31	15.6
STD =	11.99	6.0	8.24	9.4

Table 5.8 shows the Analysis of Variance for the GFPs calculated from the 1990 Waimanalo and Kapaa trials. This analysis is of the data presented in Table 5.7 with results from Waimanalo as Replicate 1 and Kapaa as Replicate 2. The analysis was performed on Lotus 123 using a spreadsheet form of Griffing's (1956) Diallel Analysis Method II. The Source "Entries" is subdivided for a comparison of results between the inbred parents and hybrids produced.

Highly significant differences were found between locations for the grain filling periods. As was expected, highly significant differences were found between Entries as a whole, but surprisingly, there were no significant differences found between Hybrids when the source was subdivided. There were highly significant differences found between the inbred parents which is also reflected in Table 5.7 with observance of the range of differences. The F value of 23.13 which indicates highly significant differences between the Parents vs. Hybrids is not nearly as great as the F value of 367.37 for the DMA rates of the same source (Table 5.4). Such may indicate that breeding for increased rates of DMA may be more successful than trying to extend the GFP. Further studies should be conducted to pursue this interesting premise. A very low coefficient of variation (C.V.) of 4.75% was calculated for this analysis.

Table 5.12. Analysis of variance for the calculated grain filling periods (GFP) from the 1990 Waimanalo and Kapaa trials.

Source	df	SS	MS	F
TOTAL	41	6005.60		
LOCATIONS	1	2229.43	2229.43	48.33**
ENTRIES	20	2853.56	142.68	3.09**
Parents	5	1437.21	287.44	6.23**
Parents vs. Hybr	1	1066.90	1066.90	23.13**
Hybrids	14	349.45	24.96	0.54ns
ERROR	20	922.62	46.13	

C.V. = 4.75%

* Significance at 0.05 level of probability
** Significance at 0.01 level of probability

A diallel matrix of parental combinations and resultant GFPs is shown in Table 5.9. Results are quite interesting yet more difficult to analyze than for the same form of matrix observations of the DMA rates. In general, the two parental inbreds with the shortest GFPs were B37 and Hi27 at 36.9 and 36.2 days respectively. Each of these produced hybrids with extended filling periods for all F_1s except one for B37 and two for Hi27. Therefore, it is possible to extend the period over which grain fills with some genetic manipulation, but the results do not appear to be as optimal as increasing the rate of DMA for maximizing overall yield.

The remaining four parental inbreds performed about the same in their effects on GFP. As noted in the ANOV Table 5.8, no significant differences were detected between the hybrids for the number of days in their GFPs. The range of GFPs calculated for the hybrids with these four parents were as follows:

Parent	Range of F_1 GFPs
Fla2AT116	34.9 - 40.1 days
KU1414	30.0 - 38.6 days
Tx601	30.0 - 41.2 days
Tzi3	32.0 - 41.2 days

The two inbred parents with average GFPs were Fla2AT116 and KU1414, but hybrids produced by these performed similarly to those produced by the long, extended, filling parents Tx601 and Tzi3. From review of Table 5.5 where KU1414 was noted as producing hybrids with the fastest DMA rates, this inbred also produced F_1's with the shortest GFPs. These short GFPs were 30.0 days for KU1414 x Tx601 and 32.0 days for KU1414 x Tzi3 where Tx601 and Tzi3 were the parental inbreds with the longest GFPs. It seems that the high increase in DMA rate was exchanged for the longer grain filling period.

Table 5.13. Diallel matrix of parental combinations and resultant GFPs for the 1990 Waimanalo and Kapaa trials.

	GFP (days)						
Parent	B37	Fla2AT116	Hi27	KU1414	Tx601	Tzi3	F_1 AVG
B37	36.9	40.1	39.7	37.5	40.1	33.3	38.14
Fla2AT116		45.1	34.9	38.6	36.4	37.4	37.48
Hi27			36.2	31.7	37.6	39.8	36.74
KU1414				44.2	30.0	32.0	33.96
Tx601					58.6	41.2	37.06
Tzi3						66.0	36.74

An analysis of general and specific combining abilities using Griffing's (1956) Method II for the Random Model is shown in Table 5.10. The entry "Hybrids" from Table 5.8 is subdivided for degrees of freedom (df) and Sum of Squares (SS) to permit comparisons of general combining ability (g.c.a.) and specific combining ability (s.c.a.). The degrees of freedom are divided in the following way: GCA has (n-1) df, and SCA has (n(n-3)/2) df where n = the number of parents which produced the hybrids. Estimations of the components of additive, dominant, and error variances are calculated at the bottom of Table 5.10. These components were used to estimate the percentage of heritability which was determined to be -6.60% for the duration of grain filling in the hybrids studied.

Table 5.14. Analysis of variance of GFPs from the 1990 Waimanalo and Kapaa trials for combining ability analysis in Griffing's Method II.

Source	df	SS	MS	Random Model
GCA	5	382.63	76.53	Ve + rVsca + r(p+2)Vgca
SCA	9	1044.15	116.02	Ve + rVsca
ERROR	20	461.31	23.07	Ve

where Vgca = 1/(p+2) (MSgca - MSsca) = 0.882
Vsca = MSsca - MSE = 46.590
And, Vgca = 1/2 Va (Additive variance)
Vsca = Vd (Dominance variance); therefore
Va = 2 Vgca = 1.76
Vd = Vsca = 46.59
Ve = MSerror = 23.066, and,
Heritability in the narrow sense can be estimated by nH = Va/(Va + Vd + Ve) = 2.46%.
Broad sense heritability was:
bH = (Va + Vd)/(Va + Vd + Ve) = 67.7%.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Study 1 was conducted to determine the dry matter accumulation (DMA) rates and grain filling periods (GFP) of 100 tropically derived maize inbreds, and to assess their response to solar radiation and temperature. The 100 inbreds were grown in two trials at two locations, Waimanalo and Kapaa, under two seasons, summer and winter. Attempts at collecting solar radiation data at both locations had interfence and equipment failure. Therefore, sections on solar radiation effects on DMA rate and GFP duration had to be deleted from the analysis and discussion.

The maize inbreds observed in this study are listed in Appendix Table 1. Specific plot complications and germination percentages are shown in Appendix Table 2. The observed kernel dry weights at final maturity, estimated DMA rates, and calculated GFP durations for each inbred at each location are listed in Appendix Table 3. The Waimanalo trial was conducted under summer conditions and showed a mean final kernel weight of 295.4 g/MVK and mean DMA rate of 7.79 g/day. Final kernel weights and DMA values were significantly lower for the winter trial at Kapaa with means of 200.6 g/MVK and 4.68 g/day respectively. The GFP durations were significantly longer under winter conditions at the

Kapaa trial with an average of 43.5 days versus 39.1 days at Waimanalo in the summer. Such variations appear to be directly related to temperature values as noted also by Jong et al.'s (1982) research in Hawaii. It should be noted that reduced amounts of solar radiation due to increased cloud coverage at Kapaa during the winter probably had significant effects on the DMA rates and GFP durations. It is unfortunate that the solar radiation data was erroneous and incomplete during these trials and could not be used in this analysis.

From the results of Study 1, six of the maize inbreds were crossed in diallel fashion and the parents with their 15 F_1 hybrids were evaluated for genetic control of DMA and GFP. Parental inbred crossing was performed at Waimanalo during the spring season, then two trials were planted simultaneously at Waimanalo and Kapaa during late July. Trial results of observed final kernel weights (KW), estimated DMA rates, and calculated GFPs are summarized for Waimanalo in Table 5.1 and Kapaa in Table 5.2. The final KWs were lower at Kapaa with a mean of 216.3 g/MVK whereas the Waimanalo mean was 292.1 g/MVK. Such reduced weights are most likely due to increased cloud coverage at Kapaa causing lower amounts of solar insolation received for DMA. However, solar radiation data was not available to prove such an assumption. The average DMA rate was lower for Waimanalo at 6.53 g/day than the mean of 6.8 g/day for

Kapaa. The mean GFP duration was longer for Waimanalo at 47.1 days than for Kapaa at 32.6 days. Since final kernel weights may be seen as yields, they are viewed as the product of DMA and GFP. Therefore, even though the mean DMA rate was lower for Waimanalo, the GFP was extended enough to yield an overall higher final kernel weight.

Broad-sense heritability was determined to be 83.5% for kernel dry weight at final maturity, 96.8% for rate of dry matter accumulation, and 67.7% for grain filling period duration.

Analysis of variance conducted on the parent and hybrid materials indicated that increasing the rate of DMA may have more of a significant effect on grain yields than trying to extend the grain filling period. Data implied that effects from breeding for the DMA rate may be easier to determine than selecting for extensions in the filling period. Further studies should be conducted to verify and expand on knowledge gained through these trials and analyses.

APPENDIX

Table 1. Passport data of tropical-adapted maize inbreds from the Hawaii Foundation Seed Facility at Waimanalo, Oahu.

Inbred	CLR	TYPE	MAT	DS	Origin	Date
A619 (Hi)	PY	D	E	LO	Minnesota	1961
A632 (Hi)	YBz	D	E	LO	Minnesota	1964
Antigua Comp	Y	F	EM	HI	Thailand	1975
B37 (Hi)	Y	DF	M	LO	Iowa	1958
B73 (Hi)	Y	D	EM	LO	Iowa	1972
B77 (Hi)	Y	D	M	LO	Iowa	1974
CI64 (Hi)	PY	DF	EM	MED	USDA	1965
CI66 (Hi)	Y	DF	EM	LO	USDA	1965
CIM.A-6	Y	FD	L	HI	CIMMYT	
CIM.A-21	Y	F	ML	HI	CIMMYT	
CIM.T11ES	W	F	L	HI	CIMMYT	
CM103 (Hi)	Y	F	M	HI	India	
CM116	Y	F	ML	HI	India	
CM117	Y	F	ML	MED	India	
CM118	Y	F	ML	HI	India	
CM119	Y	F		LO	India	
CM201 (Hi)	Y	FD	EM	MED	India	
CM207	Y	FD	L		India	
F44 (Hi)	Y	DF	ML	MED	Florida	
Fla2AT113	Y	FD	ML	MED	Florida	
Fla2AT114	Y	FD	L	MED	Florida	
Fla2AT115	Y	D	ML	HI	Florida	
Fla2AT116	Y	FD	ML	HI	Florida	
Fla2BT106	Y	D	ML	HI	Florida	
Fla2BT54	Y	D	ML	HI	Florida	
Fla2BT73	Y	D	ML	HI	Florida	
Ga209 (Hi)	W	DF	L	MED	Georgia	
GT112Rf	PY	FD	L	HI	Georgia	1965
H55 (Hi)	Y	DF	ML	MED	Indiana	1967
H632F	W	DF	ML	MED	Kenya	
H632G	W	DF	ML	HI	Kenya	
HIX4231	Y	FD	L	LO	Hawaii	1984
HIX4263	Y	D	M	LO	Hawaii	1984
HIX4267	Y	D	ML	LO	Hawaii	1984
HIX4283	W	F	L	MED	Hawaii	1984
Hi25	Y	D	M	LO	Hawaii	1975
Hi26	Y	D	M	LO	Hawaii	1975
Hi27	Y	F	M	HI	Hawaii	2975
Hi28	Y	F	M	MED	Hawaii	1975
Hi29	Y	F	M	MED	Hawaii	1975
Hi30	Y	F	EM	MED	Hawaii	1975

APPENDIX

(Table 1 - continued)

Inbred	CLR	TYPE	MAT	DS	Origin	Date
Hi31	Y	D	M	LO	Hawaii	1975
Hi32	Y	D	EM	LO	Hawaii	1975
Hi33	Y	D	EM	LO	Hawaii	1975
Hi34	Y	F	ML	HI	Hawaii	1980
Hi35	YBz	F	M	MED	Hawaii	1981
Hi39	Y	DF	ML	MED	Hawaii	1983
Hi40	PY	DF	M	MED	Hawaii	1983
Hi41	Y	DF	L	MED	Hawaii	1983
ICA L210	Y	FD	M	HI	Colombia	1961
ICA L219	Y	F	ML	HI	Colombia	1974
ICA L221	Y	F	ML	HI	Colombia	1974
ICA L223	W	F	ML	HI	Colombia	1975
ICA L224	W	F	ML	HI	Colombia	1975
ICA L27	W	F	L	HI	Colombia	1955
ICA L29	Y	F	ML	HI	Colombia	1959
ICA L36	Y	F	ML	HI	Colombia	1955
INV 138	Y	F	EM	MED	Texas	
INV 302	W	F	EM	MED	Texas	
INV 534	W	F	EM	HI	Texas	
INV 575	Bz	F	EM		Texas	
Ky226 (Hi)	PY	DF	M	LO	Kentucky	1967
KU1403	Y	F	M	LO	Thailand	1982
KU1409	Y	F	ML	HI	Thailand	1982
KU1414	Y	F	L	HI	Thailand	1982
KU1418	Y	F	L	HI	Thailand	1982
MIT 11-S3	W	F	M		Thailand	1975
MIT 2-S6	W	F	M	HI	Thailand	1975
Mo5 (Hi)	Y	D	EM	LO	Missouri	1958
Mo20W	W	D	ML	LO	Missouri	1970
Mp496	Y	FD	ML	HI	Mississippi	1974
Mp68:616 (Hi)	Y	FD	EM	MED	Mississippi	
N139	Y	D	ML	LO	Nebraska	1979
N28 (Hi)	Y	D	M	LO	Nebraska	1964
N6G (Hi)	Y	D	EM	LO	Nebraska	1966
NC246	Y	FD	ML	MED	N.Carolina	1976
NC248	Y	FD	ML	MED	N.Carolina	1976
NC296	W	D			N.Carolina	
Narino 330-S6	Y	F	L	MED	Thailand	1976
Oh43 (Hi)	Y	D	EM	LO	Ohio	1949
PAC90038	Y	FD	EM	LO	Australia	
Phil DMR6-S5	W	F	M	HI	Thailand	1976
SC213	Y	FD	ML	MED	S.Carolina	1957
SC301D (Hi)	W	FD	ML	MED	S.Carolina	
SC43	Y	DF	M	MED	S.Carolina	1980

(Table 1 - continued)

Inbred	CLR	TYPE	MAT	DS	Origin	Date
SR52F	W	D	ML	MED	Zimbabwe	
T232 (Hi)	Y	DF	ML	MED	Tennessee	1969
T256	Y	DF	ML	MED	Tennessee	1979
T258	Y	DF	M	MED	Tennessee	1979
TZi14	W	DF	M		Nigeria	1983
TZi17	W	F	ML	MED	Nigeria	1983
TZi18	Y	F	ML		Nigeria	1983
TZi3	W	F	M	HI	Nigeria	1983
TZi4	W	F	L		Nigeria	1983
Tuxpeno-S5	Y	D	L	HI	Thailand	1976
Tx29A (Hi)	W	FD	M	MED	Texas	1974
Tx5855	Y	D	M	LO	Texas	1977
Tx601 (Hi)	Y	F	ML	MED	Texas	1960
Tx602	Y	FD	VL		Texas	1960
Va35 (Hi)	Y	D	E	LO	Virginia	1961
W64A (Hi)	Y	D	EM	LO	Wisconsin	1956

CLR = color; W (white), Y (yellow), PY = pale yellow, R = red.
TYPE = endosperm type; D (dent), F (flint), DF (denty flint. with more flint, less dent), FD (flinty dent)
MAT = maturity to silking; VE (very early), E (early), M (midseason), L (late), VL (very late)
DS = daylength sensitivity; LO = low, MED = average, HI = high
LAT = latitude of origin

APPENDIX

Table 2. Germination percentages and trial complications HFSF maize inbred from the 1989 Waimanalo summer and Kapaa winter trials.

WAIMANALO - SUMMER			KAPAA - WINTER		
INBRED	Germ. (%)*	Complic.*	Germ. (%)*	Complic.*	TOTAL MEAN
A619	52.5	PG	54	2MD, PG	53.25
A632	80		70	2MD at FH, Fus, BD	75
Antigua Comp	80		88		84
B37	80	1MD, WD	88	2MD, PH rot	84
B73	77.5		88		82.75
B77	25	4MD, PG	22	8MD, PG	23.5
C164	85		98		91.5
C166	85	2WD	84		84.5
CIM.A-6	50		91		70.5
CIM.A-21	80		76		78
CIM.T-11ES	50		90		70
CM103	82.5		80		81.25
CM116	75		86		80.5
CM117	85		98		91.5
CM118	57.5	2MD, PG	86		71.75
CM201	70		62	2MD at FH, Fus.	66
CM207	85	1MD, WD	94		89.5
F44	65		92		78.5
Fla2AT113	60		98		79
Fla2AT114	85		96		90.5
Fla2AT115	80		78		79
Fla2AT116	82.5		82		82.25
Fla2BT54	85		62.5		73.75
Fla2BT73	100		96		98
Fla2BT106	100		90		95
Ga209	97.5	FH WD	96		96.75
GT112Rf	15	PG	72	PG	43.5
H55	77.5		36	12MD, ext. Fus.	56.75
H60	60	2MD, PG	92	1MD, BD	76
H84	97.5		94		95.75
H95	95		76		85.5
H98	10	7MD, PG	18	14MD, PG, Fus.	14
H632F	85		74		79.5
H632G	7.5	ALL MD, PG	92		49.75
Hi26	70		70		70
Hi27	80		78		79
Hi28	60		78		69
Hi29	100		100		100

APPENDIX

(Table 2 - continued)

INBRED	WAIMANALO - SUMMER Germ. (%)*	Complic.*	KAPAA - WINTER Germ. (%)*	Complic.*	TOTAL MEAN
Hi30	100		90		95
Hi31	70		92		81
Hi32	25	5MD, PG	70		47.5
Hi33	100		84		92
Hi34	95		96		95.5
Hi35	87.5		76.5		82
Hi39	55		32	PG	43.5
Hi40	50	PG	80		65
Hi41	57.5		88	4MD, PH rot	72.75
HIX4231	62.5	1WD	68		65.25
HIX4263	80		88		84
HIX4267	85		88		86.5
HIX4283	90		88		89
ICA L210	100	1WD	88	1MD, Fus.	94
ICA L219	52.5		94		73.25
ICA L221	52.5		100		76.25
ICA L223	15	PG	92		53.5
ICA L224	85		88		86.5
ICA L27	60		52	2MD, Fus.	56
ICA L29	100		97		98.5
ICA L36	100		96	2MD, PH rot	98
INV138	75		92	1MD, BD	83.5
INV302	100	1MD, 3WD	90	3MD, Fus.	95
INV36	100		100		100
INV534	100		94		97
KU1403	100		94		97
KU1409	82.5		74	15MD, ext. Fus.	78.25
KU1414	65		96		80.5
KU1418	90		58		74
Ky226	60		82		71
MIT 2-S6	75		90		82.5
Mo5	95	1MD, WD	98		96.5
Mo20W	70		90		80
Mp496	30	PG	88		59
Mp68:616	97.5		92		94.75
N28	65		88	2MD at FH	76.5
N139	55		92	15MD, ext. Fus.	73.5
N6G	87.5		92		89.75
Narino 330-S6	65		82	8MD,Fus,BD,no FH	73.5
NC246	60	2MD, WD	70	1MD	65
NC248	95	WD	98		96.5
Oh43	70		70		70

APPENDIX

(Table 2 - continued)

INBRED	WAIMANALO - SUMMER Germ. (%)*	Complic.*	KAPAA - WINTER Germ. (%)*	Complic.*	TOTAL MEAN
PAC90038	60		94		77
Phil DMR6-S5	85		90		87.5
SC43	90		100		95
SC213	60		84		72
SC301D	50		82	6MD, Fus., no FH	66
T232	95	1MD, WD	90	2MD, PH rot	92.5
T256	60		88	6MD, Fus., no FH	74
T258	92.5		88		90.25
Tuxpeno-S5	80		86	2MD, Fus.	83
Tx29A	100		88	9MD, ext. Fus., BD	94
Tx5855	100		92		96
Tx601	85		86		85.5
Tx602	100		86		93
TZi3	60		96		78
TZi4	100		82	2MD, Fus.	91
TZi14	80		94	1MD	87
TZi17	85		84	Fus.	84.5
TZi18	70	1MD, WD	94		82
Va35	80	1MD, WD	88		84
W64A	77.5		84		80.75
MEANS =	74.82		83.79		79.30

* Germ. (%) = Germination percentages as described in Section 3.1.4.

Complic. = Complications with each inbred at each location.

PG = poor germination

#MD = # of missing data out of 20

#WD = # of samples with corn weevil damage

FH = final harvest

Fus. = Fusarium moniliformi rot of corn plants and ears.

ext. Fus. = extreme Fusarium damage

BD = bird damage of eating corn ear samples

PH rot = post harvest rot diseases of any combination of: Fusarium sp., Aspergillus sp., Penicillium sp.

APPENDIX

Table 3. Final kernel weights (KW), dry matter accumula tion rates (DMA), grain filling periods (GFP), and R-sqr values for goodness of fit to a linear regression for 96 inbreds from the 1989 Waimanalo summer and Kapaa winter trials.

	1989	WAIMANALO - SUMMER				KAPAA - WINTER			
	INBRED	KW*	DMA*	GFP*	R-sqr*	KW*	DMA*	GFP*	R-sqr
1	A619	343.1	11.10	30.9	0.91	287.4	4.73	60.8	0.93
2	A632	288.9	8.05	35.9	0.95	232.9	5.24	44.5	0.84
3	Antigua	308.0	8.71	35.4	0.95	241.1	5.21	46.3	0.83
4	B37	278.4	7.64	36.4	0.99	168.2	3.75	44.9	0.88
5	B73	226.8	7.01	32.3	0.99	189.9	5.66	33.5	0.92
6	B77	271.8	7.07	38.4	0.94	180.7	2.48	72.8	0.71
7	C164	281.0	8.54	32.9	0.97	191.2	3.5	54.6	0.95
8	C166	309.4	4.29	72.2	0.85	197.8	4.51	43.9	0.78
9	CIM.A-21	308.6	6.17	50.0	0.96	163.3	3.46	47.2	0.91
10	CIM.A-6	351.1	6.02	58.3	0.96	226.0	3.28	68.9	0.90
11	CIM.T11ES	308.2	6.54	47.1	0.98	129.6	4.06	31.9	0.94
12	CM103	298.7	6.50	46.0	0.94	224.6	5.25	42.8	0.86
13	CM116	299.9	8.65	34.7	0.95	239.9	4.56	52.6	0.89
14	CM117	233.2	5.17	45.1	0.91	201.5	4.5	44.8	0.84
15	CM118	274.9	7.69	35.7	0.93	237.4	4.39	54.1	0.87
16	CM201	312.7	7.34	42.6	0.97	164.5	4.64	35.5	0.83
17	CM207	296.7	7.15	41.5	0.98	189.4	4.23	44.8	0.79
18	F44	242.4	6.04	40.1	0.94	164.6	4.57	36.0	0.82
19	Fla2AT113	311.6	7.83	39.8	0.96	213.1	1.99	107.1	0.89
20	Fla2AT114	314.6	9.08	34.6	0.90	252.0	4.92	51.2	0.72
21	Fla2AT115	265.0	7.43	35.7	0.92	229.4	4.54	50.5	0.88
22	Fla2AT116	258.4	4.97	52.0	0.87	221.1	4.49	49.2	0.88
23	Fla2BT106	306.3	9.79	31.3	0.95	193.4	4.41	43.8	0.92
24	Fla2BT54	322.0	6.80	47.4	0.96	194.9	5.08	38.4	0.82
25	Fla2BT73	341.5	6.77	50.5	0.97	209.6	4.74	44.2	0.95
26	Ga209	281.5	4.57	61.7	0.83	190.9	5.01	38.1	0.67
27	H55	253.8	7.64	33.2	0.93		5.36		0.98
28	H60	327.0	7.82	41.8	0.99	236.1	4.5	52.5	0.91
29	H632F	384.6	12.95	29.7	0.92	303.9	5.08	59.8	0.90
30	H84	218.7	6.79	32.2	0.94	166.6	6.14	27.1	0.93
31	H95	302.8	8.08	37.5	0.99	223.0	6.99	31.9	0.84
32	H98	310.6	7.63	40.7	0.90				
33	HIX4231	142.0	7.01	20.2	0.98	152.6	4.41	34.6	0.77
34	HIX4263	291.4	6.00	48.6	0.95	134.5	5.07	26.5	0.83

APPENDIX

(Table 3 - continued)

1989 INBRED	WAIMANALO - SUMMER KW*	DMA*	GFP*	R-sqr*	KAPAA - WINTER KW*	DMA*	GFP*	R-sqr
35 HIX4267	300.4	7.99	37.6	0.90	143.5	3.94	36.4	0.91
36 HIX4283	287.6	7.50	38.3	0.95	190.0	7.17	26.5	0.83
37 Hi26	330.0	11.33	29.1	0.96	230.1	4.48	51.4	0.94
38 Hi27	293.5	8.40	34.9	0.97	221.2	5.68	38.9	0.88
39 Hi28	246.8	7.50	32.9	0.97	252.4	4.39	57.5	0.88
40 Hi29	302.8	6.67	45.4	0.88	211.6	8.3	25.5	0.81
41 Hi30	286.7	6.35	45.2	0.98	234.1	4.13	56.7	0.76
42 Hi31	282.3	8.14	34.7	0.94	202.6	6	33.8	0.95
43 Hi32	211.0	8.72	24.2	0.82	183.4	6.27	29.3	0.87
44 Hi33	334.0	8.73	38.2	0.97	171.1	4.59	37.3	0.81
45 Hi34	246.9	6.54	37.8	0.92	189.3	3.91	48.4	0.94
46 Hi35	236.2	6.62	35.7	0.95	183.0	6.12	29.9	0.87
47 Hi39	301.9	6.17	49.0	0.93	185.2	5.1	36.3	0.83
48 Hi40	292.0	9.71	30.1	0.98	178.2	4.01	44.4	0.93
49 Hi41	266.5	5.52	48.3	0.88	208.5	4.45	46.9	0.83
50 ICA L210	278.1	10.39	26.8	0.95	219.9	6.95	31.6	0.93
51 ICA L219	322.2	6.44	50.0	0.92	168.8	6.59	25.6	0.93
52 ICA L221	351.2	6.98	50.3	0.97	236.9	2.5	94.7	0.88
53 ICA L224	367.4	9.86	37.2	0.92	235.8	4.37	54.0	0.76
54 ICA L27	385.2	8.98	42.9	0.98	204.3	2.59	78.9	0.83
55 ICA L36	284.5	7.28	39.1	0.95	170.3	4.02	42.4	0.86
56 INV138	265.5	9.93	26.7	0.96	251.9	9.99	25.2	0.92
57 INV302	234.4	8.13	28.8	0.96	219.3	6.66	32.9	0.84
58 INV36	266.4	8.90	29.9	0.94	170.7	4.23	40.3	0.92
59 INV534	295.3	8.54	34.6	0.96	205.9	2.78	74.1	0.88
60 KU1403	387.6	7.37	52.6	0.98	208.4	6.01	34.7	0.84
61 KU1409	346.9	8.35	41.5	0.95				
62 KU1414	329.4	9.37	35.2	0.97	257.1	4.63	55.5	0.78
63 KU1418	283.7	7.78	36.5	0.98	259.8	4.95	52.5	0.85
64 Ky226	240.2	8.03	29.9	0.97	208.4	5.73	36.4	0.90
65 MIT 2-S6	242.5	7.78	31.2	0.98	210.3	3.44	61.1	0.96
66 Mo20W	250.3	5.91	42.3	0.91	136.9	3.37	40.6	0.84
67 Mo5	305.8	7.80	39.2	0.95	189.7	8.65	21.9	0.96
68 Mp496	224.5	6.30	35.6	0.97	163.0	3.38	48.2	0.85
69 Mp68:616	285.9	8.70	32.9	0.98	250.2	4.26	58.7	0.90
70 N139	279.2	6.76	41.3	0.98				
71 N28	315.9	6.47	48.8	0.97	218.4	4.3	50.8	0.86
72 N6G	251.7	7.51	33.5	0.98	155.2	4.87	31.9	0.84
73 NC246	309.8	7.19	43.1	0.95	211.0	6.54	32.3	0.87
74 NC248	353.8	11.80	30.0	0.97	195.1	4.09	47.7	0.89
75 Narino330	278.1	7.84	35.5	0.98		4.34		0.93
76 Oh43	278.9	7.59	36.7	0.96	188.3	4.56	41.3	0.73

APPENDIX

(Table 3 - continued)

1989 INBRED	WAIMANALO - SUMMER KW*	DMA*	GFP*	R-sqr*	KAPAA - WINTER KW*	DMA*	GFP*	R-sqr
77 PAC90038	302.9	6.53	46.4	0.97	153.6	3.8	40.4	0.83
78 PhilDMR6	323.9	5.27	61.4	0.95	257.7	8.06	32.0	0.91
79 SC213	347.8	6.33	54.9	0.88	181.6	2.95	61.5	0.74
80 SC301D	342.7	8.72	39.3	0.97		2.8		0.90
81 SC43	250.0	7.26	34.4	0.99	94.5	2.55	37.0	0.90
82 T232	440.2	11.37	38.7	0.99	197.9	7.58	26.1	0.91
83 T256	256.5	6.27	40.9	0.91		6.96		0.76
84 T258	270.1	7.14	37.8	0.95	160.4	5.11	31.4	0.95
85 TZi14	340.5	10.72	31.8	0.97	171.3	5.47	31.3	0.82
86 TZi17	313.9	9.56	32.8	0.99	181.6	3.45	52.6	0.88
87 TZi18	284.0	7.89	36.0	0.99	194.6	5.64	34.5	0.88
88 TZi3	343.5	9.54	36.0	0.99	232.0	5.26	44.1	0.91
89 TZi4	277.3	6.79	40.8	0.96	174.1	2.6	67.0	0.84
90 Tuxpeno	308.9	8.00	38.6	0.97	179.4	2.74	65.5	0.79
91 Tx29A	356.3	8.55	41.6	0.96	194.4	1.54	126.2	0.20
92 Tx5855	339.3	8.45	40.1	0.96	175.9	6.04	29.1	0.91
93 Tx601	287.3	7.17	40.0	0.90	181.6	4.81	37.8	0.94
94 Tx602	355.1	10.95	32.4	0.99	217.3	6.85	31.7	0.86
95 Va35	256.1	8.61	29.7	0.99	269.9	5.76	46.9	0.87
96 W64A	266.4	8.41	31.7	0.98	163.5	6.55	25.0	0.87
MEANS =	295.4	7.79	39.1	0.95	200.6	4.83	45.47	0.86

* KW = Observed final kernel weights measured in grams per 1000 kernels (g/MVK) based on 2 reps, 2 samples/rep.

DMA = Dry matter accumulation rate in grams per day as estimated by linear regression analysis of kernel weights for 4 harvest dates based on 2 reps, 2 samples/rep.

GFP = Grain filling period duration as calculated by the Johnson and Tanner method =(Final KW)/(DMA rate).

R-sqr. = Coeffecient of determination for linear regression analysis of kernel weights for 4 harvest dates based on 2 reps, 2 samples/rep.

Missing values are due to trial complications as listed in Appendix Table 2.

APPENDIX

Table 4. HFSF maize inbred final grain yields sorted in descending order for the 1989 Waimanalo/summer and Kapaa/winter trials.

WAIMANALO - SUMMER INBRED	FINAL* KW (g/MVK)	KAPAA - WINTER INBRED	FINAL* KW (g/MVK)
T232	440.2	H632F	303.9
KU1403	387.6	A619	287.4
ICA L27	385.2	Va35	269.9
H632F	384.6	KU1418	259.8
ICA L224	367.4	Phil DMR6-S5	257.7
Tx29A	356.3	KU1414	257.1
Tx602	355.1	Hi28	252.4
NC248	353.8	Fla2AT114	252.0
ICA L221	351.2	INV138	251.9
CIM.A-6	351.1	Mp68:616	250.2
SC213	347.8	Antigua Comp	241.1
KU1409	346.9	CM116	239.9
TZi3	343.5	CM118	237.4
A619	343.1	ICA L221	236.9
SC301D	342.7	H60	236.1
Fla2BT73	341.5	ICA L224	235.8
TZi14	340.5	Hi30	234.1
Tx5855	339.3	A632	232.9
Hi33	334.0	TZi3	232.0
Hi26	330.0	Hi26	230.1
KU1414	329.4	Fla2AT115	229.4
H60	327.0	CIM.A-6	226.0
Phil DMR6-S5	323.9	CM103	224.6
ICA L219	322.2	H95	223.0
Fla2BT54	322.0	Hi27	221.2
N28	315.9	Fla2AT116	221.1
Fla2AT114	314.6	ICA L210	219.9
TZi17	313.9	INV302	219.3
CM201	312.7	N28	218.4
Fla2AT113	311.6	Tx602	217.3
H98	310.6	Fla2AT113	213.1
NC246	309.8	Hi29	211.6
C166	309.4	NC246	211.0
Tuxpeno-S5	308.9	MIT 2-S6	210.3
CIM.A-21	308.6	Fla2BT73	209.6
CIM.T-11ES	308.2	Hi41	208.5

APPENDIX

(Table 4 - continued)

WAIMANALO - SUMMER INBRED	FINAL* KW (g/MVK)	KAPAA - WINTER INBRED	FINAL* KW (g/MVK)
Antigua Comp	308.0	KU1403	208.4
Fla2BT106	306.3	Ky226	208.4
Mo5	305.8	INV534	205.9
PAC90038	302.9	ICA L27	204.3
Hi29	302.8	Hi31	202.6
H95	302.8	CM117	201.5
Hi39	301.9	T232	197.9
HIX4267	300.4	C166	197.8
CM116	299.9	NC248	195.1
CM103	298.7	Fla2BT54	194.9
CM207	296.7	TZi18	194.6
INV534	295.3	Tx29A	194.4
Hi27	293.5	Fla2BT106	193.4
Hi40	292.0	C164	191.2
HIX4263	291.4	Ga209	190.9
A632	288.9	HIX4283	190.0
HIX4283	287.6	B73	189.9
Tx601	287.3	Mo5	189.7
Hi30	286.7	CM207	189.4
Mp68:616	285.9	Hi34	189.3
ICA L36	284.5	Oh43	188.3
TZi18	284.0	Hi39	185.2
KU1418	283.7	Hi32	183.4
Hi31	282.3	Hi35	183.0
Ga209	281.5	Tx601	181.6
C164	281.0	SC213	181.6
N139	279.2	TZi17	181.6
Oh43	278.9	B77	180.7
B37	278.4	Tuxpeno-S5	179.4
ICA L210	278.1	Hi40	178.2
Narino 330-S6	278.1	Tx5855	175.9
TZi4	277.3	TZi4	174.1
CM118	274.9	TZi14	171.3
B77	271.8	Hi33	171.1
T258	270.1	INV36	170.7
Hi41	266.5	ICA L36	170.3
INV36	266.4	ICA L219	168.8
W64A	266.4	B37	168.2
INV138	265.5	H84	166.6
Fla2AT115	265.0	F44	164.6

APPENDIX

(Table 4 - continued)

WAIMANALO - SUMMER INBRED	FINAL* KW (g/MVK)	KAPAA - WINTER INBRED	FINAL* KW (g/MVK)
Fla2AT116	258.4	CM201	164.5
T256	256.5	W64A	163.5
Va35	256.1	CIM.A-21	163.3
H55	253.8	Mp496	163.0
N6G	251.7	T258	160.4
Mo20W	250.3	N6G	155.2
SC43	250.0	PAC90038	153.6
Hi34	246.9	HIX4231	152.6
Hi28	246.8	HIX4267	143.5
MIT 2-S6	242.5	Mo20W	136.9
F44	242.4	HIX4263	134.5
Ky226	240.2	CIM.T-11ES	129.6
Hi35	236.2	SC43	94.5
INV302	234.4	Narino 330-S6	
CM117	233.2	N139	
B73	226.8	KU1409	
Mp496	224.5	SC301D	
H84	218.7	H98	
Hi32	211.0	T256	
HIX4231	142.0	H55	
MEAN:	295.4		200.6

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* Final KW = Observed final kernel weights measured in grams per 1000 viable kernels (g/MVK) based on 2 reps, 2 samples/rep.

Missing values are due to trial complications as listed in Table 2 of the Appendix.

APPENDIX

Table 5. Maize inbred dry matter accumulation (DMA) rates sorted in descending order for the 1989 Waimanalo/summer and Kapaa/winter trials.

WAIMANALO - SUMMER INBRED	DMA* RATE	KAPAA - WINTER INBRED	DMA* RATE
H632F	12.95	INV138	9.99
NC248	11.80	Mo5	8.65
T232	11.37	Hi29	8.30
Hi26	11.33	Phil DMR6-S5	8.06
A619	11.10	T232	7.58
Tx602	10.95	HIX4283	7.17
TZi14	10.72	H95	6.99
ICA L210	10.39	T256	6.96
INV138	9.93	ICA L210	6.95
ICA L224	9.86	Tx602	6.85
Fla2BT106	9.79	INV302	6.66
Hi40	9.71	ICA L219	6.59
TZi17	9.56	W64A	6.55
TZi3	9.54	NC246	6.54
KU1414	9.37	Hi32	6.27
Fla2AT114	9.08	H84	6.14
INV36	8.90	Tx5855	6.04
Hi33	8.73	KU1403	6.01
Hi32	8.72	Hi31	6.00
SC301D	8.72	Va35	5.76
Antigua Comp	8.71	Ky226	5.73
Mp68:616	8.70	Hi27	5.68
CM116	8.65	B73	5.66
Va35	8.61	TZi18	5.64
Tx29A	8.55	TZi14	5.47
C164	8.54	H55	5.36
INV534	8.54	TZi3	5.26
Tx5855	8.45	CM103	5.25
W64A	8.41	A632	5.24
Hi27	8.40	Antigua Comp	5.21
KU1409	8.35	T258	5.11
Hi31	8.14	Hi39	5.10
INV302	8.13	Fla2BT54	5.08
H95	8.08	H632F	5.08
A632	8.05	HIX4263	5.07
Ky226	8.03	Ga209	5.01

APPENDIX

(Table 5. - continued)

WAIMANALO - SUMMER INBRED	DMA* RATE	KAPAA - WINTER INBRED	DMA* RATE
Tuxpeno-S5	8.00	KU1418	4.95
HIX4267	7.99	Fla2AT114	4.92
TZi18	7.89	N6G	4.87
Narino 330-S6	7.84	Tx601	4.81
Fla2AT113	7.83	Fla2BT73	4.74
H60	7.82	A619	4.73
Mo5	7.80	CM201	4.64
KU1418	7.78	KU1414	4.63
MIT 2-S6	7.78	Hi33	4.59
CM118	7.69	F44	4.57
B37	7.64	CM116	4.56
H55	7.64	Oh43	4.56
H98	7.63	Fla2AT115	4.54
Oh43	7.59	C166	4.51
N6G	7.51	CM117	4.50
HIX4283	7.50	H60	4.50
Hi28	7.50	Fla2AT116	4.49
Fla2AT115	7.43	Hi26	4.48
KU1403	7.37	Hi41	4.45
CM201	7.34	Fla2BT106	4.41
ICA L36	7.28	HIX4231	4.41
SC43	7.26	CM118	4.39
NC246	7.19	Hi28	4.39
Tx601	7.17	ICA L224	4.37
CM207	7.15	Narino 330-S6	4.34
T258	7.14	N28	4.30
B77	7.07	Mp68:616	4.26
HIX4231	7.01	INV36	4.23
B73	7.01	CM207	4.23
Fla2BT54	6.80	NC248	4.09
TZi4	6.79	CIM.T-11ES	4.06
H84	6.79	ICA L36	4.02
Fla2BT73	6.77	Hi40	4.01
N139	6.76	HIX4267	3.94
Hi29	6.67	Hi34	3.91
Hi35	6.62	PAC90038	3.80
CIM.T-11ES	6.54	B37	3.75
Hi34	6.54	C164	3.50
CM103	6.50	TZi17	3.45
N28	6.47	MIT 2-S6	3.44

APPENDIX

(Table 5. - continued)

WAIMANALO - SUMMER		KAPAA - WINTER	
INBRED	DMA* RATE	INBRED	DMA* RATE
ICA L219	6.44	Mp496	3.38
Hi30	6.35	Mo20W	3.37
SC213	6.33	CIM.A-6	3.28
Mp496	6.30	SC213	2.95
T256	6.27	SC301D	2.80
CIM.A-21	6.17	INV534	2.78
Hi39	6.17	Tuxpeno-S5	2.74
F44	6.04	TZi4	2.60
CIM.A-6	6.02	ICA L27	2.59
HIX4263	6.00	SC43	2.55
Mo20W	5.91	ICA L221	2.50
Hi41	5.52	B77	2.48
Phil DMR6-S5	5.27	Fla2AT113	1.99
CM117	5.17	Tx29A	1.54
Fla2AT116	4.97	KU1409	
Ga209	4.57	N139	
C166	4.29	H98	
MEAN:	7.79		4.83

* DMA RATE = Dry matter accumulation rate in grams per day (g/day) as estimated by linear regression analysis of kernel weights for 4 harvest dates based on 2 reps, 2 sample/rep.

Missing values are due to trial complications as listed in Appendix Table 2.

APPENDIX

Table 6. Maize inbred grain filling period (GFP) durations sorted in descending order for the 1989 Waimanalo/summer and Kapaa/winter trials.

WAIMANALO - SUMMER INBRED	GFP* (days)	KAPAA - WINTER INBRED	GFP* (days)
C166	72.2	Tx29A	126.2
Ga209	61.7	Fla2AT113	107.1
Phil DMR6-S5	61.4	ICA L221	94.7
CIM.A-6	58.3	ICA L27	78.9
SC213	54.9	INV534	74.1
KU1403	52.6	B77	72.8
Fla2AT116	52.0	CIM.A-6	68.9
Fla2BT73	50.5	TZi4	67.0
ICA L221	50.3	Tuxpeno-S5	65.5
ICA L219	50.0	SC213	61.5
CIM.A-21	50.0	MIT 2-S6	61.1
Hi39	49.0	A619	60.8
N28	48.8	H632F	59.8
HIX4263	48.6	Mp68:616	58.7
Hi41	48.3	Hi28	57.5
Fla2BT54	47.4	Hi30	56.7
CIM.T-11ES	47.1	KU1414	55.5
PAC90038	46.4	C164	54.6
CM103	46.0	CM118	54.1
Hi29	45.4	ICA L224	54.0
Hi30	45.2	TZi17	52.6
CM117	45.1	CM116	52.6
NC246	43.1	KU1418	52.5
ICA L27	42.9	H60	52.5
CM201	42.6	Hi26	51.4
Mo20W	42.3	Fla2AT114	51.2
H60	41.8	N28	50.8
Tx29A	41.6	Fla2AT115	50.5
KU1409	41.5	Fla2AT116	49.2
CM207	41.5	Hi34	48.4
N139	41.3	Mp496	48.2
T256	40.9	NC248	47.7
TZi4	40.8	CIM.A-21	47.2
H98	40.7	Va35	46.9
Tx5855	40.1	Hi41	46.9
F44	40.1	Antigua Comp	46.3

APPENDIX

(Table 6 - continued)

WAIMANALO - SUMMER INBRED	GFP* (days)	KAPAA - WINTER INBRED	GFP* (days)
Tx601	40.0	B37	44.9
Fla2AT113	39.8	CM117	44.8
SC301D	39.3	CM207	44.8
Mo5	39.2	A632	44.5
ICA L36	39.1	Hi40	44.4
T232	38.7	Fla2BT73	44.2
Tuxpeno-S5	38.6	TZi3	44.1
B77	38.4	C166	43.9
HIX4283	38.3	Fla2BT106	43.8
Hi33	38.2	CM103	42.8
T258	37.8	ICA L36	42.4
Hi34	37.8	Oh43	41.3
HIX4267	37.6	Mo20W	40.6
H95	37.5	PAC90038	40.4
ICA L224	37.2	INV36	40.3
Oh43	36.7	Hi27	38.9
KU1418	36.5	Fla2BT54	38.4
B37	36.4	Ga209	38.1
TZi3	36.0	Tx601	37.8
TZi18	36.0	Hi33	37.3
A632	35.9	SC43	37.0
CM118	35.7	HIX4267	36.4
Hi35	35.7	Ky226	36.4
Fla2AT115	35.7	Hi39	36.3
Mp496	35.6	F44	36.0
Narino 330-S6	35.5	CM201	35.5
Antigua Comp	35.4	KU1403	34.7
KU1414	35.2	HIX4231	34.6
Hi27	34.9	TZi18	34.5
Hi31	34.7	Hi31	33.8
CM116	34.7	B73	33.5
Fla2AT114	34.6	INV302	32.9
INV534	34.6	NC246	32.3
SC43	34.4	Phil DMR6-S5	32.0
N6G	33.5	CIM.T-11ES	31.9
H55	33.2	H95	31.9
Hi28	32.9	N6G	31.9
C164	32.9	Tx602	31.7
Mp68:616	32.9	ICA L210	31.6
TZi17	32.8	T258	31.4

APPENDIX

(Table 6 - continued)

WAIMANALO - SUMMER INBRED	GFP* (days)	KAPAA - WINTER INBRED	GFP* (days)
Tx602	32.4	TZi14	31.3
B73	32.3	Hi35	29.9
H84	32.2	Hi32	29.3
TZi14	31.8	Tx5855	29.1
W64A	31.7	H84	27.1
Fla2BT106	31.3	HIX4263	26.5
MIT 2-S6	31.2	HIX4283	26.5
A619	30.9	T232	26.1
Hi40	30.1	ICA L219	25.6
NC248	30.0	Hi29	25.5
Ky226	29.9	INV138	25.2
Va35	29.7	Mo5	21.9
H632F	29.7	N139	
Hi26	29.1	H55	
INV302	28.8	KU1409	
ICA L210	26.8	SC301D	
INV138	26.7	T256	
Hi32	24.2	Narino 330-S6	
HIX4231	20.2	H98	
MEAN =	39.1		45.47

* GFP = Grain filling period duration as calculated by the Johnson and Tanner method = (Final KW)/(DMA rate).

Missing values are due to trial complications as listed in Appendix Table 2.

APPENDIX

Table 7. Mean plant height, ear height, and difference for each inbred in the 1989 Waimanalo and Kapaa trials.

1989	WAIMANALO - SUMMER			KAPAA - WINTER		
INBRED	Plant Height (m)	Ear Height (m)	PH-EH (m)	Plant Height (m)	Ear Height (m)	PH-EH (m)
A619	2.00	0.70	1.30	1.73	0.45	1.28
A632	2.00	0.85	1.15	1.63	0.45	1.18
Antigua	1.80	0.90	0.90	1.45	0.55	0.90
B37	2.20	1.05	1.15	1.98	0.63	1.35
B73	2.25	0.80	1.45	2.03	0.53	1.50
B77	2.10	0.80	1.30	2.09	0.55	1.54
CI64	2.00	1.00	1.00	1.60	0.60	1.00
CI66	2.20	0.90	1.30	2.23	0.58	1.65
CIM.A-6	2.50	1.45	1.05	2.08	0.83	1.25
CIM.A-21	2.65	1.25	1.40	2.00	0.75	1.25
CIM.T-11ES	2.40	1.35	1.05	2.03	0.93	1.10
CM103	2.50	1.35	1.15	1.90	0.68	1.23
CM116	2.60	1.45	1.15	2.10	0.70	1.40
CM117	2.65	1.25	1.40	2.03	0.80	1.23
CM118	1.70	0.95	0.75	1.55	0.58	0.98
CM201	2.25	1.00	1.25	1.93	0.65	1.28
CM207	2.15	1.05	1.10	2.05	0.70	1.35
F44	2.60	1.15	1.45	2.30	0.83	1.48
Fla2AT113	2.20	1.00	1.20	1.95	0.65	1.30
Fla2AT114	2.05	1.05	1.00	1.70	0.55	1.15
Fla2AT115	2.20	0.90	1.30	1.85	0.58	1.28
Fla2AT116	2.40	1.30	1.10	2.05	0.58	1.48
Fla2BT54	2.55	1.25	1.30	2.08	0.70	1.38
Fla2BT73	2.20	1.00	1.20	1.93	0.68	1.25
Fla2BT106	2.60	1.20	1.40	1.58	0.60	0.97
Ga209	2.10	0.85	1.25	1.75	0.53	1.23
H55	2.10	0.80	1.30	1.60	0.50	1.10
H60	2.40	0.85	1.55	1.85	0.48	1.38
H84	2.20	0.75	1.45	1.88	0.48	1.40
H95	2.20	0.80	1.40	2.08	0.45	1.63
H98	1.55	0.55	1.00	1.40	0.30	1.10
H632F	2.35	1.25	1.10	2.10	0.78	1.33

APPENDIX

(Table 7 - continued)

1989 INBRED	WAIMANALO - SUMMER Plant Height (m)	Ear Height (m)	PH-EH (m)	KAPAA - WINTER Plant Height (m)	Ear Height (m)	PH-EH (m)
Hi26	2.65	1.10	1.55	2.30	0.83	1.48
Hi27	2.35	1.00	1.35	2.25	0.83	1.43
Hi28	2.20	1.15	1.05	2.05	0.73	1.33
Hi29	2.65	1.10	1.55	2.23	0.73	1.50
Hi30	2.35	0.75	1.60	2.05	0.53	1.53
Hi31	2.25	0.75	1.50	2.07	0.55	1.52
Hi32	2.20	0.60	1.60	2.15	0.55	1.60
Hi33	2.10	0.60	1.50	1.98	0.50	1.48
Hi34	2.10	1.00	1.10	2.00	0.73	1.28
Hi35	2.45	1.30	1.15	2.00	0.73	1.28
Hi39	1.90	1.00	0.90	1.65	0.60	1.05
Hi40	2.50	1.05	1.45	1.98	0.60	1.38
Hi41	2.00	1.00	1.00	1.50	0.48	1.03
HIX4231	1.85	0.75	1.10	1.65	0.48	1.18
HIX4263	2.40	0.95	1.45	2.03	0.70	1.33
HIX4267	2.45	1.00	1.45	1.95	0.60	1.35
HIX4283	2.45	1.20	1.25	2.13	0.68	1.45
ICA L210	2.35	1.10	1.25	2.03	0.60	1.43
ICA L219	1.85	0.55	1.30	1.60	0.50	1.10
ICA L221	2.00	0.70	1.30	1.65	0.45	1.20
ICA L224	1.85	0.75	1.10	1.58	0.48	1.10
ICA L27	2.30	0.75	1.55	1.95	0.60	1.35
ICA L36	2.45	1.25	1.20	2.15	0.85	1.30
INV138	2.75	1.25	1.50	2.15	0.80	1.35
INV302	2.50	1.35	1.15	2.05	0.83	1.23
INV36	2.45	1.25	1.20	2.08	0.80	1.28
INV534	2.60	1.15	1.45	2.10	0.70	1.40
KU1403	2.05	0.80	1.25	1.70	0.50	1.20
KU1409	2.25	1.25	1.00	1.75	0.68	1.08
KU1414	2.25	1.15	1.10	2.00	0.75	1.25
KU1418	2.35	1.10	1.25	1.95	0.60	1.35
Ky226	2.15	1.00	1.15	2.00	0.58	1.43
MIT2-S6	1.95	1.05	0.90	1.65	0.53	1.13
Mo5	2.20	0.80	1.40	2.10	0.73	1.38
Mo20W	1.75	0.75	1.00	1.35	0.45	0.90
Mp496	2.05	0.70	1.35	1.40	0.45	0.95
Mp68:616	2.50	1.00	1.50	2.03	0.50	1.53

APPENDIX

(Table 7 - continued)

1989	WAIMANALO - SUMMER			KAPAA - WINTER		
	Plant	Ear		Plant	Ear	
	Height	Height	PH-EH	Height	Height	PH-EH
INBRED	(m)	(m)	(m)	(m)	(m)	(m)
N28	2.15	0.70	1.45	1.80	0.50	1.30
N139	1.85	0.60	1.25	1.65	0.43	1.23
N6G	2.10	0.90	1.20	1.88	0.55	1.33
Narino330	2.15	1.15	1.00	1.55	0.68	0.88
NC246	2.15	0.70	1.45	1.80	0.53	1.28
NC248	2.55	1.10	1.45	2.10	0.58	1.53
Oh43	2.10	0.80	1.30	1.65	0.43	1.23
PAC90038	2.40	1.00	1.40	1.88	0.40	1.48
PhilDMR6	2.55	1.30	1.25	2.00	0.68	1.33
SC43	2.35	0.95	1.40	1.85	0.68	1.18
SC213	2.05	0.80	1.25	1.80	0.45	1.35
SC301D	2.20	0.70	1.50	1.90	0.55	1.35
T232	2.45	1.00	1.45	1.80	0.53	1.28
T256	1.75	0.50	1.25	1.60	0.28	1.33
T258	1.80	0.30	1.50	1.80	0.28	1.53
Tuxpeno	2.45	1.10	1.35	1.98	0.78	1.20
Tx29A	2.55	0.95	1.60	2.23	0.68	1.55
Tx5855	2.65	1.10	1.55	2.00	0.53	1.48
Tx601	2.30	1.30	1.00	1.94	0.68	1.26
Tx602	2.85	1.55	1.30	2.40	0.80	1.60
TZi3	2.25	1.25	1.00	1.75	0.65	1.10
TZi4	2.00	1.10	0.90	1.55	0.50	1.05
TZi14	2.60	1.15	1.45	1.98	0.58	1.40
TZi17	2.00	0.95	1.05	1.65	0.58	1.08
TZi18	2.25	0.95	1.30	2.40	0.68	1.73
Va35	2.15	0.70	1.45	1.55	0.38	1.18
W64A	2.40	0.85	1.55	2.00	0.63	1.38
MEAN =	2.25	0.98	1.27	1.90	0.59	1.30
STD =	0.26	0.24	0.20	0.23	0.13	0.18

APPENDIX

Table 8. Number of days to silking for each inbred during the 1989 Waimanalo summer and Kapaa winter trials.

1989 INBRED	DAYS TO SILK Waimanalo, Oahu Rep1	Rep2	Mean	DAYS TO SILK Kapaa, Kauai Rep1	Rep2	Mean	OVERALL MEAN
A619	47	50	48.5	58	56	57.0	52.8
A632	47	47	47.0	58	61	59.5	53.3
Antigua Comp	55	54	54.5	61	58	59.5	57.0
B37	50	47	48.5	61	58	59.5	54.0
B73	52	48	50.0	61	61	61.0	55.5
B77	54	50	52.0	61	61	61.0	56.5
C164	52	50	51.0	65	65	65.0	58.0
C166	52	48	50.0	61	61	61.0	55.5
CIM.A-6	56	56	56.0	72	72	72.0	64.0
CIM.A-21	62	55	58.5	72	72	72.0	65.3
CIM.T-11ES	62	59	60.5	75	75	75.0	67.8
CM103	54	55	54.5	65	61	63.0	58.8
CM116	55	54	54.5	65	65	65.0	59.8
CM117	52	52	52.0	68	63	65.5	58.8
CM118	54	51	52.5	65	65	65.0	58.8
CM201	52	48	50.0	65	61	63.0	56.5
CM207	54	53	53.5	65	63	64.0	58.8
F44	56	54	55.0	68	68	68.0	61.5
Fla2AT113	58	55	56.5	70	65	67.5	62.0
Fla2AT114	56	50	53.0	68	63	65.5	59.3
Fla2AT115	59	55	57.0	69	68	68.5	62.8
Fla2AT116	56	54	55.0	70	65	67.5	61.3
Fla2BT54	55	55	55.0	70	68	69.0	62.0
Fla2BT73	56	55	55.5	70	68	69.0	62.3
Fla2BT106	52	49	50.5	65	68	66.5	58.5
Ga209	52	54	53.0	68	61	64.5	58.8
GT112Rf	64	59	61.5	79	79	79.0	70.3
H55	58	56	57.0	72	72	72.0	64.5
H60	50	47	48.5	61	58	59.5	54.0
H84	52	50	51.0	68	65	66.5	58.8
H95	47	46	46.5	61	58	59.5	53.0
H98	50	50	50.0	72	79	75.5	62.8
H632F	58	58	58.0	70	68	69.0	63.5
H632G	59	59	59.0	75	72	73.5	66.3
Hi26	52	52	52.0	61	65	63.0	57.5
Hi27	56	50	53.0	70	61	65.5	59.3
Hi28	49	47	48.0	61	61	61.0	54.5

APPENDIX

(Table 8 - continued)

1989 INBRED	DAYS TO SILK Waimanalo, Oahu Rep1	Rep2	Mean	DAYS TO SILK Kapaa, Kauai Rep1	Rep2	Mean	OVERALL MEAN
Hi29	50	52	51.0	65	65	65.0	58.0
Hi30	48	46	47.0	61	61	61.0	54.0
Hi31	50	54	52.0	68	63	65.5	58.8
Hi32	46	47	46.5	58	61	59.5	53.0
Hi33	48	46	47.0	61	61	61.0	54.0
Hi34	56	55	55.5	70	68	69.0	62.3
Hi35	52	52	52.0	70	68	69.0	60.5
Hi39	52	54	53.0	70	72	71.0	62.0
Hi40	54	54	54.0	70	70	70.0	62.0
Hi41	59	57	58.0	79	72	75.5	66.8
HIX4231	52	52	52.0	72	70	71.0	61.5
HIX4263	54	52	53.0	68	68	68.0	60.5
HIX4267	55	52	53.5	70	68	69.0	61.3
HIX4283	56	55	55.5	68	68	68.0	61.8
ICA L210	54	52	53.0	70	68	69.0	61.0
ICA L219	56	56	56.0	70	68	69.0	62.5
ICA L221	55	55	55.0	70	65	67.5	61.3
ICA L223	57	55	56.0	72	72	72.0	64.0
ICA L224	57	55	56.0	72	72	72.0	64.0
ICA L27	58	49	53.5	70	72	71.0	62.3
ICA L29	56	56	56.0	72	68	70.0	63.0
ICA L36	58	56	57.0	68	72	70.0	63.5
INV138	48	52	50.0	61	65	63.0	56.5
INV302	55	53	54.0	68	68	68.0	61.0
INV36	54	50	52.0	68	65	66.5	59.3
INV534	54	50	52.0	61	61	61.0	56.5
KU1403	55	54	54.5	70	68	69.0	61.8
KU1409	55	54	54.5	61	63	62.0	58.3
KU1414	56	54	55.0	65	65	65.0	60.0
KU1418	58	55	56.5	68	72	70.0	63.3
Ky226	57	55	56.0	65	68	66.5	61.3
MIT 2-S6	58	56	57.0	68	65	66.5	61.8
Mo5	47	52	49.5	61	65	63.0	56.3
Mo20W	55	53	54.0	65	65	65.0	59.5
Mp496	54	55	54.5	68	65	66.5	60.5
Mp68:616	52	48	50.0	61	61	61.0	55.5
N28	50	52	51.0	65	61	63.0	57.0
N139	52	53	52.5	68	68	68.0	60.3
N6G	52	49	50.5	61	65	63.0	56.8
Narino 330-S6	61	58	59.5	79	82	80.5	70.0

(Table 8 - continued)

1989 INBRED	DAYS TO SILK Waimanalo, Oahu Rep1	Rep2	Mean	DAYS TO SILK Kapaa, Kauai Rep1	Rep2	Mean	OVERALL MEAN
NC246	56	52	54.0	65	65	65.0	59.5
NC248	55	54	54.5	63	63	63.0	58.8
Oh43	50	48	49.0	61	63	62.0	55.5
PAC90038	52	57	54.5	68	65	66.5	60.5
Phil DMR6-S5	57	55	56.0	61	63	62.0	59.0
SC43	54	50	52.0	65	65	65.0	58.5
SC213	56	56	56.0	72	68	70.0	63.0
SC301D	54	54	54.0	68	72	70.0	62.0
T232	56	55	55.5	70	72	71.0	63.3
T256	55	55	55.0	72	82	77.0	66.0
T258	54	54	54.0	68	72	70.0	62.0
Tuxpeno-S5	55	56	55.5	70	72	71.0	63.3
Tx29A	52	52	52.0	68	72	70.0	61.0
Tx5855	54	55	54.5	72	72	72.0	63.3
Tx601	58	56	57.0	72	75	73.5	65.3
Tx602	54	55	54.5	68	68	68.0	61.3
TZi3	56	55	55.5	72	72	72.0	63.8
TZi4	56	58	57.0	79	75	77.0	67.0
TZi14	52	50	51.0	65	61	63.0	57.0
TZi17	54	54	54.0	68	82	75.0	64.5
TZi18	55	54	54.5	65	68	66.5	60.5
Va35	44	44	44.0	61	56	58.5	51.3
W64A	45	45	45.0	61	65	63.0	54.0
MEAN =	54.0	52.6	53.0	67.2	66.8	67.0	60.0
STD =	3.7	3.3	4.0	4.8	5.5	4.8	3.9

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